Nitrogen use efficiency in F1 hybrid, improved and local cultivars of rice (Oryza sativa L.) during different cropping seasons.

Cuong, Pham Van
Faculty of Agronomy, Hanoi University of Agriculture

Nguyen, Thi Huong
Faculty of Agronomy, Hanoi University of Agriculture

Hang, Duong Thi Thu
Faculty of Agronomy, Hanoi University of Agriculture

Hanh, Tang Thi
Faculty of Agronomy, Hanoi University of Agriculture

他

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NITROGEN USE EFFICIENCY IN F_1 HYBRID, IMPROVED AND LOCAL CULTIVARS OF RICE (*ORYZA SATIVA* L.) DURING DIFFERENT CROPPING SEASONS

Hiệu suất sử dụng N trong lúa lai, lúa cải tiến và lúa địa phương (*Oryza sativa* L.) ở các vụ trồng khác nhau

Pham Van Cuong[1], Nguyen Thi Huong[1], Duong Thi Thu Hang[1], Tang Thi Hanh[1], Takuya Araki[2], Toshihiro Mochizuki[2]

[1] *Faculty of Agronomy, Hanoi University of Agriculture, Vietnam*
[2] *Faculty of Agriculture, Kyushu University, Japan*

Corresponding author : *pvcuong@hua.edu.vn; +84- 912907621*

TÓM TẮT

Nghiên cứu này tiến hành nhằm xác định ảnh hưởng của liều lượng phân đạm ở các mức (0, 60, 90 và 120 kgN/ha) đến chất khô tích lũy và năng suất hạt của giống lúa lai (Bồi tạp Sơn thanh), lúa cải tiến (Khang dân 18) và giống lúa địa phương (Khẩu sửu) trong cả vụ xuân và vụ mùa. Khi tăng lượng N bón trong cả hai vụ, chất khô tích lũy và một số chỉ tiêu liên quan khác như số nhánh đẻ, chỉ số diện tích lá tăng nhiều hơn ở lúa lai so với lúa cải tiến và lúa địa phương ở giai đoạn đẻ nhánh hữu hiệu và giai đoạn trỗ. Ngược lại hàm lượng N trong lá tại giai đoạn trỗ tăng nhiều hơn ở lúa cải tiến và lúa địa phương so với ở lúa lai. Không có sự khác biệt ở mức ý nghĩa về chỉ số SPAD hay chỉ số độ dày lá ở tất cả các giống lúa trên các nền N bón. Khi tăng lượng đạm bón từ 90 lên 120N ở cả hai vụ trồng, năng suất hạt của lúa lai F1 tăng ở mức ý nghĩa trong khi năng suất không tăng ở lúa cải tiến và lúa địa phương. Ở tất cả các giống lúa, hiệu suất sử dụng đạm (NUE) trong vụ xuân đều cao hơn trong vụ mùa. Trong cả hai vụ trồng NUE (Kg thóc/kg N bón) ở lúa lai F1 đều cao hơn so với ở lúa cải tiến và lúa địa phương. Khi tăng lượng N bón từ 60 lên 120 N, NUE giảm ở lúa cải tiến (21,20 - 16,62 trong vụ xuân và 7,97 - 2,39 trong vụ mùa) và ở lúa địa phương (30,35 - 10,99 trong vụ xuân và 6,86 - 2,42 trong vụ mùa), trong khi đó lúa lai F1 vẫn duy trì được NUE cao (31,36 - 27,89 trong vụ xuân và 17,61- 19,68 trong vụ mùa. NUE cao ở lúa lai ở cả hai vụ là do cao hơn về số bông trên khóm và số hạt trên bông. Như vậy sử dụng lúa lai sẽ góp phần vào việc phát triển nông nghiệp bền vững cũng như bảo vệ môi trường khi giảm lượng phân bón.

Từ khóa: Chất khô tích lũy, hàm lượng N, hiệu suất sử dụng N, lúa lai, năng suất hạt, .

SUMMARY

This study was conducted in order to determine the affects of N fertilizer levels (0, 60, 90 and 120 kg N per ha) on dry matter accumulation (DM) and grain yield in F_1 hybrid rice cultivar (BoiTapSonThanh), improved cultivar (Khangdan 18) and local cultivar (KhauSuu) in both Spring and Autumn cropping seasons. As increasing amount of N fertilizer was applied in both cropping seasons, DM and other related characters such as number of tiller and leaf area index (LAI) were much higher in the F_1 hybrid than in those of the improved and local cultivars at most active tillering and flowering stages. In contrast, leaf N content were much higher in the improved and local cultivar than that in the F_1 hybrid as N levels were increased at the flowering stage in both cropping seasons. There were no significant differences in the SPAD reading or specific leaf area in all rice cultivars under all N fertilizer levels. When N increased from 90 to 120N in both cropping seasons, grain yield significantly increased in the F_1 hybrid, whereas it was not found in improved or local cultivars. In all rice cultivars, nitrogen use efficiency (NUE) for the grain yield was higher in the Spring season than in the Autumn season. In both cropping seasons, NUE was higher in the F_1 hybrid than in other cultivars under all N levels. As N fertilizer increased from 60 to 120N, the NUE for grain yield was decreased in the improved cultivar (from 21.20 to 16.62 in Spring season and from 7.97 to 2.39 in Autumn season) and in local cultivar (from 30.35 to 10.99 in Spring season and from 6.86 to 2.42 in Autumn season), whereas it was maintained in the F_1 hybrids (31.36 - 27.89 in Spring and 17.61 - 19.68 in Autumn season). The higher levels of NUE found in the F_1 hybrid rice than in other cultivars in both cropping seasons was attributed to both the higher

number of panicles and spikelets per panicles. Thus, hybrid rice can contribute to sustainable and ecologically benificial agricultural practice in Vietnam using low-input cultivation.

Key words: Dry matter accumulation, grain yield, hybrid rice, leaf N content, nitrogen use efficiency.

1. INTRODUCTION

F_1 hybrid has been cultivated in larger areas in Vietnam. In our previous research heterosis for morphological and physiological characters of F1 hybrid over parents and inbred cultivars (Pham et al., 2003) has been demonstrated. However, most farmers used the same methods of nitrogen (N) fertilizer applications for F_1 hybrids and inbred rice cultivations. Conversely farmers applied vast amounts of N fertilizer during rice cultivation, which damages growth at later stages. Some examples of damage are lodging, low grain filling rate and reduction of grain yield. Also high N fertilizer application during the early growth stage is a cause of disease, insect infestation and environmental pollution. Heterosis for grain yield in F_1 hybrid rice was mainly due to the heterosis for dry matter accumulation (Virmani, 1994; Pham et al., 2004). Also, a large heterosis for photosynthesis was mediated by high leaf N content in F1 hybrids. NUE in rice plants was reported to be higher in subtropical than in tropical condition (Sinclair and Horie., 1989; Jing et al., 1998). Therefore, to determine the NUE of photosynthetic and agronomic characters in F1 hybrid, inbred and local cultivars is important to create a method for rice cultivation under low-input conditions.

2. MATERIALS AND METHODS

2.1. Materials

Three rice cultivars including 1 F1 hybrid rice (Boi Tap Son Thanh), 1 improved rice (Khang Dan 18) and 1 local (Khau Suu) were used in this experiment.

The experiment was conducted using 4 different levels of nitrogen fertilizer (0:60:90:120 kgN/ha at the same base of 90kg P_2O_5 and 90kg K_2O per ha. The experiment was laid out in a split – plot design with three replications. Seedlings of all the rice cultivars at 4-5 leaf stage were transplanted in the field in both Apring and Autumn, 2007.

2.2. Measurement

At the three growth stages (active tillering, flowering and dough-ripening stage) ten plants in each plot were randomly sampled for measuring several morphological characters. For example, the leaf area was measured with an automatic area meter (ANA, GA45, Japan) immediately after sampling. The whole-plant dry matter weight was measured after oven drying at 80°C to a consistent mass.

At the flowering stage, the SPAD value (an indicator of chlorophyll content) of two flag leaves of the sampled plants was measured using SPAD (Monrota 502, Japan). The leaf N content was then dried and analyzed using the Keldal method. The grain yield and yield components of ten randomly selected plant of cultivar were assessed. The number of spikelets and filled grains/panicle of three randomly selected panicles of each plant was determined.

2.3. Data analysis

Data was analyzed using the ANOVA method in the SAS ver. 8.1 system.

Nitrogen use efficiency (NUE) was calculated as a formula;

- NUE for chlorophyll content = SPAD/leaf N content

- NUE for grain yield = grain yield of N applied- grain yield of non-N/ kg N applied.

3. RESULTS

3.1. Affects of N fertilizer on LAI

Even though the N fertilizer LAI increased in all rice cultivars during the active tillering and flowering stages, the increased value was much higher in the hybrid (1.39-3.22 and 2.08-3.43 in Spring and Autumn, respectively) than in both of the improved (1.09-2.53; 2.03-2.67) and local cultivars (1.38-2.78; 1.97-2.67) (Table 1). As N was increased from 0 to 90, the LAI also increased in all rice cultivars in both the flowering and dough-ripening stage. However in spring, the levels of 90 N to 120 N, LAI significantly increased only in the F1 hybrid.

3.2. Affects of N fertilizer on Leaf N and SPAD

In both cropping seasons, the leaf N content value was increased in all cultivars with higher N fertilizer when it was applied at the flowering stage (Table 2).

Table 1. Affects of N fertilizer on LAI in rice cultivars at different growth stages in Spring and Autumn season

Cultivars	N fertilizer (kg N ha^{-1})	Active tillering stage		Flowering stage		Dough-ripen stage	
		Spring season	Autumn season	Spring season	Autumn season	Spring season	Autumn season
F1 hybrid	0	1.39	2.08	2.01	3.21	1.62	2.25
	60	2.55	2.88	3.43	4.15	2.74	2.71
	90	2.86	2.98	4.12	4.46	2.96	3.24
	120	3.22	3.43	4.68	4.89	3.53	2.96
	Average	*2.51*	*2.84*	*3.56*	*4.15*	*2.72*	*2.79*
Improved	0	1.09	2.03	2.11	2.61	2.04	2.66
	60	1.86	2.14	3.11	3.73	2.24	2.99
	90	2.28	2.36	3.48	3.97	3.02	2.33
	120	2.53	2.67	3.69	4.12	3.01	3.01
	Average	*1.94*	*2.3*	*3.59*	*3.61*	*2.58*	*2.75*
Local	0	1.38	1.97	1.64	2.60	2.02	3.09
	60	2.53	2.64	3.75	3.95	2.87	2.94
	90	2.74	2.58	3.53	4.43	2.72	3.39
	120	2.78	2.67	3.95	4.34	2.61	3.62
	Average	*2.35*	*2.47*	*3.21*	*3.93*	*2.58*	*3.26*
$LSD_{0.05}$ (N& cultivar)		0.43	0.49	0.51	0.74	0.54	0.79

In Spring season, the increase was much greater in both hybrid rice (22.50 - 25.65) and local rice (16.56 - 22.04) than in improved rice (20.34 - 21.95). The increase was the greatest in improved rice in Autumn. In both cropping seasons, there were no significant differences in the SPAD value of any cultivars (Table 2) despite fertilizer levels being increased from 60 to 120 N.

In general, as N levels were increased from 0 to 120kg/ha, the NUE for chlorophyll was decreased in all rice cultivars, the hybrid rice cultivar (1.71 - 1.59 in Spring season and 1.63 - 1.46 in Autumn season); improved cultivar (2.20 - 1.81 in Spring and 1.49 - 1.57 in Autumn); and improved rice cultivar (1.57 to 1.42 in 2.02 - 2.00 in Autumn season) (Table 2).

3.3. Affects of N fertilizer on Dry Matter Accumulation

At active tillering stage, dry matter accumulation (DM) in all of the rice cultivars were increased along with increasing N levels of 0 to 90N in both cropping seasons (Table 3). As higher N levels were applied (90-120N), the DM value was increased from 3.12 to 3.96 in hybrid rice. In contrast, it was decreased from 3.46 to 3.45 in improved cultivar and from 3.67 to 3.08 in local cultivar in Spring. However, in Autumn the DM value was decreased in both hybrid rice (6.65-6.01) and improved rice cultivars (6.50-4.49), but increased in local cultivar (4.98-5.37) (Table 3).

At the flowering stage, higher levels of N caused an increase of DM in all cultivars in both cropping seasons. However, as N levels were increased from 90-120N, a significant increase was only observed in hybrid rice (14.72 -16.24) in Spring and in local cultivars (14.91-16.84) in Autumn season.

At the dough-ripening stage, as N levels were increased from 90-120N, the DM accumulation was decreased in local cultivar (19.24-18.56 in Spring and 21.19-20.98 in Autumn seasons). Conversely, DM value was increased in improved rice cultivar in both seasons (19.18-21.52 in Spring and 18.28-20.50 in Autumn) (Table 3).

Table 2. NUE for chlorophyll in rice cultivars at flowering stage in Spring and Autumn season

Cultivars	N fertilizer (kg N ha^{-1})	Leaf N (mg/100)		SPAD Value		NUE for chlorophyll (SPAD/leaf N)	
		Spring Season	Autumn Season	Spring Season	Autumn Season	Spring Season	Autumn Season
F1 hybrid	0	22.50	23.62	35.2	38.53	1.71	1.63
	60	22.92	27.03	38.5	39.82	1.74	1.47
	90	25.00	26.90	38.2	40.24	1.61	1.49
	120	25.65	27.97	38.2	40.96	1.59	1.46
	Average	*24.02*	*26.38*	*37.5*	*39.94*	*1.66*	*1.51*
Improved	0	20.34	24.84	40.36	39.10	1.92	1.57
	60	20.25	27.38	41.73	40.95	2.02	1.50
	90	21.60	28.46	41.91	43.27	2.00	1.52
	120	21.95	29.24	43.28	41.50	1.89	1.42
	Average	*21.03*	*27.48*	*42.45*	41.33	*1.96*	*1.50*
Local	0	16.56	24.41	35.37	36.4	2.20	1.49
	60	20.86	27.06	37.24	37.6	1.80	1.39
	90	22.89	26.26	37.16	38.4	1.68	1.46
	120	22.04	27.17	37.18	39.9	1.81	1.47
	Average	*18.71*	*26.23*	*36.76*	38.1	*1.87*	*1.45*
$LSD_{0.05}$ (N& cultivar)		2.72	1.13	1.71	1.9	-	-

Table 3. Affects of N fertilizer on dry matter accumulation in rice cultivars at different growth stages (g plant^{-1}) in Spring and Autumn

Cultivars	N fertilizer (kg N ha$^{-1)}$	Active tillering stage		Flowering stage		Dough-ripening stage	
		Spring	Autumn	Spring	Autumn	Spring	Autumn
F1 hybrid	0	1.65	4.05	8.53	13.61	11.91	18.05
	60	3.02	5.31	11.95	15.67	17.77	18.70
	90	3.12	6.65	14.72	14.84	19.07	20.99
	120	3.96	6.01	16.23	15.15	21.36	18.98
	Average	*2.94*	*5.53*	*12.86*	*14.82*	*17.53*	*19.18*
Improved	0	1.55	3.38	8.37	9.67	12.83	17.14
	60	3.21	5.11	12.27	11.45	16.50	18.73
	90	3.46	6.50	13.54	11.10	19.18	18.28
	120	3.45	4.94	14.43	12.39	21.52	20.5
	Average	*2.92*	*4.98*	*12.15*	*11.65*	*17.51*	*18.66*
Local	0	1.63	3.74	7.92	9.74	12.66	18.42
	60	2.69	5.09	13.73	15.63	19.41	19.03
	90	3.67	4.98	14.08	14.91	19.24	21.19
	120	3.08	5.37	14.29	16.84	18.56	20.89
	Average	*2.77*	*4.8*	*12.5*	*14.28*	*17.47*	*19.88*
$LSD_{0.05}$ (N& cultivar)		0.52	0.58	1.48	1.42	1.64	1.51

Table 4. Affects of N fertilizer on yield components, grain yield and NUE of rice cultivars in Spring season

Cultivars	N fertilizer (kg N ha^{-1})	Number of panicle per m^2		Number of spikelets per panicle		Grain filling (%)		1000 –grain weight (g)		Grain yield (100 kg ha^{-1})		NUE (kg grain/kgN)	
		Spri.	Aut.	Spri.	Aut.	Spri.	Aut.	Spri.	Aut.	Spri.	Aut.	Spri.	Aut.
F1 hybrid	0	157.3	194.7	126.5	172.8	94.0	73.6	21.5	21.2	30.1	34.1	-	-
	60	248.0	224.0	137.1	201.6	93.0	63.1	20.8	21.0	49.8	44.8	31.3	17.6
	90	280.0	240.0	159.9	210.6	92.5	64.7	20.2	21.1	58.5	49.7	30.6	17.1
	120	312.0	237.3	163	224.3	91.7	65.6	20.0	20.7	64.5	57.7	27.9	19.7
	Average	*249.3*	*224.0*	*146.2*	*202.3*	*92.8*	*66.8*	*20.6*	*21.0*	*51.2*	*46.6*	*30.2*	*18.1*
Improved	0	141.3	176.0	159.2	201.5	94.4	84.9	19.8	18.6	32.3	38.3	-	-
	60	194.7	224.0	165.2	206.2	93.9	80.8	19.3	18.6	45.3	48.5	21.2	8.0
	90	224.0	198.7	152.7	207.0	95.2	78.9	19.2	19.1	49.0	49.4	18.3	10.0
	120	232.7	240.7	178	209.0	94.2	76.8	18.9	18.2	52.3	45.3	17.0	2.4
	Average	*198.2*	*209.8*	*163.5*	*205.9*	*94.4*	*80.4*	*19.3*	*18.6*	*45.0*	*45.4*	*18.8*	*6.8*
Local	0	152.0	189.3	157.6	201.9	91.7	81.5	20.9	20.2	35.2	41.3	-	-
	60	234.7	210.7	183.4	217.7	92.1	77.7	20.6	19.9	55.5	45.0	33.8	6.9
	90	236.7	229.3	179.8	210.2	90.4	77.3	20.5	19.6	51.6	47.5	18.2	7.2
	120	213.3	218.0	194.4	205.0	84.9	79.4	19.9	18.8	48.5	44.2	11.0	2.4
	Average	*209.2*	*211.8*	*178.8*	*208.7*	*89.8*	*79.0*	*20.5*	*19.6*	*47.7*	*45.1*	*21.0*	*5.5*
LSD $_{0.05}$	(N& cultivar)	29.2	11.0	24.5	27.2	2.7	6.7	0.5	1.3	5.9	6.1		

3.4. Affects of N fertilizer on grain yield and nitrogen use efficiency

As N levels were increased from 0 to 90N, the number of panicles significantly were increased in all rice cultivars in both cropping seasons as well (Table 4). In the case of higher N levels (120N), a significant increase was only observed in F_1 hybrid cultivar in Spring, which indicate that F_1 hybrid rice cultivar was required greater amounts of N for tillering in Spring season. Without N application, the number of panicles in all cultivars were higher in Spring than in Autumn seasons (Table 4).

Generally, the greater the amounts of N are applied the greater the decrease of filled grain rate in all cultivars for both cropping seasons. In particular, the increase was greater in hybrid rice during Autumn (73.6-65.6) when it was compared with Spring seasons (94.0-91.7) (Table 4).

As N levels were increased to 90N, grain yield also increased in hybrid rice cultivar. As N levels were increased to 120N, the grain yield became significantly higher in hybrid rice. Meanwhile, there was a tendency to decrease grain yield in improved rice in Spring and in local rice in both seasons. The increase in grain yield in hybrid rice was higher in Spring (30.1-64.5) than in Autumn season (34.1-57.7).

NUE for grain yield was higher in hybrid rice than in local and improved rice cultivars in both cropping seasons. As levels of N were increased, the NUE for grain yield significantly decreased in both improved and local rice in both seasons, while it was maintained in F_1 hybrid rice in Autumn season, even it was increased in Spring season.

3.5. Correlation between grain yield and related characters

A significant and positive correlation was found between grain yield and SPAD value in all rice cultivars under all N conditions at active tillering stage in Spring season (r = 0.53), whereas this correlation was observed at flowering stage in Autumn season (r = 0.59). At dough- ripen stage, the correlation was not significant in all rice cultivars when data computed together, however it was significant in F1 hybrid and improved cultivars in both Spring season (r = 0.85 and r = 0.78) and Autumn season (r = 0.99 and r = 0.92) when data computed separately (Fig. 1).

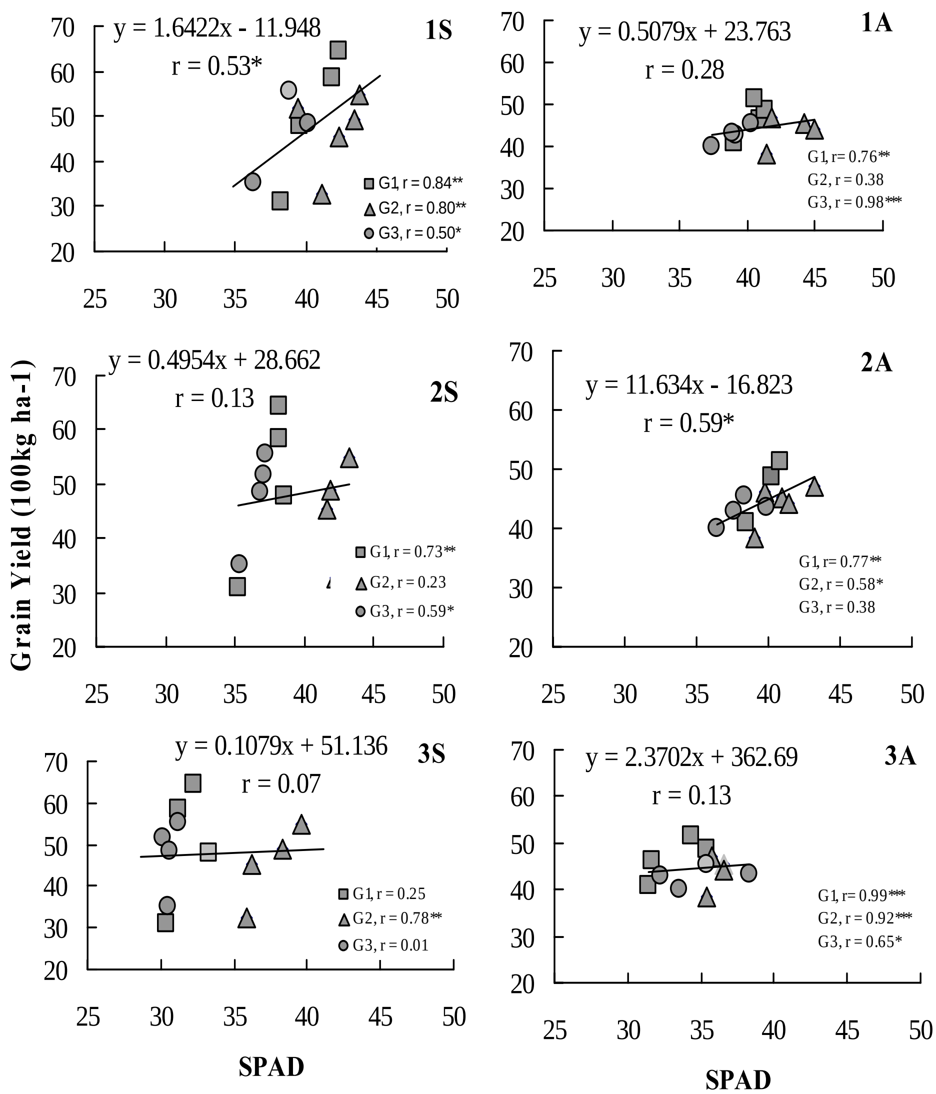

Fig 1. Correlation between Grain yield and SPAD value in Hybrid (G1-square), improved (G2-angle) and local rice (G3-round) at active tillering (1), floweing (2) and dough-ripen stage (3) in Spring (S) and Autumn season (A).

, ** and *: Significant at 0.5, 0.1 and 0.01 probality level.*

In all rice cultivars, grain yield was significantly and positively correlated with both LAI at active tillering stage and flowering stage in both Spring and Autumn seasons (Fig.2).

At dough-ripen stage, this correlation was obserbed only at Spring season, but not significant in Autumn season. A positive correlation was found between grain yield and dry matter accumulation in all rice cultivars at all growth stages, but the correlation was more strongly at active tillering stage (Fig.3).

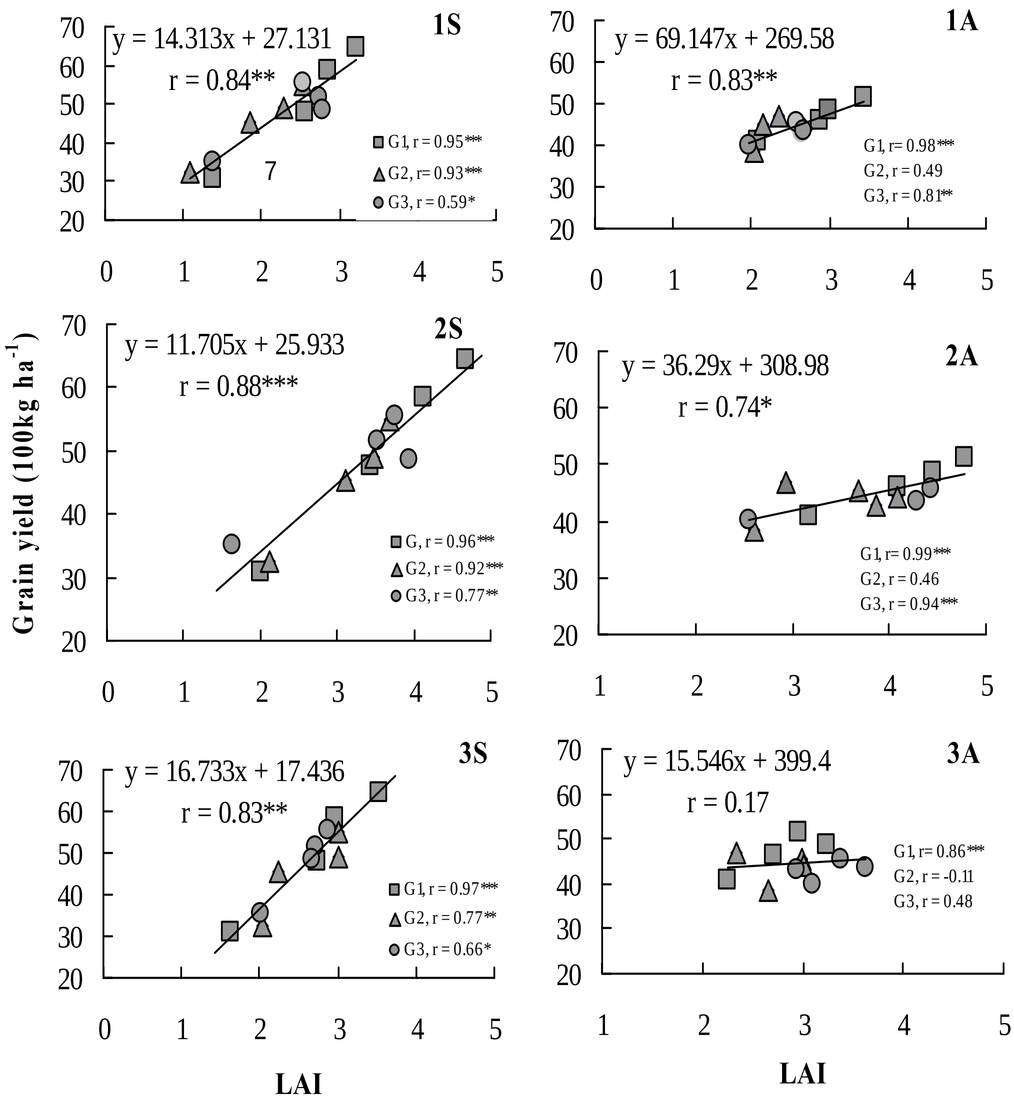

Fig 2. Correlation between Grain yield and LAI in Hybrid (G1-square), improved (G2-angle) and local rice (G3-round) at active tillering (1), floweing (2) and dough-ripen stage (3) in Spring (S) and Autumn season (A)

, ** and *: Significant at 0.5, 0.1 and 0.01 probality level*

Fig.3 showed that grain yield was positively correlated with the number of panicle per plant in both Spring (r = 0.85) and Autumn seasons (r = 0.78). Also, a positive correlation was observed between grain yield and the number of spikelets per panicle in all rice cultivars, however the correlation in F1 hybrid was more strongly than improved and local rice cultivars.

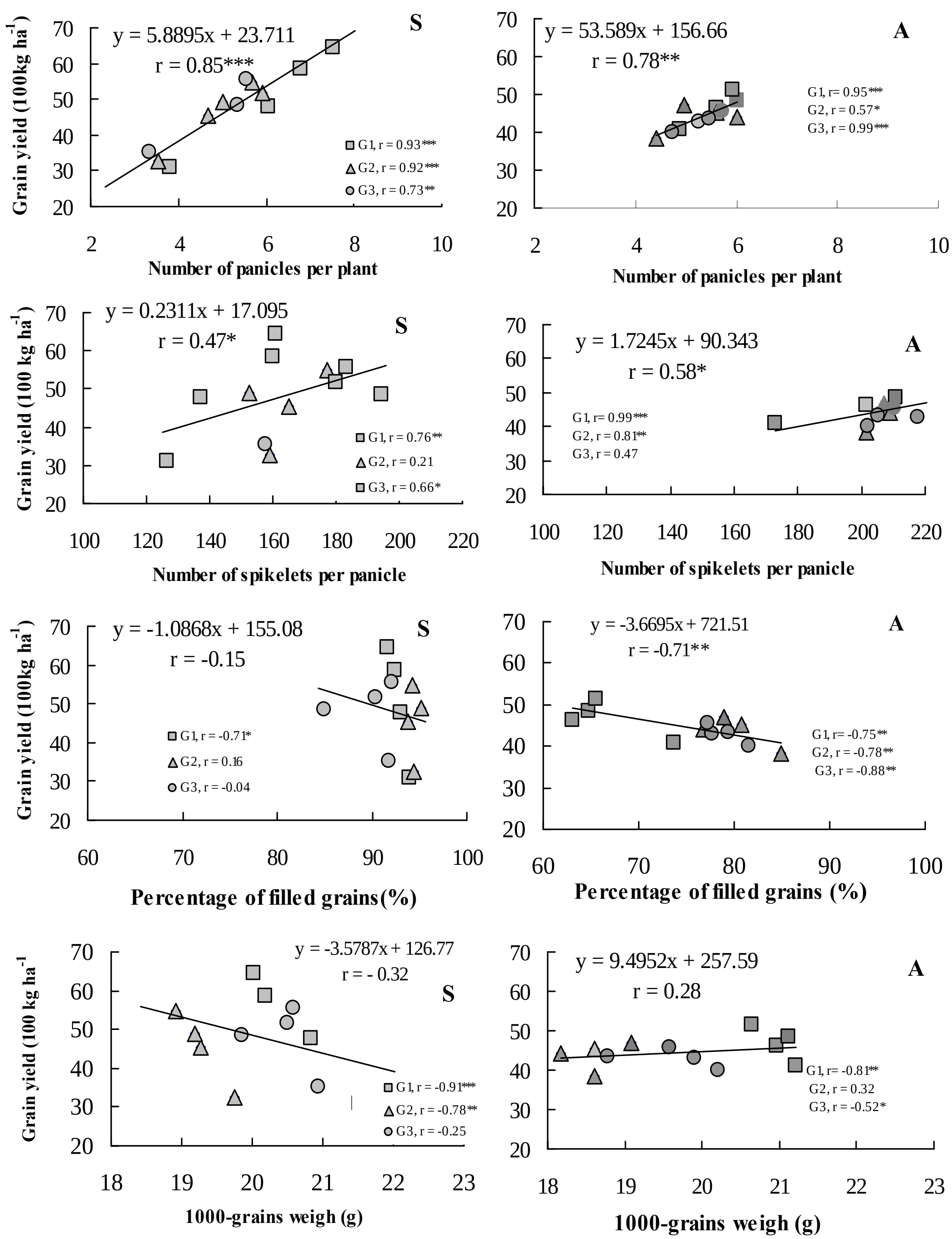

Fig 3. Correlation between Grain yield and yeild components in Hybrid (G1-square), improved (G2-angle) and local rice (G3-round) in Spring (S) and Autumn season (A)

, ** and *: Significant at 0.5, 0.1 and 0.01 probality level*

4. DISCUSSION

As increasing N fertilizer, LAI was increased much higher in F1 hybrid rice cultivar, this proved that the F1 hybrid rice cultivar was absorbed a greater amount of nitrogen for leaf development than other cultivars at the early growth stage (Yang et al., 1999; Pham et al., 2003). In Autumn, the LAI did not significantly increase in the F1 hybrid at 120 N level, which might be due to bacterial leaf blight disease (unpublished data) and/or high amounts of N from the soil (Hasegawa et al., 2000). The NUE for chlorophyll of all the cultivars was higher in Spring than in Autumn seasons, due to both the longer growth duration (data unpublished) and either the lower temperatures or lower rainfall in Spring season (Edward et al., 1998; Hasegawa, 2000).

As increasing N from 90 N to 120 N, DM value significantly was increased in F1 hyrbid cultivar but it was decreased in improved and local cultivars at the active tillering stage in Spring season, this was due to the heterosis for faster growth at early growth stage and possibly the greater root system development (Saitoh et al., 2000; Kobayashi et al., 1995).The increase grain yield as higher N applications was caused by both a higher number of panicles per hill and a larger number of spikelets per panicle (Fig.3). These facts indicate that F_1 hybrid rice demonstrated greater NUE in comparison to other cultivars at all N levels, especially in Spring season. This correlated to previous reports (Jing et al., 1998; Wada and Cruz, 1989; Pham et al., 2003). Nitrogen fertilizer application in this study was at lower than normal levels of N in F_1 rice cultivars in Vietnam, therefore, it is necessary to use F_1 hybrid rice in low - input conditions.

5. CONCLUSIONS

As N fertilizer was increased from 90 to 120N in both cropping seasons, grain yield significantly increased in the F1 hybrid, but not in improved and local cultivars.

In all rice cultivars, nitrogen use efficiency (NUE) for the grain yield was higher in the Spring than in Autumn seasons. In both cropping seasons, NUE was higher in the F1 hybrid than in other cultivars under all N levels.

As N fertilizer was increased from 60 to 120N, NUE for grain yield was decreased in the improved rice cultivar (from 21.20 to 16.62 in Spring and from 7.97 to 2.39 in Autumn seasons) and in local rice cultivar (from 30.35 to 10.99 in Spring and from 6.86 to 2.42 in Autumn seasons), whereas it was maintained in the F1 hybrid rice cultivar (31.36-27.89 in Spring and 17.61-19.68 in Autumn seasons).

The NUE in the F1 hybrid rice was higher than in other cultivars in both cropping seasons and it was was attributed to both the higher number of panicles and number of spikelets per panicle.

REFERENCES

Edward, A.B., Sato, H. and Ichii, M. (1998). Nitrate reductase activities in rice genotypes in irrigated lowland. *Crop science*. 38: 728-734.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural.

Hiroshi Hasegawa. (2000). High-Yielding Rice cultivars perform best even at reduced nitrogen fertilizer rate. *Crop Science*. 43. 921-926.

Kobayashi, M., Kubota, F., Hirao, K. and Agata, W. (1995). Characteristic of Photosynthesis and matter partitioning in leading hybrid rice, *Oryza sativa* L., Bred in China. *J. Fac. Agr., Kyushu Univ*. 39 (3-4). 175-182.

Pham Van Cuong, Murayama, S. and Kawamitsu, Y. (2003). Heterosis for photosynthesis, dry matter production and grain yield in F_1 hybrid rice (*Oryza sativa* L.) from thermo-sensitive genic male sterile line cultivated at different soil nitrogen levels. *Environ. Control in Biol*. 41 (4) : 335-345.

Pham Van Cuong, Murayama, S., Ishimine, Y., Kawamitsu, Y., Motomura, K. and Tsuzuki, E. (2004). Sterility of TGMS line, heterosis for grain yield and related characters in F_1 hybrid rice (*Oryza sativa* L.). *Plant Prod. Sci*. 1 (4) : 22-29.

Saitoh, K., Doi, T. and Kuroda, T. (2000). Effects of nitrogen fertilization on dark respiration and growth efficiency of field grow rice plants. *Plant Pro Sci.* 3: 238-242.

Sinclair, T.R. and Horie, T. (1989). Leaf nitrogen, photosynthesis, and crop radiation use efficiency: A review. *Crop Sci.* 29: 90-98.

Virmani, S.S. (1994). Heterosis and Hybrid Rice Breeding. Springer-Verlag, Berlin. 1-189.

Yang, X., Zhang, W. and Ni, W. (1999). Characteristics of nitrogen nutrition in hybrid rice. *In* Hybrid Rice. IRRI, Los Banos. 5-8.

Ying, J., Peng, S., Yang, G., Zhou, N., Visperas, R.M. and Cassman, K.G. (1998). Comparison of high-yield rice in tropical and subtropical environments. II. Nitrogen accumulation and utilization efficiency. *Field crop Research*. 57: 85-93.

Wada, G. and Cruz. P.C.S. (1989). Varietal difference in nitrogen response of rice plant with special reference to growth condition. *Jpn. J. Crop Sci*. 58:...