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Original Research Article

Estimation of Genetic Variability and Trait Association in Nitrogen Use Efficiency of Upland Rice Varieties in North Western Ethiopia

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ABSTRACT

Use of nitrogen efficient genotypes is an important complementary strategy in improving rice yield and reducing cost of production in subsistence farming. A field experiment was conducted at Woreta, South Gondar Zone of Western Amhara Region during the 2009 main cropping season. The objectives were to investigate genetic variability in nitrogen use efficiency of upland rice genotype, to identify genotypes with best nitrogen use efficiency and to assess nature of association of nitrogen use efficiency and yield traits. Twelve upland rice genotypes (6 released and 6 pipelines) with two nitrogen levels (0 and 64 kg N ha^{-1}) were evaluated in a factorial randomized complete block design of three replications. Analysis of variance revealed significant differences among genotypes for yield, nitrogen use efficiency, uptake efficiency and utilization efficiency traits. Differences were significant between nitrogen levels for number of filled spikletes per panicle, grain yield, and biomass yield and nitrogen use efficiency component traits. Genotype × nitrogen interaction effect was not significant for all traits. Grain yield ranged from 2852.9 (Getachew) to 5437.7(NERICA-3) kg ha^{-1}. Nitrogen uptake, nitrogen utilization and nitrogen use efficiency varied from 21.87 to 48.43%, 21.46 to 53.4 kg kg^{-1} N and 6.47 to 17.58 kg kg^{-1} N respectively. Superica-1, NERICA-3, Andassa and NERICA-4 had the highest nitrogen use efficiency values. Grain yield, harvest index, grain nitrogen yield, nitrogen harvest index, nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen use efficiency had high genotypic and phenotypic coefficient of variation and high broad sense heritability estimates. Grain yield showed significant and positive correlation with grain nitrogen yield, and nitrogen harvest index. Grain nitrogen concentration had significant and positive correlation with nitrogen uptake efficiency and nitrogen use efficiency. The results suggested that varieties including Superica-1, NERICA-3, Andassa and NERICA-4 were relatively nitrogen efficient and could be used for cultivation and/or used as parents in future breeding program to produce better nitrogen use efficiency varieties.

Key words: N uptake, grain yield, yields component, heritability.

INTRODUCTION

Rice, *Oryza sativa* (2n = 24) is the second most important cereal crop and staple food for more than one third of the world's population (FAO, 2004). It has two cultivated and more than 30 named wild species with a broad geographic distribution (Watanabe, 1997). The cultivated species are *Oryza sativa* L., which has an Asian origin and *Oryza glaberrima* Steud, with an African origin.

Rice production mostly has been focused on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment. Excessive N fertilization can cause nitrate pollution as only about 33% of N up taken by plants while the rest is lost due to leaching, volatization, run off and denitrification (Koutroubas and Ntanos, 2003). One of the inputs limiting rice production is nitrogen (N). Results of several studies have indicated that application of N fertilizer increases grain yield of rice by increasing the magnitude of its yield attributes (Panda *et al.*, 1995). However, 50–70% of the applied nitrogen (N) is not used by crop plants and this resulted nitrogen use efficiency (NUE) to be not more than 32% (Tilman *et al.*, 2002). Nitrogen use efficiency (NUE) is the ability of the plant to produce a unit of grain per kg of nitrogen applied to the soil (kg grain kg^{-1} N) and it is determined by the ability of the plant to extract soil nitrogen (Nitrogen uptake efficiency, NUPE %), and by the ability to convert the absorbed nitrogen into grain yield (Nitrogen utilization efficiency, NUTE, kg grain kg^{-1} N) (Moll *et al*., 1982).

To address the concerns of nutrient loss and the associated environmental pollution, improving NUE is crucial (Tilman *et al*., 2002). The need for developing and identifying superior N efficient genotypes is evident from the low recovery of N fertilizer, associated with economic and environmental concerns (Singh et al., 1995). Moll *et al*. (1982) recommended selecting cultivars with high NUPE and NUTE. Samon *et al*. (2006) also indicated that NUE should be considered during developing rice cultivars and making fertilizer N recommendations as well.

Through selection and plant breeding techniques, high yielding and diseases and pest resistant rice varieties have been developed in Ethiopia. However, genetic selection to improve the rice crop's N-use efficiency has not yet been done. Thus, there is no information on NUE variability and its relation with yield and yield related traits among rice cultivars in Ethiopia. Moreover, in Ethiopian subsistence farming, fertilizer inputs are very expensive and mostly not affordable. Therefore, to minimize the costs of production associated with fertilizer use for resource poor farmers and environmental pollution and to develop a sustainable rice production, evaluation of rice genotypes for N use efficiency is necessary. The study aimed at investigating genetic variability in N use efficiency among upland rice genotypes, identifying genotypes with best N use efficiency and also assessing nature of association among N use efficiency and yield and yield related traits.

MATERIALS AND METHODS

Experimental site: The experiment was conducted at Woreta (13^{O}19’ N and 37^{O}03’E) located at an altitude of 1815m above sea level in Fogera district of South Gondar Zone in 2009 main cropping season from June to December. Woreta receives an average annual rain fall of 1285 mm and the mean maximum and minimum temperatures during the main cropping season are 26.7 ^{O}C and 12.2^{O}C, respectively. The experimental site is characterized by a pH of 6.5, organic carbon 3.4%, total N 0.18%, available P 21.2mg kg^{-1} , CEC 56.5 cmol (+)kg^{-1} soil and exchangeable K of 0.93 cmol (+)kg^{-1} soil.

Experimental materials and design: Twelve upland rice genotypes comprising six released varieties and six pipelines (Table 1) were used for this study. Genotypes were studied under two N fertilizer levels (0 and 64 kg N ha^{-1}) using a factorial randomized complete block design with three replications. Each experimental plot had 6 rows of 20 cm apart and the gross plot area was 3.6 m^2 (1.2m ×3m) with harvestable plot size of 2.4 m^2 (0.8m ×3m). The space between blocks and plots was 1.5 m and 50 cm, respectively. The trial was manually drilled at the seed rate of 80 kg ha^{-1}. Nitrogen fertilizer, in the form of urea, was applied in three equal parts at planting, tillering and at panicle initiation time. Phosphorus fertilizer in the form of triple super phosphate (TSP) was uniformly applied to all plots at the rate of 46 kg P_2O_5 ha^{-1} at planting.

Table 1: Description of varieties used in the stud

Variety name	Code	Source	Remark
NERICA-3	G1	Pwe research centre	Released
NERICA-4	G2	Pawe research centre	Released
Superica-1	G3	Pawe research center	Released
Andassa (AD012)	G4	Adet research centre	Released
Tana (AD048)	G5	Adet research centre	Released
Getachew (AD01)	G6	Adet research centre	Released
CNAX3031-15-2-1-1	G7	Adet research centre	Pipe line
IRGA370-38-1-1F-B1-1	G8	Adet research centre	Pipe line
WAB502-8-5-1	G9	Adet research centre	Pipe line
WAB450-11-1-1-P31-HB	G10	Adet research centre	Pipe line
WAB95-B-B-40-HB	G11	Adet research centre	Pipe line
WAB368-B-HI-HB	G12	Adet research centre	Pipe line

Data collection : Physiological parameters (days to heading, flowering, and maturity); yield and yield components (including plant height, panicle length, number of tillers per meter row, number of spikelets per panicle, number of filled spikelets per panicle, grain yield, thousand–kernel weight, biomass yield, harvest index (grain yield/grain and shoot yield), tissue N content, N harvest index (N uptake in grain/N uptake in grain and shoot) and grain protein content were data collected. The percentage of grain N (GNC) and straw N concentrations (SNC) were determined by Kjeldahl method for N analysis(Jackson,1958) and the percentage of N content was estimated using the equation : $\%N = \frac{(a-b)\times M\times 14}{SM}\times 100$; Where: %N = is the N content for grain and straw, a= is the volume of HCl acid consumed in the titration of the sample, b = is the volume of HCl acid consumed in the titration by the blank sample, M = is the molality of HCl, 14= molecular weight of N, SM = sample mass. Then, grain protein content (GPC) in percent, grain N yield (GNY) in kg ha^{-1}, straw N yield (SNY) in kg ha^{-1}, biomass N yield (BNY) in kg ha^{-1} and N harvest index (NHI) in percent was calculated as follows: $GPC=GNC\times 5.13$, $GNY = \frac{(GNC\times GY)}{100}$ $SNY = \frac{SNC\times(BY-GY)}{100}$, $BNY = (GNY+SNY)$, $NHI(\%) = \left(\frac{GNY}{BNY}\times 100\right)$

Where: GNC= grain N concentration (%), GY = grain yield (kg ha^{-1}), SNC = straw N concentration (%) and BY = biomass yield (kg ha^{-1}). In addition, N uptake efficiency (UPE; %), utilization Efficiency (UTE; kg kg^{-1}N) and N use efficiency (NUE; kg kg^{-1}N) were calculated as follows: $UPE = \left(\frac{BNYf - BNY0}{Nf}\right)\times 100$, $UTE = \left(\frac{GYf - GY0}{BNYf - BNY0}\right)$, $NUE = UPE \times UTE$; Where: BNYf= biomass N yield in N–fertilized plot (kg ha^{-1}), BNY0 = biomass N yield in non N-fertilized plot (kg ha^{-1}), Nf = N fertilizer applied (kg ha^{-1}), GYf = grain yield in N-fertilized plot (kg ha^{-1}) and GY0 = grain yield in non- N fertilized plot (kg ha^{-1})

Statistical analysis: Analysis of variance (ANOVA) was performed following SAS PROC GLM procedure (version 8.1). Mean separation was done using LSD comparison test. Variance component analysis was used to estimate coefficient of variability and broad sense heritability. Association of traits between N use efficiency traits and grain yield and yield components were determined following the correlation coefficient analysis using SAS software (SAS. 2000).

Variances, coefficient of variability and broad-sense heritability: The components of variance were determined following SAS system of analysis. And then phenotypic variance (σ^2_{ph}) was obtained as: $\sigma^2_{ph} = \sigma_g^2 + \sigma^2_{gn}/n + \sigma^2_e/nr$: Where: σ_g^2 =genotypic variance, σ_{gn}^2 = G × N interaction component of variance, σ_e^2 = error variance, n= number of nitrogen levels, r= number of replications. Phenotypic (PCV) and genotypic (GCV) coefficients of variations were computed according to the method described by Hansen *et al.* (1956):

$$PCV = \frac{\sqrt{\text{phenotypic variance}}}{\text{population mean for the trait}} \times 100,$$

$$GCV = \frac{\sqrt{\text{Genotypic variance}}}{\text{population mean for the trait}} \times 100.$$

Heritability (H) in broad sense was estimated from the total genetic variance using the formula given by Falconer and Mackay (1996) :$\boldsymbol{H}(\%) = \frac{\sigma_g^2}{\sigma_{ph}^2} \times 100$;

where: $\sigma_g^2 = genotypic\ variance$

And $\sigma_{ph}^2 = phenotypic\ variance$.

RESULTS AND DISCUSSION

Table 2: Means for yield and yield related traits of twelve upland rice genotypes averagedacross two N levels at Woreta in 2009

Varieties	DTH	DTM	PH	PL	NSPP	NFSPP	GY	TKW	BY	HI
G1	102.3	148.0	79.3	19.1	110.2	103.5	5437.7	25.0	16451	37.5
G2	102.7	149.8	84.5	19.1	115.3	107.2	5252.9	24.5	14224	39.6
G3	107.7	160.0	91.4	18.7	101.7	78.8	4004	25.6	14104	28.6
G4	118.2	170.7	99.1	20.1	100.0	73.1	3535.9	26.1	16264	20.8
G5	113.8	168.0	96.7	19.4	103.0	81.2	3104.3	26.2	17350	15.4
G6	113.8	172.7	90.4	19.8	97.5	75.4	2852.9	24.8	12770	23.3
G7	103.0	161.0	79.6	18.1	101.7	80.1	3694.1	25.8	13606	27.7
G8	101.0	154.3	75.4	17.9	91.3	72.1	5058	27.7	14938	37.8
G9	108.8	171.2	95.4	18.7	105.7	82.0	3026.9	29.5	12247	25.2
G10	105.5	166.0	95.2	20.2	118.0	88.5	5008.9	25.2	16323	31.1
G11	106.7	165.3	97.8	19.2	100.0	76.5	4206.5	27.6	19330	24.0
G12	107.7	160.3	72.8	17.7	94.9	76.0	3053.8	31	12337	23.2
Mean	107.7	162.3	88.2	19.0	103.3	83.0	4019.7	26.6	14995.2	28.0
CV (%)	2.08	3.79	7.66	4.72	9.03	11.98	7.28	19.01	25.65	26.46
LSD (5%)	2.60	7.15	7.84	1.04	11.89	11.53	888.18	2.25	4470.9	8.57

DTH= days to heading, DTM= days to maturity, PH= plant height (cm), PL= panicle length (cm), NSPP= number of spikeletes per panicle, NFSPP= number of filled spikelets per panicle, GY= grain yield (kg/ha), TKW= thousand kernel weight (g), BY= biomass yield (kg/ha) and HI=harvest index (%).

Table 3: Means for N use efficiency and its component traits of twelve upland ricegenotypes averaged across two N levelsatWoretain2009

Varieties	GNC	GPC	GNY	SNC	SNY	BNY	NHI	UPE	UTE	NUE
G1	1.77	9.06	96.85	0.59	65.17	162.01	62.33	34.87	49.92	17.41
G2	1.88	9.66	99.79	0.54	47.16	146.95	67.17	48.43	27.63	13.38
G3	1.66	8.09	65.08	0.61	61.38	126.6	52.34	43.42	40.49	17.58
G4	1.86	9.36	65.73	0.65	82.71	148.45	42.98	40.44	33.37	13.49
G5	1.81	9.27	56.01	0.67	90.7	146.71	36.27	31.25	23.93	7.48
G6	1.78	9.11	51.36	0.66	65.34	116.7	44.15	30.16	21.46	6.47
G7	1.51	7.75	55.94	0.61	60.62	116.56	48.22	25.78	36.21	9.33
G8	1.59	8.09	80.61	0.73	69.15	149.75	54.95	25.43	32.33	8.22
G9	1.64	8.39	49.85	0.59	54.26	104.1	47.68	29.53	22.79	6.72
G10	1.57	8.04	78.54	0.62	69.76	148.3	51.99	34.40	35.6	12.24
G11	1.62	8.06	68.08	0.68	98.09	166.21	44.16	37.50	27.53	10.32
G12	1.51	7.78	46.1	0.69	66.5	112.6	42.08	21.87	53.4	11.68
Mean	1.68	8.55	67.83	0.64	69.23	137.08	49.53	33.61	33.72	11.20
CV (%)	10.84	11.43	19.28	18.89	32.58	21.18	17.75	27.13	30.15	28.82
LSD (5%)	0.21	1.36	15.2	0.14	26.22	33.74	10.22	18	17.21	9.39

GNC= grain N concentration (%), GPC= grain protein content (%), SNC= straw N concentration (%), GNY=grain N yield (kg/ha), SNY= straw N yield (kg/ha), BNY= biomass N yield (kg/ha), NHI= N harvest index (%), UPE= N uptake efficiency (%), UTE= N utilization efficiency (kg kg^{-1}N), and NUE= N use efficiency (kg kg^{-1}N).

Yield and yield related traits: Analysis of variance revealed significant differences among the genotypes for most of the traits considered ($p<0.05$) indicating the presence of genetic variation among genotypes and possibility of manipulating these variations for improvement. This is in accordance with the previous reports on rice by Fageria and Filho (2001), Sokat (2006) and Singh *et al.* (1998). The genotype by nitrogen (G×N) interaction component was not significant for all traits implying the performance of genotypes were independent of the levels of N fertilizer.

Grain yield of genotypes ranged from 2852.9 to 5437.7 kg ha^{-1} (Table 2). The highest grain yield was recorded from NERICA-3(5437.7 kg ha^{-1}) followed by NERICA-4 (5252.9 kg ha^{-1}). They also have the highest number of filled spikelets per panicle (103.5 and 107.17), respectively (Table 2). This indicates that number of filled spikelets per panicle contributes for high grain yield performance. Similarly, Fageria and Baligar (1999) reported that filled spikelets per panicle and total grains per panicle were most important and important yield components in determining grain yield in rice genotypes, respectively. Harvest index of the genotypes varied from 15.4 to 39.6%. In the present study, harvest index seems to be important yield component as high yielding genotypes (NERICA-3, NERICA-4, IRGA370-38-1-1F-B1-1 and WAB450-11-1-1-P31-HB) had the highest harvest index (37.5, 39.6, 37.8 and 31.1 %), respectively.

Nitrogen use efficiency and its component traits: Analysis of variance revealed that genotypic effects were significantly different for all N use efficiency and its component traits ($p<0.05$) (Table 3). In the current study, wide ranges of mean values were recorded for grain N yield, straw N yield, biomass N yield and N harvest index (Table 3). Similar reports were stated by Singh *et al.* (1998), Fageria *et al.* (2010) and Wolde yes us *et al.* (2004). Higher and significant grain N concentration was obtained from NERICA-3, NERICA-4, Andassa, Tana and Getachew. Grain protein content was the highest for NERICA-4(9.7%) and lowest for CNAX3031-15-2-1-1(7.7%). NERICA-4 is one of widely cultivated and consumed varieties. And this appreciable amount of grain protein content can help consumers to meet their nutritional requirements.

Genotypes showed significant differences for N harvest index with the overall mean of 49.5%. N harvest index of NERICA-3, NERICA-4, Superica-1, IRGA370-38-1-1F-B1-1 and WAB450-11-1-1-P31-HB were higher than the overall mean. Rattunde and Frey (1986) reported that genetic variability for N harvest index exists within the small seeded genotypes and high N harvest index is associated with efficient utilization of N.

In this study, wide ranges of means were recorded for UPE (21.9 to 48.4%), UTE (21.46 to 53.40 kg kg^{-1} N) and NUE (6.47 to 17.58 kg kg^{-1}N) indicating presence of exploitable genotypic variations for these traits. NERICA-3, NERICA-4, Andassa, Superica-1, WAB450-11-1-1-P31-HB and WAB95-B-B-40-HB had higher UPE than the overall mean. The highest grain yield producing genotype such as NERICA-3, NERICA-4, Superica-1, and Andassa had the highest NUE. It was also reported that nitrogen efficient genotypes could be able to produce high grain yields under both low and high N fertility conditions (Beatty *et al.*, 2010). Use of such better N use efficient varieties could enhance profitability of farmers as much of applied N can be taken up and converted to economically important produces.

Genotypic and phenotypic coefficient of variations: Genotypic and phenotypic coefficients of variation are used to measure the variability that exists in a given population (Burton and Devane, 1953). Genotypic coefficient of variation (GCV) was less than its corresponding estimates of phenotypic coefficient of variation (PCV) for all traits indicating significant role of environment in the expression of these traits. The difference between PCV and GCV was wide for the three N use efficiency traits, biomass N yield and number of filled spikelets per panicle indicating these traits were highly influenced by the environment as compared to the genotypic effect. For the other traits, however, both the environment and genetic component are nearly equally important for the depiction of phenotypes. Khan *et al*. (2009) reported on rice genotypes that PCV values were higher than GCV values for all important traits considered.

Heritability: In the present study, broad-sense heritability estimates for the 22 traits ranged from 40.4 % to 99.4% (Table 6). Dabholkar (1992) generally classified heritability estimates as low (5-10 %), medium (10-30 %) and high (30-60%). Based on this classification, almost all traits under this study exhibited high to very high heritability estimates (Table 4).

Table 4: Estimate of mean, variances, coefficients of variation and heritability in the broadsense of various traits in twelve upland rice genotypes grown under two N levelsat Woreta in 2009

Traits	Mean	σ_g^2	σ^2_{ph}	GCV	PCV	H
Days to heading	107.7	27.38	28.69	4.86	4.98	95.43
Days to maturity	162.3	63.41	67.79	4.9	5.07	93.54
Plant height(cm)	88.2	78.91	87.70	10.1	10.6	89.98
Panicle length(cm)	18.9	0.49	0.68	3.7	4.4	71.71
Spikelet /panicle	103.3	42.50	62.80	6.3	7.7	67.67
Fertile spikelet/panicle	82.8	109.65	130.30	1.26	13.8	84.15
1000 seed weight(g)	26.6	3.26	3.86	6.79	7.39	84.43
Grain yield(kg/ha)	4019.7	8666033.80	8716464.95	73.24	73.44	99.42
Biomass yield (kg/ha)	14995.2	2412843.20	4792916.17	10.36	14.59	50.34
Harvest index (%)	27.9	50.5	55.4	25.5	26.7	91.2
Grain N concentration (%)	1.7	0.012	0.02	6.6	7.8	72.2
Grain protein concentration (%)	8.6	0.4	0.5	7.3	8.1	81.5
Straws N concentration (%)	0.6	0.001	0.003	5.18	8.07	41.25
Grain N yield (kg ha^{-1})	67.8	296.64	318.31	25.39	26.3	93.19
Straw N yield (kg ha^{-1})	69.2	155.50	214.73	18.01	21.17	72.41
Biomass N yield (kg ha^{-1})	137.0	355.87	428.83	3.76	15.11	82.99
N harvest index (%)	49.5	69.0	77.8	16.8	17.8	88.7
N uptake efficiency (%)	60.9	27.0	54.3	26.9	38.2	49.7
N utilization efficiency(kg kg^{-1}N)	33.7	69.95	173.29	24.80	39.04	40.37
N use efficiency (kg kg^{-1}N)	19.1	36.67	67.41	31.47	42.62	54.40

N= nitrogen, σ_g^2= genotypic variance, σ^2_{ph}= phenotypic variance, GCV= genotypic coefficient of variation, PCV= phenotypic coefficient of variation, H= heritability in the broad sense

Table 5: Phenotypic correlation coefficients between yield and yield related and N useefficiency traits in 12 upland rice varieties at Woreta in 2009

Traits	DTH	DTM	PH	PL	GY	BY	HI
GNC	0.360*	0.005	0.08	0.09	-0.05	0.17	-0.17
SNC	0.14	0.111	0.01	0.14	-0.19	0.11	-0.23
GP	0.34*	0.02	0.06	0.09	-0.05	0.15	-0.18
SNY	0.29	0.22	0.48**	0.46**	0.005	0.81***	-0.61***
GNY	-0.48**	-0.670***	-0.23	-0.19	0.93***	0.44**	0.58**
BNY	-0.13	-0.33	0.04	0.07	0.60***	0.62***	0.09
NHI	-0.61***	-0.680***	-0.52**	-0.49**	0.65***	-0.3	0.93***
UPE	0.36	0.09	0.24	0.09	0.09	-0.04	-0.05
UTE	-0.20	-0.23	-0.39*	0.22	0.03	0.07	-0.05
NUE	0.20	-0.12	-0.07	-0.14	0.06	0.03	-0.04

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels, respectively. DTH= days to heading, DTM= days to maturity, PH= plant height, PL= panicle length, GY = grain yield, BY= biomass yield, HI= harvest index, TKW= 1000 kernel weight, GNC= grain N concentration, SNC= straw N concentration, GPC= grain protein content, SNY= straw N yield, GNY= grain N yield, BNY= biomass Nyield, UPE= uptake efficiency, UTE= utilization efficiency, NUE= N use efficiency, NHI = N harvest index.

Table 6: Phenotypic correlation coefficients among N use efficiency and its componenttraits in twelve upland rice genotypes at Woreta in 2009

Trait	GNC	SNC	GPC	SNY	GNY	BNY	NHI	UPE	UTE	NUE
GNC										
SNC	0.07									
GPC	0.95***	-0.01								
SNY	0.18	0.60***	0.14							
GNY	0.29	-0.16	0.29	0.05						
BNY	0.36*	0.12	0.35*	0.44**	0.72***					
NHI	0.03	-0.47**	0.02	-0.66***	0.64***	0.14				
UPE	0.37*	-0.26	0.31	-0.12	0.04	0.04	0.09			
UTE	-0.01	0.21	-0.04	0.16	0.04	0.06	-0.08	-0.46**		
NUE	0.34*	-0.06	0.21	-0.23	0.05	0.05	0.06	0.61***	0.37*	

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels, respectively. GNC= grain N concentration, SNC= straw N concentration, GP= grain protein, SNY= straw N yield, GNY= grain N yield, BNY= biomass N yield, UPE= uptake efficiency, UTE= utilization efficiency, NUE= N use efficiency, NHI= N harvest index.

Similar result was reported by Woldeyesus *et al*. (2004) on barely genotypes and by Alemayehu *et al*. (2006) on tef genotypes that broad-sense heritability estimates were higher for grain yield, grain N yield, biomass N yield, nitrogen harvest index and for N use efficiency traits.

Correlations among traits: Improvement for a trait of interest can be achieved by selection through other traits that are more heritable and easy to select. It, therefore, requires understanding the interrelationship of the other traits among themselves and with traits of interest. In this study, significant positive correlations were observed for grain N concentration with days to heading (r=0.36), days to flowering (r=0.33). Similarly, grain protein content showed significant correlation with days to heading and days to flowering (r=0.34) (Table 5). This positive association indicated that application of N fertilizer in early type rice varieties may enhance grain nutritional quality in terms of grain N concentration and grain protein content.

On the other hand, grain N yield had significant and negative correlation with days to heading (r=-0.48) and days to maturity (r=-0.67). Grain N yield showed significant and positive correlation with grain yield(r=0.93), biomass yield(r=0.44) and with harvest index (r=0.58) (Table 5). Similarly, Samont *et a*l. (2006) reported significant and positive correlation between grain N yield and grain yield (r=0.49) in rice.

The present study revealed that correlations between grain yield and N use efficiency traits were positive and very weak (Tables 5). However, positive and very weak correlation between grain yield and N use efficiency traits may not prevent concurrent improvement of these traits. Grain N yield had significant correlation with biomass N yield (r=0.72) and N harvest index(r=0.64) (Table 6) which offers possibility of simultaneous improvement of these traits. Nitrogen uptake efficiency had significant and positive correlation with N use efficiency with a correlation coefficient of (r) 0.61. On the other hand, N uptake efficiency exhibited significant and negative correlation with N utilization efficiency (r=-0.46). Significant and positive correlation was observed between N utilization efficiency and N use efficiency (r=0.37) (Table 6).

Similar reports were indicated by Van Sanford and Mackown (1986) that significant correlation was observed between N use efficiency and N utilization efficiency (r=0.31), N use efficiency and N uptake efficiency (r=0.70), N utilization efficiency and N uptake efficiency (r=-0.33). Under this study, N uptake efficiency had stronger correlation with N use efficiency as compared to the correlation between N utilization efficiency and N use efficiency. According to this result, N uptake efficiency seems more important in determining N use efficiency. Similarly, Muurinen *et al*. (2006) on rice and Woldeyesus *et al*. (2004) on barely genotypes reported that N uptake efficiency was more important than N utilization efficiency in determining N use efficiency.

CONCLUSION

The analysis of variance revealed the presence of highly significant variations among genotypes for yield and yield related traits and for N uses efficiency traits implying the existence of variability among genotypes. NERICA-3 and NERICA-4 were genotypes with high mean values for grain yield, number of filled spikelets per panicle, harvest index, grain N concentration and N harvest index. Nitrogen use efficiency was higher for Superica-1, Andassa, NERICA-4, and NERICA-3. Phenotypic coefficient of variation (PCV) and genotypic coefficients of variation (GCV) values were high for grain yield, harvest index, N use efficiency, utilization efficiency, uptake efficiency and N harvest index. Heritability estimates were high for grain yield, days to heading, days to maturity, harvest index and grain N yield. Grain yield had significant and positive correlations with grain N yield and N harvest index. Harvest index showed significant and positive correlation with grain N yield and N harvest index. Nitrogen uptake efficiency was positively correlated with grain N concentration.

The information generated from this study has significant insinuation in nitrogen use efficiency variability among genotypes considered. Based on results of this study it can be concluded that upland rice average yield can substantially be increased using better N efficient genotypes. However, to provide practical information to farmers, further investigations using more number of genotypes is suggested for the national rice breeding program.

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