# Evaluation of Rice Landraces for Nitrogen Use Efficiency on Soil of Toje Series

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**ABSTRACT**

**Background**: To ameliorate challenges of environmental pollution due to over-use of nitrogen fertilizer, juxtaposed with soil-nitrogen depletion as a limitation to subsistent farming, utilizing varieties responsive to minimal application of fertilizer is of priority.

**Aim**: The goals of the study were to: identify genotypes that are nitrogen use efficient, assess genotypic variations including relationship and heritability of yield related traits and nitrogen use efficiency components.

**Methods**: Twenty rice landraces with two nitrogen levels (0 and 50 kg/ha) replicated thrice in pot and field experiments were conducted. The experimental design for pot experiment was completely randomized design in a factorial arrangement while split plot design was used for field experiment.

**Results**: Landraces such as GH1550, GH1801, GH1822, GH1535, GH1590, GH1515 and GH2145 were efficient and responsive to both nitrogen levels. Analysis of variance showed significant differences for filled spikelets, panicle number, panicle length, 1000-grain weight, spikelet per panicle and harvest index. Nitrogen Use Efficiency, Nitrogen Uptake Efficiency, Nitrogen Utilization Efficiency, Grain Nitrogen Concentration and Straw Nitrogen Concentration showed significant increase under 0kg/ha of N compared to 50kg/ha in both pot and field experiments. Nitrogen use efficiency correlated significantly with filled spikelet, grain yield, panicle length, 1000-grain weight and nitrogen uptake efficiency. Broad-sense heritability estimates were high for traits such as filled spikelet, grain yield, panicle number, panicle length, 1000-grain weight, spikelet per panicle and harvest index as well as nitrogen use efficiency and its components.

**Conclusion**: The identified Nitrogen Use Efficient landraces have the genetic potential needed to accelerate rice improvement for increased productivity in the characteristic smallholder low input cultivation systems in Ghana.

**Keywords:** Heritability, Nitrogen Uptake Efficiency, Nitrogen Utilization Efficiency, Traditional cultivars

## Introduction

Rice occupies a leading position among cereal crops along with wheat and maize, thus, considered a food security crop (*Maclean* et al. 2002). Aside from the provision of food and forage, it aids in alleviating poverty via the provision of raw materials for industries, and the generation of income for small holder farmers (*Olembo* et al. 2010). Despite its numerous benefits, its production is faced with lots of challenges especially in sub-Saharan Africa (SSA). Its cultivation in SSA is mostly carried out via subsistent farming with high dependence on soil nitrogen availability (*Saito* and *Futakuchi,* 2009). In situations where access to industrial fertilizer is available, its application is in high doses to replenish the already


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depleted nitrogen for increased yield. Though adoption of industrial nitrogen fertilizers aids in improving crop yield, it has caused havoc to the environment due to its over-use. Analysis on application of synthetic fertilizer globally for the past 4 decades, indicates the amount of fertilizer agricultural crops utilized is 7.4-fold as against the yield of 2.4-fold. This suggests that the application of fertilizers in high doses does not necessarily guarantee high yield, but rather has considerable negative effect on biodiversity and the environment (*Samonte* et al., 2006even though it has economic and ecological implications. This study examined the significance and magnitude of variation in N content, NUE, N translocation ratio (NTR; *Hirel* et al., 2011). To curb the environmental and ecological challenges faced with nitrogen fertilizer, an optimum fertilization level in paddy fields where Nitrogen Use Efficiency (NUE) is of utmost priority is the need of the hour.

Nitrogen use efficiency (NUE) can be described as the total biomass or grain yield produced per unit available N fertilizer. It may be due to the interplay between the environment and genetic factors (*Xu* et al., 2012; *Haung* et al., 2004). It is divided into two main mechanisms: the absorption of N; nitrogen uptake efficiency (NUpE) and the assimilation of the absorbed N necessary for grain production; nitrogen utilization efficiency (NUtE) (*Han* et al. 2015 ). The decline in NUE among rice genotypes may be due to deficiency in either/both NUpE and NUtE. Thus, screening for genotypic variability and heritability of traits related to NUE and its components (NUpE and NUtE) in breeders' germplasm, coupled with genotype x Nitrogen (N) interactions as well as the precision in selection under varied levels of N is essential (*Garnett* et al. 2015). More so, to allow understanding of phenotypes associated with high NUE from simplistic to complex growth conditions, relating data from both pot and field experiments is imperative (*Beatty* et al. 2010). Several studies show that variability in the genotypes used as well as heritability of traits related to NUE and its components have been investigated in irrigated or rainfed low land rice in Asia (*Inthapaya* et al., 2000; *Koutroubas* and *Ntanos*, 2003; *Haefele* et al., 2008; *Wu* et al., 2016). In addition, a negative relationship has been recorded among NUtE, grain and straw N concentrations (*Inthapanya* et al., 2000; *Koutroubas* and *Ntanos*, 2003; *Samonte* et al., 2006), while another study indicated a strong association between grain yields of rice and NUE (*Haefele* et al. 2008). *Kumar* et al. (2016) recorded high heritability for plant height, number of productive tillers, panicle length, number of spikelets per panicle, grain yield per plant and NUE at low N levels. *Rao* et al. (2018) studied NUE on rice landraces in Asia and they identified donors for high N uptake and N translocation in grain resulting in higher yields under low N.

Landraces are better adapted to environmental stress under low input conditions and constitute a unique germplasm for ascertaining NUE lines (*Ali* et al. 2018). Though NUE lines have been identified in various rice genotypes in Asia and some parts of Africa (*Fageria* et al., 2010; *Segda* et al., 2014; *Rao* et al., 2014; *Lakew*, 2015; *Rao* et al., 2018), there is a dearth of information on the identification of NUE lines in rice germplasm collections in several countries in West Africa which includes Ghana (*Segda* et al. 2014). Hence, the objectives of this study were to: identify landraces that are nitrogen use efficient; assess genotypic variations including relationships and heritability of yield related traits and nitrogen use efficiency components.

## 3 Materials and methods

### *3.1 Experimental Site*

Field and Pot experiments were conducted at the research farm of the Department of Crop Science, University of Ghana, Legon from February 2019 to June 2019. The farm experiences a bi-modal seasonal rainfall pattern with an annual average precipitation of 700-1000 mm. It lies within latitude 5° 39′ N and longitude 0° 539′ W and has a gentle topography of 0.30. The major and minor rainfall seasons start from April - July and September - December, respectively. Average annual temperature recorded at the site during the period is about 26.9 °C and relative humidity ranges from 60 to 90 % at night and 20 - 55 % throughout the year. The soil type is savanna ochrosol locally called Toje series classified by *Eze*, (2008) as a Rhodustalf and Rhodic Lixisol according to *USDA* (1999, 2003). Toje series is among the most widely cultivated soils of the Accra Plains. Toje is developed on Quartzite schist (*Fiagbedzi*, 1989). The soil contained 0.13% of nitrogen, 30.1% of phosphorus, 0.79 cmol/kg of potassium, 2.99 mg/kg of carbon and particle size constituting; 56% sand, 25% clay and 19% silt in the top 15cm of the soil profile.

### *3.2 Plant material:*

Twenty (20) rice landraces were used for the study out of which nineteen were from the Plant Genetic Resource Research Institute, Bonsu (PGRRI), and one was from the Crop Research Institute, Kumasi (Table 1).

**Table 1: The twenty accessions used in the study and the respective institutions from which they were collected.**

| Accessions | Institutions |
|---|---|
| GH1514, GH1515, GH1516, GH1519, GH1531, GH1535, GH1538, GH1549, GH1550, GH1552, GH1574, GH1583, GH1587, GH1590, GH1599, GH1597, GH1801, GH1822, GH2145 | Plant Genetic Resource Research Institute, Bonsu |
| Aunty Jane | Council for Scientific and Industrial Research - Crops Research Institute, Kumasi |

### *3.3 Experimental design and nitrogen application*

A total of 120 polythene bags serving as pots with width 23 cm and length 20 cm were used. Five kilograms (5 kg) of the experimental soil was weighed into each pot. A completely randomized design arranged in a factorial manner was employed with three replicates. Forty combinations of treatments were compared (20 varieties × 2 levels of fertilization) with three seeds sown in each pot. The field experiment was conducted using a split plot design with three replicates. Plot size was 2 m by 1.7 m. Beds were raised and the spacing between each bed and row was 70 cm with an alley of 1 m between blocks. Two treatment levels of nitrogen (N) were used thus, available N (no N) and low N (50 kg/ha). Nitrogen fertilizer was applied in two split doses: 50% at tillering (25 kg/ha) and 50 % at panicle initiation (25 kg/ha). Other major nutrients such as phosphorus (P) and potassium (K), were applied to all pots at 90 kg/ha. Phosphorus (P) in the form of triple superphosphate and potassium (K) in the form of potassium chloride were applied in two split applications; tillering (45 kg/ha) and panicle initiation (45 kg/ha). Plants were watered on a daily basis to maintain moisture in the soil. The trial was conducted in an upland condition during the rainy season. Weeds on beds were controlled by hand.

### *3.4 Phenotypic data*

Data collection was conducted during harvest as prescribed by *Getachew* and *Nabiyu* (2018) for both pot and field experiments. For each sampling, three representative plants (in pot experiments) or hills (in field trials) for each landrace were garnered. At maturity, plants were reaped and disjointed into straw and panicle. Filled grains (spikelets) were separated from unfilled spikelets, oven dried at 60˚C for 72 h and weighed. Filled grains were used to evaluate grain yield (GY) and grain N concentration (GNC). 250 filled grains and 250 empty grains were weighed for the estimation of the total number of filled and empty grains. Straw samples were oven dried at 60 °C for 72 h and weighed to measure straw yield (SY). Fifteen trait were calculated as suggested by *Rakotoson* et al. (2017) (Table 1). Based on the grain yield data, landraces were grouped into efficient (E), responsive (R), and efficient and responsive (ER) as per *Fageria* and *Baliger* (1993).

**Table 2: Description of the 15 measured and calculated yield and NUE related traits**

| Code | Trait | Method | Unit |
|---|---|---|---|
| FG | Filled grain | 100 × FG / total number of spikelets | % |
| GNC | Grain N concentration | Grain N concentration of 3 hills at maturity | % |
| GY | Grain yield | PN × SPIPAN × FG × TGW | kg/ha |
| HI | Harvest Index | GY/(GY + SY) | - |
| NUE | Nitrogen use efficiency | GY/N supply | kg grain kg/N |
| NUpE | Nitrogen uptake efficiency | TNUP/N supply | kg N kg/N |
| NUtE | Nitrogen utilization efficiency | GY/TNUP | kg grain kg/N |
| PN | Number of panicles | Mean of panicle number of 3 hills | - |
| SNC | Straw N concentration | SNC of 3 hills at maturity | - |
| SPIPAN | Number of spikelets per panicle | Mean of number of spikelets of 3 hills | % |
| SY | Straw Yield | Biomass of 9 hill | - |
| TGW | 1000-grain weight | Weight of 250 filled spikelets × 4 | kg/ha |
| TNUP | Total plant N uptake | GNC × GY + SNC × SY | g |

## 3.5 Tissue nitrogen concentration

N concentration in the straw and grain were analyzed by Kjeldahl procedure using the standard protocol (*Piper*, 1966). The samples were oven dried at 65°C for 72 hours and pulverized separately into fine powder. 0.1g of the samples was used for the analysis. The percent N was calculated using the formula below:

$$\% \text{ Total Nitrogen} = \frac{(\text{Titre value} - \text{Blank}) * 1400}{\text{weight} * 5 * 1000} \quad \text{.... Equation (1)}$$

## 3.6 Statistical Analysis

### *3.6.1 Growth parameters, yield and NUE components*

Analysis of variance was computed using GENSTAT statistical package (version 12) sources of variation such as genotype, N level, replication and the interaction of genotype × N level were used in the statistical model. These were considered as fixed effects (genotype, N level, replication, genotype × N). A significant level of $p \leq 0.05$ was computed and a Post Hoc test for values with $p \leq 0.05$ using Turkey's test was carried out.

Pearson *phenotypic correlation* coefficients based on means of varieties over replicates were calculated for all traits using Minitab® 19 statistical analysis package

### *3.6.2 Estimates of variance components*

The population's variability was estimated using mean, phenotypic, genotypic and coefficient of variation based on *Rosmania et al.* (2016) as follows:

$$\sigma^2 G = [(MSG) - (MSE)] / r \quad \text{..... Equation (2)}$$

$$\sigma^2 P = [\sigma^2 G + (\sigma^2 E/r)], \quad \text{........ Equation (3)}$$

Where: $\sigma^2$ G = Genotypic variance; $\sigma^2$ P = Phenotypic variance; $\sigma^2$ E = Environmental variance (error mean square from the analysis of variance); MSG = mean square of genotypes; MSE = error mean square; r = number of replications. Genotypic coefficient of variation (GCV) = $(\sigma^2 G)^{1/2}/x) \times 100$; Phenotypic coefficient of variation (PCV) = $(\sigma^2 P)^{1/2}/X) \times 100$, where: $\sigma^2$ G = Genotypic variance; $\sigma^2$ P = Phenotypic variance; X is grand mean of a character. Broad-sense *heritability* ($H^2$) for all traits at each level of N was calculated from variance components using the formula:


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$H = \sigma^2_G / \sigma^2_P$ ……………….. Equation (4)

## 4 Results

### 4.1 Grain yield at two levels of N application in both pot and field experiments

The grain yield recorded at N0 and N50 aided grouping of the landraces into four; efficient (E), responsive (R), efficient and responsive (ER), and non-efficient and non-responsive (NE, NR) as prescribed by *Fageria* and *Baliger* (1993). Similar landraces were observed to fall into the four categories under pot and field experiments respectively, indicating that the yield was consistent in spite of environmental variability (Table 2). GH1587 was efficient (E) due to its yield being higher than the mean yield of the 20 landraces at N0 level but its response to N application at N50 was lower than average yield ($p < 0.001$). GH1549 belonged to the responsive (R) group, because its yield was less than the mean yield of the 20 landraces at N0 level but had more yield than the average at N 50. The third group is considered as efficient and responsive (ER) and had yields that were above the average yield of 20 landraces both at N0 and N50 levels ($p < 0.001$). GH1822, GH1550, GH1515, GH1535, GH2145, GH1801 and GH 1590 fell into this category.

**Table 2: Mean Grain yield (kg/ha) under two levels of N treatment**

| Grain yield (kg/ha) pot | | | Grain yield (kg/ha) field | | | |
|---|---|---|---|---|---|---|
| Land race | N0 | N50 | | N0 | N50 | |
| GH1549 | 357.00 | 2970.00 | | 403.33 | 3002.00 | |
| GH1587 | 1117.10 | 1459.00 | | 1131.00 | 1481.00 | |
| GH1574 | 597.10 | 1449.00 | | 621.00 | 1551.00 | |
| GH1822 | 1676.10 | 2841.00 | | 1702.00 | 2941.00 | |
| GH1514 | 957.50 | 1173.00 | | 1009.00 | 1251.00 | |
| GH1550 | 1099.00 | 4703.00 | | 1201.00 | 4804.00 | |
| GH1515 | 1024.00 | 3564.00 | | 1051.00 | 3701.00 | |
| GH1552 | 699.10 | 2448.00 | | 711.00 | 2551.00 | |
| GH1535 | 1160.10 | 2995.00 | | 1201.00 | 3002.00 | |
| GH1538 | 703.00 | 1921.00 | | 721.00 | 2001.00 | |
| GH1531 | 679.00 | 1792.00 | | 691.00 | 1801.00 | |
| GH2145 | 2092.10 | 8035.00 | | 2121.00 | 8107.67 | |
| GH1801 | 1970.00 | 2800.00 | | 2003.00 | 2851.00 | |
| GH1519 | 599.20 | 1652.00 | | 611.00 | 1701.00 | |
| GH1599 | 450.00 | 627.00 | | 497.00 | 636.00 | |
| GH1590 | 1785.00 | 3420.00 | | 1801.00 | 3501.00 | |
| GH1583 | 579.20 | 1741.00 | | 601.00 | 1761.00 | |
| GH1591 | 576.00 | 1359.00 | | 651.00 | 1381.00 | |
| GH1516 | 779.10 | 1539.00 | | 806.00 | 701.00 | |
| Aunty Jane | 699.10 | 3002.00 | | 1591.00 | 3051.00 | |
| **Mean** | **979.94** | **2574.08** | | **1011.72** | **2633.33** | |
| G | | | ** | | | ** |
| N | | | ** | | | ** |
| G × N | | | ** | | | ** |
| CV (%) | | | 0.4 | | | 0.1 |

## 4.2 *,**,ns are significant at the 5 and 1% probability level and non-significant respectively

### *Yield related traits of rice landraces under no and low nitrogen levels in pot and field experiments*

Genetic variations were observed among the landraces due to significant differences and interactions indicated by analysis of variance (Table 3). A wide range with a general trend of reduction for eight yield related traits was observed in the twenty landraces under N0 compared to N50 across both pot and field evaluation (Table 3). However, unfilled spikelets (UFS) was higher as nitrogen level increased which ranged from 70 – 750 and 86 – 781 in pot and field experiments respectively. Low UFS was recorded at N0 level ranging from 10 – 90 and 31 – 71 in pot and field experiments, respectively. Genotypes showed significant differences for harvest index (HI) with mean ranging from 38.36 – 50.06 % in pot experiment and 33.19 % - 46.78 % in field experiment under N0 and N50 respectively.

## 4.3 Nitrogen use efficiency and its component traits in pot and field experiments

Analysis of variance indicated that genotypic effects were significantly different for N use efficiency and its component traits ($p < 0.05$) (Table 4). In this study, varied ranges of means were recorded with a common trend in increase for NUE, NUpE, and NUtE under N0 as compared to N50 in pot and field experiments.

**Table 3: Summary of ANOVA for yield related traits under no and low nitrogen levels of twenty rice landraces in pot and field experiment**

| Trait | Range | | | | Mean | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pot | | Field | | Pot | | Field | | | | |
| | No N | Low N | No N | Low N | No N | Low N | No N | Low N | N | G | G × N |
| FS | 300.00-1400.00 | 522.00 – 3360.00 | 311.00 – 1461.00 | 580.00 – 3407.00 | 683.40 | 1419.20 | 730.83 | 1482.25 | ** | ** | ** |
| GY | 357.00-2092.00 | 627.13 – 8035.00 | 403.00 – 2121.00 | 636.00 – 8107.00 | 979.94 | 2574.08 | 1011.72 | 2633.33 | ** | ** | ** |
| PN | 7.00 – 14.00 | 11.00 – 30.00 | 10.00 – 19.00 | 15.00 – 34.00 | 10.40 | 19.83 | 14.18 | 23.35 | ** | ** | * |
| PL | 16.00 – 26.50 | 20.00 – 30.00 | 18.00 – 29.00 | 22.00 – 33.00 | 20.80 | 25.31 | 22.27 | 26.83 | ** | ** | ** |
| TGW | 10.00 – 20.00 | 10.00 – 25.00 | 9.00 – 24.00 | 17.00 – 32.00 | 14.45 | 17.75 | 16.41 | 20.77 | ** | ** | ** |
| UFS | 10.00 – 90.00 | 70.00 – 750.00 | 31.00 – 71.00 | 86.00 – 781.00 | 32.72 | 381.91 | 50.65 | 415.70 | ** | ** | ** |
| SPN | 50.00 -100.00 | 70.00 – 150.00 | 55.00 – 121.33 | 76.00 – 161.00 | 65.45 | 91.15 | 77.55 | 101.15 | ** | ** | ** |
| HI | 21.36 – 61.65 | 29.43 – 65.25 | 21.23 – 50.31 | 26.14 – 69.25 | 38.36 | 50.06 | 33.19 | 46.78 | ** | ** | ** |

*, **, ns are significant at the 5 and 1% probability level and non- significant, respectively

FS: Filled spikelet
UFS: Unfilled spikelet
TGW: 1000-grain weight
GY: Grain yield
SPN: Spikelet per panicle
PL: Panicle Length
PN: Panicle number
HI: Harvest Index

### 4.4 Genotypic and phenotypic coefficient of variations and heritability estimates for yield related traits and NUE components in pot and field experiments

Genotypic coefficient of variation (GCV) was less than its corresponding estimates of phenotypic coefficient of variation (PCV) for all yield related traits (Table 5). GCV was lower than its equivalent evaluations of PCV for all yield related traits and NUE components signifying the vital role of the environment in the expression of these traits. The GCV for NUtE, GNC and SNC are same as their PCV resulting in zero environmental variance. This makes the heritability of such characters 100%. Broad-sense heritability estimates for the yield related traits ranged from 97.83% to 100% under pot and field conditions (Table 6). NUE components observed for both pot and field experiments had heritability estimates of 95.37% to 100.00% (Table 6).

| Trait | Range | | | | Mean | | | | N | G | G × N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pot | | Field | | Pot | | Field | | | | |
| | No N | Low N | No N | Low N | No N | Low N | No N | Low N | | | |
| NUE | 27.46 – 160.88 | 27.17 – 160.71 | 30.94 – 163.11 | 12.72 – 163.11 | 75.38 | 51.47 | 76.11 | 71.75 | ** | ** | ** |
| NUpE | 79.77 – 609.20 | 34.15 – 567.85 | 102.80 – 566.71 | 41.89 – 546.57 | 255.98 | 159.10 | 262.19 | 159.44 | ** | ** | ** |
| NUtE | 0.13 – 0.93 | 0.22 – 0.69 | 0.19 – 0.75 | 0.23 – 0.59 | 0.33 | 0.35 | 0.32 | 0.35 | ** | ** | * |
| GNC | 0.65 – 2.37 | 0.78 – 2.88 | 0.68 – 2.33 | 0.79 – 2.82 | 1.53 | 1.79 | 1.53 | 1.77 | ** | ** | ** |
| SNC | 0.71 – 1.77 | 0.82 – 1.87 | 0.53 – 1.72 | 0.65 – 1.97 | 1.07 | 1.21 | 0.88 | 1.05 | ** | ** | ** |

**Table 4: Summary of ANOVA for Nitrogen use efficiency parameters under no and low nitrogen levels in pot and field experiments of twenty rice landraces.**

**, * Significant at 1% and 5% probability level respectively

NUE: Nitrogen Use Efficiency NUtE: Nitrogen Utilization Efficiency NUpE: Nitrogen Uptake Efficiency GNC: Grain nitrogen concentration SNC: Straw nitrogen concentration

**Table 5: Estimation of genetic variability parameters for yield related traits in rice landraces under pot and field conditions.**

| Trait | Mean | | $\sigma^2$G | | $\sigma^2$P | | GCV (%) | | PCV (%) | | H (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pot | Field | Pot | Field | Pot | Field | Pot | Field | Pot | Field | Pot | Field |
| **FG** | 1051.3 | 1106.54 | 11200.89 | 12246.05 | 11201.97 | 12246.05 | 10.00 | 9.74 | 10.00 | 9.75 | 99.00 | 100.00 |
| **GY** | 1777.01 | 1822.53 | 74874.29 | 80090.67 | 74874.99 | 80092.08 | 15.39 | 15.53 | 15.40 | 15.53 | 99.99 | 99.99 |
| **PN** | 15.11 | 18.76 | 0.69 | 0.90 | 0.70 | 0.91 | 5.50 | 5.05 | 5.54 | 5.08 | 98.57 | 98.90 |
| **PL** | 23.05 | 24.55 | 0.45 | 0.68 | 0.46 | 0.69 | 2.91 | 3.35 | 2.94 | 3.38 | 97.83 | 98.55 |
| **TGW** | 16.10 | 18.59 | 0.93 | 1.01 | 0.94 | 1.02 | 5.98 | 5.40 | 6.02 | 5.43 | 98.94 | 99.02 |
| **UFS** | 211.32 | 233.18 | 755.60 | 782.37 | 756.87 | 782.38 | 13.01 | 11.99 | 13.02 | 11.99 | 99.83 | 99.99 |
| **SPIPAN** | 78.30 | 89.35 | 23.75 | 26.59 | 23.76 | 26.59 | 6.22 | 5.77 | 6.23 | 5.77 | 99.96 | 100.00 |
| **HI** | 44.26 | 39.98 | 7.61 | 6.24 | 7.64 | 6.26 | 6.23 | 6.25 | 6.24 | 6.26 | 99.61 | 99.68 |

FG: Filled spikelet
GY: Grain yield
HI: Harvest Index
PN: Panicle number
PL: Panicle length
TGW: 1000- grain weight
SPIPAN: Spikelet per panicle
UFS: Unfilled spikelet

**Table 6: Estimation of genetic variability parameters for nitrogen use efficiency in rice landraces under pot and field under conditions.**

| **Trait** | **Mean** | | **$\sigma^2$G** | | **$\sigma^2$P** | | **GCV (%)** | | **PCV (%)** | | **H (%)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Pot** | **Field** | **Pot** | **Field** | **Pot** | **Field** | **Pot** | **Field** | **Pot** | **Field** | **Pot** | **Field** |
| **NUE** | 63.43 | 73.93 | 76.98 | 170.44 | 80.72 | 171.54 | 13.83 | 17.65 | 14.16 | 17.72 | 95.37 | 99.34 |
| **NUpE** | 207.54 | 210.81 | 1220.39 | 1187.08 | 1221.31 | 1187.38 | 16.83 | 16.34 | 16.84 | 16.35 | 99.92 | 99.97 |
| **NUtE** | 0.34 | 0.33 | 0.01 | 0.01 | 0.01 | 0.01 | 29.41 | 30.30 | 29.41 | 30.30 | 100.00 | 100.00 |
| **GNC** | 1.65 | 1.65 | 0.01 | 0.01 | 0.01 | 0.01 | 6.06 | 6.06 | 6.06 | 6.06 | 100.00 | 100.00 |
| **SNC** | 1.14 | 0.96 | 0.01 | 0.01 | 0.01 | 0.01 | 8.68 | 9.43 | 8.73 | 9.43 | 100.00 | 100.00 |

NUE: Nitrogen Use Efficiency
NUpE: Nitrogen Uptake Efficiency
NUtE: Nitrogen Utilization Efficiency
GNC: Grain nitrogen concentration

### 4.5 Correlations among yield related traits and NUE components in pot and field experiments

Significant correlations were observed for 21% of trait combinations (Fig.1, 2). GY correlated positively with FS and PL. SPIPAN showed positive correlation with FS and UFS. NUE had strong correlation with FS, GY, PL, 1000-grain weight. NUpE had strong correlation with FS and GY. HI also correlated with GY, PL, 1000 - grain weight, NUE. On the other hand, 59% of the trait combinations had weak correlations. GNC and SNC correlated with FS, GY, NUE and NUpE.

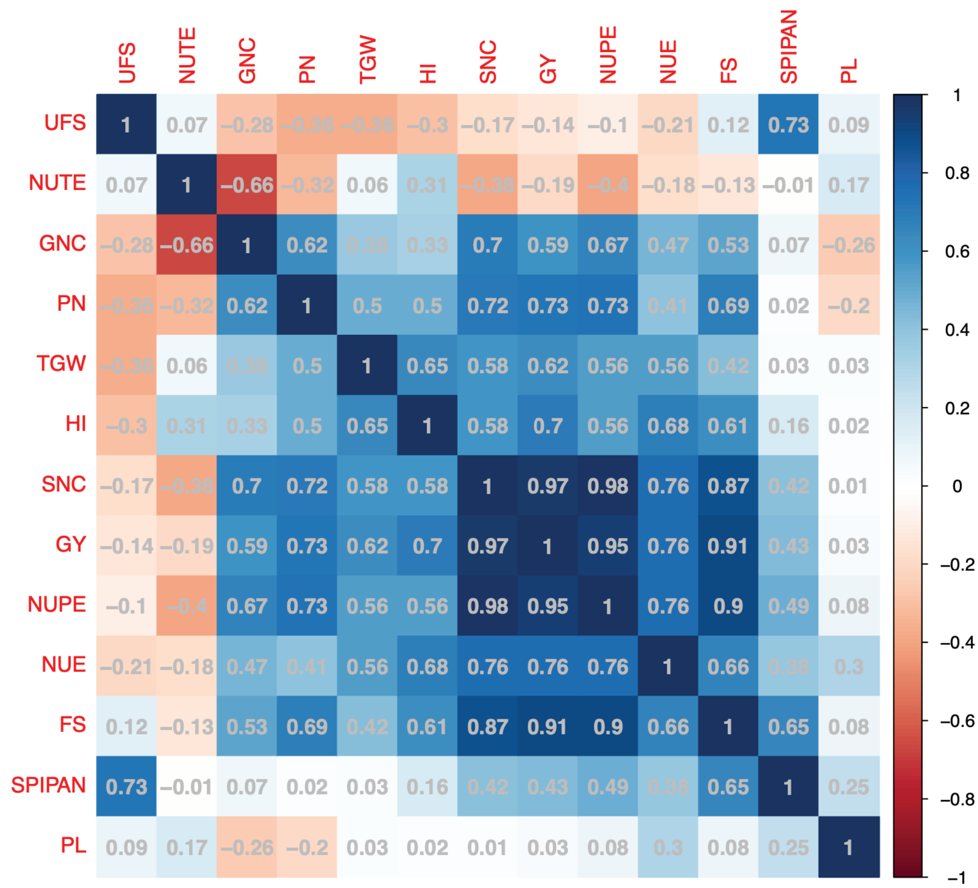


Fig 1: Correlation for yield related traits and nitrogen use efficiency in field experiment

*, **, ns are significant at the 5 and 1% probability level and non- significant, respectively

| | | |
|---|---|---|
| FG: Filled spikelet | UFS: Unfilled spikelet | NUpE: Nitrogen uptake efficiency |
| GY: Grain yield | SPN: Spikelet per panicle | GNC: Grain N concentration |
| PN: Panicle number | HI: Harvest Index | SNC: Straw N concentration |
| TGW: 1000-grain weight | NUE: Nitrogen use efficiency | NUtE: Nitrogen utilization efficiency |

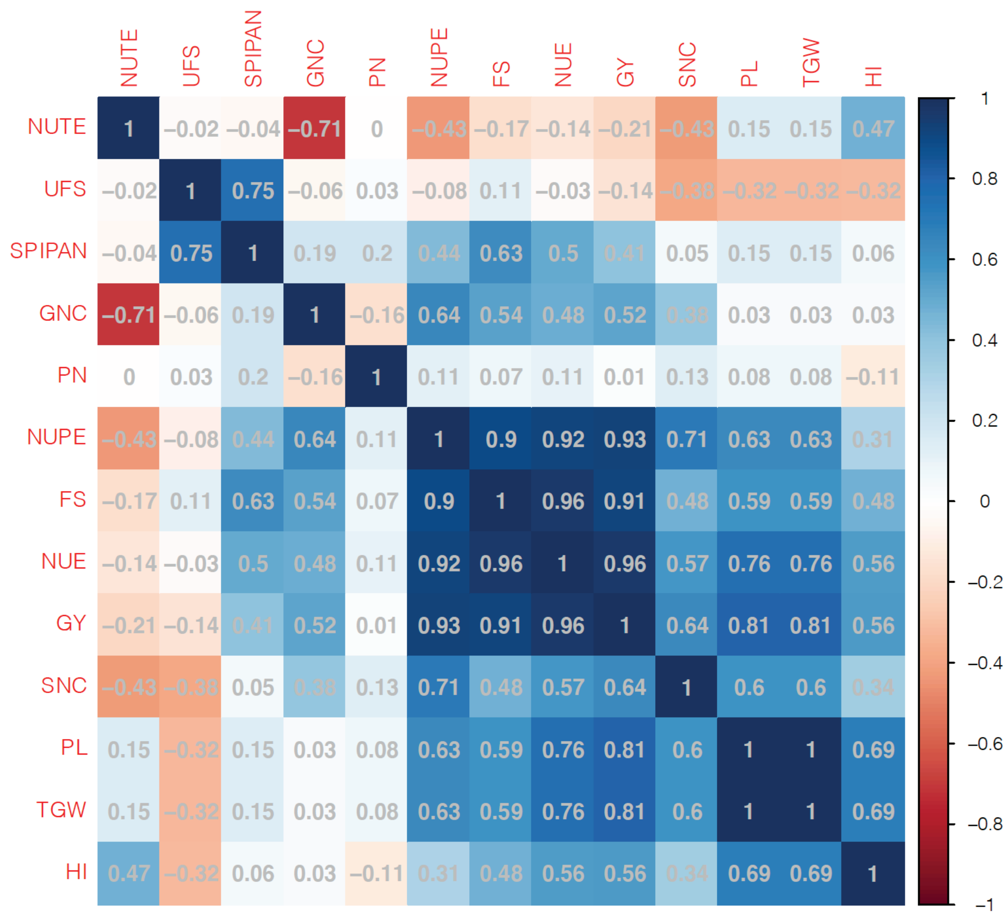


Figure 2: Correlation for yield related traits and nitrogen use efficiency in pot experiment

*, **, ns are significant at the 5 and 1% probability level and non- significant, respectively

## 5 Discussion

ER group are most desirable because they produce more at N0 and respond to applied N indicating their ability to strive in varied N environments. The second desirable group is E because they produce more yield under N0 level which will aid resource poor farmers. The R group may be used in breeding programs. The remaining landraces fall into the fourth group: NE, NR and are less desired in terms of NUE. Similar groupings were reported in earlier studies (*Fageria* and *Filho*, 2001; *Surekha*, et al., 2019; *He* et al., 2017).

Genetic variations showed high yielders had more FS. This indicates that number of FS promotes high grain yield due to adequate supply of N fertilizer. A study observed similar findings (*Lawal* and *Lawal*, 2002; *Rao* et al.,2018). Conversely, *Lakew* (2015) experienced reduction in FS when nitrogen was applied. UFS increased when N was applied. This could be because N increases the SPIPAN as a result of increase in PN which may reduce production of carbohydrate from sink to support growth of all spikelet leading to a reduction in FS. Similar result was observed in a study carried out by *Yuan* et al. (2013). The reduction in PN under N0 could be due to competition for assimilates among young panicles and tillers in the course of panicle development. This leads to slow growth among many young tillers which may senesce without producing panicle (*Fageria* and *Baligar*, 2001). Analogous observations were described by other authors (*Mendhe* et al., 2002; *Uddin* et al., 2011). SPIPAN increased as nitrogen fertilizer was applied. 1000 - grain weight was relatively low between the two levels of nitrogen because it has been reported to be a genetically controlled character. Comparable results were established by other scientists and they concluded that there is little opportunity to improve grain size through agronomic management (*Maske* et al., 1997; *Ahmed* et al., 2005). High yielding genotypes had high HI indicating the importance of HI as a yield component. *Rao et al.* (2018) also reported similar results.

Although the variations between N0 and N50 was small, similar trend of NUE at N0 and N50 indicates that rice landraces in the current study are able to absorb or utilize N at N0. This may be due to the fact that they are landraces with the ability to grow mostly under low or minimal input conditions and are likely to harbor the trait of resource use efficiency such as NUE. Perhaps, higher levels of N (levels above sub-optimal level used in the present study) may have shown lower NUE as observed in previous studies (*Lakew*, 2015; *Haque* and *Haque*, 2016). The assessment of NUE in crop plants is significantly required to measure the fate of applied nitrogen and their role in improving maximum economic yield through efficient absorption or utilization by the plant. GNC and SNC increased slightly under N0 as compared to N50 indicating that GNC and SNC may not be affected by nitrogen fertilizer. This significant correlation portrays that nitrogen may boost grain nutritional quality in terms of GNC and SNC which can be used as feeds for livestock or used to improve soil nutrient. Similar results were obtained in a previous study (*Lakew*, 2015).

Broad-sense heritability estimates for traits such as FS, GY, PN, PL, TGW, SPIPAN and HI as well as NUE and components had high to very high heritability estimates. High heritability estimates can be used as a baseline for selection according to the morphological traits (*Woldeyesus* et al., 2004; *Alemayehu* et al., 2006). The difference between PCV and GCV for the yield related parameters indicates that these traits were influenced by the environment. The GCV for NUtE, GNC and SNC are same as their PCV resulting in zero environmental variance. This makes the heritability of such characters a 100%. The progeny of these lines will show semblance to their parents because there are no visible environmental effects on the expression of these characters. *Lakew*, (2015) also observed similar results in his study.

In this study, NUpE had strong association with NUE than the comparison between NUtE and NUE. Hence, NUpE seems more important in determining NUE. Earlier studies showed strong correlation between NUE and NUpE and weak correlations between NUE and NUtE (*Van Sanford* and *Mackown* 1986; *Lakew*, 2015). *Muurinen* et al. (2006) and *Woldeyesus* et al. (2004) found out that NUpE was more significant than NUtE in influencing NUE.

Variations between pot and field experiments and their correlations may be ascribed to dissimilarity in the light intensity, nutrient absorption and water availability. Pot experiment appears to be more vulnerable to no N conditions for FS, GY, PN, PL, 1000-grain weight, SPIPAN and HI, whereas, UFS seem vulnerable in field experiment at N0.

## 6 Conclusions

Landraces with promising yield under N0 and N50 with efficient utilization of absorbed N were identified. They include; GH2145, GH1550, GH1515, GH1535, GH1590 and GH1801. Based on these results, it can be concluded that the identified landraces can be used in breeding programs. GH 1587 was the only efficient landrace (N0) and may be beneficial in areas with resource deprived farmers whereas GH1549 was the only responsive landrace (N50) and may be useful in breeding programs. Genotypic variations were observed among the landraces, while NUE correlated positively with FS, GY, PL, 1000-grain weight and NUpE. These traits will provide adequate variability for which selections through GWAS and QTL can be made for genetic improvement for NUE. Based on the information from this study, breeders can select rice landraces with high heritability for NUE for breeding programs.

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