Study on The Efficacy of Nitrogen Utilization by Rice Genotypes Part 1: Clustering and Selection for Rice Genotypes

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Abstract

This experiment was carried out in a greenhouse as, the first part of four consecutive experiments. Sixty rice genotypes comprising 30 national and 30 local genotypes were evaluated for their responses and efficacy to nitrogen (N, urea) fertilizer application. Two levels of N fertilizer, i.e., 0 (N1) and 120 (N2) kg of N per hectare were applied. Randomized Block Design (RBD) with three replications was used as the experimental design. The observed parameters were grain yield per pot and grain yield index (GI). Based on average of grain yield of N1, average of grain yield of N2, and grain yield index (GI), the 60 evaluated genotypes were classified into four clusters. These clusters consisted of 26 efficient and responsive (ER) genotypes, 7 efficient and non-responsive (ENR) genotypes, 6 non-efficient and responsive (NER) genotypes, and non-efficient and non-responsive (NENR) genotypes. Replacement of cultivars in rice cultivation, from non efficient (NE)-genotype to efficient (E)-genotype has a potential of yield increase of 90.83%, replacement of non-responsive (NR) with responsive (R) genotype has a potential yield increase of 59.57%, replacement of local genotypes with national genotypes has a potential to increase yield 8.66% only. Of the 26 ERs, genotypes with the highest efficiency were Singkil, IR-66, Indragiri, Sintanur, and Widas. Genotypes with the highest response were Ciliwung, IR-66, Ciherang, Sintanur, and Cisadane. These genotypes can be used to increase rice production, to reduce production costs and to reduce environmental pollution. The ER, ENR and NER genotypes can be used as parents in breeding for high yielding and N efficient rice genotypes.

Key words: rice genotypes, efficacy, response, nitrogen nutrition

Abstrak

Penelitian ini dilakukan di rumah kaca sebagai bagian pertama dari empat percobaan berturut-turut. Enam puluh genotipe padi terdiri dari 30 genotipe nasional dan 30 genotipe lokal dievaluasi untuk respon mereka dan kemanjuran dengan Nitrogen (N, urea) aplikasi pupuk. Dua tingkat pemupukan N, yaitu 0 (N1) dan 120 (N2) kg N per hektar diberikan. Rancangan Acak Kelompok (RAK) dengan tiga ulangan digunakan sebagai rancangan eksperimental. Parameter yang diamati adalah hasil gabah per pot dan biji-bijian hasil indeks (GI). Berdasarkan rata-rata hasil gabah dari N1, rata-rata hasil gabah dari N2, dan biji-bijian hasil indeks (GI), dengan 60 genotipe dievaluasi diklasifikasikan ke dalam empat cluster. Kelompok ini terdiri dari 26 efisien dan responsif (ER) genotipe, 7 efisien dan tidak responsif (ENR) genotipe, 6 non-efisien dan responsif (APM) genotipe, dan non-efisien dan tidak responsif (NENR) genotipe. Penggantian kultivar dalam budidaya padi, dari non efisien genotipe-(TL) untuk efisien genotipe-(e) memiliki potensi peningkatan hasil dari 90,83%, penggantian non-responsif (NR) dengan responsif (R) genotipe memiliki potensi hasil peningkatan 59,57%, penggantian lokal genotipe dengan genotipe nasional memiliki potensi untuk meningkatkan hasil 8,66% saja. Dari 26 ERs, genotipe dengan efisiensi tertinggi adalah Singkil, IR-66, Indragiri, Sintanur, dan Widas. Genotipe dengan respon tertinggi adalah Ciliwung, IR-66, Ciherang, Sintanur, dan Cisadane. Genotip ini dapat digunakan untuk meningkatkan produksi beras, untuk mengurangi biaya produksi dan mengurangi pencemaran lingkungan. Genotipe ER, ENR dan APM dapat digunakan sebagai tetua dalam pemuliaan untuk menghasilkan tinggi dan N genotipe padi efisien.

Kata kunci: padi, genotipe, khasiat, respon, nutrisi, nitrogen

Introduction

Effort to increase rice production is absolutely necessary if Indonesia does not want to continue to be a rice importing country, or if Indonesia wants to be rice exporting country. The main input in the process of rice production is Nitrogen (N)-Urea $(CONH_2)_2$ fertilizer. However, many studies have shown that N fertilizer efficiency is only 20-40%, while a large number of the rest (60-80%) is lost to the environment. This is not only wasting but also results in environmental pollution. While the easiest and cheapest solution of such problem is planting high yielding rice genotypes that are efficient nutrient N, such genotypes are not available. Therefore, clustering and selection for rice genotypes efficient in N utilization, and studies of N nutrient in the rice fields are important preliminary efforts for development of superior genotypes with high yielding potential and efficient nutrient N.

Efforts to increase utilization efficiency of N fertilizer have been done through management of soil, fertilizer and rice cultivation system, but efforts through manipulation of plant traits have not been done because N efficient rice properties have not been much studied. The later, according to Peng and Senadhira (2000), was because people have assumed that low efficiency in N absorption is a problem of soil N deficiency that can simply be solved by N fertilizer application.

In Indonesia, there are rice germplasm with various levels of nutrient efficiency. From the available rice germplasm, clustering and selection can be carried out to obtain genotype that has high yielding potential, efficient in N utilization, and responsive to N fertilizer. Genotypes with such characteristics can be used for minimizing the use of inorganic N fertilizer, for cultivation of rice field with depleted N, to reduce the effect of N pollution to the environment, and to be used as parental genotypes in breeding for high yielding and N efficient rice cultivars.

Realizing N as a limiting factor in rice production, cultivation of N-efficient rice cultivars is inevitable to cope with higher price of N fertilizer and increasingly limited supply of N fertilizer in the market. This corresponds to Shenoy *et al.* (2001) that the efficiency of nutrient N absorption from soil and N utilization efficiency in rice plants is a major potential in increasing rice yield. Increased efficiency will reduce N fertilizer needs. Ray *et al.* (2003) also noted that efforts to maximize photosynthetic carbon fixation, growth rate, and high production capabilities in low N input conditions are very relevant in the economic development of rice cultivation. According to Good *et al.* (2004), crop experts have long claimed the necessary development of plant genotypes that can absorb and use nutrients more efficiently.

Cassaman *et al.* (1998) predicted that consumption of urea fertilizer for rice crop in 2025 will reach 20 million tons for 70 million hectares of land area with only fertilizer uptake efficiency of 33%. This means that 67% of the cost of fertilizer will be lost uselessly and result in greater environmental pollution. Eagle *et al.* (2000) noted that reduction in N fertilizer loss will increase the efficiency of N fertilizer utilization and decrease the cost for saving the environment from pollution caused by N fertilizer application in rice cultivation. Today the world spends more than 45 billion U.S. dollars every year to produce N fertilizer (Ladha and Reddy, 2003). Increased N utilization efficiency of 1% on cereal crops would mean a saving of 234,658,462 U.S. dollars, and increased efficiency of 20% can save 4.7 billion dollars per year (Round and Johnson, 1999).

Materials and Methods

This study was a part of serial studies conducted since the beginning of 2007 until the end of 2009. The study was conducted in a greenhouse at the Faculty of Agriculture, Jenderal Soedirman University, Purwokerto. Growth media were coastal regosol soil, that based on soil analysis, is deficient in N. The experimental factors were level of N-urea fertilizers and rice genotypes. The N levels were 0 kg N / ha (N1) and 120 kg N / ha or 1.2 g urea / pot (N2). The rice genotypes included 30 national superior genotypes and 30 local genotypes. Most seeds of these genotypes were kindly provided by Rice Research Institute at Sukamandi, West Java, and partly by local farmers of Central Java, Indonesia.

Approximately 8.48 kg of ground and 5-mm-sieved air-dried soil (a weight of 20x20x20 cm^3 volume of *regosol* soil) was used to prepare growth media. This soil was put into a 10 kg capacity pot. Soil mudding in pots was performed seven days before seedling transplant. TSP and KCl fertilizers were applied to the mudded soil just before planting, with a rate of 60 kg / ha or equals to 0.24 g / pot for TSP, and 100 kg / ha or equals to 0.4 g / pot for KCl.

Three twenty-one day old seedlings were transplanted into a pot. Each experimental unit consisted of two pots.

Flooding was maintained as high as 10 cm above the mud surface up to 7 days before harvest. N fertilizer was applied gradually and equally in three consecutive times, i.e.: at the time of transplant, 25 days after transplant, and at flower primordial. Harvesting was carried out at physiological maturity. Grain yield per hill was measured at 14% moisture content.

The experimental design was Randomized Block Design (RBD) with three replications. Based on filled-grain weight per hill, grain yield index (GI) was calculated following Fageria and Baligar (1993), where GI = (Grain yield under optimal condition with N fertilizer - Grain yield under condition without N fertilizer) : (Optimal level of N fertilizer – 0 kg of N fertilizer) kg^{-1}. Based on average grain yield without fertilizer, average grain yield with fertilizer, and GI value, all the tested genotypes are grouped into four categories, namely efficient and responsive genotype (ER), efficient but non-responsive genotype (ENR), non-efficient but responsive genotype (NER), and non-efficient and non-responsive genotype (NENR).

Results and Discussion

Nutrient-efficient genotypes are reflected by its ability to provide high yield in limited circumstances of one or more nutrients (Marschner, 1995). In rice, efficient plants are capable of producing high grain by using least fertilizer (De Datta and Broadbent, 1988). Blair (1993), and Fageria and Baligar (1993) have grouped plants into 4 classes based their responses to a nutrient availability. The four classes include: (i) *Efficient and responsive* (ER) - a group of plants capable of producing high product at a low level of nutrients and responsive to increased levels of nutrients, (ii) *Efficient but non-responsive* (ENR) - a group of plants that is able to produce high at low nutrient levels but not responsive to increased levels of nutrients, (iii) *Non-efficient but responsive* (NER) - a group of plants which produce low in low nutrient level but responsive to increased levels of nutrients, and (iv) *non-efficient and non-responsive* (NENR) - a group of plants which produce low in low nutrient levels and not responsive to increased levels of nutrients.

The results of clustering of all evaluated rice genotypes are listed in Table 1 and Table 2. Levels of N efficiency level and N response varied among genotypes, and also between national superior genotypes and local genotypes. ER national genotypes comprised of 25.0%, local ER 18.3%, ENR national genotypes 10.0%, local ENR 1.7%, NER national genotypes 5.0%, local NER 3.3 %, NENR national genotypes 8.3%, local NENR 26.7%. Genotypes that fall into ER class were mostly national genotypes, while those classified into NENR are mostly local genotypes (Table 2).

The above results proved that Indonesian rice germplasm has all classes of N efficient/responsive rice as grouped by Blair (1993) and Fageria and Baligar (1993). Baligar and Fageria (1997) reported that there are differences in the nature of response to environmental factors within and between species, including the response to changes in the N level. As with N nutrient, Karno (2009) in a study of P utilization efficiency in rice plants using red yellow podzolic soil also obtained four categories of efficiency/responsiveness to P. Phosphor efficient and responsive genotypes represented by IR-64, P responsive but non-efficient represented by Silugonggo, inefficient and responsive to P was represented by Leah, inefficient and non-responsive to P was represented by Mount David. Shi *et al.* (2010) found that the rate of absorption of ammonium N-efficient rice cultivars was much higher than the cultivars that are non-efficient, the absorption of nitrate N-inefficient cultivars is greater than the efficient cultivars.

Table 2 presents genotypes with the highest efficiency and genotypes with the highest response to N. Genotypes that efficient in N nutrient such as Singkil, IR-66, Indragiri, Sintanur, Widas, Tukad Belian, and the rest can be cultivated in N depleted rice field, or can be suggested to be grown by farmers with lower capability to afford N fertilizer cost. Nitrogen responsive genotypes such as Ciliwung, IR-66, Ciherang, Sintanur, Cisadane, Barry, Ranggong, Digul and others can be cultivated in N-rich rice field, or suggested to wealthier farmer who can cope with N fertilizer cost. Clustering rice genotypes based on their efficiencies and responsiveness to N are useful for selection of genotypes to be used as parents in development of high yielding genotypes with better efficiency in N utilization and responsive to N fertilizer application.

Figure 1 illustrates the differences in efficiencies and responsiveness to N fertilizer application of eight genotypes with regard to their grain yield. Each of national (Nt) and local (Lc) genotypes represents a certain grouping category. These eight genotypes were Ciliwung (ER-Nt), Barry (ER-Lc), Ciapus (ENR-Nt), Solo (ENR-Lc), IR-42 (NER-Nt), Arias B (NER-Lc), Tukad Petanu (NENR-Nt), and Dusel (NENR-Lc).

Table 1. Genotype clustering based on responsiveness to N fertilizer.

No.	Genotype	Grain yield N_1 & criteria		Increased yield (ΔY in g)	Grain yield index (GI) & criteria		Criteria of efficancy and responsiveness
		Weight (g)	E or NE		GI (Kg / Kg)	R or NR	
1	Dusel	1.10	NE	11.30	23.54	NR	NENR
2	Bengawan Solo	1.40	NE	19.90	41.46	R	NER
3	Lems	1.40	NE	10.23	21.31	NR	NENR
4	Padi Halus	1.60	NE	4.97	10.35	NR	NENR
5	Bawi	1.67	NE	6.60	13.75	NR	NENR
6	Banda	1.73	NE	12.37	25.77	NR	NENR
7	Tokong	1.73	NE	10.24	21.33	NR	NENR
8	Mayor	1.90	NE	12.47	25.98	NR	NENR
9	Rojo Lele	1.90	NE	14.87	30.98	NR	NENR
10	Tukad Petanu	1.93	NE	11.74	24.46	NR	NENR
11	IR 42	2.00	NE	23.77	49.52	R	NER
12	Omas	2.03	NE	11.74	24.46	NR	NENR
13	Baluyan	2.10	NE	11.60	24.17	NR	NENR
14	Sirantau	2.20	NE	13.30	27.71	NR	NENR
15	Diah Suci	2.20	NE	10.50	21.88	NR	NENR
16	Gilirang	2.23	NE	14.30	29.79	NR	NENR
17	Luk Ulo	2.23	NE	16.74	34.88	NR	NENR
18	Cisanggarung	2.30	NE	17.00	35.42	NR	NENR
19	Cibogo	2.33	NE	21.27	44.31	R	NER
20	Brandi	2.37	NE	14.16	29.50	NR	NENR
21	Satelika	2.37	NE	14.00	29.17	NR	NENR
22	Silanting	2.40	NE	14.70	30.63	NR	NENR
23	Asemmandi	2.40	NE	15.07	31.40	NR	NENR
24	Batanghari	2.47	NE	21.43	44.65	R	NER
25	Arias B	2.60	NE	21.07	43.90	R	NER
26	Utari	2.60	NE	14.37	29.94	NR	NENR
27	Hawarabunar	2.67	NE	19.86	41.38	R	NER
28	Anak Daro	2.83	E	19.57	40.77	R	ER
29	Luwung	2.83	E	20.74	43.21	R	ER
30	Cisadane	2.93	E	22.17	46.19	R	ER
31	Aromatik Palu	3.03	E	20.64	43.00	R	ER
32	Lumbuk	3.07	E	18.26	38.04	R	ER
33	Basmati	3.07	E	19.83	41.31	R	ER
34	Solo	3.07	E	17.13	35.69	NR	ENR
35	Gundil Tambunan	3.07	E	18.50	38.54	R	ER
36	Fatmawati	3.10	E	11.40	23.75	NR	ENR
37	Menthik Wangi	3.13	E	18.50	38.54	R	ER
38	Genjah Anak	3.20	E	18.47	38.48	R	ER
39	Banjar Kuning	3.20	E	19.63	40.90	R	ER
40	IR-36	3.30	E	18.87	39.31	R	ER
41	Digul	3.37	E	21.36	44.50	R	ER
42	Cihujung	3.43	E	18.37	38.27	R	ER
43	Cimelati	3.53	E	19.14	39.88	R	ER
44	Ranggong	3.63	E	21.90	45.63	R	ER
45	Mayangsari	3.67	E	22.06	45.96	R	ER
46	Cipunegara	3.67	E	14.76	30.75	NR	ENR
47	IR-64	3.67	E	21.16	44.08	R	ER
48	Angke	3.73	E	18.44	38.42	R	ER
49	Ciliwung	3.73	E	30.00	62.50	R	ER
50	Membramo	3.80	E	16.90	35.21	NR	ENR
51	Ciherang	3.87	E	25.63	53.40	R	ER
52	Batanggadis	3.87	E	11.76	24.50	NR	ENR

No.	Genotype	Grain yield N_1 & criteria		Increased yield (ΔY in g)	Grain yield index (GI) & criteria		Criteria of efficancy and responsiveness
		Weight (g)	E or NE		GI (Kg / Kg)	R or NR	
53	Mekongga	3.93	E	15.84	33.00	NR	ENR
54	Tukad Belian	4.00	E	20.47	42.65	R	ER
55	Ciapus	4.13	E	17.70	36.88	NR	ENR
56	Widas	4.30	E	20.07	41.81	R	ER
57	IR-66	4.33	E	26.80	55.83	R	ER
58	Indragiri	4.33	E	21.27	44.31	R	ER
59	Sintanur	4.33	E	22.57	47.02	R	ER
60	**Singkil**	**4.37**	**E**	**21.20**	**44.17**	**R**	**ER**

Description: E = Efficient, R = Responsive, NE = Non Efficient, NR = Non Responsive

Table 2. Genotypes of ER (efficient and responsive), ENR (efficient non-responsive), NER (non-efficient and responsive) and NENR (non-efficient and non-responsive)

Criteria		The order of the level of efficiency			The order of the level of responsiveness		
		Level of efficacy	Genotype	Nt or Lc	Level of responsivity	Genotype	Nt or Lc
ER (Efficient and responsive)	1	4.37	Singkil	Nt	62.5	Ciliwung	Nt
	2	4.33	IR-66	Nt	55.83	IR-66	Nt
	3	4.33	Indragiri	Nt	53.4	Ciherang	Nt
	4	4.33	Sintanur	Nt	47.02	Sintanur	Nt
	5	4.3	Widas	Nt	46.19	Cisadane	Nt
	6	4.0	Tukad Belian	Nt	45.96	Mayangsari	Lc
	7	3.87	Ciherang	Nt	45.63	Ranggong	Lc
	8	3.73	Angke	Nt	44.5	Digul	Nt
	9	3.73	Ciliwung	Nt	44.31	Indragiri	Nt
	10	3.67	Mayangsari	Lc	44.17	Singkil	Nt
	11	3.67	IR-64	Nt	44.08	IR-64	Nt
	12	3.63	Ranggong	Lc	43.21	Luwung	Lc
	13	3.53	Cimelati	Nt	43.0	Aromatik Palu	Lc
	14	3.43	Cihujung	Nt	42.65	Tukad Belian	Nt
	15	3.37	Digul	Nt	41.81	Widas	Nt
	16	3.3	IR-36	Nt	41.31	Basmati	Lc
	17	3.2	Genjah Anak	Lc	40.9	Banjar Kuning	Lc
	18	3.2	Banjar Kuning	Lc	40.77	Anak Daro	Lc
	19	3.13	Menthik Wangi	Lc	39.88	Cimelati	Nt
	20	3.07	Lumbuk	Lc	39.31	IR-36	Nt
	21	3.07	Basmati	Lc	38.54	Gundil Tambunan	Lc
	22	3.07	Gundil Tambunan	Lc	38.54	Menthik Wangi	Lc
	23	3.03	Aromatik Palu	Lc	38.48	Genjah Anak	Lc
	24	2.93	Cisadane	Nt	38.42	Angke	Nt
	25	2.83	Anak Daro	Lc	38.27	Cihujung	Nt
	26	2.83	Luwung	Lc	38.04	Lumbuk	Lc
ENR (Efficient and non-responsive)	1	4.13	Ciapus	Nt	36.88	Ciapus	Nt
	2	3.93	Mekongga	Nt	35.69	Solo	Lc
	3	3.87	Batanggadis	Nt	35.21	Membramo	Nt
	4	3.8	Membramo	Nt	33.0	Mekongga	Nt
	5	3.67	Cipunegara	Nt	30.75	Cipunegara	Nt
	6	3.1	Fatmawati	Nt	24.5	Batanggadis	Nt
	7	3.07	Solo	Lc	23.75	Fatmawati	Nt

Criteria		The order of the level of efficiency			The order of the level of responsiveness		
		Level of efficacy	Genotype	Nt or Lc	Level of responsivity	Genotype	Nt or Lc
NER (Non-efficient and responsive)	1	2.67	Hawarabunar	Lc	49.52	IR-42	Nt
	2	2.6	Arias B	Lc	44.65	Batanghari	Nt
	3	2.47	Batanghari	Nt	44.31	Cibogo	Nt
	4	2.33	Cibogo	Nt	43.9	Arias B	Lc
	5	2.0	IR 42	Nt	41.46	Bengawan Solo	Nt
	6	1.4	Bengawan Solo	Nt	41.38	Hawarabunar	Lc
NENR (Non-efficient and non-responsive)	1	2.6	Utari	Lc	35.42	Cisanggarung	Nt
	2	2.4	Silanting	Lc	34.88	Luk Ulo	Nt
	3	2.4	Asemmandi	Lc	31.4	Asemmandi	Lc
	4	2.37	Brandi	Lc	30.98	Rojo Lele	Lc
	5	2.37	Satelika	Lc	30.63	Silanting	Lc
	6	2.3	Cisanggarung	Nt	29.94	Utari	Lc
	7	2.23	Gilirang	Nt	29.79	Gilirang	Nt
	8	2.23	Luk Ulo	Nt	29.5	Brandi	Lc
	9	2.2	Sirantau	Lc	29.17	Satelika	Lc
	10	2.2	Diah Suci	Nt	27.71	Sirantau	Lc
	11	2.1	Baluyan	Lc	25.98	Mayor	Lc
	12	2.03	Omas	Lc	25.77	Banda	Lc
	13	1.93	Tukad Petanu	Nt	24.46	Tukad Petanu	Nt
	14	1.9	Mayor	Lc	24.46	Omas	Lc
	15	1.9	Rojo Lele	Lc	24.17	Baluyan	Lc
	16	1.73	Banda	Lc	23.54	Dusel	Lc
	17	1.73	Tokong	Lc	21.88	Diah Suci	Nt
	18	1.67	Bawi	Lc	21.33	Tokong	Lc
	19	1.6	Padi Halus	Lc	21.31	Lems	Lc
	20	1.4	Lems	Lc	13.75	Bawi	Lc
	21	1.1	Dusel	Lc	10.35	Padi Halus	Lc

Description: Nt = national genotype; Lc = local genotype

Based on grain yield per pot, among the national genotypes, replacement of NE genotypes (average of 1.97 g) with E genotype (average of 3.9 g) results in a potential yield increase of 99.49%, replacement of NR genotypes (average of 17.75 g) with genotype R (average of 29.75 g) results in a potential yield increase of 67.61%. Among local genotypes, replacement of NE genotype (average of 1.85 g) with E genotype (average of 3.37 g) results in a potential yield increase of 82.16%, replacement of NR genotype (an average of 16, 3 g) with R genotype (average of 24.7 g) results in a potential yield increase of 51.53%. Percentage of yield increase among national genotype is greater than potential yield increase among local genotypes. However, percentage yield increase due to replacement of E genotype with NE genotype was much greater than that due to replacement of R genotype with NR genotype. Therefore, efforts to increase rice production by utilization of N efficient genotypes would be much more effective than those by utilization of N responsive genotypes.

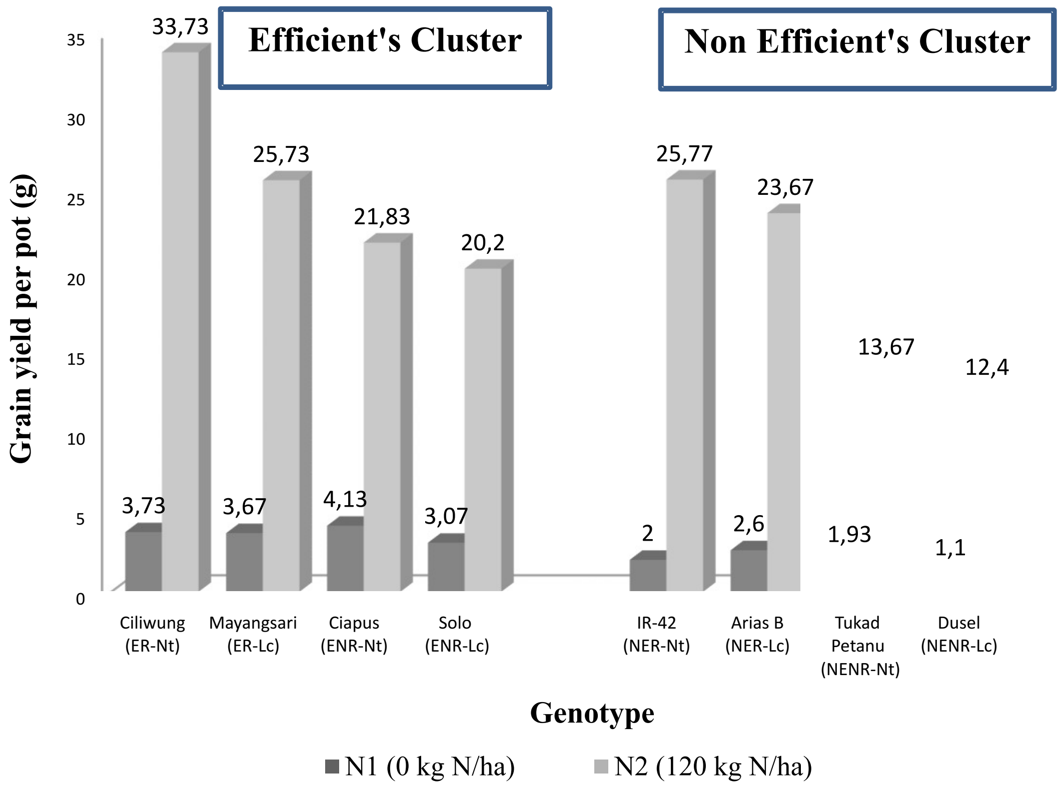

Figure 1. Grain yield per pot of all selected genotypes representing all categories

There are more rice cultivars or genotypes in Indonesia of which their characteristics, especially their nutrient utilization efficacy, have not been studied yet. Such a grouping of rice cultivars and genotypes is useful for farmers to improve their rice productivity, minimize fertilizer cost, and reduce the risk of environmental pollution. In addition, cultivation of nutrient efficient rice genotypes will help government to improve rice production for self-sufficiency in rice production.

Conclusion

The 60 evaluated rice genotypes can be grouped into 43.33% ER genotype (25.0% national superior genotypes; 18.3% of local genotype), 11.7% ENR genotype (10.0% national superior genotypes; 1.7% local genotype), 8.3% NER genotype (5.0% of national superior genotypes; 3.3% local genotype), and 35.0% NENR genotype (8.3% of national superior genotypes; 26.7% of local genotypes). Replacement of rice cultivars of NE genotype with E genotype results in a potential yield increase of 90.83%, while replacement R genotype with NR genotype results in a potential yield increase of 59.57%. Replacement of local genotypes with national superior genotypes has a potential yield increase of 5.05 - 8.66%. ER genotypes can be used as cultivars in the effort of increasing rice production to reduce the cost of N and decrease environmental pollution. ER, ENR, and NER genotypes can be used as parental genotypes in an effort to develop high yielding cultivars with high efficiency and responsiveness to N.

Recommendation

ER genotypes can be suggested to be used momentarily in a program for increasing rice production until multi-location trials to test ER genotypes are completed and the result is confirmed. Clustering and selection of other rice genotypes are necessary to avoid loss of farming investment and to reduce the risk of environmental pollution.

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