Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 6 (4): 638-642, 2007
ISSN 1682-3974

Regional Trial Results Show Wheat Yield Declining in the Eastern Gangetic Plains Of South Asia

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Abstract: A study was undertaken at 9 to 11 sites in seven years (2000-2006) in the Eastern Gangetic Plains (EGP) to examine yield trend through optimum managed wheat crop in the region using 21 experimental lines and four checks (Bhrikuti, PBW343, Kanchan and Sonalika). Data on grain yield, 1000-kernel weight (TKW), spot blotch severity, maturity and plant height were analyzed. Trend analysis revealed decreasing trend in grain yield and TKW. Spot blotch (*Cochliobolus sativus*) severity has increased over this period. Results indicate an effect of spot blotch severity on the reductions in grain yield and TKW. These findings have direct implications for developing strategies to improve wheat yields in the EGP region.

Key words: Eastern Gangetic Plains (EGP), spot blotch, *Triticum aestivum*, wheat, yield trend

INTRODUCTION

Livelihood of millions of resource poor farmers in the Eastern Gangetic Plains of South Asia depends on successful cultivation of wheat. It is estimated that South Asia may face substantial wheat deficit by 2020 (Agcaoili-Sombilla and Rosegrant, 1994). India alone will need to increase its wheat production from 72 to about 109 million tons by 2020 (Nagarajan, 2005). This will require increasing wheat yield from 2.7 to almost 4.0 t ha^{-1}.

This is a significant challenge given that resources for research are shrinking and that the present estimated yield gap between farmers and experimental yields is about 1.8 t ha^{-1} in the region (Ortiz-Ferrara *et al.*, 2007).

There are many biotic and abiotic constraints to successful wheat production in the EGP region. The three factors that primarily determine wheat production in the region are temperature during the grain filling period, input application and the incidence of diseases such as rusts and leaf blight (Ortiz-Ferrara, 2007). Since most of the leading wheat cultivars in the region have good level of resistance to leaf rust (*Puccinia triticina*), spot blotch (*Cochliobolus sativus*) has become the most important disease (Duveiller *et al.*, 2005) causing substantial grain yield reductions in recent on-station and farmers' field trials (Sharma *et al.*, 2004a, b; Sharma and Duveiller, 2006, 2007). Heat stress during grain development is becoming a serious bottleneck to high wheat yields in Bangladesh, eastern India and the southern plains of Nepal (Black, 2006). It particularly affects late sown wheat due to long duration rice varieties in the dominant rice-wheat cropping sequence in the region. Wheat planted after Nov. 30 would be expected to show reductions by 1.3% per day of delay (Hobbs and Giri, 1997). Results from long-term trials have shown that soil nutrient status is declining at key sites in India (Bhandari *et al.*, 2002) and Nepal (Regmi *et al.*, 2002). The status of soil fertility and fertilizer use is directly related to wheat yield in the rice-wheat cropping system (Nagarajan, 2005; Tirol-Padre and Ladha, 2006). The above research findings underscore the importance of crop management factors and improved germplasm that can tolerate prevalent biotic and abiotic stresses in the EGP region.

In order to develop improved wheat cultivars for the EGP region, CIMMYT initiated Eastern Gangetic Plains Wheat Screening Nursery (EGPSN) in 1998 and Eastern Gangetic Plains Wheat Yield Trial (EGPYT) in 2000 with the objective to introduce and exchange improved wheat germplasm in the region. Such germplasms were intended for direct release as well as to serve as parents for wheat improvement in the region. Prior to their inclusion in the trials the germplasm had been selected for high yield and 1000-kernel weight (TKW), early maturity, medium tall plant height and resistance to foliar diseases prevalent in the region. The objective of this study is to examine data from the EGPYT trials conducted in seven years in order to determine trends in grain yield, TKW, spot blotch resistance, maturity and plant height. Such information could assist in developing future germplasm need and crop management strategies in the region.

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MATERIALS AND METHODS

Each year the trial included 21 new breeding lines; a widely grown improved cultivar each from Bangladesh (Kanchan), India (PBW343) and Nepal (Bhrikuti); and a long-term check, Sonalika. Though released in different countries, all four checks are well adapted to the entire EGP region. Kanchan (UP301/C306; CIMMYT CID 2565) is an early maturing high yielding cultivar released in 1983 but still occupies substantial wheat area in Bangladesh (Ortiz-Ferrara *et al*., 2007). It is susceptible to spot blotch. Bhrikuti (Cdo/Coc/3/Plo//Fury/Ana; CIMMYT CID 251774) is a medium maturing high yielding cultivar released in 1994 in Nepal. It is moderately resistant to spot blotch (Sharma *et al*., 2004b). PBW343 (Attila = Nd/VG9144//Kal/Bb/3/Yaco/4/Vee#5; CIMMYT CID 8890) is a medium maturing high yielding cultivar released in 1996. It is grown over seven million hectares in India (Ortiz-Ferrara *et al*., 2007) and has shown high level of resistance to spot blotch (Bhushan *et al*., 2002). Sonalika (CIMMYT CID 6977), an early maturing wheat variety released in 1971, still occupies around 1.0 million hectares in eastern India (states of Uttar Pradesh, Bihar, West Bengal and Assam) and the hills of Nepal (Ortiz-Ferrara *et al*., 2007). It is highly susceptible to spot blotch (Sharma and Duveiller, 2007).

The field trial was planted in an alpha lattice design with two replicates in each year at each site. The trial locations included two sites (Dinajpur and Jessore) in Bangladesh, five to seven (Coochbehar, Kanpur, Karnal, Kumarganj, Sabour, Shillongani and Varanasi) in India and two to four (Bhairahawa, Hardinath, Rampur and Tarahara) in Nepal. The trials were planted at 9, 10, 11, 11, 11, 9 and 9 sites in 2000, 2001, 2002, 2003, 2004, 2005 and 2006 wheat seasons, respectively. Individual plots (4.5 m^2) were seeded at the standard rate of 120 kg ha^{-1}. Each plot comprised 6 rows of 3 m each sown 0.25 m apart. Fertilizers application, irrigation and other management practices were standard for each site. Data were recorded on days to heading and maturity, plant height spot blotch severity, grain yield and TKW.

Regression analysis was used to detect trends over years in grain yield, TKW, disease severity, days to heading and maturity and plant height. Grain yield and TKW was also regressed over spot blotch severity to determine disease effects on this trait. Linear regression coefficient (b) was used to infer tendency for a trait; the positive and negative values representing increasing and decreasing trends, respectively.

RESULTS

There was a significant decreasing trend in mean grain yield ($r = -0.89$; $p<0.01$) and TKW ($r = -0.82$; $p = 0.02$) across seven years. There was an average decline of 210 kg ha^{-1} and 1.1 g $year^{-1}$ in grain yield and TKW, respectively (Fig. 1). All four checks showed a significant declining trend in grain yield ($p = 0.02$ to 0.03). Bhrikuti and Kanchan showed higher mean decline than PBW343 and Sonalika. Downward trend in TKW was significant for Bhrikuti, Kanchan and Sonalika.

Mean spot blotch severity increased 3.5% $year^{-1}$ (Fig. 1). Among checks PBW343 and Bhrikuti with relatively lower disease severity than Sonalika and Kanchan showed a greater increase in disease severity. There was an average decline of 1 day $year^{-1}$ in days to maturity (Fig. 2). Average plant height decreased 1.3 cm $year^{-1}$ (Fig. 2).

Regression of grain yield and TKW over mean spot blotch severity showed a negative effect of disease on these two traits (Fig. 3). On average, grain yield and TKW showed a decrease of 51 kg ha^{-1} and 0.2 g per 1% increase in spot blotch severity, respectively. TKW showed a direct relationship with grain yield ($r = 0.66$, $p = 0.10$) (Fig. 4). Grain yield increased by 119 kg ha^{-1} g^{-1} increase in TKW.

DISCUSSION

There was an overall decline in mean grain yield and TKW of the check cultivars over seven years, suggesting that factors other than genotype are at work. Yield declines can be attributed in part to the increased severity of spot blotch. This finding supports the previous reports (Sharma *et al*., 2004a; Duveiller *et al*., 2005) showing lower wheat yields in years with high spot blotch severity in the region. The increase in foliar blight severity was observed despite continuous and successful efforts in improving resistance in the region's commercial wheat cultivars (Siddique *et al*., 2006; Sharma and Duveiller, 2007). This suggests that new wheat genotypes must possess high levels of spot blotch resistance to perform well in South Asia.

The findings of this study is in line with the broad statistics of the region where wheat yields in South Asia have been reported to be stagnant (Mehla *et al*., 2000) or indicated slightly declining in recent years (FAO, 2007) and at least one country-India-has started importing wheat grain (Reuters, 2006). Though not a part of this

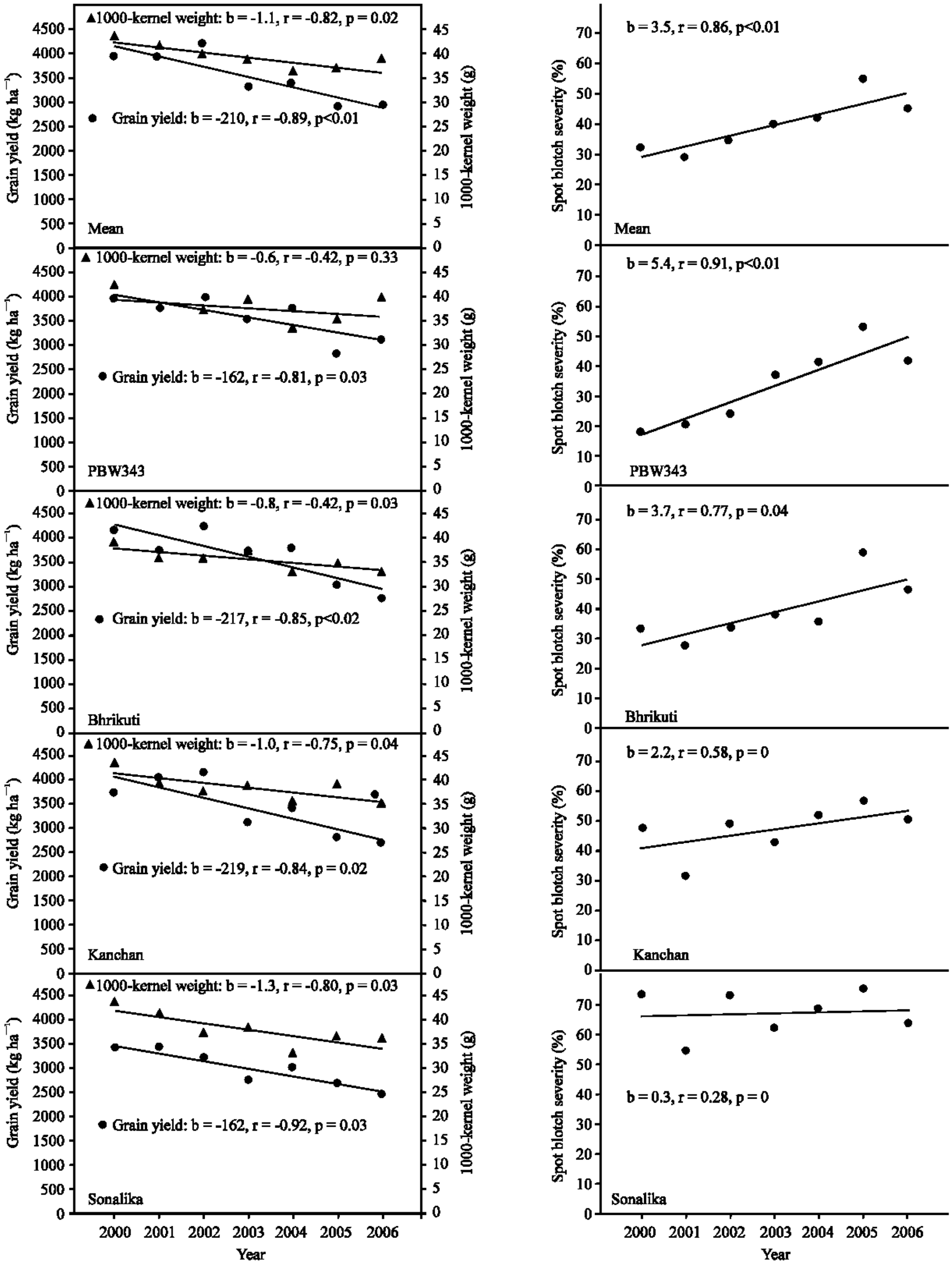

Fig. 1: Trend in grain yield, 1000-kernel weight and spot blotch severity of four checks and mean of trials in each of the seven years in the Eastern Gangetic Plains of South Asia

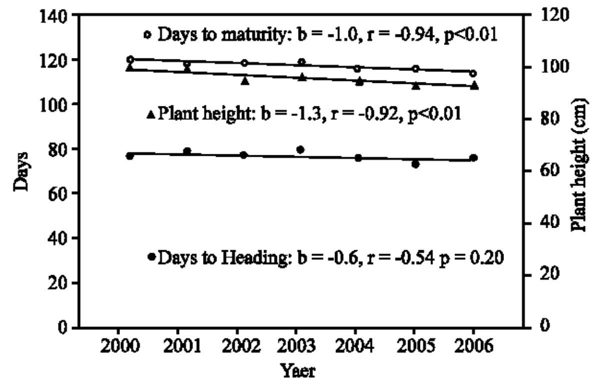

Fig. 2: Trend in days to heading, days to maturity and plant height averaged over 25 genotypes tested in the Eastern Gangetic Plains Wheat Yield Trials over across sites in seven years

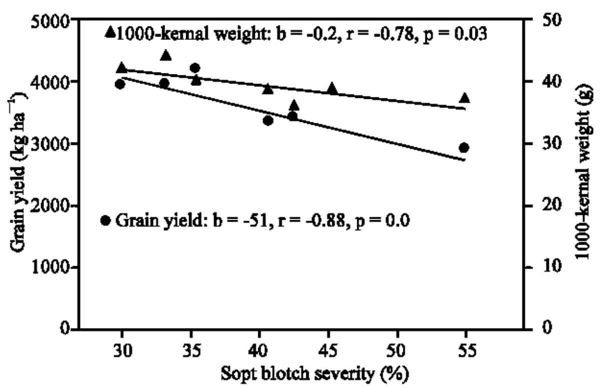

Fig. 3: Regression analysis of mean grain yield and 1000-kernel weight over mean spot blotch severity in seven years in the Eastern Gangetic Plains Wheat Yield Trials in South Asia

study, other studies have reported that heat stress caused by increasing temperatures (Nagarajan, 2005; Black, 2006) and longer foggy weather (Debi, 2003) during winter months in the region are additional constraints that could cause reduction in wheat grain yield like the one observed in this regional study. Other factors that could cause reduction in grain yield are related to fertilizer use (Nagarajan, 2005; Tirol-Padre and Ladha, 2006) and seeding time (Hobbs and Giri, 1997). However, these two factors couldn't have a significant influence on the results of this study because the trials were planted around optimum seeding time (November 20 to December 10) and received optimum fertilization and management practices based on recommendations for individual sites. There are also indications from this study that breeders have been selecting for earlier maturity and shorter plant height. The small shift towards earlier maturity observed

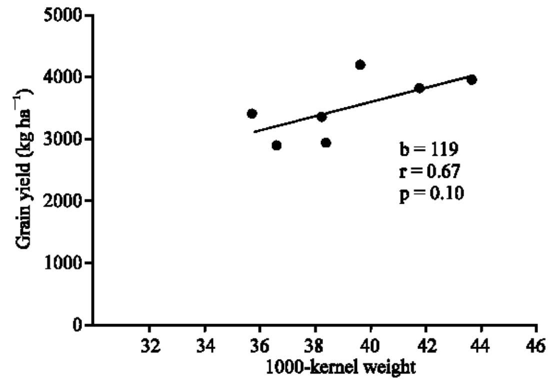

Fig. 4: Regression analysis of mean grain yield over mean 1000-kernel weight in seven years in the Eastern Gangetic Plains Wheat Yield Trials in South Asia

in this study could also result from climate warming noted in South Asia (Black, 2006). These factors are likely to affect biomass yield and in turn grain yield. A previous study in the region has shown that there is a significant positive association between biomass and grain yield in wheat (Sharma, 1993). A balance of maturity and plant height may be needed to indirectly increase grain yield trough improvement in biomass yield.

Results from regional trials conducted in seven years in the EGP region indicate that grain yield is declining. Spot blotch epidemics, which have been shown to affect grain yield in the region (Sharma *et al.*, 2004a; Sharma and Duveiller, 2007), is increasing. These findings have direct implications for developing strategies to sustain wheat yields in the EGP region where livelihood of millions of resource poor farmers depend on wheat production.

ACKNOWLEDGMENTS

The authors appreciate the assistance of Mr. S. Pradhan in preparing the figures. We gratefully acknowledge the collaboration of the scientists of wheat programs in India (Directorate of Wheat Research, Karnal; Banaras Hindu University, Varanasi; Narendra Dev University of Agriculture and Technology, Kumarganj; Chandra Shekhar Azad Univ. of Agric. and Technology, Kanpur; Uttar Banga Krishi Viswavidyalaya, Coochbehar; Assam Agricultural University, Shillongani; Bihar Agricultural College, Sabour); Nepal (National Wheat Research Program, Bhairahawa; Institute of Agriculture and Animal science, Rampur; Regional Agricultural Research Station, Tarahara, National Rice Research Program, Hardinath) and Bangladesh (Regional Agricultural Research Station, Jessore; Wheat Research Center, Dinajpur; Wheat Research Center, Jamalpur).

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