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Classification of Rice Genotypes based on NUE under Changing Climate

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Abstract: In the event of high input agriculture, more emphasis on fertilizer use efficiency, especially nitrogen use efficiency (NUE) has to be given to safeguard the economic as well as environmental resources under rice production system. Though the nutrient use efficiency mainly depends on the efficient fertilizer management practices, the existing N use efficiency pattern under varied doses and the factors responsible for N use efficiency in existing fertilization application in various soil and crop varieties need to be studied for further improvement in N use efficiency. With this view, field experiment was initiated to determine various classes of NUE at different N levels under the promising rice varieties/genotypes by following split plot design. The genotypes were grouped as efficient & responsive (9), non-efficient & responsive (4), efficient & non-responsive (6) and non-efficient & non-responsive (13) genotypes. The efficient and responsive genotypes can be used for high input Agriculture. The lowest agronomic nitrogen use efficiency was observed under higher dose of 150 % recommended dose of nitrogen than other doses. The physiological nitrogen use efficiency of the genotypes decreased with increasing nitrogen fertilizer.

Keywords: Rice, NUE, ANUE, PNUE, Efficient and responsiveness

The rapid rate of climate change and its magnitude is a great concern globally nowadays. Variation in climatic events and the increase in extreme weather have a significant serious threat to socioeconomic and livelihood (Zhang et al 2014). Soltani et al (2016) reported that alteration in the frequency of temperature and rainfall leads to increases in extreme events like heat waves (extreme temperature), flood and cyclones (extreme rainfall), drought (an increase of dry spell, evapotranspiration and failure of monsoon). Highest number of extreme weather events (>15%) have occurred in Maharashtra in the past 50 years followed by West Bengal (9%), Kerala (7.5%), Karnataka (7.5%), Uttar Pradesh (7.1%), and Rajasthan (7.1%). The states most vulnerable to cyclones are Andhra Pradesh (32%), Odisha (20%), West Bengal (15%), Tamil Nadu (15%) and Gujarat (5%) (Annals 2024).

Recently, the cyclone Michaung ravaged Tamil Nadu's capital city during the first week of December, 2023 and several localities received the season's total rainfall in just 36 hours. In the January, 2024, southern districts of Tamil Nadu experienced a record of 110 cm rainfall in a day. This heavy rain lashed the southern districts of Tamil Nadu and completely wiped out farmland in Thoothukudi district, leaving farmers high and dry. Thousands of acres of farmland had been entirely inundated owing to the heavy-rain induced flood. Further, a considerable increase in the count, intensity and duration of heat waves and warm night episodes across Tamil Nadu between the periods 1951-1983 and 1984-2016 was observed. During flooding lot of fertile soil along with nutrients are washed out. It is estimated that over 5.3 billion tonnes of soil has been lost annually through water erosion with a loss of ~8 Mt of NPK. Therefore, the nutrient deficiency is appearing on the crop plants during these extreme climatic events. It is observed that in India the nutrient deficiency in the order of: 95, 94, 48, 25, 36.5, 23.4, 12.8, 7.1 and 4.2% for N, P, K, S, Zn, B, Fe, Mn and Cu, respectively (Annals 2024). The limiting nutrients do not allow the full expression of other nutrients, thereby, lowering the fertilizer responses and crop productivity. Nitrogen being a basic component of many organic molecules *viz*., nucleic acids and proteins (Lea and Miflin 2018), it is a major limiting mineral source for most of the plant species in its acquisition and assimilation. In the event of climatic impact, more emphasis on nutrient use efficiency, especially nitrogen use efficiency (NUE) has to be given to safeguard the economic as well as environmental resources in Agriculture.

Though the nutrient use efficiency mainly depends on the efficient fertilizer management practices, the existing N use efficiency pattern under varied doses and the factors responsible for N use efficiency in existing fertilization methods in various soil and crop varieties need to be studied for further improvement in N use efficiency, grouping and classification of genotypes.

MATERIAL AND METHODS

Field experiment was conducted during *pishanam* season, 2017 at Agricultural Research Farm, Rice Research station, Tamil Nadu Agricultural University, Ambasamudram, Tirunelveli, with split plot design comprising of thirty two rice genotypes asmain plots and four N levels (N_0 (control), N_1 (50 %RDN), N_2 (100 % RDN) and N_3 (150 % RDN) as subplots with three replications. All there commended package of practices was followed to raise a good crop (CPG, 2020). The nursery was raised separately for 32 different rice genotypes under SRI methods (raised beds with dimension of 120 cm wide, 15 cm height with buffer channel of half meter wide all round to facilitate easy drainage).The N fertiliser (urea) was applied as per the treatment schedule. The urea was applied in four equal split doses during before planting (basal 25 %) and top dressing at tillering at 30 DAT (25 %), panicle initiation at 60DAT (25 %) and flowering stage at 75 DAT (25 %).The grain and straw yields was recorded plot wise on harvest and converted in to kg ha^{-1} with 14% moisture. Soil samples before and after the crops was analysed for various physical, chemical and biological properties. The following nitrogen use efficiencies were derived from the parameters such as quantity of N applied quantity of N taken up and grain yield of N applied and control treatment etc. under various rice genotypes at different levels of nitrogen application.

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

The rice genotypes were classified as Efficient and Responsive (ER), Efficient and Non- responsive (ENR), Non-efficient and Responsive (NER) and Non- efficient and Non-responsive to nitrogen fertilizer based on the NUE. The various methods and the parameters used to classify the genotype in to various classes using normal scatter diagram are listed below.

X axis	Y axis	Author
Grain yield at low level nitrogen	Nitrogen use efficiency	Fageria (2003)
Grain yield at low level nitrogen	Physiological N use efficiency	Kosar et al (2003)
Dry matter yield at low level of nitrogen	Efficiency index	Siddiqi and Glass (1981)
Dry matter yield at low level of nitrogen	Dry matter yield at high level of nitrogen	Gill et al (2011)
Grain yield at low level of nitrogen	Total uptake of nitrogen at high level nitrogen application	
Efficiency Index	N utilization efficiency	Fageria (2007)

RESULTS AND DISCUSSION

Grain and straw yields of rice: 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). 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 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 did not respond to higher dose nitrogen (180 kg ha^{-1}). ASD 16 recorded highest mean yield of 6698 kg ha^{-1} followed by MDU5 (6014 kg ha^{-1}), ADT 45 (5875 kg ha^{-1}) responded to higher dose of N applied. In cultivars, the highest mean yield was observed in 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 gave 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}. The variation in yield among different rice varieties was due to the differential efficiency in converting dry matter into grain. Similar findings were also reported in rice varieties under different nitrogen levels by Priyadarsini and Prasad (2003).The significant and positive correlation existed between grain yield and other yield attributes such as number of tillers leaf area index clearly showed the genotypic characters influenced the growth parameters, which in turn contributed more canopy structure i.e. leaf area index by canopy photosynthetic efficiency of the particular variety which resulted higher dry matter production (Amanullah et al 2007). The higher level of nitrogen application influenced the growth parameters such as root length, root volume, leaf area index, plant height, number of tillers $hill^{-1}$ resulted increased dry matter production which is evidenced from the positive correlation associated between the grain yield and other growth and yield attributing parameters such as root length, root volume, leaf area index, plant height, number of tiller $hill^{-1}$ and dry matter production.

For grain yield, the same trend was followed as straw yield. 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 in 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.

Nitrogen use efficiency: The nitrogen use efficiency has been considered in three different perspectives as:

1. Production efficiency (ANUE and PFP_N)
2. Absorption efficiency (N uptake and ANRE) and
3. Utilization efficiency (PNUE, NHI and NP)

Production efficiency: The production efficiency of applied N is reflected in two ways since the crop uses native and applied N. The combined effect of applied and native N on grain yield production is termed as partial factor productivity (PFP_N) and the effect of applied N alone for the production of grain yield is termed as agronomic nitrogen use efficiency (ANUE). The efficiency of applied N on production of grain yield, biomass, protein yield and number of filled grains with respect to genotypes and levels of nitrogen application are discussed below.

Partial factor productivity: PFP_{GY} is an aggregate efficiency index of uptake of both indigenous soil N, fertilizer N, and the efficiency with which acquired N converted to grain yield (Cassman et al 2003). In general, the partial factor

Table 1. Grain and straw yields (Kg ha^{-1}) of rice influenced by genotypes and levels of nitrogen application

Genotypes/N level	Grain yield (Kg ha^{-1})					Straw yield (Kg ha^{-1})				
	N_0	N_{50}	N_{100}	N_{150}	Mean	N_0	N_{50}	N_{100}	N_{150}	Mean
ASD 16	5284	6175	7183	8150	6698^{a}	7333	8235	9675	10292	8884^{b}
ADT 39	3682	4921	5778	6814	5299^{h}	6031	7484	7906	8478	7474^{k}
ADT 43	4259	4691	5500	6723	5293^{h}	7405	7909	8051	8739	8026^{g}
ADT 45	4606	5339	6299	7256	5875^{d}	7239	7932	8267	9251	8172^{f}
CO 51	4587	4940	5576	6371	5368^{g}	7163	7399	8091	8414	7767^{i}
TPS 5	3643	4660	5550	5924	4944^{ij}	5124	6723	7268	7528	6660^{m}
MDU 5	5549	5660	6188	6659	6014^{c}	7823	7754	8584	8713	8218^{ef}
ANNA 4	5289	5355	5512	5577	5433^{f}	7061	7445	7405	7751	7415^{k}
AS 12051	3889	4410	4754	4681	4433no	5778	6663	6798	6174	6353^{n}
AS 12104	4556	5493	6226	6428	5676^{e}	5292	7833	8288	8411	7456^{k}
AD 09206	3254	4374	4969	5372	4492^{n}	6759	7072	7304	7903	7259^{l}
AD 10034	4968	5317	5390	5497	5293^{h}	7333	7961	8000	8351	7911^{h}
ACK 14001	4837	5844	6678	6929	6072^{c}	6757	7888	9290	9753	8422^{c}
ACK 14004	4510	5549	5864	5771	5423^{fg}	6333	7288	7857	7298	7194^{l}
CB 06803	3536	4775	5542	6012	4966^{i}	6661	7055	7577	8557	7462^{k}
CB 08702	4335	4811	5287	5078	4878^{k}	7612	7984	8900	8453	8237^{f}
CB 13539	3029	3401	3750	3429	3402^{r}	6113	6198	6831	6424	6391^{n}
CB 14508	4350	5156	6144	7051	5675^{e}	6777	7949	8655	9724	8276de
CB 14533	1543	2030	2526	4420	2433^{s}	3011	3701	5000	7479	4798^{p}
TR 09027	2878	3291	4294	5107	3892^{q}	4173	6400	6926	7992	6373^{n}
TR 05031	4632	5895	6275	6717	5880^{d}	7209	7811	8500	9621	8285de
TR 13069	3811	4204	4795	5873	4671^{m}	7013	7373	7500	8507	7598^{j}
TR 13083	5778	6479	7188	7333	6695^{a}	8540	8979	9773	10262	9388^{a}
TR 13007	5056	5762	6220	6627	5916^{d}	7724	7999	8557	8972	8313^{d}
TM 07335	4947	5495	6209	6862	5878^{d}	6000	7225	8253	8739	7554^{j}
TM 09135	3660	4594	4890	5502	4661^{m}	5889	7310	8111	8310	7405^{k}
TM 10085	3673	5015	6051	7157	5474^{f}	4944	7407	8273	9823	7612^{j}
TM 12059	3868	4587	5085	5512	4763^{l}	6552	6989	7367	7873	7195^{l}
TM 12061	2911	3322	4542	5438	4053^{p}	4000	5703	7013	7513	6057^{l}
TM 12077	4304	6020	7119	7206	6162^{b}	6190	8639	8957	9233	8255de
PM 12009	3372	5222	5536	5418	4887^{k}	6070	7823	8017	7845	7438^{k}
EC 725224	2956	4517	4611	5419	4376^{o}	5051	6359	6501	7383	6323^{n}
Mean	4111^{d}	4916^{c}	5548^{b}	6047^{a}	5155	6342^{d}	7328^{c}	7922^{b}	8430^{a}	7505
		G	N	G × N	N× G		G	N	G × N	N× G
CD (p=0.05)		61.84	22.15	124.92	125.31		70.81	26.12	146.27	147.79

productivity rice genotypes varied from 35.7 to 69.3 kg (kg N)$^{-1}$ (Fig. 1a). The efficient rice varieties such as ASD16, ADT39, ADT45, MDU5, AS12104, AD10034, ACK14001, ACK14004, CB14508, TR05031, TR13083, TM13007, TM10085, TM12077 and PM12009 recorded the PFP_{GY} with more than the average PFP_{GY} of rice genotypes, which is almost equal to the PFP_{GY} of irrigated rice in well-managed systems (60 kg kg^{-1}). The genotypic potential and differences of partial factor productivity in rice were significantly changed with cultivar types. The partial factor productivity of grain yield decreased with increased dose of nitrogen from 50 to 150 % recommended dose of nitrogen in all the rice genotypes (Fig. 1b). The cultivars recorded more PFP of grain yield under low level of 50 % recommended dose of nitrogen level than 100 and 150 % recommended dose of nitrogen and it ranged from 19.05 to 108 kg (kg N)$^{-1}$. The highest partial factor productivity of grain yield produced by the genotype TR13083, ASD16 and TM12077 under 50 % recommended dose of nitrogen application (Fig. 1c) mainly because of the higher yield supported by native nitrogen ratio of Y_0/N_t (native nitrogen efficiency) observed in this experiment. This is evidenced by Janaki (2000). Similar trends were observed in the partial factor productivity from the reported work of biomass yield, protein yield and number of filled grains.

Agronomic N use efficiency: The ANUE for rice genotypes varied from 1.52 to 22.73 kg (kg N)$^{-1}$ with an average value of 12.09 kg of grain produced per kg of N applied (Fig. 2a). The genotypes namely ASD16, ADT39, ADT45, TPS5, AD09206, ACK14001, CB06803, TR05031, TM10085, PM12009 and EC725224 had agronomic N use efficiency of more than 15 kg (kg N)$^{-1}$ and other varieties / culture showed less than 15 kg (kg N)$^{-1}$. The variation in agronomic N use efficiency among the genotypes indicates difference in biochemical and physiological characteristics, nutrient uptake by roots, remobilization and translocation of absorbed N to different plant organs Samonte et al (2006) also stated that the large genotypic variation in agronomic nitrogen use efficiency was probably due to low yield potential. The lowest agronomic nitrogen use efficiency was observed under higher dose of 150 % recommended dose of nitrogen than other doses (Fig.

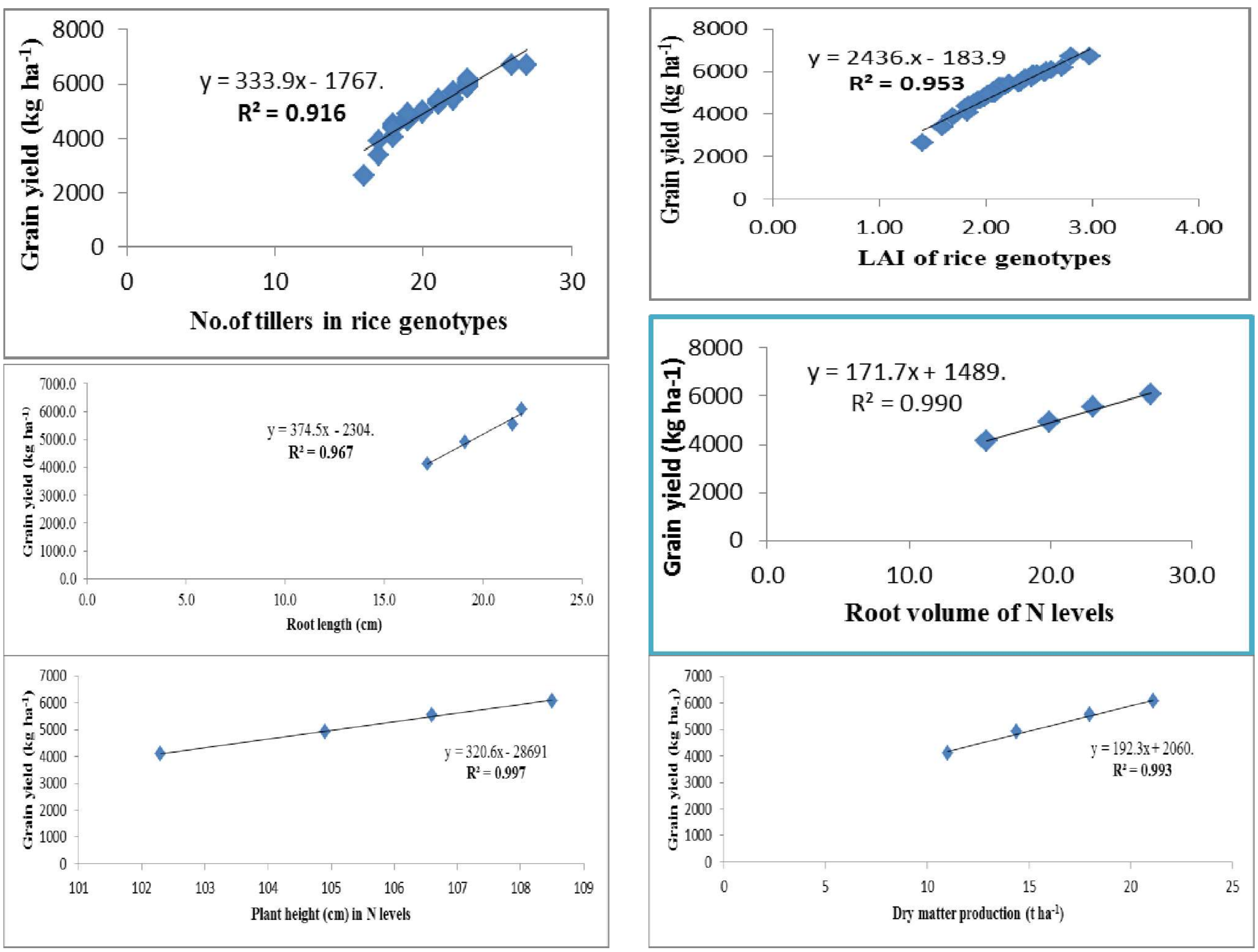

Fig. 1. Correlation between rice grain yield (kg ha^{-1}) and growth parameters

2b). This is in agreement with Peng *et al*. (2007). The agronomic nitrogen use efficiency showed a decreased linear response to applied N because there was no increase in utilization efficiency but increase in production of grain yield with enhanced N fertilization in rice can only be achieved by higher N uptake. The reason for decreased nitrogen use efficiency with N application is not clear (Artacho et al 2009). Among the interaction between rice genotypes and nitrogen levels (Fig. 2c), the decreasing trend of ANUE with increasing N level noticed in the rice genotypes of ADT39, TPS5, AS12051, AS12104, AD09206, AD10034, ACK14001, ACK14004, CB06803, CB08702, CB13539, TR05031, TM13007, TM09135, TM10085, TM12059, TM12077, PM12009 and EC725224 was due to non-response of variety to higher level nitrogen application as observed by Noureldin et al (2013) who reported that agronomic efficiency increased up to optimum levels of nitrogen application and decreased beyond. Low agronomic N use efficiency reflect limited yield response to fertilizer N application because of high indigenous soil N levels (Peng et al 2006). The rice genotypes namely ASD16, ADT45, CO51, MDU5, CB14533, CB14508, TR13069, TM07335 and TM12061 showed increasing trend of ANUE with increasing N levels from 50% recommended dose of nitrogen (60 kg N ha^{-1}) to 150% recommended dose of nitrogen (180 kg N ha^{-1}) which indicated the yield response of genotypes to high level of fertilizer N addition high with less utilization efficiency. This trend indicated the larger variation between nitrogen uptake and N utilization for the particular genotypes. Therefore, it is necessary to develop cultivars that have more efficient in absorption of applied N, in order to minimize loss of N from soil to nearby water bodies and make more economic use of applied fertilizer with higher utilization efficiency, which not only increase rice grain yield but also present environmental pollution

Absorption efficiency: Large genotypic variations also exist in many varieties under this experiment. The efficiency of the crop in absorbing native N from the no fertilizer N added is different from fertilizer N added, due to the indirect effect of applied N on the availability or acquisition of native N and called “added N interactions” (Jenkinson et al 1985).

Recovery or apparent recovery efficiency: The recovery efficiency ranged from 11.90 % by the genotypes CB13539 to 65.10 % by the genotype CB14508 due to greater variation (Fig. 3a) in physiological or morphological characteristics of the genotype might result in this kind of phenomenon (Roy et. al, 2004). The study on genotypic variations for grain yield and N use efficiency were prevalent. Wang et al (2015) also supported the result of this experiment. In general, the apparent N recovery efficiency decreases with increasing fertilizer N rates (Fig. 3b). The excess N supply is susceptible to loss through runoff, leaching and gaseous emissions (Fageria and Baligar 2001). The interaction of genotypes with levels of nitrogen application (Fig. 3c), grouped the varieties into two groups. In one group the apparent N recovery efficiency generally decreases as the nitrogen doses increased in the genotypes viz., ASD16, ADT39, TPS5, AD09206, AD10034, ACK14001, CB06803, CB08702, CB14508, TR09027, TR05031, TM12077, PM12009 and EC725224. These varieties doesn't have the capacity to absorb excess N supply whereas in another group of genotypes with ADT43, CO51, ANNA 4, AS12104, AS12051, ACK14004, CB13539, TR13083, TM13007, TM07335, TM09135, TM10085, TM12059 and TM12061 showed increasing trend of ANRE up to 100 % recommended dose of nitrogen. The nitrogen use efficiency at higher N rate pointed out that rice plant are unable to absorb or utilize N at higher rates or the rate of N uptake by plant cannot keep pace with the loss of nitrogen. The similar result of negative correlation of recovery efficiency with N application rate was obtained by Dong et al (2012). The relative amount of N that the crop can recover from the available N pool depends on the relative sink strength of physiological or morphological character of the variety (Inthapanya et al 2000, Shi 2002). Apparent N recovery efficiency reflect the percentage of fertilizer N recovered in above ground plant biomass (Dobermann 2007).

Physiological N use efficiency: The physiological nitrogen use efficiency varied from 6.90 to 74.71 kg (kg $N)^{-1}$ with a mean of 31.59 kg(kg $N)^{-1}$. the genotypes CB14533 had maximum physiological efficiency of 71.71 kg (kg $N)^{-1}$ followed by PM12099 (62.39 kg (kg $N)^{-1}$) and the minimum efficiency of 8.82 kg (kg $N)^{-1}$ under AD10034 (Fig. 4a). This is due to the difference among the varieties in PNUE. Among the various nitrogen level, 50 % RDN enhanced physiological N use efficiency of 32.50 kg (kg $N)^{-1}$ followed by 100 % of RDN which was on par with 150 % RDN (30.98 kg (kg $N)^{-1}$) which were statistically equal (Fig. 4b).In general, the physiological nitrogen use efficiency of the genotypes decreased with increasing nitrogen fertilizer. The higher physiological N use efficiency of 81.93 kg (kg $N)^{-1}$ by the genotype CB14533 with 100 % recommended dose of nitrogen might be due to genotypic character of the variety under the sufficient level of N application. However, the 16genotypes showed decreasing trend with increased nitrogen application (Table 1). The uptake of N by different rice genotypes increases with increasing the rates of N application, but it reduces the N utilization efficiency (Fig. 4c). The capability of increase in yield per kg nitrogen declined remarkably with increasing nitrogen application (Devika et al 2018).PNUE increased with enhancement of nitrogen application under the genotypes ASD 16, ADT43, CO51, MDU 5, ANNA 4, CB08702, CB14508, TR0927, TR13069, TM07335, and TM12061 due to responsiveness of these varieties to the applied N. López-Bellido and López-Bellido (2001) suggested that physiological N use efficiency increased with nitrogen application and reflected the utilization of absorbed nitrogen efficiently by rice plant.

The genotype CB14533 at higher level of 150 % recommended dose of nitrogen application showed the diminishing trend of PNUE at higher N rates pointed out that rice plants indicated the inability to absorb or utilize nitrogen at higher rates or the rate of nitrogen uptake by plant cannot keep pace with the loss of nitrogen (Feng et al 2011).

Classification of rice genotypes: The various methods and the parameters are used to classify the rice genotypes as efficient and responsive (ER), efficient and non- responsive (ENR), non-efficient and responsive (NER) and non- efficient and non- responsive to applied nitrogen fertilizer. The low N use, high cost of N fertilizers, various N losses through leaching and NH_3 volatilization and other geopolitical issues has compelled the scientists to identify more N efficient genotypes and their mechanisms to increase N use efficiency in agriculture is a first pre-requisite for future production and productivity of rice. A number of methods and parameters have been proposed for classifying genotypes for their N use efficiency. Most of the above mentioned methods classify genotypes at low N conditions, hence this categorization may not classify the genotypes responded under high N level (Jothimani 2021).

However, the genotypes were classified based on absorption and utilization capacities such as agronomic N

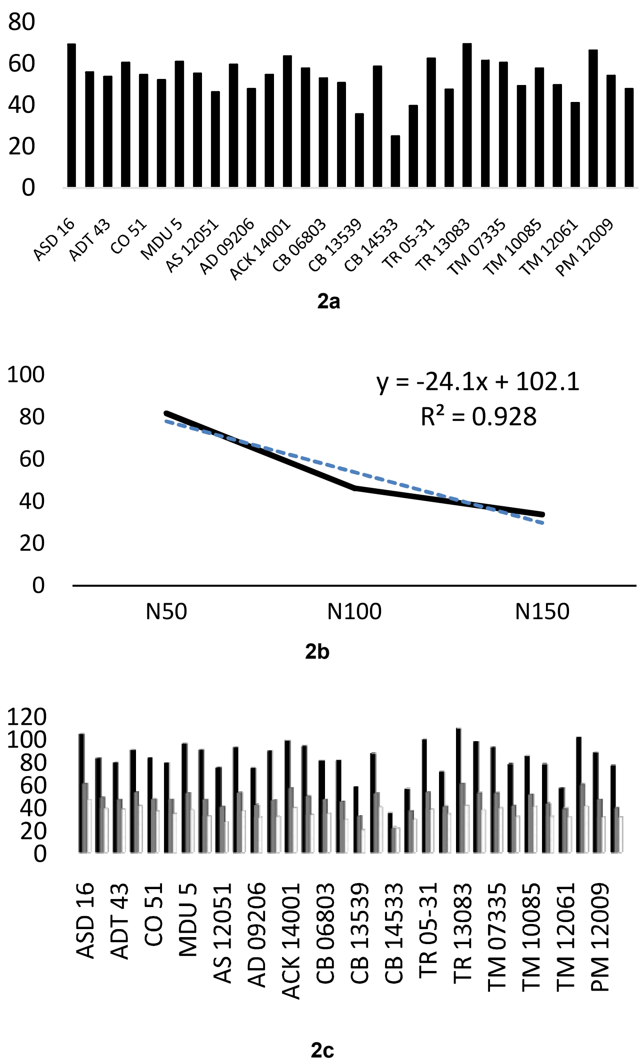

Fig. 2. PEP (Kg (kg (N)$^{-1}$) as influenced by genotypes (a), N level (b) and their interaction (c)

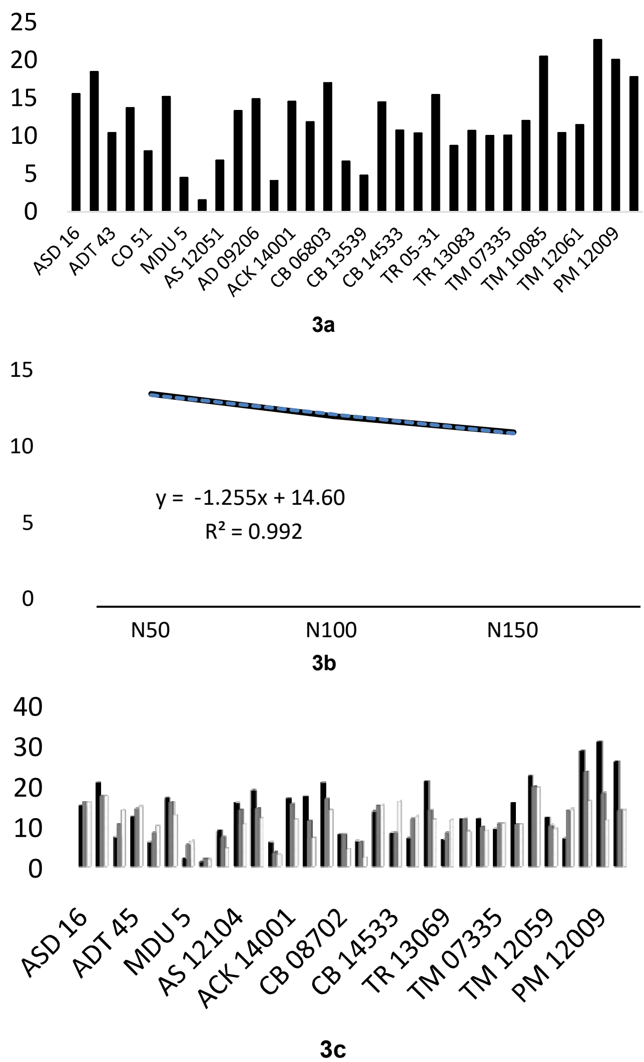

Fig. 3. ANUE PEP (Kg (kg (N)$^{-1}$) as influenced by genotypes (a), N level (b) and their interaction (c)

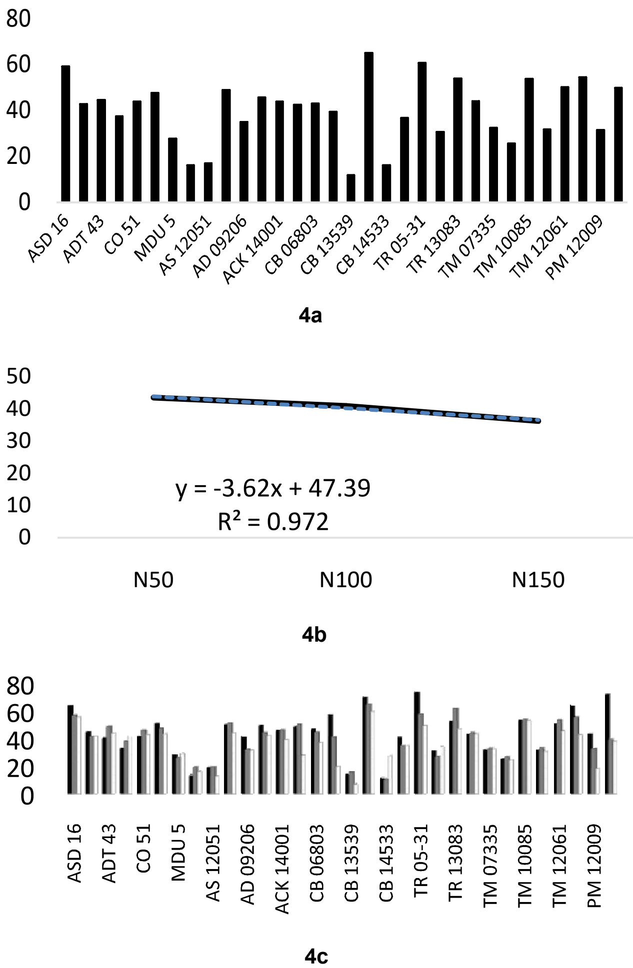

Fig. 4. ANRE as influenced by genotypes (a), N level (b) and their interaction (c)

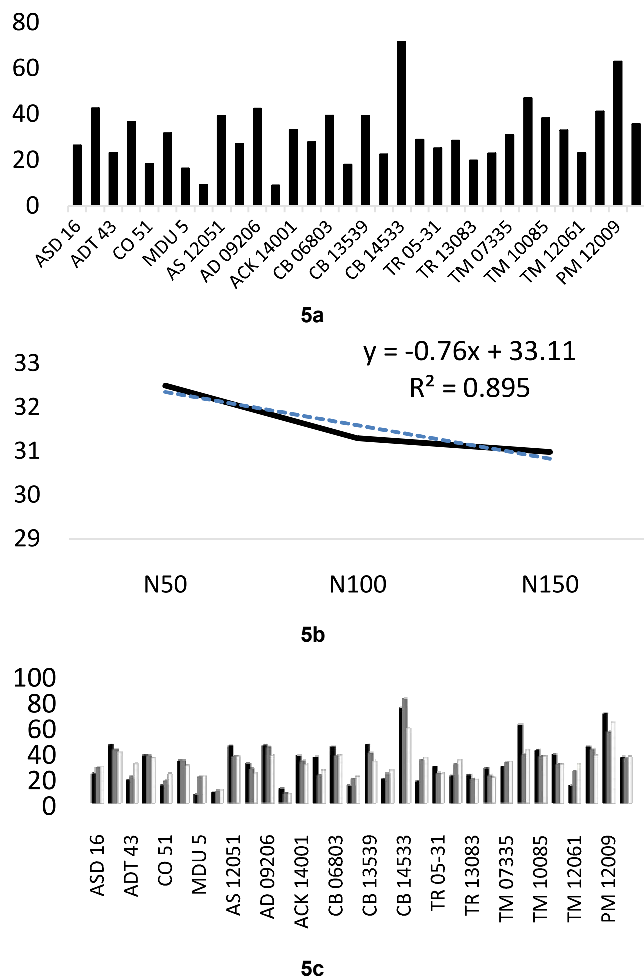

Fig. 5. PNUE as influenced by genotypes (a), N level (b) and their interaction (c)

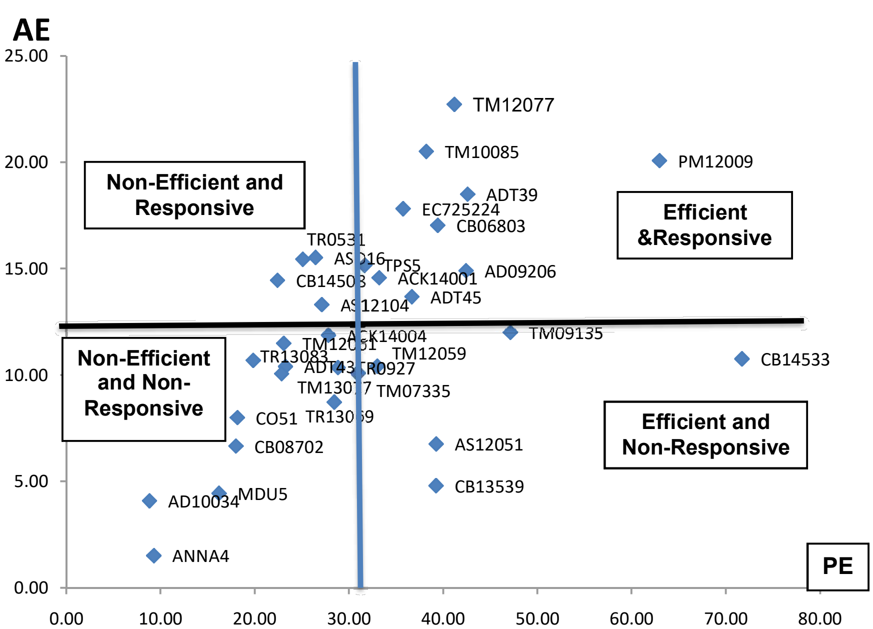

Fig. 6. AE and PE model to classify rice genotypes based on NUE

use efficiency and physiological N use efficiency at six different combinations of N levels (kg ha^{-1}) used in this experiment viz., 0x60, 0x120, 0x180, 60x120, 60x180, 120x180 (Table 2). The symbol x shows that the genotypes were efficient and responsive at the combinations of low and high rate of N application. Some genotypes showed their

Table 2. Efficiency of genotypes at different combinations of N doses

Efficient	0x60	0x120	0x180	60x120	60x180	120x180
ASD 16	x	x	x	x	x	x
ADT 39	x	x	x	x	x	x
ADT 43	0	0	0	0	0	0
ADT 45	x	x	x	x	x	x
CO 51	0	0	0	0	0	0
TPS 5	x	x	x	x	x	x
MDU 5	0	0	0	0	0	0
ANNA 4	0	0	0	0	0	0
AS 12051	0	0	0	0	0	0
AS 12104	x	x	0	x	0	x
AD 09206	x	x	x	x	x	x
AD 10034	0	0	0	0	0	0
ACK 14001	x	x	x	x	x	x
ACK 14004	x	0	0	0	0	0
CB 06803	x	x	x	x	x	0
CB 08702	0	0	0	0	0	0
CB 13539	0	0	0	0	0	0
CB 14508	x	x	x	0	0	x
CB 14533	0	0	0	0	0	x
TR 0927	0	0	x	0	x	x
TR 05-31	x	x	x	x	x	0
TR 13069	0	0	x	0	0	x
TR 13083	0	0	x	x	0	0
TM 13007	0	0	0	0	0	0
TM 07335	0	0	x	0	x	0
TM 09135	x	0	0	0	0	0
TM 10085	x	x	x	x	x	x
TM 12059	0	0	0	0	0	0
TM 12061	0	x	0	0	0	x
TM 12077	x	x	x	x	x	x
PM 12009	x	x	x	x	x	x
EC 725224	x	x	x	x	x	x

X – Efficient and Responsive

Table 3. Grouping and classification of rice genotypes based on NUE

Group	Cultivars	Number
Efficient and responsive	ADT 45, ADT 39, TPS 5, PM 12009, TM 10085, CB 06803, AD 09206, ACK 14001, EC 725224	9
Efficient and non-responsive	ASD 16, TR 0531, CB 14508, AS 12104	4
Non-efficient and responsive	CB 14533, TM 09135, CB 13539, AS 12051, TM 07335, TM 12059	6
Non-efficient and non-responsive	Anna 4, MDU 5, Co 51, ADT 37, TR 0927, AD 10034, CB 08702, TM 13077, TR 13069, TR 13083, TM 12061, ACK 14004, TR 0927	13

efficiency and responsive to the all the combination of applied N rates. Some genotypes were efficiency and responsive in nature at the limited combination of applied N. However, the symbol 0 shows that the genotypes were not either responsive or efficient to the application of N in combinations.

Further, a scattered diagram was drawn by plotting agronomic N efficiency in X axis and physiological N efficiency in Y axis. An intercept line was drawn at the mean agronomic and physiological efficiencies with perpendicular and parallel line on the scattered diagram which divided the graph into four equal quadrants. The top left quadrant had non efficient and responsive varieties, the top right quadrant represented the efficient and responsive group of rice varieties, the bottom left quadrant had non-efficient and non-responsive varieties and the bottom right quadrant represented non efficient and responsive varieties (Fig. 5).

The9 efficient and responsive (ER), 5 efficient and non-responsive (ENR),6 Non-efficient and responsive (NER) and 13 Non – efficient and non-responsive (NENR) genotypes were classified.

CONCLUSION

This AE vs PE model classified rice genotypes for varied types and practices of rice farming. The efficient and responsive genotypes can be used for high input Agriculture whereas the efficient and non-responsive cultures can be used for low input Agriculture (organic farming).

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