วารสารเกษตร 5,1 : 1 - 10 (2532)
Journal of Agriculture 5,1 : 1 -10 (1989)

GRAIN SET FAILURE AND BORON DEFICIENCY IN WHEAT IN THAILAND

Benjavan Rerkasem [1], *D. A. Saunders* [2] *and B. Dell* [3]

ABSTRACT: Failure in grain set, in up to 100% of the florets, was frequently observed in the Thailand Yield Nurseries (TYNs), Thailand Observation Nurseries (TONs) and other wheat experiments in Thailand in the 1986/87 growing season. At Chiangmai University in 1987/88 the poor grain set in wheat depressed seed yield by 40-50% on Tropaqualf soils with low boron (0.08 - 0.12 mgB/kg). An application of borax increased the number of grains per spikelet by 37 to 107%. Wheat growing in the low boron soils exhibited symptoms of male sterility, which included poorly developed anthers and nonviable pollen grains. Grain set failure, lower seed yield and male sterility symptoms were associated with low boron concentrations in the flag leaf, 5- 6 mgB/kg at booting and 5- 7 mgB/kg at anthesis, compared with 12 - 13 mgB/kg at booting and 11 - 16 mgB/kg at anthesis in unaffected crops. Boron concentrations in the flag leaf at anthesis were determined for 13 sites in Northern and Northeastern Thailand from the 1987/88 TYNs and found to range from 4- 6 mgB/kg at 10 of the sites. These data suggested a potential for widespread boron deficiency in wheat in Thailand.

INTRODUCTION

In the 1986/87 growing season sterility of wheat ears was frequently observed in the Thailand Yield Nurseries (TYNs), Thailand Observation Nurseries (TONs) and other wheat experiments in the country. Generally the number of grains/spikelet was decreased; in some cases so severely that entire ears were sterile. Many factors have been reported to cause ear sterility in wheat. For example, effects of low temperature (Kim *et al.*, 1985) and high temperature (Kirichenko *et al.*, 1975) have been reported, but these extreme temperatures lie outside the range of prevailing conditions in Thailand. Deficiency of two micronutrients, copper (Graham., 1975) and boron (Li *et al.*, 1978, Silva and Andrade, 1983) can cause grain set in wheat to fail through male

[1] Department of Agronomy, Faculty of Agriculture, Chiangmai University, Chiangmai, Thailand 50002.

[2] CIMMYT, c/o Canadian High Commission, House 16, Road 48, Gulshan, Dhaka, Bangladesh.

[3] School of Biological and Environmental Sciences, Murdoch University, Murdoch, Western Australia, 6150.

sterility. A survey of hollow heart in peanut, a symptom specific to boron deficiency, has shown that there is a potential for widespread boron deficiency in Northern Thailand (Rerkasem *et al*., 1988 a). This study examined the performance of wheat in typical upland soils of Northern Thailand, and its response to boron application. An attempt was also made to determine the boron status of wheat grown at different locations in the North and Northeast.

MATERIALS AND METHODS

Boron experiments at Chiangmai University

Three experiments were carried out at Chiangmai University during the 1987/88 growing season. The wheat used were SW23 and SW41, selections of Kasetsart University observed to set grains poorly in the previous season. All experiments received, at sowing, an application of 86 kgN/ha, half in the form of ammonium sulphate and half as 15-15-15 which also supplied 19 kgP/ka and 39 kgK/ka. Seeds were sown in rows 0.25 m apart at the rate of 130 kg/ha. From each plot a sample of 20 flag leaves was collected at booting (Feeke's 9) and anthesis(Feeke's 10.5), and a sample of 20 ears at anthesis. These plant materials were dried at 80° C for 48 hours, and along with grain samples, were analysed for boron by the Azomethine-H method (Lohse, 1982). At the end of the experiments a soil sample was collected from each plot; available boron was determined by the hot water method (Dible and Berger,1952). The central four 2 m rows in each plot were harvested for grain yield. The ear number was counted from whole samples; other yield components were determined from subsamples of 20 ears. Samples of ears were collected just before heading and fixed in buffered glutaraldehyde for microscopic examination. For scanning electron microscopy tissues were critical point dried, coated with carbon and gold and photographed at 30 kv. For light microscopy pollen grains were mounted in I_2- KI solution.

Experiment 1: SW41 wheat was sown on December 15 at the Multiple Cropping Centre on San Sai soil with available boron (hot water soluble, HWS) at 0.10 mgB/kg. There were two treatments : nil (Bo), and plus borax at 1.1 kgB/ha (B+), arranged in completely randomized blocks with three replicates; each plot consisted of six 6.7 m rows. The crop was flood irrigated with six irrigations, each with approximately 50 mm water.

Experiment 2: SW23 wheat was sown on November 6 at the Multiple Cropping Centre on San Sai soil with two boron levels, Bo and B+,created by applications of borax at 0 and 2.3 kgB/ha to previous crops of soybean, peanut and black gram.The experiment was in completely randomized blocks with four replicates; each plot consisted of eight

4 m rows. The wheat was grown as a rainfed crop. It received a total of 92.6 mm of rain, which fell in the first three weeks. At anthesis the number of ears with most florets not closing after anthesis, with palea and lemma at wide angles, was determined from 4 randomly selected 1 m rows.

Experiment 3: The wheat used was SW41, sown on November 7, at Mae Hia Farm under rainfed conditions, with two boron levels: nil (Bo) and borax at 1.1 kgB/ha (B+). The experiment was replicated six times, in completely randomized blocks; each plot consisted of six 6.7 m rows.

Boron status of wheat in 1987/88 TYNs

The Thailand Yield Nurseries (TYNs) for wheat in the 1987/88 season consisted of 25 selections. Each line was planted in 1.5x 2 . 5 m plots. The experiment was in completely randomized blocks with four replicates. A mixed fertilizer, 15-15-15, at the rate of 400 kg/ha was applied at sowing, which supplied 60 kgN/ha, 26 kgP/ha and 54kgK/ha. A top dressing of ammonium sulphate was made 30 days from sowing at the rate of 40 kgN/ha. Sampling was carried out at 13 sites (Figure 1). Plants and leaf samples were collected for boron analysis from three lines : Samoeng 2, Fang 60 and SW57. From each plot a 20 plant sample was harvested at above ground level at four weeks after sowing, and 150 flag leaves were sampled at anthesis. For each line at each harvest samples from the four replicates were bulked, dried at 80 C for 48 hours, and analysed for boron (By CSBP and Farmers Ltd, Perth, Western Australia).

RESULTS

Boron responses (Experiments 1 - 3)

Soil boron : By the end of the experiments the levels of soil boron in Bo ranged from 0.08 to 0.12 mgB/kg and those in B + from 0.42 to 0.56 mgB/kg.

Yield loss : In all three experiments grain yield in Bo was significantly lower than in B + (Table 1). Grain yield in Bo ranged from 766 to 1312 kg/ha, which amounted to only 51% to 61% of those in B+. In Bo the numbers of grains set per spikelet were about half of those in B+. Ear number and size, ears/m^2 and spikelets/ear, were unaffected by boron levels. In general the weight of individual seeds was greater in Bo.

Male sterility : During anthesis a large number of ears in Bo remained open for several days. In experiment 2 these accounted for 62% of the ears in Bo compared with only 1% in B + (Table 1). These ears contained mostly undevelloped anthers

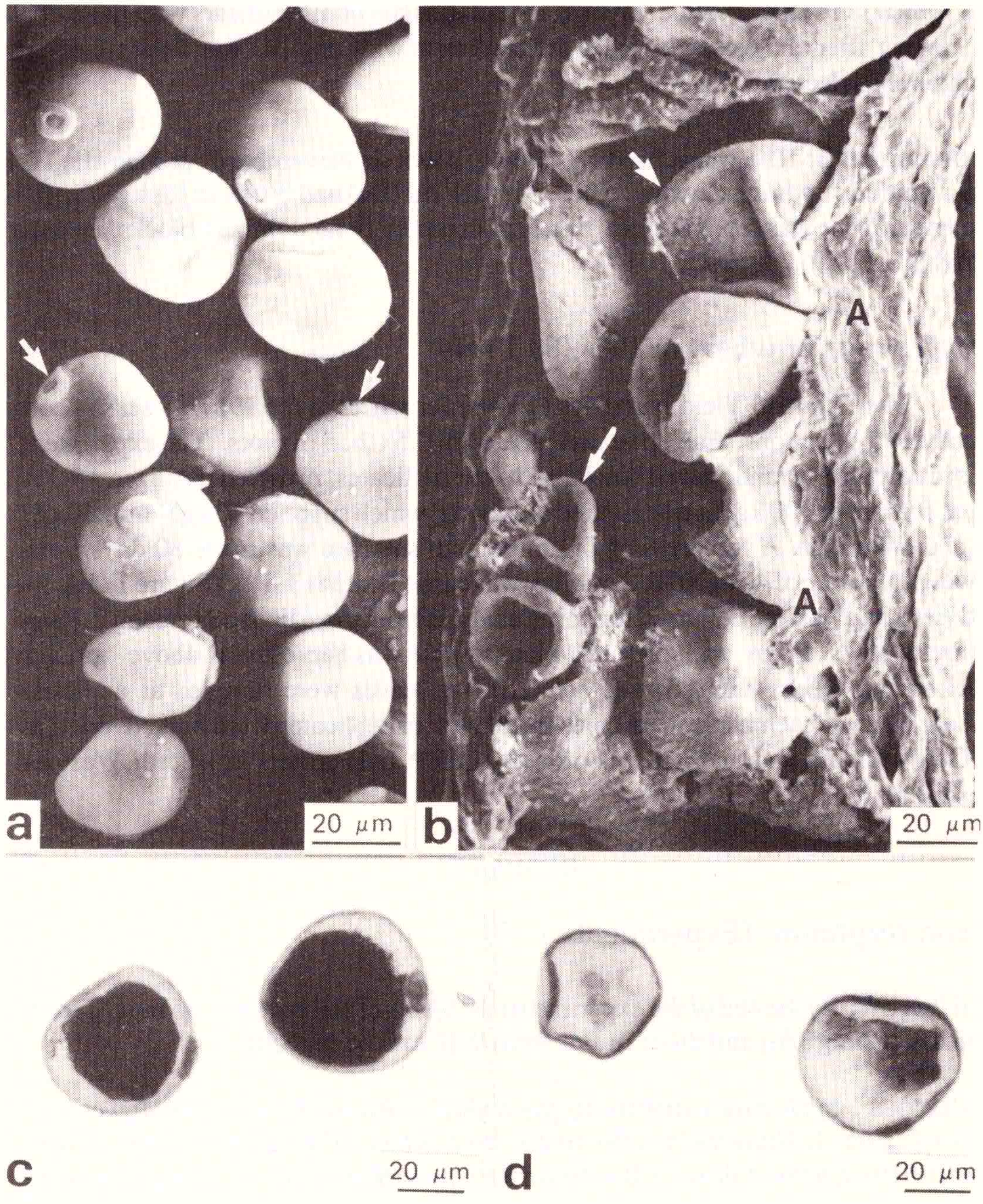

Figure 1. Scanning electron micrographs (a, b) and light micrographs (c, d) of wheat pollen towards anthesis. (a) Normal turgid grains with prominent germ pores (arrows) from B+ plant. (b) Shrivelled grains (arrows) inside anther tissue (A) from Bo plant. (c) Pollen grains from B+ plant mounted in iodine solution. The cytoplasm contains numerous small starch grains. (d) Pollen grains from Bo plant showing distorted shape and reduced cytoplasm.

Table 1. Effects of boron application on wheat yield, yield components and other related parameters.

	Experiment [1]		Experiment [2]		Experiment [3]	
Boron treatment*	Bo	B+	Bo	B+	Bo	B+
(a) Yield and yield components.						
Seed yield (kg/ha)	766	1488	1223	2005	1312	2294
% maximum yield	51	100	61	100	57	100
Grains/spikelet	1.30	2.70	1.20	2.10	1.60	2.20
1000 grains wt. (g)	35	29	36	30	35	33
Spikelets/ear	12	12	10	10	12	12
Ears/m^2	249	260	282	299	272	249
% Open ears**	+	-	62	1	+	--
(b) Tissue boron (mgB/kg dry matter)						
Booting: flag leaf	6	12	5	13	6	13
Anthesis: flag leaf	6	13	5	16	7	11
Ear	4	6	3	5	4	4
Grain	1.2	1.2	1.4	1.8	1.2	1.2
(c) Soil boron, hot water soluble						
0-25 cm (mgB/kg)	0.09	0.46	0.08	0.53	0.12	0.42

* Comparison between Bo and B+ in each experiment; pairs of Bo and, B + joined by an underline are not significantly different at $p<.05$; pairs not underlined are significantly different at $p<0.05$.

** At anthesis florets in Bo remained open for several days, quantitative data for experiment 2 only, for other 2 experiments + = open florets observed; - = no open florets.

with few pollen grains. The pollen grains were irregularly shaped or dented like deflated footballs and had very reduced cytoplasm (Figure 2). Unlike pollen from B + plants they did not accumulate starch, and the nuclei when present were abnormal in appearance.

Boron concentration in wheat tissues : Boron concentrations of the flag leaf , at booting as well as anthesis, were significantly lower in Bo than in B + in all three experiments(Table 1). The flag leaf boron at booting ranged from 5 to 6 mgB/kg in Bo compared with 12 to 13 mgB/kg in B+, and at anthesisthe values were 5 to 7 mgB/kg in Bo and 11 to 16 mgB/kg in B+. Boron concentrations in the ears at anthesis and in the grain at harvest were less responsive to boron treatments, in general the values in Bo did not differ significantly from those in B+.

Boron status of the wheat in TYNs

Boron values at each TYNs site did not differ markedly among the three wheat lines; averages for each site are shown in Table 2. The boron concentration of whole wheat tops at 4 weeks was$\leq$ 6 mgB/kg at eight sites (Table 2) and in the flag leaf at anthesis was$\leq$6 mgB/kg at ten sites.

DISCUSSION

This study has clearly shown that grain yield of wheat was depressed by boron deficiency through poor seed set, which was associated with male sterility. Similar effects have been reported in China (Li *et al* .,1978) and Brazil (Silva and Andrade, 1983).

The symptoms of male sterility caused by boron deficiency found in the present study and those reported in China and Brazil are similar to those associated with copper deficiency (Graham, 1975). Copper deficient wheat plants may be distinguished by their typical symptoms of wilting, wither-tip, rat-tailed ears and delayed maturity (Graham, 1975); none of these symptoms have been observed in boron deficient wheat. However, a critical boron value or range would provide a better diagnostic criterion than visual symptoms.

It has been suggested that boron deficiency affected pollen development during the pollen mother cell stage (Li *et al.*, 1978). Pollen development is associated with the booting stage. Thus the boron concentrations in wheat plants at booting may predict effects of boron deficiency on seed set and grain yield. Male sterility and depressed grain set were associated with boron levels in the flag leaf at booting of 5- 6 mgB/kg. The boron treatment, which prevented male sterility and increased seed set, increased the boron in flag leaf to 12 - 13 mgB/kg or more. Previously, Bergmann (1983) has suggested

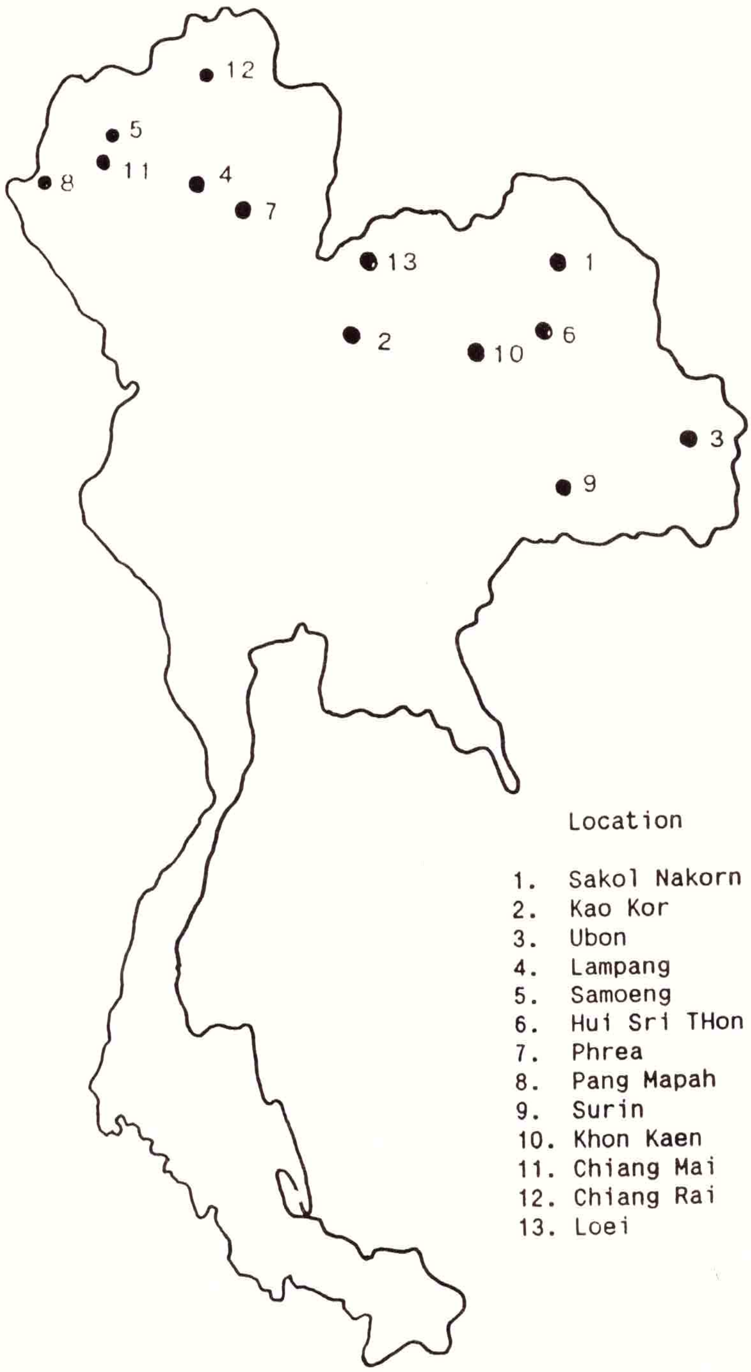

Figure 2. Map of Thailand showing 13 sites of wheat TYNs1987/88.

Table 2. Boron concentrations in wheat tissues from the 1987/88 TYNs.

Site	Boron concentration (mgB/kg)*	
	Whole tops at 4 weeks	Flag leaf at anthesis
1. Sakol	4	nd**
2. Kao Kor	14	6
3. Ubon	8	8
4. lampang	8	5
5. Samoeng	5	4
6. Hui Sri Thon	11	4
7. Phrae	4	6
8. Pang Mapah	3	5
9. Surin	6	4
10. Khon Kaen	3	10
11. Chiangmai	4	5
12. Chiang Rai	nd	5
13. loei	5	4

* Boron concentrations are mean values for three cultivars which did not differ from one another
** nd = not determined

that boron concentrations in the range of 5- 10 mgB/kg were adequate for growth of wheat plants. However, boron requirement for seed production is usually higher than that needed for vegetative growth (Marschner, 1986). The critical boron concentration for male fertility does not appear to have been reported in wheat. Boron concentrations of wheat from the Thailand TYNs for 1987/88 suggested potential boron deficiency at most of the sites.

Monocotyledons such as wheat are generally considered to be less sensitive to boron deficiency than dicotyledons (Marschner, 1986). The doubling of number of grains/spikelet and increases in grain yield, in response to boron application, found in this study are similar to the level of responses found in crops considered more sensitive such as black gram, green gram and sunflower grown in the same soil series (Predisritpat, 1988 and Rerkasem *et al.*, 1988 b). The potential for boron deficiency in wheat may also be related to its characteristically poorer capacity to take up boron compared with other crops (Marschner 1986) At 4weeks, wheat in the TYNs contained 3 - 14 mgB/kg, where as mungbean and peanuts at 4 weeks may contain 20-30 mgB/kg in similar soils (Rerkasem, unpublished). Results from the present study suggest that wheat yield may be more likely to be depressed by boron deficiency, through male sterility, than generally believed.

ACKNOWLEDGEMENTS

This work has been supported by the Multiple Cropping Centre, Chiangmai University and CIMMYT. The authors wish to thank Sithichai Lodkaew for boron analysis and Prof. J. F. Loneragan and Dr. R. W. Bell for valuable suggestions and comments.

REFERENCES

Bergmann, (1983) Ernahrungsstorungen bei Kulturpflanzen, Entstehung und Diagnose. Fischer, Jena.

Dible, W.T. and Berger,K.C.(1952). Boron content of alfalfa as influenced by boron supply. Soil Sci. Soc. Am. Proc. 16:60-62.

Graham,R.D. (1975). Male sterility in wheat plants deficienct in copper. Nature 254:514-515.

Kim, S.D, Park, M.E, Ha, Y.W.and Kwon, Y.W. (1985). Effect of low temperature on floral sterility, pollen viability and grain yield in barley and wheat. Wheat and Barley Research Inst., Suweon, Korea Republic, Research Report 27:114-119.

Kirichenko , F. G, Protsenko , D. F, Musienko, N.N. and Slavnyi,P.S. (1975). Effect of high temperature on the formation of reproductive organs and yield of wheat. Vsesoyuznyi Selektsionno-Geneticheskii Institut, Odessa, Ukrainian SSR, Vestnik Sel'skokhozyaistvennoâ Nauki, Moscow, USSR.

Li, W.H., M.C., Chao, N.S., Jern , M.P., Li C.R., Chu W.J. and Wang, C.L. (1978). Studies on cause of sterility of wheat. Jour Northeastern Agric. College, 3,1-19. (In Chinese).

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

Marschner, H. (1986). Mineral nutrition of higher plants. Academic Press, London. 674 p.

Predisripipat, S 1988 Responses to boron applications in Vigna. M Sc .Thesis, Depart ment of Agronomy, Faculty of Agriculture, Chiangmai University, Thailand.

Rerkasem, B., Netsangtip, R., Lodkaew, S., Tongrod, P., Predisripipat, S., Meejui, S. and Polwong, N.(1988 a). A survey of hollow heart in peanuts as an indicator of boron deficiency in Northern Thailand. In Proceedings of the 7th National Groundnut Research Meeting.

Rerkasem, B., Netsangtip, R., Bell, R.W., Loneragan, J.F. and Hiranburana, N. (1988 b) Comparative species responese to boron on a Typic Tropaqualf in Northern Thailand. Plant and Soil 106:15-21.

Sillanpaa, M. (1982). Micronutrients and nutrient status of soils. FAO of Soil Bull.48.

Silva, A.R. da. and Andrade, J.m.V. da. (1983). Influence of micronutrients on the male sterility, on upland wheat and on rice and soybean yields in red-yellow latosol. Pesq. agropec.bras. Brasilia 18:593-601. (In Portuguese).