BROCHURE

Achieving high rice yield and quality with U.S. Borax fertilizers

20 MULE TEAM BORAX™
RioTinto

As one of the micronutrients that all plants need, boron plays an important role in a number of vital processes in rice growth including:

- Cell wall synthesis
- Cell membrane functions
- Root development
- Pollen tube germination
- Flower initiation
- Seed production

Boron's importance in achieving high yield and quality is illustrated by Liebig's Law of the Minimum which states that the nutrient in shortest supply—whether it is a macro, secondary, or micronutrient—will limit yield[1]. Growers can apply the optimal levels of all the macronutrients (including N, P, K) and secondary nutrients such as Mg. However, once the rice plant is boron deficient, yield will be limited due to imbalanced nutrition. When you apply all of the nutrients—including boron—in optimal levels, the yield and quality will be maximized.

This is balanced nutrition.

Boron deficiency symptoms in rice plants

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
- Acid soils derived from igneous rocks
- Soils formed from marine sediments
- 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 borate fertilizers in rice

U.S. Borax offers several products to prevent and cure boron deficiency in rice:

- *Granubor*®: Ideal for dry blends that are applied broadcast before transplanting
- *Fertibor*®: Works best in fertilizer suspensions for preplant broadcasts, side-dressing, or band sprayed over the pre-emergent seed row
- *Solubor*®: 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.

GRANUBOR®

15.0% B
7 kg product required for 1 kg B
2.8 mm particle size

FERTIBOR®

15.0% B
6.7 kg product required for 1 kg B
Crystalline

SOLUBOR®

20.5% B
4.9 kg product required for 1 kg B
Powder

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. The recommended concentration of the foliar spray solution is 10 g of *Solubor* in 15 litre of water. Split the *Solubor* foliar spray into 3-4 applications along with the insecticidal or fungicidal spraying rounds after transplanting, and before and after the flowering stages. Foliar spray of *Solubor* can also be used as an alternative source of boron for rice during 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.

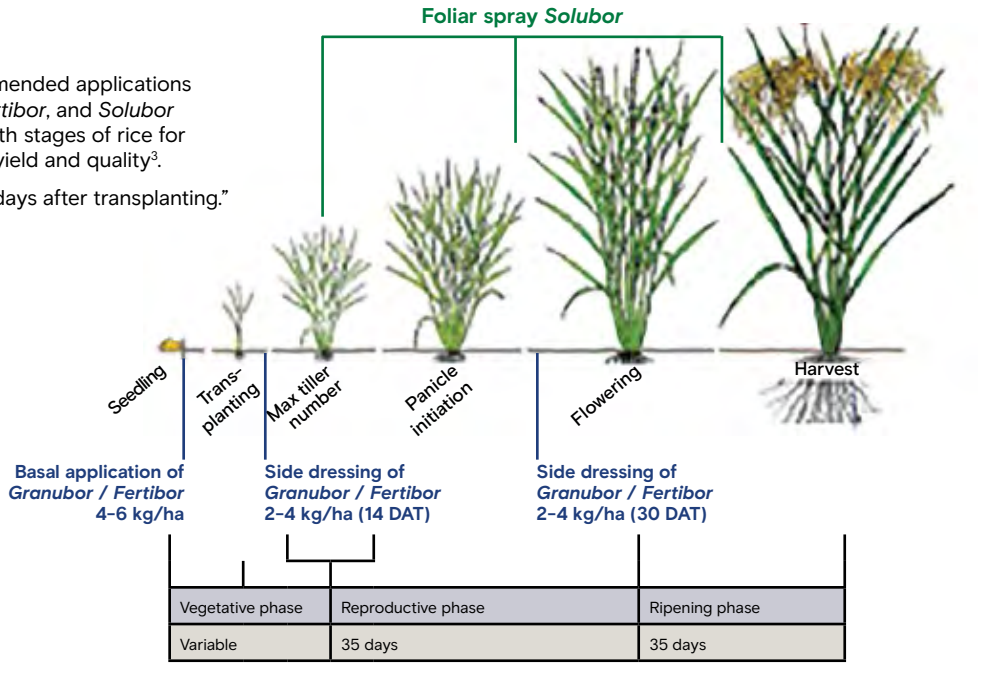


Figure 1: Recommended applications of *Granubor*, *Fertibor*, and *Solubor* at different growth stages of rice for increased grain yield and quality[3].

DAT stands for "days after transplanting."

Field studies demonstrate increased rice yield and quality with U.S. Borax fertilizers

Compared with other mineral borate fertilizers, U.S. Borax 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 by the China National Rice Research Institute in Zhejiang, China, to study the performance of our fertilizers in rice growth and production. 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 broadcast 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 the flowering stage (Figure 2b).

Figure 2: Pictures from field trial 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

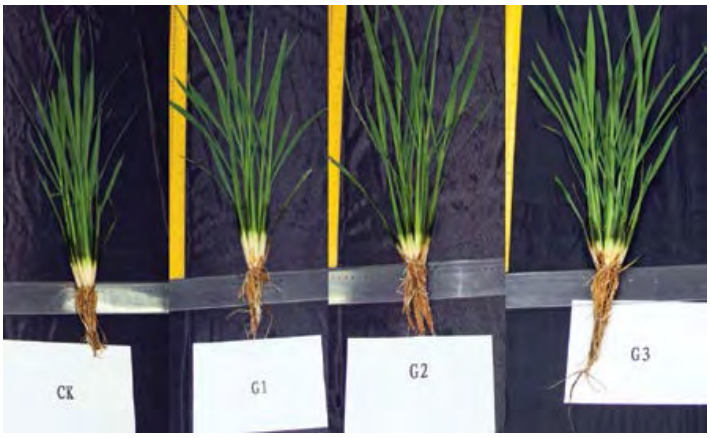
Figure 3 shows some key results from the field trial. Due to the applications of *Granubor* and/or *Solubor*, remarkable rice grain yield increase was achieved.

Particularly, with *Granubor* applied at 11.25 kg/ha, the grain yield was significantly increased by 7.9% over the control. The substantial increase in yield was primarily the consequence of enhancement in the numbers of tillers and effective panicles, as shown in Figure 3.

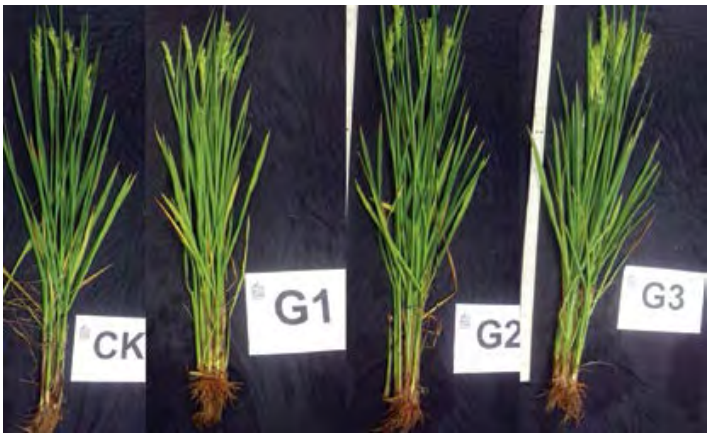
Considering the yield increase alone, the economics of *Granubor* and *Solubor* in rice production is very attractive. For example, with a combined application of *Granubor* at 3.75 kg/ha and *Solubor* at 1.8 kg/ha, a significant yield increase of 8.5% was realised, leading to a value-cost ratio of 7.2.

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 (the proportion of chalky rice grain in the total grain) and chalkiness degree (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 the milling process.

Figure 3: Key results from the field study conducted in China demonstrating the benefits of *Granubor* and *Solubor* for increased rice grain yield and quality

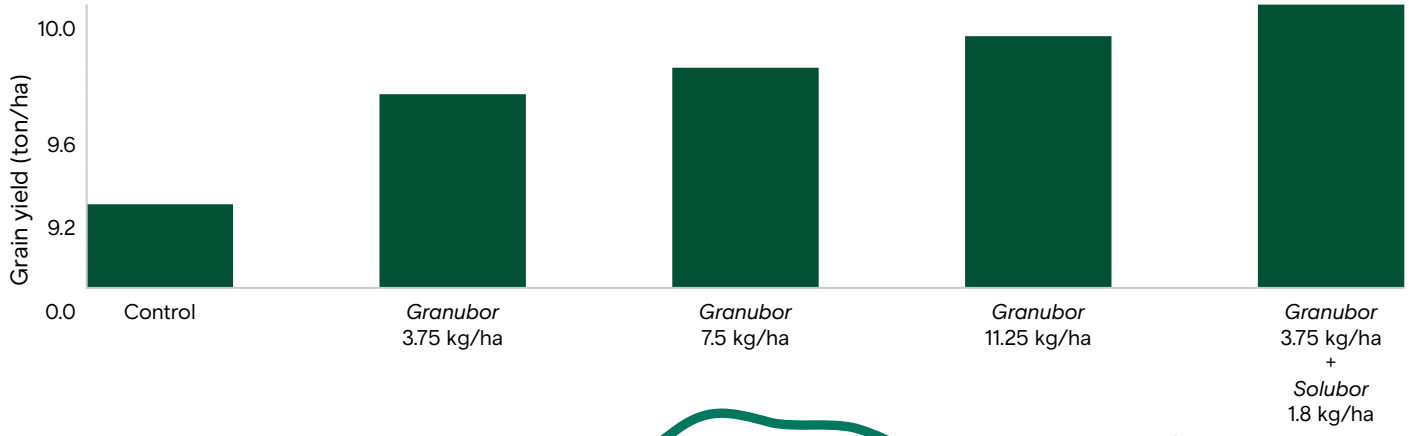


A. Increase in maximum tiller numbers in rice due to the application of *Granubor*



B. Increase in effective panicle number due to the application of *Granubor*

C. Grain yield increase due to the applications of *Granubor* and/or *Solubor*
G1, G2, and G3 (Figure 3b) denote the applications of *Granubor* at 3.75 kg/ha, 7.5 kg/ha, and 11.25 kg/ha



Acknowledgements

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References

[1]Salisbury F. 1992. Plant Physiology. Belmont (CA): Wadsworth.

[2]Dobermann A and Fairhurst TH. 2000. Rice: Nutrient Disorders & Nutrient Management. Handbook Series, Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC), and International Rice Research Institute, Philippine.

[3]Fairhurst TH, Witt C, Buresh RJ, and Dobermann A. 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 650 customers with more than 1,800 delivery locations globally. We supply around 30% of the world's need for refined borates from our worldclass mine in Boron, California, about 100 miles northeast of Los Angeles.

Our local agriculture experts understand the uses and benefits of boron on crops. In addition to a global sales team, we have a number of agronomists on staff to help fertilizer distributors maximize the benefits of borates in agriculture applications. Our ag team can answer individual growers' questions and concerns about their particular crop.

High quality, high reliability, high performance borate products. It's what we're known for.