Pilot Studies on Rice Yield Enhancement with Foliar Application of SBAJA in Sungai Besar, Selangor, Malaysia

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Abstract: Fertilizer application and inherent soil fertility are known to affect rice yields. We conducted large scale 12 ha multi-locations trial in the main- and off-seasons of 2007 through 2009 in Sungai Besar, Selangor's North West Project, Malaysia to assess the enhancing effect of SBAJA™ (formerly known as BIPOMIX™) on the growth and yields of rice (*Oryza sativa* L. var. MR 220). The clonal growth of SBAJA™ -treated rice crop based on plant height and tiller numbers plant^{-1}, albeit temporal inconsistencies, did not register any significant difference from each other at $p<0.05$, save for those in the control plots at 45, 75 DAT, and at harvest with measurably lower tiller numbers plant^{-1}. The mean panicle length plant^{-1} and mean number of panicles m^{-2} were significantly ($p<0.05$) longer and higher, respectively in plots treated with SBAJA™ *vis-à-vis* the control. While no significant differences were recorded in the 1000 grain weight, the percentage of filled grains panicle^{-1} and the number of grains panicle^{-1} were higher among rice plants in plots receiving the SBAJA™ treatments. Invariably, the Crop Cutting Tests (CCT) in plots subjected to foliar applications of SBAJA™ registered measurable increase in rice yields from 15 to 29% *vis-à-vis* the equivalent foliar-applied fertilizer subsidy from the government, and the conventional NPK fertilizer applications of 100:30:20 (here served as the control), respectively. The SBAJA™ treated plots registered a mean yield of 9.66 tons ha^{-1} compared with 7.49 tons ha^{-1} in the control plots. The parallel average yield from the equivalent foliar-applied fertilizer subsidy from the government was 8.38 tons ha^{-1}. In monetary terms, a yield increase of 1 ton ha^{-1} is translated as an extra net profit of RM 1,000 ha^{-1} season^{-1}. With the application of SBAJA™ a farmer would boost his gross returns by a minimal extra of *ca*. RM 2,000 ha^{-1} season^{-1} from an extra investment of *ca*. RM200 ha^{-1} season^{-1} compared with the control.

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1. Introduction

Rice is the staple food for more than half of the world's population. The crop influences the livelihood and economies of several billion people, and for hundreds of millions it is the only thing between them and starvation (IRRI, 2006). For 700 million Asians surviving on incomes of less than one dollar per day rice can account for as much as 70% of their daily calories and 40 percent of their income (IRRI, 2006 and 2008). In 2003, approximately 151 million ha were cultivated worldwide, of which Asia accounted for some 138 million ha, constituting 90 percent of global rice production (Bambaradeniya and Amerasinghe, 2003). It is important to increase the yield per hectare of rice by applying modern agricultural techniques; using hybrid seeds, irrigation, weed control, insecticides and pesticides, as well as fertilization practices (Dobermann et al., 2004).

Crop plants grow almost entirely by photosynthesis which plays a central role in biomass production. Indeed it is well documented in the literature that a higher intensity of leaf photosynthetic activity will contribute to an increased growth and yield in most major crops (Zelitch, 1982; Evans, 1993, Cassman, 1994; Ying et al., 1998; Peng et al., 2002). The yield of a crop is a function of biomass harvest index (HI), and to achieve high grain yield a balanced growth at the different growth stages must be achieved. The limitations to biomass production and crop yield are determined by the light capturing efficiency of the chlorophyll molecules in the leaves of the plant as well as the essential micro- and macro-elements needed for its general well-being and healthy growth. Maintaining green leaf area for a longer duration, particularly after anthesis when there is usually a rapid decline in leaf area index, is an important means of increasing total crop photosynthesis and hence biomass production and yield. Indeed it has been shown that an increased in photosynthetic activity has contributed to increased yield in most major crops (Zelitch, 1982; Peng et al., 1995; Peng 2000; Yang and Lee, 2001). A distinguished group of scientists, representing the diverse areas of photosynthetic research have anonymously agreed that 'redesigning rice photosynthesis to increase yield' will be the way to go in the future because genetic gains in yield are becoming harder to achieve (Peng, 2000).

A foliar spray technique was chosen for this trial because it can be designed to meet the crop's specific needs. It has long been established that plant leaves and stems are capable of absorbing micro- and macronutrients through a process called foliar feeding. Foliar feeding has been reported to stimulate plant roots to become more efficient in the uptake of all nutrient requirements. Furthermore, it is an economical way of supplementing the plant's nutrients when they are in short supply or unavailable from the soils and it has been shown that the efficiency of foliar application is three - five folds greater than soil-applied fertilizers, and can thus significantly reduce the amount of fertilizer usage. In many cases aerial spray of nutrients is preferred, and this gives quicker and better results than the soil application (Jamal et al., 2006). Recently, foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil remains the basic method of feeding the majority of the crop plants. Fang et al. (2008) reported the effects of a foliar application of zinc, selenium and iron fertilizers on nutrient concentration and yield of rice grain. In this study we have taken a physiological approach to yield improvement, specifically targeting the leaves to boost chlorophyll content and photosynthetic activity which are one of the key constraints currently limiting yields. We have developed a yet-to-be-patented propriety tentatively known as SBAJA™, a growth and yield enhancer for rice in the form of liquid foliar spray, comprising of an organic blend of emulsified, triacontanol, plant extracts, and micro-molar concentrations of the macro- and micronutrients required, in an aqueous solution including natural chelating agents, humic acid, fulvic acid, and a quality spreader/sticker synergist. Triacontanol [CH_3 $(CH_2)_{28}$ CH_2OH] is a straight chain fatty alcohol of 30 carbon atoms and exist as constituent of cuticular waxes and and beeswax. Triacontanol has recently been recognized as a potent enhancer of photosynthesis and as a plant growth promoter and regulator (Chen et al., 2002). It has great stimulatory effect on several enzyme activities in various plant growth processes and photosynthesis leading to enhancement of plant biomass growth and crop yield (Ries et al., 1977; Rice and Wert, 1982; Ries, 1985; Ivanov and Angelov, 1997).

In light of the recent government policy to increase the self-sufficiency level (SSL) in rice, currently only at the 70% level, we conducted large scale multi-location trials in Sungai Besar, Selangor with the primary objective of demonstrating the yield enhancement capacity of foliar-applied fertilizer, SBAJA™ *vis-a-vis* the conventional NPK fertilizer applications of 100:30:20 (here served as the control) or the equivalent foliar-applied fertilizer subsidy from the government on rice (*Oryza sativa* L. var MR 220). Other growth parameters were also compared.

2. Materials and methods

Experimental site and treatment application

A large scale farmers' managed field trial was conducted in Sungai Besar, Selangor covering a total area of *ca*. 12 ha. The farmers seeded 150 kg ha^{-1} of rice var MR 220 in each of the main- and off-seasons of 2007 through 2009, with conventional crop care and fertilizer requirements of N:P:K at 100:30:20. Each 1.2 ha plots were divided into 4 sub-plots of 0.3 ha each. These plots were allocated with conventional fertilizer treatment (T1), the Vitagro® (T2), and SBAJA™ diluted with water at 1:300 (T3) and 1:400 (T4). As for T3 and T4, three foliar sprays were made at 25, 45 and 75 days after seeding (DAS).

Measurement of growth and yield parameters

The clonal growth data (plant height and tillers number m^{-2}) of the rice crop were recorded at 25, 45 and 75 DAS and at harvest, while the yield and yield components data (panicle number m^{-2}, panicle length, percentages of filled and unfilled grains, 1000 grains weight, grain yield m^{-2}) were recorded at harvest. The heights of ten plants at random were taken in each subplot. For the yield and yield components five one m^{-2} quadrates were placed at random but diagonally in each subplot where the crop cutting tests (CCT) were carried out. The CCT were also carried in other farmers' fields where similar SBAJA™ applications to the rice crop were made.

Measurement of chlorophyll content and net photosynthetic rate

A chlorophyll meter [SPAD-502, Soil and plant analysis development (SPAD), Minolta Camera Co. Osaka, Japan] was used for chlorophyll measurement on ten top fully expanded flag leaves per plot at 45 DAS and three SPAD readings (dimension less values, 650/940 nm wave lengths transmittance ratio) were taken around the midpoint of each leaf blade, 30 mm apart from one side of the midrib. Thirty SPAD readings were averaged to represent the mean SPAD readings of each plot. Photosynthetic rates were determined using Li-Cor Photosynthesis Meter at 25, 45, 75 and 85 days after treatment. Measurements were made immediately after treatment application at 9.00 am to 1.00 pm and forty leaves were selected from treated and control plots. Before measuring the photosynthetic parameter, the cuvette chamber conditions were set to provide photosynthetic photon flux density of 50, 100, 200, 250, 500, 750, 1000, 1250, 1500, 1750 and 2000 µmol m^{-2} s^{-1} and cuvette block temperature was maintained at 24°C, and the concentration of CO_2 was set at 350 µmol mol^{-1} with a flow rate of 500 mL s^{-1}.

Statistical analysis

The growth and yield data collated before being subjected to ANOVA and HSD tests to differentiate any significant difference between treatment means. As for the percentages filled- and unfilled grains in each panicle, the data were transformed into arsine values before the statistical tests were carried out.

3. Results and discussion

It has been reported that nutrient management practices determine the sustainability of the most intensively cropped systems (Flinn and DeDatta, 1984). They also stated that K^+ utilization to plants, through foliar application is well recognized and is being practiced in agriculturally advanced countries.

The clonal growth of rice based on plant height and tiller numbers $plant^{-1}$, albeit temporal inconsistencies, did not register any significant difference from each other at $p < 0.05$, save for those in the control plots at 45, 75 days after treatment (DAT), and at harvest with measurably lower tiller numbers $plant^{-1}$ (Figs. 1& 2). Fig. 1 displays that the mean plant height of rice var. MR 220 at 25 DAT was significantly affected different treatments with the highest plant height recorded in T2 or T3 treatments followed by T1 treatment. The lowest plant height was in T4 treatment.

Similarly at 45 DAT, plant height also higher in T2 or T3 treatments followed by T4 treatment, whereas, T1 treatment produced the lowest plant height. The parallel figures of plant height at 75 DAT and at harvest did not register significant differences among the treatments and control. Similar results were reported by Khang (2011), with fulvic foliar fertilizer application which significantly increased the rice and radish plant heights The mean tiller numbers m^{-2} at 25 DAT were not statistically significant among the treatments. In contrast, mean tiller numbers m^{-2} were significantly different at 45, 75 DAT, and at harvest.

The highest tiller number was observed in T2 or T3 or T4 treatments, while, the lowest tiller number recorded in T1 treatment (Fig. 2). Our results were supported by the findings of Shayganya et al. (2011), who reported that foliar application of different nutrients increased tiller number of direct-seed rice plants.

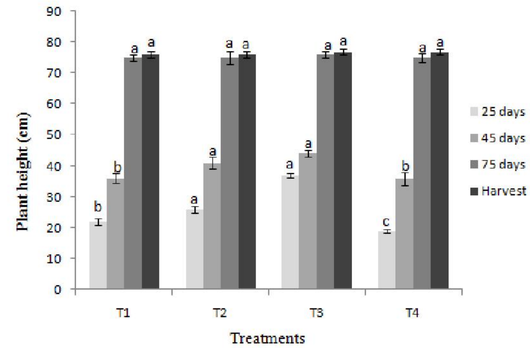

Fig. 1. Plant height of rice var. MR220 at 25, 45, 75 DAT and at harvest following treatments with SBAJA, Vitagrow and normal fertilizer (control). Values followed by the same lowercase letters are not significantly different at $p < 0.05$ (HSD tests). T1 = normal fertilizer, T2 = Vitagro; T3 = SBAJA 1:300) and T4 = SBAJA (1:400). Bars represent ± SD values.

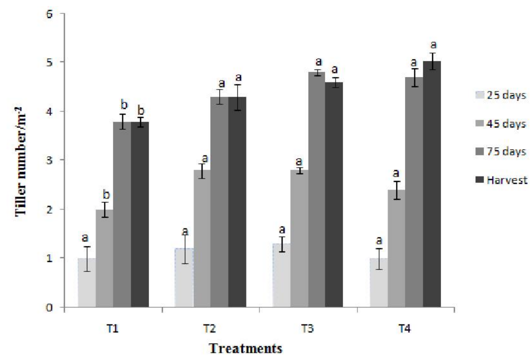

Fig. 2. Mean tiller number m^{-2} of rice var. MR220 at 25, 45, 75 DAT and at harvest following treatments with SBAJA, Vitagrow and normal fertilizer (control). Values followed by the same lowercase letters are not significantly different at $p < 0.05$ (HSD tests). T1 = normal fertilizer but no foliar enhancer; T2 = Vitagro (Jabatan Pertanian); T3 = SBAJA (1:300); T4 = SBAJA (1:400). Bars represent ± SD values.

It has been stated that leaf chlorophyll contents, are a good indicator of photosynthesis activity, mutations, stress and nutritional state, are of special significance to precision agriculture. Hansen and Schjoerring (2003) reported that leaf chlorophyll content altered the leaf transmittance and reflectance in the visible region. Leaf nitrogen is closely related leaf chlorophyll content, which had significant effects on photosynthetic rate and grain yield in rice (Peng et al., 1995).

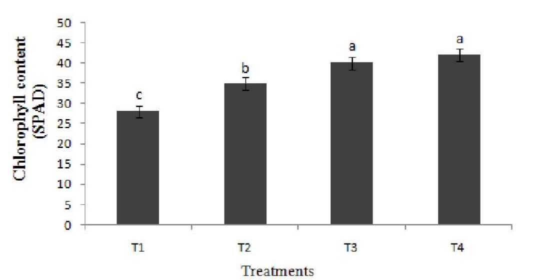

Fig. 3. Mean chlorophyll contents of rice var. MR220 by SPAD readings following treatments with SBAJA, Vitagrow and normal fertilizer (control). The readings were taken at grain filling stage. Values followed by the same lowercase letters are not significantly different at $p < 0.05$ (HSD tests). T1 = normal fertilizer but no foliar enhancer; T2 = Vitagro (Jabatan Pertanian); T3 = SBAJA (1:300); T4 = SBAJA (1:400). Bars represent ± SD values.

This study shows that leaf chlorophyll contents (SPAD meter readings) of rice were significantly affected by different treatments (Fig. 3). It can be seen that the highest chlorophyll content recorded in the T3 or T4 treatments, followed by T2 treatment, whilst, the lowest chlorophyll content was found in T1 treatment (normal fertilization without foliar application). Tejada and Gonzalez (2004) also reported similar positive effects of foliar fertilization on chlorophyll *a* and *b,* and carotenoids content of rice plant, which presumably favored photosynthesis.

Sultana et al. (2001) stated that foliar application of nutrient solutions partially alleviates the adverse effects of salinity on photosynthesis and photosynthesis-related parameters. Such applications were observed to increase yield and yield components through mitigating the nutrient demands of salt-stressed plants. The photosynthetic rates of leaves are dependent on their stomatal and non stomatal components (Bethke and Drew, 1992), and each of the components has a unique response to an environmental variable. Stomatal conductance is related to turgor pressure of cells. The turgor pressure is controlled by solute regulation within the guard cell protoplast and the relative water content of epidermal tissues. Accumulation of K^+ and other organic ion increased the osmotic activity, causing a reduction in water potential and an influx of water from the surrounding cells. In addition, phytohormones and Ca^{2+} play important signaling role on the regulation of stomata (Sage and Reid, 1994) and Mn^{2+} bind firmly to the lamellae of chloroplasts, possibly to the outer surface of thylakoid membranes, affecting the chloroplast structure and photosynthesis (Lidon and Teixerira, 2000). It would be another venue of research to assess the effects of SBAJA application on stomatal conductance, phytohormonal activity, and mineral ions uptake particularly, K^+, Ca^{2+} and Mn^{2+} in rice.

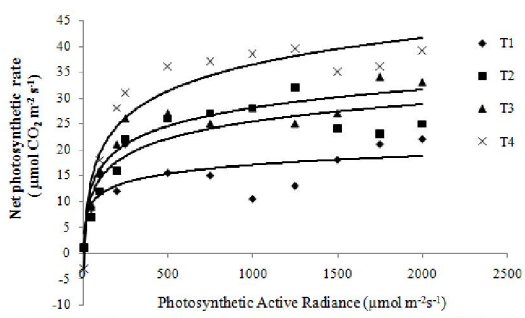

Fig. 4. Effect of SBAJA™ on photosynthetic rate of rice var MR 220 at different light irradiance as affected by different fertilizer application. Data were recorded at harvesting time. T1 = normal fertilizer but no foliar enhancer; T2 = Vitagro (Jabatan Pertanian); T3 = SBAJA (1:300); T4 = SBAJA (1:400). Bars represent ± SD values.

The optimal balance of these physico-chemical components in the cells is directly or indirectly related to photosynthesis. The minerals Na^+, Ca^{2+}, K^+ and Mn^{2+} are not only involved in the regulation of photosynthesis but have other cellular regulatory function, which are directly or indirectly involved in growth and physiology of the plant. In this study, it was observed that net photosynthetic rates of rice plant increased with foliar fertilization with SBAJA™ than the normal application. It was statistically significant different between the foliar applications and normal top dressing (Fig. 4). Foliar fertilization may be increased the level of macro- and micro-nutrients in the leaf, thus it enhanced the net photosynthetic rate of treated rice plant. Our results are in agreement with the findings of Sultana et al. (2001), who reported that foliar application nutrient solution increased the net photosynthesis of salt-stressed rice plants. Invariably, supplementation of Ca^{2+}, Mn^{2+} and K^+ through the foliar fertilization increased the rate of photosynthesis.

Soylu et al. (2005) and Kenbaev and Sade (2002) reported that foliar application of different micronutrients individually or in combination significantly increased in number of panicles m^{-2}. In this study, the results also showed that panicle numbers m^{-2} of rice var MR 220 were significantly affected by different foliar fertilizer treatments. The highest panicle number recorded in T4 treatments, followed by T3 and T2 treatments, while the lowest number of panicle was recorded in T1 treatment (Table 1).

Recently, it has been reported that a small amount of nutrients (nitrogen, potash or phosphate) applied by foliar spraying increases significantly the yield of crops (Asenjo et al., 2000; Haq and Mallarino, 2000). Many researchers have reported the positive response of K_2SO_4 foliar application to rice and wheat crops as well as higher plants (Ali et al., 2005).

Chopra and Chopra (2004) reported that nitrogen had significantly effects on yield attributes such as plant height, panicle plant^{-1} and 1000-seed weight with increasing levels of N up to 120 kg N ha^{-1} in rice. It has been reported that application of either 80 or 120 kg N ha^{-1} improved the entire yield attributes compared with control (Chopra and Chopra, 2000). Similarly in our study, the results showed that the mean panicle length plant^{-1} and mean number of panicles m^{-2} were significantly (p<0.05) longer and higher, respectively, in plots treated with SBAJA™ *vis-à-vis* the control. While no significant difference were recorded in terms of weight of 1000 grains and percentage of filled grains panicle^{-1} among treatment means, the number of grains panicle^{-1} was higher in plots receiving the SBAJA™ treatments (Table 1).

Table 1. Effects of SBAJA™ application on yield and yield components of rice (*Oryza sativa* L. var. MR 220).

Treatment	Panicle number /m^{-2}	Grain/ panicle	Filled grain (%)	1000 grain weight	Grain yield /m^{-2}
T1	340 ± 5.7 b	79 ± 2.0 c	84 ± 1.2 a	31.0 ± 0.3 a	780 ± 8.1 b
T2	360 ± 5.7 b	87 ± 1.2 b	86 ± 1.8 a	30.8 ± 0.2 b	850 ± 5.5 b
T3	400 ± 7.6 a	91 ± 1.5 b	87 ± 2.0 a	31.8 ± 0.2 a	940 ± 6.4 a
T4	420 ± 5.8 a	105 ± 1.2 a	90 ± 1.6 a	31.6 ± 0.3 a	900 ± 8.5 a

T1 = normal fertilizer but no foliar enhancer, T2 = Vitagro, T3 = SBAJA (1:300), T4 = SBAJA (1:400). Means within the same column followed by the same letters are not significantly different (HSD test at p=0.05)(N = 25).

Grain weight is the main yield component of rice and other cereal crops. In this study, it was observed that 1000 grain weight was also significantly affected by fertilizer treatments. Maximum 1000 grain weight was recorded in T1, T3 or T4 Treatment, whereas, minimum grain weight was found in T2 treatment. Different treatments produced significant variations among them selves. The results are in line with those of Soylu et al. (2005) and Guenis et al. (2003) who reported a significant increase in 1000 grain weight with the foliar application of micronutrients.

Fang et al. (2008) reported that foliar application of zinc, selenium and iron fertilizers increased grain yield. Similar results were explained as a positive effect of N topdressing on increasing panicle length, consequently increasing the total grain number per plant (Russo et al. 1991). The average grain number per panicle was highest in T4, or T3 treatment, while, the lowest grain number was recorded in T1 or T2 treatments. Our results showed that, different fertilizer treatments did not produced significant effect on average filled grain percentage of rice var MR 220 (Table 1). In case of grain yield per m^{-2}, maximum yield was recorded in T3 and T4 treatments, whereas, the minimum yield wasrecorded in T1 and T2 treatments. The differences among the treatments and control (T1) were statistically significant (Table 1). Lin and Zhu (2000) found that foliar spray of fertilizer at heading stage increased grain yield as a result of increasing grain number per panicle. They also reported that leaf senescence was inhibited and the leaf chlorophyll and photosynthesis were increased by foliar application of fertilizer at heading stage. Tejada and Gonzalez (2004) reported that the foliar fertilization with a byproduct rich in humic substances with macro- and micronutrients increased the concentration of micronutrients Fe, Cu, Zn and Mn, and macronutrients N, P, and K in leaves up taken by plants**.** Calderon (2000), suggested that these high K values in the plant contribute to the higher protein content of the grain. It has also been stated that K^+ promotes the incorporation of amino acid in grain protein of wheat (Mengel et al. 1981).

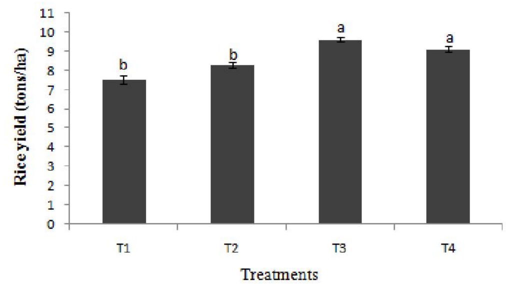

Fig. 5. Mean grain yield of rice var. MR220 in Sungai Besar, Selangor following treatments with SBAJA, Vitagrow and normal fertilizer (control). Values followed by the same lowercase letters are not significantly different at $p < 0.05$ (HSD tests). T1 = normal fertilizer but no foliar enhancer; T2 = Vitagro (Jabatan Pertanian); T3 = SBAJA (1:300); T4 = SBAJA (1:400). Bars represent ± SD values.

Invariably, the Crop Cutting Tests (CCT) in plots subjected to foliar applications of SBAJA™ registered measurable increase in rice yields from 15 to 29% *vis-à-vis* the equivalent foliar-applied fertilizer subsidy (Vitagrow) from the government, and the conventional NPK fertilizer applications of 100:30:20 (here served as the control), respectively (Figs. 5). The SBAJA™ plots yielded 9.66 tons ha^{-1} compared with 7.49 tons ha^{-1} in the control plots. The parallel average yield from the Vitagrow-treated plots was 8.38 tons ha^{-1}. In monetary terms, a yield increase of 1 ton ha^{-1} is translated as an extra net profit of RM 1,000 ha^{-1} season^{-1}. With the application of SBAJA™ a farmer would boost his net returns by an extra of *ca*. RM 2,000 ha^{-1} season^{-1} from an extra investment of < RM 200 ha^{-1} season^{-1} compared to the control. Tejada and Gonzalez (2003) reported that foliar application of organic fertilizer increased grain weight for the rice cultivar in the Guadalquivir Valley. They also reported that foliar fertilizer treatments affect the percentage of total filled and unfilled grains and gave a significant rice yield of about 6%. Based on our findings if 50% of our effective rice lands receive the SBAJA™ foliar fertilizer, we should get an extra of no less than 300,000 tons season^{-1} or no less than 600,000 tons year^{-1}, thereby boosting our rice SSL to almost 100%. This is of course based on the understanding that farmers do the normal crop care and standard agronomic practices as advised by the extension services, Ministry of Agriculture and Agro-based Industry of Malaysia.

4. Conclusion

The employment of SBAJA™ to augment normal fertilizer applications in rice fields by Malaysian farmers not only help to achieve national SSL target in rice to meet domestic market demand, thus reducing dependence on foreign supply and import bills, but also meet the national needs of food security in the ensuring decades. We are equally confident that should SBAJA™ be adopted by farmers in the ASEAN region and beyond, food security in terms of rice supply for the growing populace can be met.

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