Achieving High Rice Yield and Quality with the *20 Mule Team*® Borate Fertilizers

As one of the micronutrients that all plants need, boron plays an important role in a number of vital processes in rice growth such as cell wall synthesis, cell membrane functions, root development, pollen tube germination, flower initiation and seed production. Boron as a micronutrient is of great importance for balanced nutrition in plants to achieve high yield and quality. This is illustrated by Liebig's Law of the Minimum, ie the nutrient in the shortest supply, whether it is a macro, secondary or micro-nutrient, will limit the yield[1]. One can apply the optimal levels of all the macronutrients like N, P, K, and secondary nutrients like Mg. However, once boron in rice plant is deficient, the yield will be limited due to imbalanced nutrition. When one applies all the plant nutrients including boron in optimal levels, the yield and quality will be maximized. This is balanced nutrition.

Plant Symptoms Associated with Boron Deficiency in Rice

Boron (B) deficiency affects different growth stages of rice from vegetative to reproductive and ripening phases. Since boron is relatively immobile in rice and cannot be translocated to new growth, visible plant deficiency symptoms usually appear first on young leaves. At the early stage of boron deficiency in rice, young leaves usually do not elongate properly and remain short and narrow. A faint white/yellow chlorosis may possibly develop near the leaf tip. The next emerging leaves will be folded, bent and almost white. If such leaves open up, a large part of the blade will quickly dry up. With the development of boron deficiency in rice, the older leaves remain dark green but later many white chlorotic spots are likely to develop on both young and old leaves. During severe boron deficiency, new tillers may still develop but these quickly show the same symptoms and remain stunted. If boron deficiency occurs at the panicle initiation stage, the plants are unable to produce panicles. Complete failure to set seed has been observed under severe boron deficiency. Roots of severely affected plants are stubby, tough and light brown in color.

In addition to the observation of visible deficiency symptoms, boron deficiency in rice can also be diagnosed through soil and plant tissue analysis. Soil boron deficiency has been found widespread in many regions of the world. It can occur in highly weathered acid red soils and sandy soils in China, acid soils derived from igneous ricks, soils formed from marine sediments and soils with high organic matters[2].
The critical soil level for occurrence of boron deficiency is in the range between 0.1 and 0.7 ppm B (by hot water extraction method)[2]. Generally, boron availability decreases in acid soils and increases in alkaline soils after flooding. When wetland soils are drained, the pH decreases and boron is desorbed and may be leached.

Plant tissue analysis provides an excellent check on the actual crop availability of boron from the soil and applied boron fertilizer. It is particularly useful in diagnosing "hidden hunger" before evident boron deficiency symptoms are observed. The normal range of leaf boron content is between 25 and 30 ppm B. Leaf boron content of lower than 5 ppm B in rice tissue indicates the deficiency of boron whereas boron levels of higher than 40 ppm in leaf implies high boron status in the rice plant.

Applications of the *20 Mule Team* Borate Fertilizers in Rice

Table 1 lists the *20 Mule Team* borate fertilizers of U.S. Borax for the prevention and cure of boron deficiency in rice. *Granubor*® (15.0% B) is an ideal material for dry blends that are applied broadcast before transplanting. *Fertibor*® (15.0% B) works best in fertilizer suspensions for preplant broadcasts, side-dressing or band sprayed over the pre-emergent seed row. *Solubor*® (20.5% B) allows the most flexibility for applying boron. It can be dissolved alone in water or in liquid fertilizers and/or pesticides and then applied to the soil or directly onto the foliage.

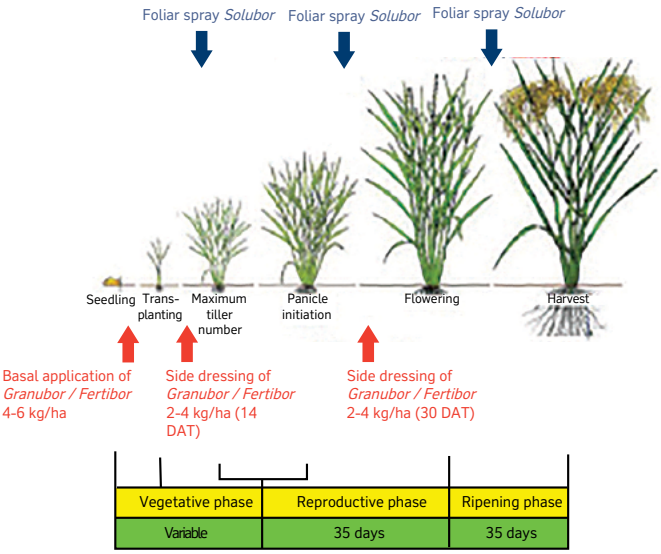
Table 1 The *20 Mule Team* borate fertilizers

GRANUBOR®	FERTIBOR®	SOLUBOR®
• 15.0% B	• 15.0% B	• 20.5% B
• 7 kg product required for 1 kg B	• 6.7 kg product required for 1 kg B	• 4.9 kg product required for 1 kg B
• 2.8 mm particle size	• Crystalline	• Powder

Figure 1 illustrates the recommended applications of *Granubor*, *Fertibor,* and *Solubor* at different growth stages in rice. For soil application, 4-6 kg/ha of *Fertibor* or *Granubor* is recommended to be broadcast or top-dressed before planting. Depending on the soil and plant tissue boron analysis results as well as the occurrence of visible plant deficiency symptoms, another two applications of 2-4 kg/ha of *Fertibor* or *Granubor* can be applied with one application before the maximum tillering number achieved during vegetative phase and the other one after panicle initiation.

Foliar application of *Solubor* has the advantages of providing micronutrient boron at critical rice growth stages such as the reproductive phase with almost immediate response of plant to the applied boron. 10 g of *Solubor* in 15 litre of water is the recommended concentration of the foliar spray solution. Split the *Solubor* foliar spray into 3-4 applications along with the insecticidal or fungicidal spraying rounds after transplanting, before and after flowering stage. Foliar spray of *Solubor* can also be used as an alternative source of boron for rice during the drought conditions. Do not foliar spray *Solubor* at the flowering stage. Any attempt to correct boron deficiency must be made with the great caution as boron toxicity can be induced.

Figure 1 Recommended applications of *Granubor, Fertibor*, and *Solubor* at different growth stages of rice for increased grain yield and quality[3]. DAT stands for "days after transplanting". The graph is modified from "Growth Stages" in R*ice: A Practical Guide to Nutrient Management* edited by TH Fairhurst, C Witt, RJ Buresh and A. Dobermann and published by IRRI, IPNI, and IPI.



Field Studies Demonstrating Increased Rice Yield and Quality with the *20 Mule Team* Borate Fertilizers

Compared with mineral borate fertilizers, the *20 Mule Team* borate fertilizers are refined products with more consistent boron content, higher purity and lower plant-toxic heavy metal levels. The benefits of *Granubor, Fertibor*, and *Solubor* for improved rice yield and quality have been extensively demonstrated by field studies in China, India, and Indonesia.

In 2014, a comprehensive field experiment was conducted to study the performance of the *20 Mule Team* borate fertilizers in rice growth and production by the China National Rice Research Institute in Zhejiang, China. In the study, hybrid japonica rice Yongyou-12 was planted in winter fallow field. The soil was loam clay with available boron of 0.2 mg/kg at the soil depth of 0-20 cm, organic matter of 43.0 g/kg, and pH of 5.3. *Granubor* was bulk blended with the granule 16-16-16 NPK compound fertilizers and broadcasted before transplanting (Figure 2a). In some treatments, in addition to the soil application of *Granubor*, a dilute solution of (at 1.8 kg/ha) was foliar sprayed before and after flowering stage (Figure 2b).

Figure 2 Pictures from the 2014 field trial study conducted in Zhejiang, China: (a) Broadcasting *Granubor* before transplanting; (b) *Solubor* foliar spray before flowering stage; (c) Rice growth during flowering stage; (d) Rice growth at ripening phase.

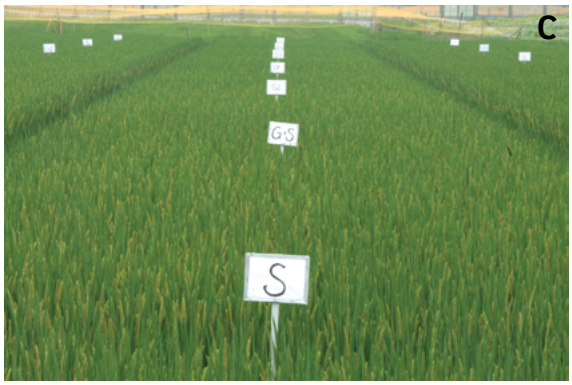
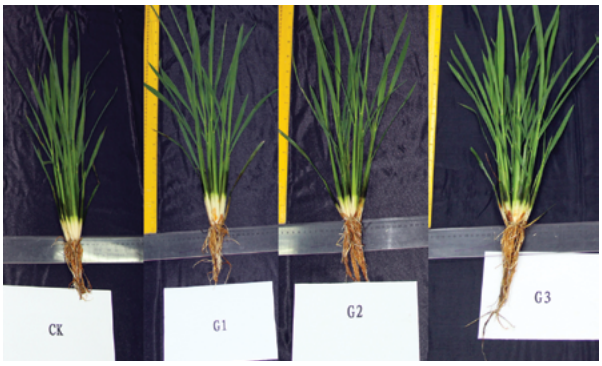


Figure 3 shows some key results from the field trial study in China in 2014. Due to the applications of *Granubor* and/or *Solubor*, remarkable rice grain yield increase was achieved in the trial. Particularly, with *Granubor* applied at 11.25 kg/ha, the grain yield was significantly increased by 7.9% over control. The substantial increase in yield was primarily consequences of enhancement in the numbers of tillers and effective panicles, as is shown in Figure 3. Considering the yield increase alone, the economics of *Granubor* and *Solubor* in rice production is very attractive. For example, with a combined application of *Granubor* at 3.75 kg/ha and *Solubor* at 1.8 kg/ha, significant yield increase of 8.5% was realised, leading to a value-cost ratio of 7.2. In addition to yield increase, applications of *Granubor* and/or *Solubor* have also substantially improved the rice grain quality with reduced undesirable factors such as chalky grain percentage (ie the proportion of chalky rice grain in the total grain) and chalkiness degree (ie the percentage of chalky area in total grain area). Chalkiness refers to the opaque part of rice grain. It not only influences the appearance of rice but also makes the grains broken in milling process.

Figure 3 Key results from the field study conducted in China in 2014 demonstrating the benefits of *Granubor* and *Solubor* for increased rice grain yield and quality: (a) Increase in maximum tiller numbers in rice due to the applications of *Granubor*; (b) Increase in effective panicle number due to the applications of *Granubor*; (c) Grain yield increase due to the applications of *Granubor* and/or *Solubor*. G1, G2, and G3 denote the applications of *Granubor* at 3.75 kg/ha, 7.5 kg/ha and 11.25 kg/ha.



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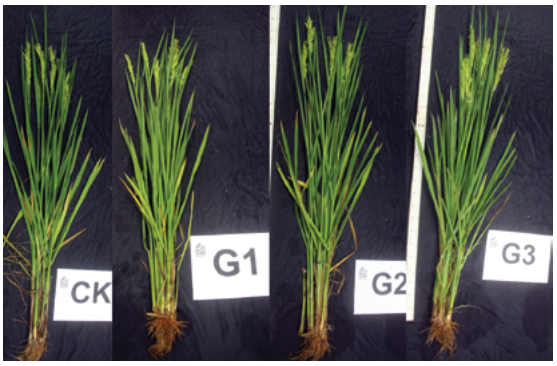

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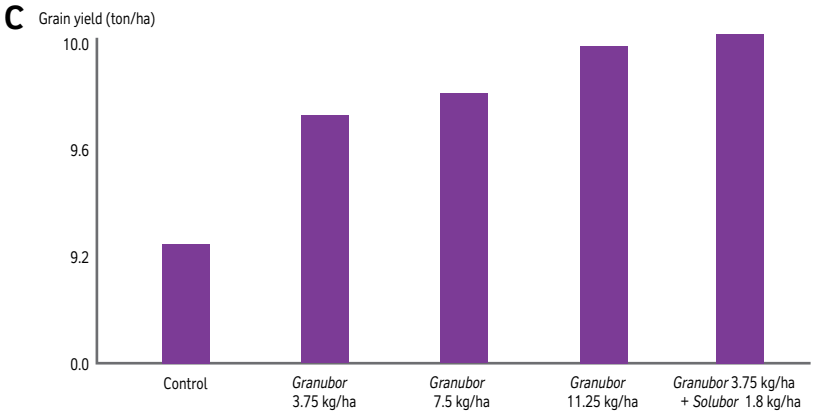

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References:

[1] F. Salisbury, 1992, Plant Physiology, Wadsworth, Belmont, CA.

[2] A. Dobermann and T.H. Fairhurst, 2000, Rice: Nutrient Disorders & Nutrient Management. Handbook Series, Potash & Phosphate Institute, Potash & Phosphate Institute of Canada and International Rice Research Institute.

[3] T.H. Fairhurst, C. Witt, R.J. Buresh and A. Dobermann, 2007, Rice: A Practical Guide to Nutrient Management. 2nd Edition, International Rice Research Institute, International Plant Nutrition Institute and International Potash Institute.

About U.S. Borax

U.S. Borax, part of Rio Tinto, is a global leader in the supply and science of borates—naturally-occurring minerals containing boron and other elements. We are 1,000 people serving 500 customers with more than 1,700 delivery locations globally. We supply 30% of the world's need for refined borates from our world-class mine in Boron, California, about 100 miles east of Los Angeles. We pioneer the elements of modern living, including:

- Minerals that make a difference: Consistent product quality secured by ISO 9000:2001 registration of its integrated quality management systems
- People who make a difference: Experts in borate chemistry, technical support, and customer service
- Solutions that make a difference: Strategic inventory placement and long-term contracts with shippers to ensure supply reliability