

Performance of formulated nitro humic acid-based rice grain booster

(Prestasi penggalak bijirin padi berasaskan asid nitro humik)

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Keywords: rice grain booster, nitro humic acid, rice yield performance

Abstract

One of the ways to increase rice yield is to ensure high percentage of filled grains. This can be done by timely delivery of appropriate nutrients during grain filling stage. MARDI has developed a nitro humic acid (NHA) -based rice grain booster and has been under evaluation since 2007. The evaluation was carried out in three phases. The first phase involved conducting screening experiments using troughs under glasshouse conditions. The second phase was conducted under field conditions in MARDI Research Station, Seberang Perai. The final stage was carried out in farmers' fields to validate the booster recommended application based on results from trials conducted at the research station. The NHA-based formulation rice grain booster produced best results when it was sprayed twice during grain filling stage. The first spray was applied when the rice plant was at 10% flowering and the second spraying 10 days later. The rice grain booster supplements additional nutrients required rapidly when the crop is undergoing active grain filling. The recommended rate of grain booster application is 6 litres/ha. The results showed that grain booster application increased rice yield by 17 to 28% over two seasons in farmers' fields.

Introduction

Much effort has been spent on increasing rice yield covering the whole aspect of rice production starting from variety development, quality seed production, postharvest field management, water management, land preparation, cultural practices, nutrient management, crop care, weed control, mechanization, harvesting and postharvest technology. There are also many dedicated projects to enhance rice yield, the latest of which is the 10-tonne project initiated by MARDI. In addition, the government has at various times provided

a host of input subsidies. These include fertilizers (both inorganic and organic), soil conditioner, land preparations, farm infrastructure and yield incentives. Yet the national rice yield increased by a mere 0.7 t/ha/season from 3.8 to 4.5 t/ha/season from 2000 to 2005 (EPU 2006). The 9th Malaysia Plan has projected a dramatic increase in paddy yield to 6.5 t/ha/season by 2010.

The recent international market turmoil in the rice trade makes it more imperative to increase rice productivity quickly. The government indicated that actions will

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be taken urgently to raise national self-sufficiency level in rice from about 70% to 95%. One of the means by which rice yield can be increased rapidly is the timely delivery of sufficient essential nutrients during critical growth stages.

MARDI (2002) has recommended very high doses of fertilizers to be applied four times consisting of one basal application and three subsequent top dressings over the entire production cycle for high rice yield production. The basal fertilizer is applied at 15 days after sowing (DAS) the second and third fertilizer applications are at 30–35 DAS and 50–55 DAS respectively. The last top dressing consisting mainly of K and N is usually applied at 75 DAS at early heading stage (based on 105 days varieties such as MR 219). This application is still insufficient to fulfil the nutrient supply bottle neck during rapid grain filling stage.

In high yielding rice, greater quantity of photosynthates and N are required for grain filling and only about 10–30% of N is absorbed via roots while the bulk is remobilized from vegetative organs (Mae and Shoji 1984). However, such remobilization of N from the senescing leaf triggers a decrease in potential photosynthetic activities. Obviously, preventing a slowdown in leaf senescence would be a logical approach to obtain high yield.

Top dressing of N at heading time is currently practised to prevent rapid decline in leaf N and photosynthesis. The effect on yield on such top dressing of N is limited to about 10% increase (Wada et al. 1986). It appears that deficient in source capacity rather than sink capacity in terms of number of panicles and spikelets is the main constraint in achieving high paddy yield (Kropff et al. 1994; Mae 2004). Starch begins to accumulate quickly immediately after anthesis and a majority of such accumulation is largely completed in 14 days. Due to the rapidness of grain filling, nutrient resources are not available fast enough via root absorption and

remobilization from other parts of the plant at the rate required for achieving high filled grain percentage.

Typically, recent MARDI introduced paddy varieties has a grain filling characteristic of 64–66% (MARDI 2000). If grain filling percentage can be increased to 70–75%, it would potentially translate into a yield increase of about 15–16%. In order to exploit this window of opportunity, a grain filling booster formulation using nitro humic acid as nutrient carrier was tested to enhance rice yield. Nitro humic acid is derived from coal and is abundant in East Malaysia. A tiller improvement booster NHA-based formulation was also evaluated. The nutrient enriched nitro humic acid (NHA) with similar chemical characteristics as humic acid when applied to the leaf will be quickly absorbed and deliver the necessary nutrients to reduce photosynthetic bottle neck which limits the full realization of yield potential.

Materials and methods

Site description

The project was carried out in MARDI Research Station, Seberang Perai in the northern part of Peninsular Malaysia from the year 2006 to 2008. Rice has been planted in the area for the past 18 years. Temperatures range from 32 °C during the day to 22 °C during the night. Rainfall is common throughout the year averaging 2,400 mm per annum. The first wet season occurs from October to November and the second from April to May. The driest months are from January to February and again from June to July. The main planting season is from October to January and the off-season falls on April to August. The main textural class of the soil is sandy clay loam with sand, silt and clay content at 55, 8 and 37% respectively.

Screening glasshouse trials

The project was carried in three phases. The first phase involved conducting an experiment using troughs (dimension 38 cm wide x 58 cm long and soil depth

of 12 cm) under glasshouse condition. A total of 11 treatments using randomized complete block design (RCBD) with three replicates were employed. NHA-based tiller booster was sprayed at 31 DAS during active tillering and grain booster at 75 DAS during grain filling. The experimental design and treatments were meant to screen the effectiveness of different nitro humic acid-based fertilizers in improving rice yield. The treatments were:

- T0 : Control – Fertilizer rate of N:P₂O₅:K₂O = 160:90:175
- T1 : T0 fertilizer rate with 100% N source from humic acid coated urea
- T2 : T0 fertilizer rate with two N sources from 50% nitro humic acid (NHA) coated urea + 50% urea
- T3 : T0 fertilizer rate with two N sources from 75% NHA nitro humic acid coated urea + 25% urea
- T4 : T0 fertilizer rate with 100% N from NHA coated urea only
- T5 : T0 fertilizer rate + NHA-based tiller booster (4 litres/ha) at 31 DAS
- T6 : T0 fertilizer rate + NHA-based tiller booster (6 litres/ha) at 31 DAS
- T7 : T0 fertilizer rate + NHA-based tiller booster (8 litres/ha) at 31 DAS
- T8 : T0 fertilizer rate + NHA-based grain filling booster (4 litres/ha) at 75 DAS
- T9 : T0 fertilizer rate + NHA-based grain filling booster (6 litres/ha) at 75 DAS
- T10: T0 fertilizer rate + NHA-based grain filling booster (8 litres/ha) at 75 DAS

The performance parameters taken included crop yield, plant height, panicle length, tiller number, dry matter above ground, filled-grain and empty-grain weights.

Open field trials in MARDI Research Station

The second phase involved field trials to validate findings from the screening glasshouse experiment. Field trials were conducted over two seasons from 2007 to 2008 using split plot design with six

replicates. The treatment plot size was 14.0 m x 8.6 m. Similar data as those for the glasshouse experiment were taken to evaluate treatment effects. For grain yield monitoring, total grain weight from crop cutting test (CCT) plot of 1 m x 1 m was obtained. The harvested grains were dried, winnowed and weighed, then converted to per unit area crop yield based on 14% grain moisture content. For yield component parameters, two samples (25 cm x 25 cm quadrant) were taken from each plot. Dry matter above ground comprises the whole vegetative part of crop above soil surface except grains. The harvested vegetative components were oven dried at 60 °C for 48 h and then weighed. The treatments were:

Main plots

- M1 : Control, fertilizer rate of N:P₂O₅:K₂O = 160:90:175
- M2 : 80% of control fertilizer rate (N:P₂O₅:K₂O = 128:72:140)
- M3 : 70% of control fertilizer rate (N:P₂O₅:K₂O = 112:63:122.5)

Subplots

- T0 : Control (N: P₂O₅: K₂O = 160:90:175)
- T1 : T0 + tiller booster at 45 DAS at 6 litres/ha
- T2 : T0 + grain filling booster (N:P₂O₅:K₂O = 3:1:11 + TE + NHA) at 85 DAS at 6 litres/ha
- T3 : T1 + T2

Two field trials were conducted in MARDI research station, Seberang Perai to test some of the observations found in the glasshouse trial. The application timing of NHA tiller booster was changed to 45 DAS and NHA grain booster changed to 85 DAS because the crop has not reached the active tillering and grain filling stage respectively in the earlier trial from the pre-determined date. The first field trial was conducted in the main season (MS) 06/07 and the second season was conducted in MS 07/08.

Farmers' field trials

The last phase of the project involved conducting field trials over two seasons (main season 07/08 and off-season 2008) on farmers' plots. Results obtained from the second phase experiment were used as input to the farmers' trials. This is to further confirm the dosage and timing of the NHA grain booster application. Three farmer's fields were chosen from Pinang Tunggal, Seberang Perai Utara areas for the two trials. A total of nine treatment plots were identified randomly in each of the farmer field which made up of three treatments and three replicates based on randomized complete block design. Dimensions of each of these treatment plots were 5 m x 5 m and only 1 m x 1 m area would be harvested for yield performance analysis. Recorded parameters included crop yield and dry matter above ground. The output from these experiments would represent the actual situation in farmers' field using NHA-based grain filling booster in enhancing paddy yield. The treatments were:

T0 : Control under farmer management practices

T1 : Control + grain filling booster at 10% flowering at 6 litres/ha

T2 : Control + grain filling booster at 10% flowering followed by second application 10 days later at 6 litres/ha

Results and discussion**Screening glasshouse trials**

The effects of different types and rates of fertilizers on paddy yield components under glasshouse condition were not significantly different (*Table 1*). Filled grain data showed that there were about 20–25% increases relative to control on the use of NHA coated urea (T2, T3 and T4). Tiller booster sprays did indicate large percentage of increases (almost 30%) in tiller number (T5 to T7) but was not reflected in grain yield. This could be due to the small number in actual tillers and the increase in tiller numbers was not sensitive to show significant effect. The increases in tiller number were also reflected in higher dry matter weight above ground (T7).

Applying grain booster at 75 DAS was not the optimal time as the crop was not at grain filling stage. It will be more appropriate to apply grain booster based on actual physiological age rather than on a predetermined chronological date. The yield increased in response to increasing grain filling booster dosage although not significant, yet it indicated the appropriate dosage to be applied in subsequent trials. Based on the filled grain weight and filled grain number, treatment (T9) using 6 litres/ha grain booster showed promising result and more economical among the grain booster

Table 1. Effects of different types and rates of fertilizer on rice crop performance at maturity

Treatment	Plant height (cm)	Panicle number	Panicle length (cm)	Filled grain weight (g)	Filled grain number	% filled grain
T0	91.9	3.3	19.9	10.4	408.7	32
T1	86.3	3.0	20.6	5.3	206.0	20
T2	93.8	3.8	20.0	15.0	493.7	41
T3	91.9	3.4	18.7	12.3	498.0	46
T4	92.5	4.2	18.8	10.4	475.0	37
T5	91.0	4.0	19.5	9.7	398.0	34
T6	91.1	4.2	17.4	4.4	191.3	23
T7	90.7	4.2	18.6	13.8	553.0	47
T8	87.8	4.2	18.3	5.1	206.3	21
T9	88.4	3.8	19.7	8.1	342.3	29
T10	91.7	3.8	19.5	9.2	380.3	36
CV	5.5	11.1	5.2	10.5	8.7	12.3
ANOVA 5%	ns	ns	ns	ns	ns	ns

treatments. The increase in tiller number upon tiller booster treatment would also be evaluated in field trial.

Yield trials in MARDI Research Station

Analysis of variance showed that the effect of foliar booster fertilizer on grain yield was significantly higher. On the other hand, no significant basal fertilizer and interaction (basal fertilizer and foliar booster) effects were obtained.

From the trials conducted in the two main seasons as mentioned, the results showed that the yields obtained from M1, M2 and M3 with different levels of fertilizer application were not significantly different from each other (*Table 2*). However in the MS 06/07 trial, decreasing fertilizer rate tends to reduce yield while the paddy yield in the second trial, MS 07/08 did not differ much with lower fertilizer rate. This may point to the possibility of reducing fertilizer rate by 20% (N:P₂O₅:K₂O = 128:72:140) without seriously affecting yield at about 5 t/ha which is the normal yield range obtained in Seberang Perai area.

The yield derived from treatments T1, T2 and T3 in the MS 06/07 trial which had grain booster sprayings were all in excess of 500 g/m² (*Table 2*). However, the lowest yield at 498 g/m² was obtained from treatment T0 that had no booster

application and only treatments T2 and T3 were significantly higher than treatment T0. Treatment T2 produced the highest yield (553 g/m²). Tiller booster treatment (T1) did increase yield but not significantly and the results obtained were consistent with the observation obtained during the screening trial for tiller booster treatment.

Yield responses derived from the second trial in the MS 07/08 season confirmed the results obtained in the preceding trial. No significant different effect was obtained from the different levels of fertilizer applications. The yields obtained from treatments T2 and T3 with grain booster during grain filling stage rather than pre-determined chronological age were significantly higher than treatment T0. This is because physiological processes during grain filling and ripening stage are rather rapid, 69–90% of carbon found in panicles at harvest came from photosynthates after heading and the flag leaf is mostly responsible for grain filling (Yoshida 1981). During this rapid grain filling stage, nutrient supply to the flag leaf may not be at a rate required for rapid starch accumulation. Foliar application of booster during this stage alleviates the natural nutrient supply bottle neck. This gave rise to grain yield increase upon treatment with grain booster.

Table 2. Yield performance from (basal fertilizer x foliar booster) interaction study at MARDI Seberang Perai

Basal fertilizer	Grain yield (t/ha)		Harvest index
	Main season 06/07	Main season 07/08	Main season 07/08
Main-plot mean effects			
M1 = Control, (N:P ₂ O ₅ :K ₂ O – 160:90:175)	5.75a	4.86a	0.40a
M2 = 80% of M1 fertilizer rate	5.03a	4.91a	0.39a
M3 = 70% of M1 fertilizer rate	5.15a	4.97a	0.41a
Subplot mean effects			
T0 = Control, without booster	4.98b	4.45b	0.39a
T1 = Tiller booster at 45 DAS 6 litres/ha	5.35ab	4.80ab	0.40a
T2 = Grain filling booster at 85 DAS (grain filling stage) at 6 litres/ha	5.53a	5.24a	0.41a
T3 = T1 + T2	5.38a	5.16a	0.41a

Means followed by a common letter are not significantly different at $p \leq 0.05$ level

Generally, plots with grain booster application at 85 DAS (T2) and plots with both tiller and grain booster applications (T3) yielded significantly more than control plots (T0). Application of only tiller booster did not boost the grain yield significantly.

Harvest Index (HI) did not show any significant difference between main treatments as well as between subtreatments (Table 2). Treatments T2 and T3 appeared slightly more superior to treatments T0 and T1. HI is less sensitive in response to nutrient treatment than grain yield. Sani (2007) also observed no significant response of HI upon nutrient treatments although paddy grain yield had responded positively.

Field trials on farmers' plots

While conducting field trials in the station, two similar field trials were also laid out on farmers' plots but they were started later in main season 07/08 and then continued to the second trial in off-season 08. The tiller booster treatment was dropped because of non-significant yield responses in the earlier trials. The application timing was changed from predetermined chronological date to physiological age. Determination of exact heading stage after sowing is difficult as it varies from seasonal effects and crop establishment methods. Thus, it is more proper to apply grain booster based on actual physiological age at 10% flowering. No additional intervention was imposed on farmers' field practices and the only difference was foliar spraying of NHA grain booster. The effects observed would therefore be solely attributed to the treatment. The results for the two seasons are shown in Table 3.

Effect of grain booster on yield Yield responses obtained from six trials on farmers' fields over two cropping seasons showed that treatments with grain booster spraying consistently performed better than the control. Even though every plots treated with grain booster outperformed the control, only treatment T2 with two spray

applications from three experimental sites (Pantai Perai 1, Permatang Berangan and Kg. Tok Soh) showed significantly higher yield. Although yield increases obtained in other sites (Permatang Berangan 1 and 2) upon two times booster treatment were not significant, yield improvement was substantial, close to 1 t/ha.

The results from the farmers' fields indicated that it required two grain booster sprays at 10 days apart to gain significant yield while the more controlled trial at MARDI station required only a one time spray to achieve significant yield increase. This could be due to more variations over field management and inputs in farmers' plots compared to more controlled situation in the station trials. It was very obvious especially when the field was not properly levelled. The depression areas usually resulted in delayed heading and grain filling compared to the surrounding crops.

When the combined overall mean yields from the two seasons were compared, it was obvious that the two time successive spray treatment (T2) showed significant higher yield for both seasons. The one time booster treatment (T1) did show significant yield increase for sites with yield at less than 4 t/ha. The two time spray regime was superior to one time spray mainly because rice flowering took place at about 10 day period. The first spray of nutrient booster took care of the early flowering plants while the second spray catered mostly for the late flowering plants. The nutrient booster helps to alleviate supply of nutrient during rapid grain filling stage. At 17 days after flowering, kernel weight was reported to reach 87.9% of potential grain weight (Ota 1998) indicating the speed of starch accumulation.

Effect of grain booster treatment on Harvest Index (HI) Booster treatment effect on HI was less consistent when compared to its effect on yield for both seasons. No significant effect on HI was observed for the 07/08 main season trials

Table 3. Paddy yield response to nitro humic acid-based grain booster on farmers' plots

Treatment	Main season 07/08			
	Yield (t/ha)			
	Pantai Perai -1	Pantai Perai -2	Permatang Berangan	Overall mean
T0	3.21b	3.59b	3.76b	3.52b
T1	3.75ab	4.09a	4.55ab	4.13a
T2	4.29a	3.78b (diseases)	5.45a	4.51a
Harvest Index				
T0	0.384a	0.382a	0.389a	0.384a
T1	0.416a	0.399a	0.416a	0.445a
T2	0.404a	0.372a	0.433a	0.411a
Treatment	Off-season 08			
	Yield (t/ha)			
	Permatang Berangan -1	Permatang Berangan -2	Kg. Tok Soh	Overall mean
T0	5.35a	5.81a	5.43b	5.53b
T1	6.78a	5.77a	5.53b	5.70b
T2	6.30a	6.73a	6.37a	6.47a
Harvest index				
T0	0.326b	0.357a	0.410a	0.365a
T1	0.377ab	0.349a	0.380a	0.369a
T2	0.372a	0.429a	0.378a	0.393a

Means in each column with the same letter are not significantly different at $p \leq 0.05$ using Tukey HSD test

T0: Control, without booster;

T1: Grain filling booster at 10% flowering at 6 litres/ha

T2: Grain filling booster at 10% flowering and 10 days later at 6 litres/ha

Table 4. Grain booster trial in farmers' fields at Mulong Lating, Kelantan

Season	Treatment	Average no. of grain (per panicle)	Filled grain % (per panicle)	1,000 grain weight (g)	Yield (t/ha)
Jul 2008	Control	88	65	29	5.4
	Grain booster	65	73	30	6.0
Oct 2009	Control	115	66	25	4.8
	Grain booster	132	72	25	5.7
Jan 2010	Control	113	52	25	6.2
	Grain booster	112	72	26	7.4

Control: without booster

Grain booster: Grain filling booster at 10% flowering and 10 days later at 6 litres/ha

although HI at booster treated plots were higher (Table 3). For the 08 off-season trial, only the Permatang Berangan-1 site showed significant effect. However, the overall mean showed that the booster treated plots had higher HI over the control. Generally, the trend showed that the plots receiving grain booster application had higher HI.

Effect of grain booster on filled grain percentage and grain weight Experiments were also conducted in farmers' fields to determine filled grain percentage. Filled grain percentage obtained from three trials on farmers' fields over three seasons in Mulong Lating, Kelantan showed that treatments with grain booster spraying

consistently outperformed the control (Table 4). The increase in filled grain percentage ranged from 6 to 20%. The average yield over three seasons increased from 5.5 to 6.4 t/ha, improvement of 16%. As explained earlier, improve in filled grain percentage was due to nutrient booster which helps to increase supply of nutrient during rapid grain filling stage. There were no differences when comparing the 1,000 grain weight. Grains chosen for 1,000 grain weight were all fully filled grain and they are more variety dependent than nutrient supply.

Conclusion

The proprietary rice grain booster can increase rice yield significantly ranging from 8 to 20% from MARDI Seberang Perai Station trials. Tests on farmers' fields showed overall yield increases of 17% and 28% respectively over two seasons. A two time booster treatment applications were recommended, the first spray to be applied when the crop is at 10% flowering followed by a second spray at 10 days later to ensure timely delivery of sufficient essential nutrients to the early and also the late pollinated flowers. The optimum dosage of the booster is 6 litres/ha. Tiller booster application did help increase paddy yield but not significantly.

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Abstrak

Satu daripada cara untuk meningkatkan hasil padi adalah dengan memastikan peratusan biji bernas adalah tinggi. Ini boleh dilakukan dengan memberi nutrien yang sesuai semasa peringkat buah berisi. MARDI telah membangunkan sejenis penggalak (booster) bijirin padi dan telah dikaji semenjak 2007. Kajian ini dilaksanakan dalam tiga fasa. Fasa pertama ialah percubaan saringan di dalam rumah kaca dengan petak mikro. Fasa kedua ialah percubaan dalam sawah di stesen penyelidikan MARDI Seberang Perai. Fasa terakhir dilakukan di petak petani untuk mengesah pengesyoran penggunaan penggalak berasaskan hasil percubaan di stesen. Penggalak bijirin padi NHA memberi hasil tertinggi apabila disemur dua kali semasa peringkat buah berisi. Semburan pertama dilakukan semasa peringkat 10% berbunga dan semburan kedua 10 hari kemudian. Penggalak bijirin padi memberi nutrien tambahan yang diperlukan dengan segera semasa peringkat buah berisi. Kadar penggalak bijirin padi yang disyorkan ialah 6 liter/ha. Hasil kajian menunjukkan penggunaan penggalak bijirin padi ini dapat meningkatkan hasil padi sebanyak 17 hingga 28% pada dua musim di sawah petani.