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Screening of rice genotypes to classify efficient and responsive cultivars based on nitrogen use efficiency

K Sivasabari and S Jothimani

Abstract
Screening experiment was conducted during 2017, *pishanam* season at Rice Research Station, Ambasamudram with the objective to screen the efficient and responsive rice genotypes based on nitrogen use efficiency under 32 rice genotypes as main plot treatment and four nitrogen levels N_0 (control), N_1 (50% recommended dose of N ha^{-1}), N_2 (100% recommended dose of N ha^{-1}) and N_3 (150% recommended dose of N ha^{-1}) as subplot treatments. The experimental results showed that, the highest grain and straw yields were recorded at N_3 (180 kg ha^{-1}) by the most of the rice genotypes, except the AS 12051, ACK 14004, CB08702, CB 13539 and PM 12009 which were not responded genotypes for higher dose of (180 kg ha^{-1}) nitrogen. In the genotypes ASD 16, ADT 43, ADT 45, CO 51, MDU 5, CB 14508, CB 14533, TR 0927, TR 13069 and TM 12061 the AE was increasing with increasing level of nitrogen, other genotypes showed decreasing sequence with increasing level of nitrogen levels. The genotypes viz., ASD16, ADT39, ADT45, TPS 5, AD09206, CB06803, ACK14001, TM10085, TM12007, PM12009 and EC725224 are under Efficient and responsive (ER) category which gives average yield at low level and high N use efficiency.

Keywords: Rice genotypes, NUE, N levels, efficient and responsive (ER)

Introduction

The rice (*Oryza sativa* L.) grain makes up 20% of the world's dietary energy supply and more than three billion people across the globe uptake rice daily (Birla *et al.*, 2017) [1]. Due to its wider adaptability under different environmental conditions, rice has been regarded as a IS strategic crop for food security worldwide by the Food and Agriculture Organization (FAO) (Montano *et al.*, 2014) [6]. Global rice consumption is projected to increase from 450 million tons in 2011 to about 490 million tons in 2020 and to around 650 million tons by 2050 (Rejesus *et al.*, 2012) [8]. India produced 106.65 million tons of rice with a productivity of 2.39 tons ha-1 was achieved during the year 2013-14. India needs to produce 120 million tons by 2030 to feed its one and a half billion plus population by then. Tamil Nadu is one of the top most rice growing states in India which is bagged fourth position after Punjab, West Bengal and AP. The main input in the process of rice cultivation is N-Urea as a major inorganic source of Nitrogen. It is the most limiting macronutrient in rice production. Given the importance of N fertilization on the yield in grain from rice plant, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and yield parameters to obtain better knowledge of productive response. Since fertilizers are considered to be quite expensive it becomes highly essential to apply doses that would prove not only appropriate but economical as well. The rice plants are inefficient at nitrogen uptake from soil, with as much as 50-75% of applied N being left unused by the plants. The haphazard use of nitrogen to rice crop creates environment related problems, leaching, emission leads to global warming and eutrophication brings many undesirable changes in ecological pyramid.

To reduce the hazardous effects and to produce higher yield at low N level, it is essential to identify the genotypes which can absorb efficiently and utilize the nitrogen. Therefore, selections of rice genotypes for efficient N use are important preliminary effort for development of superior genotypes with high yielding potential and efficient nutrient N. In the light of above consideration an attempt has been made in this present study to identify the genotypes which can efficiently utilize and response for the improvement of nitrogen use efficiency and increase crop productivity in a sustained manner.

Materials and Methods

The field experiment was conducted at rice research station, Ambasamudram, Tirunelveli, Tamil Nadu during *pishanam*, 2017 (Sep-Oct). The soils of the experimental site contained organic matter 0.35%, pH of 4.16, Available nitrogen is 183 Kg ha^{-1} and texture sandy loam (60% sand, 15% clay and 25% silt). The experimental field was laid out in split plot design with two replications. The different short duration rice varieties/ genotypes namely ASD16, ADT 39, ADT43, ADT45, CO51, TPS5, MDU5, ANNA4, AS12051, AS12104,AD09206,AD10034,ACK14001,ACK14004,CB06803,CB08702,CB13539,CB 14508,CB14533,TR0927,TR0531,TR13069,TR13083,TM1307,TM07335,TM09135,TM10085, TM12059,TM12061,TM 12077,PM12009,EC72524 were utilize for evaluation under N levels 0,50,100 and 150 Kg ha^{-1} of N. Yield was recorded plot wise and converted in to kg ha^{-1} with 14% moisture. The Nitrogen use efficiency was calculated by using the following formula

a) Agronomic efficiency = grain yield in fertilized plot – grain yield in unfertilized plot / quantity of N applied
b) Physiological N use efficiency = Gain yield in fertilized plot – grain yield in unfertilized plot / uptake in fertilized plot – uptake in unfertilized plot
c) Apparent N recovery efficiency = Difference between the uptake/quantity of N applied x 100
d) Partial factor Productivity = grain yield at N levels / N application dose

All the data were statistically analyzed by using standard procedure and results are presented and discussed at a probability level of 5%.

Results and Discussion

Grain and straw yield

Grain and straw yields increased in a linear model with the addition of nitrogen at different levels from 60 to 180 kg ha^{-1} (Table 1 & 2). Grain yield varied from 1543 kg ha^{-1} at control (CB14533) to 8150 kg ha^{-1} at 150% N (ASD 16) with an average value of 5155 kg ha^{-1}. Among four N levels of 0, 60, 120 and 180 kg ha^{-1}, the highest grain and straw yields were recorded at N_3 (180 kg ha^{-1}) by the most of the rice cultures, except the AS 12051, ACK 14004, CB08702, CB 13539 and PM 12009 which were not responded genotypes for higher dose of (180 kg ha^{-1}) nitrogen. Among the released varieties, ASD 16 recorded highest mean yield of 6698 kg ha^{-1} followed by MDU5 (6014 kg ha^{-1}), ADT 45 (5875 kg ha^{-1}) recorded and were responded to higher dose of N applied. In cultivars, the highest mean yield was observed in ASD 16 (6698 kg ha^{-1}), TR 13083 (6695 kg ha^{-1}) followed by TM 12077 (6162 kg ha^{-1}). The percent increase of grain yield was maximum (57.55%) in CB 14533 though it gives lowest yield among all the genotypes. The straw yield varied from 3011 kg ha^{-1} (CB14533) to 10292 kg ha^{-1} (ASD16) with an average of 7505 kg ha^{-1}. As that of grain yield, the same trend was followed on straw yield also. The overall highest mean yield was recorded by TR13083 (9388 kg ha^{-1}) which was on par with ASD 16 (8884 kg ha^{-1}). The lowest yield of 4798 kg ha^{-1} was recorded in the cultivar CB 14533 but the percentage increase in both grain and straw yields by computed to control by highest level of N was more in this cultivar CB14533 which indicate the response level was high in cultivar.

Table 1: Grain yield (Kg ha^{-1}) of rice genotypes/cultivar as influenced by nitrogen application

S.No	Genotypes/ Varieties	N_0	N_1	N_2	N_3	Mean
1	ASD 16	5284	6175	7183	8150	6698
2	ADT 39	3682	4921	5778	6814	5299
3	ADT 43	4259	4691	5500	6723	5293
4	ADT 45	4606	5339	6299	7256	5875
5	CO 51	4587	4940	5576	6371	5368
6	TPS 5	3643	4660	5550	5924	4944
7	MDU 5	5549	5660	6188	6659	6014
8	ANNA 4	5289	5355	5512	5577	5433
9	AS 12051	3889	4410	4754	4681	4433
10	AS 12104	4556	5493	6226	6428	5676
11	AD 09206	3254	4374	4969	5372	4492
12	AD 10034	4968	5317	5390	5497	5293
13	ACK 14001	4837	5844	6678	6929	6072
14	ACK 14004	4510	5549	5864	5771	5423
15	CB 06803	3536	4775	5542	6012	4966
16	CB 08702	4335	4811	5287	5078	4878
17	CB 13539	3029	3401	3750	3429	3402
18	CB 14508	4350	5156	6144	7051	5675
19	CB 14533	1543	2030	2526	4420	2629
20	TR 0927	2878	3291	4294	5107	3892
21	TR 05-31	4632	5895	6275	6717	5880
22	TR 13069	3811	4204	4795	5873	4671
23	TR 13083	5778	6479	7188	7333	6695
24	TM 1307	5056	5762	6220	6627	5916
25	TM 07335	4947	5495	6209	6862	5878
26	TM 09135	3660	4594	4890	5502	4661
27	TM 10085	3673	5015	6051	7157	5474
28	TM 12059	3868	4587	5085	5512	4763
29	TM 12061	2911	3322	4542	5438	4053
30	TM 12077	4304	6020	7119	7206	6162
31	PM 12009	3372	5222	5536	5418	4887
32	EC 725224	2956	4517	4611	5419	4376

		4111	4916	5548	6072	5162

	V	N	V × N	N× V
SE d	30.34	11.16	62.53	63.13
CD (P =0.05)	61.84	22.15	124.92	125.31

Table 2: Straw yield (Kg ha^{-1}) of rice genotypes/cultivar as influenced by nitrogen application

S.No	Genotypes/ Varieties	N_0	N_1	N_2	N_3	Mean
1	ASD 16	7333	8235	9675	10292	8884
2	ADT 39	6031	7484	7906	8478	7474
3	ADT 43	7405	7909	8051	8739	8026
4	ADT 45	7239	7932	8267	9251	8172
5	CO 51	7163	7399	8091	8414	7767
6	TPS 5	5124	6723	7268	7528	6660
7	MDU 5	7823	7754	8584	8713	8218
8	ANNA 4	7061	7445	7405	7751	7415
9	AS 12051	5778	6663	6798	6174	6353
10	AS 12104	5292	7833	8288	8411	7456
11	AD 09206	6759	7072	7304	7903	7259
12	AD 10034	7333	7961	8000	8351	7911
13	ACK 14001	6757	7888	9290	9753	8422
14	ACK 14004	6333	7288	7857	7298	7194
15	CB 06803	6661	7055	7577	8557	7462
16	CB 08702	7612	7984	8900	8453	8237
17	CB 13539	6113	6198	6831	6424	6391
18	CB 14508	6777	7949	8655	9724	8276
19	CB 14533	3011	3701	5000	7479	4798
20	TR 0927	4173	6400	6926	7992	6373
21	TR 05-31	7209	7811	8500	9621	8285
22	TR 13069	7013	7373	7500	8507	7598
23	TR 13083	8540	8979	9773	10262	9388
24	TM 1307	7724	7999	8557	8972	8313
25	TM 07335	6000	7225	8253	8739	7554
26	TM 09135	5889	7310	8111	8310	7405
27	TM 10085	4944	7407	8273	9823	7612
28	TM 12059	6552	6989	7367	7873	7195
29	TM 12061	4000	5703	7013	7513	6057
30	TM 12077	6190	8639	8957	9233	8255
31	PM 12009	6070	7823	8017	7845	7438
32	EC 725224	5051	6359	6501	7383	6323
		6342	7328	7922	8430	7505

	V	N	V × N	N× V
SE d	34.72	13.16	73.23	74.45
CD (P =0.05)	70.81	26.12	146.27	147.79

Agronomic efficiency

AE is a product of nutrient recovery from mineral or organic fertilizer and the efficiency (ARE) with which the plant uses each additional unit of nutrient (PE). It depends on cultural practices that influence recovery and physiological efficiency. AE was significantly affected by nitrogen application and increased with N levels and also decrease with increasing N levels in different rice genotypes (table 3). Among the genotypes, TM 12077 had the highest agronomic efficiency of 22.73 kg kg N^{-1} followed by TM 12005 (20.51 kg kg N^{-1}). Across the N levels, the agronomic efficiency decrease with increasing N levels of nitrogen from 13.41 kg kg N^{-1} at 50% RD of N to 10.90 kg kg N $^{-1}$ at 150% RD of N. In the interaction of Genotype and N levels, the highest AE was recorded in PM12009 at the rate of 50% RD of N (60 kg ha^{-1}). The lowest AE was recorded in genotypes, N levels and interaction, Anna 4 recorded the lowest AE. In the genotypes ASD 16, ADT 43, ADT 45, CO 51, MDU 5, CB 14508, CB 14533, TR 0927, TR 13069 and TM 12061 the AE was increasing with increasing level of nitrogen, other genotypes showed decreasing sequence with increasing level of nitrogen levels. Such variations may be occurred because of genetic factors, biochemical and physiological processes such as translocation, assimilation and N remobilization (Isfan 1993; Fageria and Baligar 2003) [5, 3].

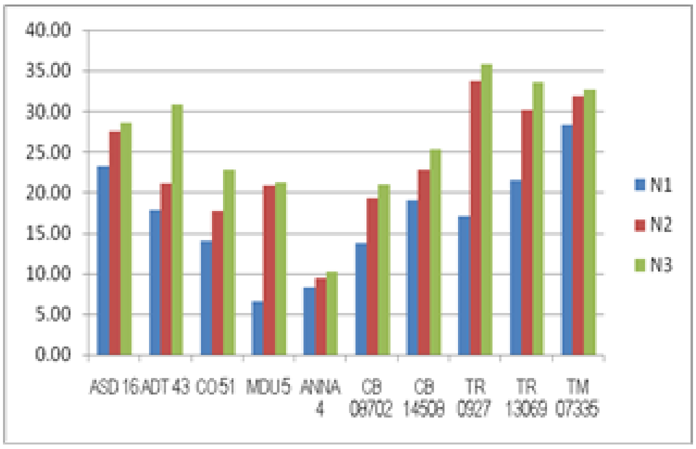
Table 3: Agronomic efficiency of rice genotypes/cultivar as influenced by nitrogen application

S.No	Genotypes/ Varieties	N_1	N_2	N_3	Mean
1	ASD 16	14.85	15.82	15.92	15.53
2	ADT 39	20.65	17.46	17.40	18.50
3	ADT 43	7.20	10.34	13.69	10.41
4	ADT 45	12.23	14.11	14.73	13.69
5	CO 51	5.88	8.24	9.91	8.01
6	TPS 5	16.96	15.90	12.68	15.18
7	MDU 5	1.85	5.33	6.17	4.45
8	ANNA 4	1.10	1.86	1.60	1.52
9	AS 12051	8.69	7.21	4.40	6.77
10	AS 12104	15.63	13.92	10.40	13.32
11	AD 09206	18.67	14.30	11.77	14.91
12	AD 10034	5.82	3.52	2.94	4.09
13	ACK 14001	16.78	15.34	11.62	14.58
14	ACK 14004	17.33	11.29	7.01	11.87
15	CB 06803	20.65	16.72	13.76	17.04
16	CB 08702	7.94	7.94	4.13	6.67
17	CB 13539	6.19	6.01	2.22	4.81
18	CB 14508	13.43	14.95	15.01	14.46
19	CB 14533	8.12	8.19	15.99	10.77
20	TR 0927	6.89	11.80	12.38	10.36
21	TR 05-31	21.06	13.70	11.58	15.45
22	TR 13069	6.55	8.20	11.45	8.73
23	TR 13083	11.69	11.75	8.64	10.70
24	TM 1307	11.77	9.70	8.73	10.07
25	TM 07335	9.13	10.52	10.64	10.10
26	TM 09135	15.56	10.25	10.23	12.01
27	TM 10085	22.37	19.82	19.36	20.51
28	TM 12059	11.98	10.14	9.13	10.42
29	TM 12061	6.85	13.59	14.04	11.49
30	TM 12077	28.60	23.46	16.12	22.73
31	PM 12009	30.85	18.03	11.37	20.08
32	EC 725224	26.01	13.79	13.68	17.82
		13.41	11.97	10.90	12.09

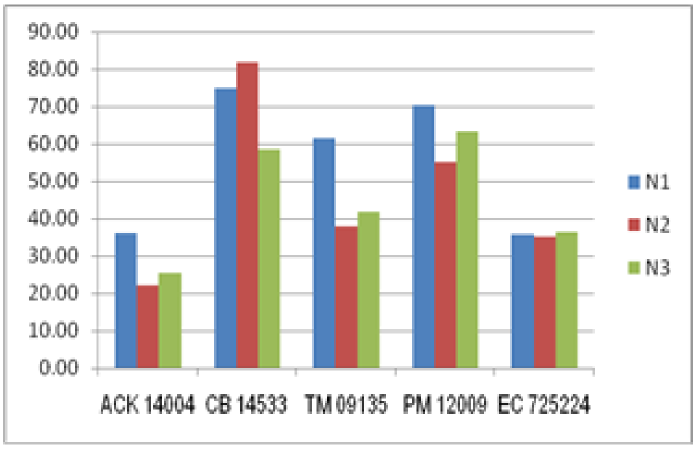
	V	N	V × N	N× V
SE d	0.69	0.12	0.90	0.69
CD (P =0.05)	1.42	0.24	1.82	1.39

Physiological use efficiency

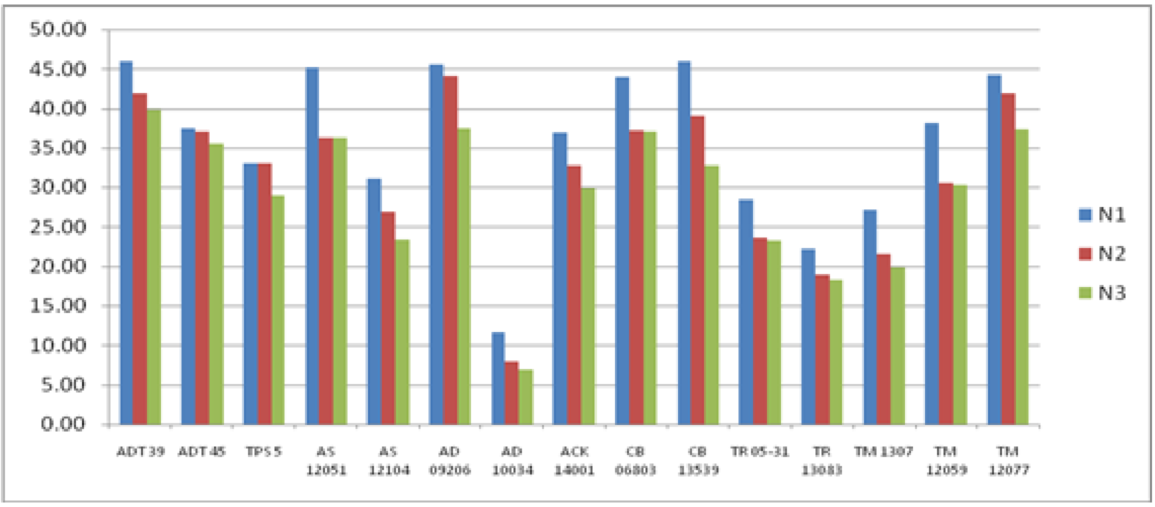
The data in figure 1 showed that significant and higher physiological efficiency (71.71 kg kg^{-1}) was recorded under CB14533 genotype followed by PM12009 and TM09135. There were three types of trend followed in PNUE. a) PNUE increased when nitrogen application increased (ASD 16, ADT43, CO51, MDU 5, ANNA 4, CB08702, CB14508, TR0927, TR13069, TMO7335, and TM12061). b) Intermediate - the genotypes ACK 14001, CB14533, TM09135, TM10085, EC725224 AND PM12009 were recorded highest PNUE at 180 kg ha^{-1} (N_3) with little bit decrease at 120 kg ha^{-1} (N_2) than control and c) PNUE decreased when nitrogen application increased (ADT 39, ADT45, TPS5, AS12051, AS12104, AD09206, AD10034, ACK14001, CBO6803, CB13539, TR0531, TR13083, TM1307, TM12059 and TM12077).



a)



b)



c)

Fig 1: PNUE of rice genotypes/cultivar as influenced by nitrogen application

Apparent N recovery efficiency

Apparent N recovery efficiency of nitrogen indicates that how much nitrogen applied is recovered. ANRE depends on the congruence between plant N demand and the quantity of N released from applied N. The table 4 showed that, ANRE influenced by genotype and N levels. The highest ANRE of 65% was recorded for rice genotype CB14508 which was on par with TR0531 had the efficiency percentage of 60, while the lowest apparent recovery efficiency 16% was recorded from the genotype Anna 4 which was statistically on par with CB14533. From the N levels, 50% RD of N showed highest ANRE of 43% followed by 100% and 150% RD of N. In the interaction of genotype x N levels, the highest ANRE was observed in TR 05-31 rice genotype of 74% at the rate of 50% RD of N (60 kg ha^{-1}) which was statistically on par with CB14508 and EC 725224 genotypes at 50% RD of N (N1). The lowest ANRE was obtained in the genotype CB13539 at the N level of 150% RD of N (180 kg ha^{-1}) which was on par with AS12051 at the same N levels and CB14533 at 100% RD of N (120 kg ha^{-1}). The normal range of recovery efficiency of rice is 40-65%. Our results ranged from 6-74%. Increased level of RE depends on crop demand for N, supply of N from indigenous sources, fertilizer rate and factors that determine the size of the crop nutrient sink (genotype, climate, plant density, abiotic/biotic stresses). The low N recovery efficiency in lowland rice may be related to N losses from soil via nitrification, Denitrification, NH_3 volatilization or leaching. Similar results were obtained by Peng and Cassman (1998) [7].

Partial factor productivity

The partial factor productivity of applied nutrient is a useful measure of nutrient use efficiency because it provides an integrative index that quantifies total economic output relating to utilization of all nutrient sources in the system. Across the genotypes TR13083 and ASD 16 showed highest PFP of 69.5 and 69.3. The lowest PFP recorded in CB14533 genotype (25).Among the N levels, 50% RD of N ha^{-1} recorded highest PFP and 150% RD of N ha^{-1} showed lowest PFP. From the interaction of GxN, the genotypes TR13083 obtained highest PFP of 108 followed by ASD16 and TM12077 at the rate 60 kg N ha^{-1} (50% RD of N ha^{-1}). From the N levels, the decreasing trend following while N application increases. It indicates the unbalance in the uptake ratio of the nutrients and the PFP can be improved by increasing the uptake and utilization of indigenous nutrients.

Table 4: Apparent N recovery efficiency of rice genotypes/cultivar as influenced by nitrogen application

S.No	Genotypes/ Varieties	N_1	N_2	N_3	Mean
1	ASD 16	64.25	57.39	55.77	59.13
2	ADT 39	45.34	41.62	41.55	42.84
3	ADT 43	40.32	49.25	44.41	44.66
4	ADT 45	32.71	38.05	41.49	37.42
5	CO 51	41.98	46.65	43.47	44.03
6	TPS 5	51.30	48.13	43.78	47.74
7	MDU 5	28.13	25.96	29.12	27.74
8	ANNA 4	13.03	19.72	15.71	16.15
9	AS 12051	19.13	19.72	12.08	16.98
10	AS 12104	50.53	51.81	44.43	48.92
11	AD 09206	41.24	32.43	31.39	35.02
12	AD 10034	49.95	44.78	42.64	45.79
13	ACK 14001	46.21	46.87	38.89	43.99
14	ACK 14004	48.76	50.94	27.69	42.46
15	CB 06803	47.25	45.00	37.11	43.12
16	CB 08702	57.49	41.06	19.80	39.45
17	CB 13539	13.52	15.38	6.81	11.90
18	CB 14508	70.67	65.35	59.28	65.10
19	CB 14533	10.95	10.00	27.41	16.12
20	TR 0927	40.56	35.03	34.67	36.75

21	TR 05-31	74.32	58.24	49.85	60.80
22	TR 13069	30.87	27.22	34.10	30.73
23	TR 13083	52.68	61.87	47.17	53.91
24	TM 1307	43.57	45.06	43.85	44.16
25	TM 07335	31.85	32.99	32.77	32.54
26	TM 09135	25.28	27.00	24.44	25.58
27	TM 10085	53.71	54.29	53.29	53.76
28	TM 12059	31.75	33.35	30.14	31.74
29	TM 12061	50.96	53.95	45.87	50.26
30	TM 12077	64.61	55.85	43.23	54.56
31	PM 12009	43.87	32.66	17.95	31.49
32	EC 725224	72.58	39.48	37.59	49.89
		43.42	40.85	36.18	40.15

	V	N	V × N	N× V
SE d	2.64	0.50	3.51	2.83
CD (P =0.05)	5.38	1.00	7.09	5.65

Table 5: Partial factor productivity of rice genotypes/cultivar as influenced by nitrogen application

S.No	Genotypes/ Varieties	N_1	N_2	N_3	Mean
1	ASD 16	102.9	59.85	45.28	69.3
2	ADT 39	82.0	48.15	37.86	56.0
3	ADT 43	78.2	45.83	37.35	53.8
4	ADT 45	89.0	52.49	40.31	60.6
5	CO 51	82.3	46.47	35.39	54.7
6	TPS 5	77.7	46.25	32.91	52.3
7	MDU 5	94.3	51.57	36.99	61.0
8	ANNA 4	89.3	45.93	30.98	55.4
9	AS 12051	73.5	39.61	26.01	46.4
10	AS 12104	91.6	51.88	35.71	59.7
11	AD 09206	72.9	41.41	29.84	48.0
12	AD 10034	88.6	44.91	30.54	54.7
13	ACK 14001	97.4	55.65	38.49	63.8
14	ACK 14004	92.5	48.86	32.06	57.8
15	CB 06803	79.6	46.18	33.40	53.1
16	CB 08702	80.2	44.06	28.21	50.8
17	CB 13539	56.7	31.25	19.05	35.7
18	CB 14508	85.9	51.20	39.17	58.8
19	CB 14533	33.8	21.05	20.19	25.0
20	TR 0927	54.9	35.78	28.37	39.7
21	TR 05-31	98.3	52.29	37.31	62.6
22	TR 13069	70.1	39.96	32.63	47.6
23	TR 13083	108.0	59.90	40.74	69.5
24	TM 1307	96.0	51.83	36.82	61.6
25	TM 07335	91.6	51.74	38.12	60.5
26	TM 09135	76.6	40.75	30.57	49.3
27	TM 10085	83.6	50.42	39.76	57.9
28	TM 12059	76.5	42.38	30.62	49.8
29	TM 12061	55.4	37.85	30.21	41.1
30	TM 12077	100.3	59.33	40.03	66.6
31	PM 12009	87.0	46.13	30.10	54.4
32	EC 725224	75.3	38.42	30.10	47.9
		81.9	46.2	33.7	54.0

	V	N	V × N	N× V
SE d	0.43	0.13	0.75	0.76
CD (P =0.05)	0.87	0.27	1.52	1.53

Classification of rice genotypes

Fageria and baligar (1993) [3] have grouped plants into 4 classes based their responses to a nutrient availability. The grain yield of each cultivar at the Agronomic efficiency and its corresponding Physiological Use Efficiency are represented in the Cartesian coordinate system. The axes intersect at the point defined by the mean productivity at the AE and PUE. These four quadrants represent the efficiency and response of the cultivars. Cultivars in the first quadrant (upper Y axis and right X axis) were classified as efficient and responsive, those in the second quadrant (upper Y and left X) were non-responsive and efficient, those in the third quadrant (lower Y and left X) were non-efficient and non-responsive and those in the fourth quadrant (lower Y and right X) were efficient and non-responsive.

The figure 2 represents, ASD16, ADT39, ADT45, TPS 5, AD09206, CB06803, ACK14001, TM10085, TM12007, PM12009 and EC725224 are under Efficient and responsive (ER) category which gives average yield at low level and high N use efficiency. The genotypes CB14508, AS12104, TR05-

31, Tm1206a are under the group of Non efficient and responsive (NER) that has low yield at low N level but responds well at higher doses of N. Efficient and Nonresponsive group genotypes are CB14533, TM12059, AS12051, CB13539 and TM09135 which yields average production at low N levels but did not respond well at higher N rates and the last group of Non efficient and Non responsive gives low production at low N levels and did not respond well at higher N rates, genotypes TR13083, CB08702, AD10034, TR13069, CO51, MDU5, Anna 4, TM1307, TR 0927 and ACK 14004 are under this group.

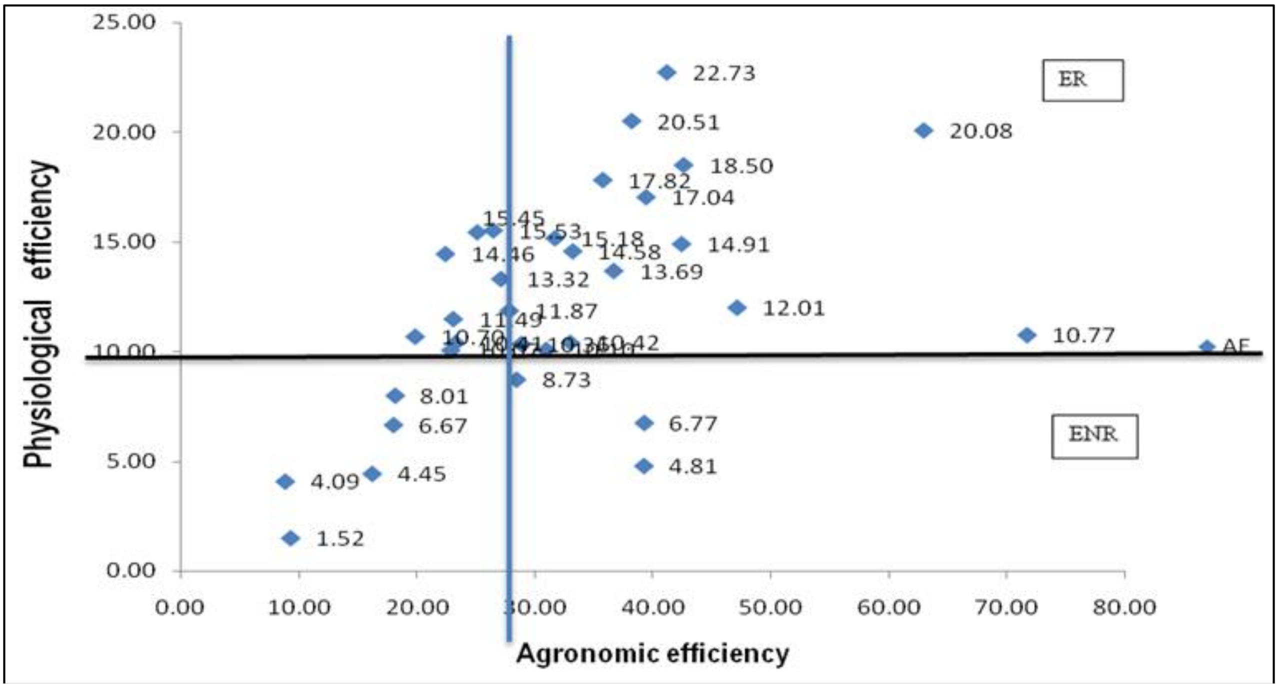


Fig 2: Classification of Efficiency and response to nitrogen of 32 rice genotypes

Conclusion

The results of this experiment identified that the application of higher doses of nitrogen increases the grain yield up to 150% recommended doses of nitrogen ha^{-1}, but in some of the genotypes viz., AS12051, ACK14004, CB08702 and PM12009 are not give any response to higher doses of N application (150% RD of N ha^{-1}). The NUE parameters varied significantly among rice genotypes. The choosing of rice genotypes and optimum N application rate for different rice genotypes is not only for producing higher yield, but also for improving soil fertility and economic net return for farmers.

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