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Effect of Application of Gypsum and Farmyard Manure on Rice (*Oryza sativa L.*) Nitrogen Use Efficiency under Saline sodic soil at Amibara, Ethiopia

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Abstract: **Abundance of soil with saline sodic property in Amibara irrigated farms is becoming a threat to crop productivity. As part of the solution to such problem soils, combine application of gypsum and farmyard manure has not been investigated well in the area. Therefore study was conducted at Worer Agricultural Research Center using rice as a test crop to evaluate Effect of GYP and FYM on nitrogen use efficiency of rice. Factorial combinations with three rates of FYM (0, 10 and 20 t ha-1) and five rates of gypsum (0%, 25%, 50%, 75%, 100% GR) were laid out in randomized complete complete block design with three replications. Composite surface soil samples before experiment and from each treatment after harvest were collected for laboratory analysis. Concerning nutrient use efficiency indices agronomic efficiency, agro physiological efficiency and apparent recovery efficiency, physiological efficiency and Nitrogen Harvest index of nitrogen were significantly(P<0.05) affected by the interaction Effect of gypsum and farmyard manure. From the results it could be concluded that the combined use of GYP and FYM can ameliorate the adverse impact of ESP and exchangeable sodium in saline sodic soil and application of 20 t ha-1 FYM+ 75 % GR enhance grain yield and nutrient use efficiency of upland rice grown on saline sodic soil of Amibara district**

Key words: **Farmyard manure, Gypsum, Nitrogen, Nutrient Use Efficiency, Salt-Affected Soil.**

1. INTRODUCTION

Land degradation is one of the major causes for depletion of soil resources; decline soil productivity and changes compostion of vegetation's thus influencing the livelihood of billions people around the globe directly or indirectly (Ravi and D'Odorico, 2005). Land degradation includes all processes that diminish the capacity of soil resources to perform essential functions and services in ecosystems (Hurni *et al.*, 2010). Principal processes of land degradation include soil erosion by water and wind, acidification, salinity, soil fertility depletion, and decrease in soil cation retention capacity, soil surface crusting, compaction, hard-setting, reduction in total and biomass carbon, and decline in land biodiversity (WMO, 2005).

Farmyard manure and compost have been investigated for their effectiveness in improving the physical conditions of soils for crop growth besides their role as fertilizers (Wahid *etal.*, 1998; Sardina *et al.*, 2003; Liang *et al.*, 2005; Tajada *et al.*, 2006). However, these amendments have very little effect on improving soil salinity and sodicity when they are applied alone (Madjejon *et al.* 2001). On the other hand, combined application of these treatments preferably FYM and gypsum on saline-sodic soils helped in maximizing and sustaining yields and in improving soil health and input use efficiency

(Madejon *et al.*, 2001; Swarp and Yaduvanshi, 2004; Tajada *et al.*, 2006; Walker and Bernal, 2008). This is particularly important where excessive soil loss has occurred (Conway, 2001)

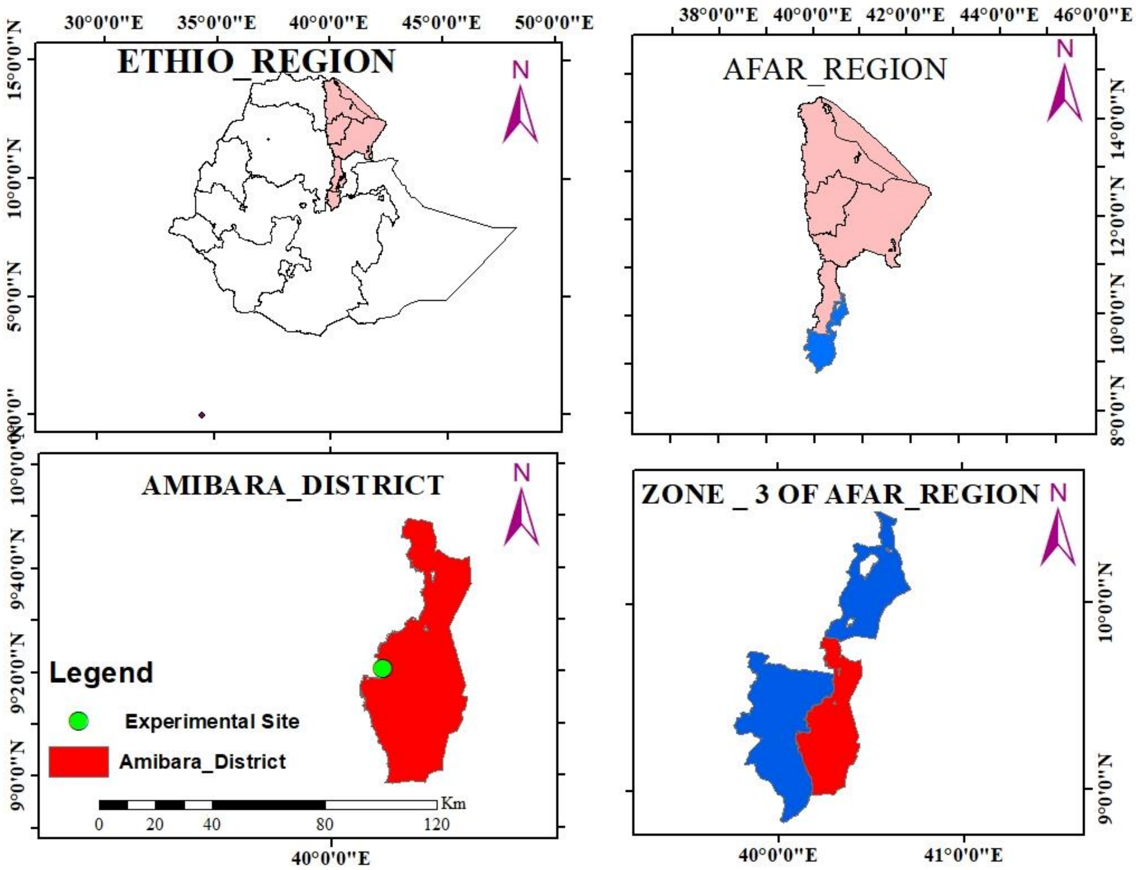
The interactions between salinity and mineral nutrition of plants are complex because it is influenced by plant species, composition and level of salinity, concentration of nutrients in the substrate and climatic conditions (Fageria *et al*., 2011). The negative interactions of salts with plants may decrease growth and consequently nutrient use efficiency (Parida and Das, 2005). Most plants are hypersensitive to saline environments (Qadir *et al*. 2007). The tissues of plants growing in saline media generally exhibit an accumulation of Na^+ and Cl^- and/or the reduced uptake of mineral nutrients, especially Ca^{2+}, K^+, N, and P (Kaya *et al*., 2001).The objective of this study was to evaluate the effects of gypsum and farmyard manure on nitrogen use efficiency of rice.

2. MATERIALS AND METHODS

Description of the Study Area

Location

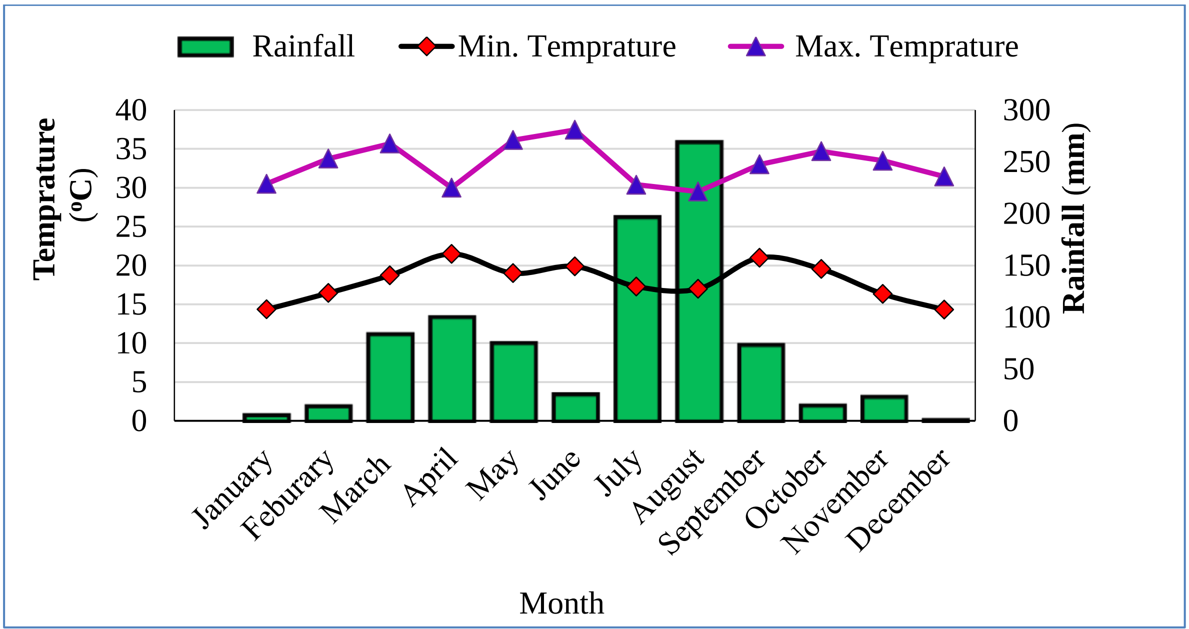
The study was conducted at Werer Agricultural Research Center in Amibara.district, Gabiressu zone of Afar National Regional State in the Middle Awash Valley. Geographically, it is located at 09°13 ′– 09°50 ′ N and 40°05 ′– 40°25 ′E and the elevation is about 740 meters above sea level. The experimental site is 280 km far from Addis Ababa and close to the main high way linking Addis Ababa to Djibouti.



Map of study Area

Climate

According to Werer Agricultural Research Center long term climatic data (1987 - 2018), the relative humidity ranges between 37 and 55%. The mean maximum temperature is 38^0C and means minimum temperature falls down to 15^0C. The mean monthly rainfall distribution of the study area are indicates, July and August are the wettest month and high rainy season(Figure 2).. It clearly indicates that bi-modal nature of rainfall distribution in the study area (Figure 2). According to the classification of agro-ecological zones the climate is semi-arid with a bimodal rainfall of 533 millimeters annually (MoARD, 2005). The average daily sunshine hour is 8.5 with an average solar radiation of 536 calories per square centimeter per day (cal/cm^2/day) (Girma and Awulachew, 2007). Annual evapotranspiration rate of Amibara is 2829 mm.



Mean monthly rainfall, minimum temperature, maximum temperature of the study area.

Experimental Design and Treatments

The experimental design was Randomized Complete Block Design (RCBD) with three replications. Experimental arrangement was factorial treatments combination of two factors. Factor one was gypsum (GYP) with five levels; 0% ,25% , 50%,75 % and 100% soil gypsum requirement and factor two was farmyard manure (FYM) with three levels; 0,10 and 20 t /ha. The overall treatment combination was fifteen.

List of treatment combinations

Treatment code	Treatment combination
T1(control)	(GYP) 0% and (FYM) 0 t/ha
T2	(GYP) 25 % and (FYM) 0 t/ha
T3	(GYP) 50% and (FYM) 0 t/ha
T4	(GYP) 75% and (FYM) 0 t/ha
T5	(GYP) 100% and (FYM) 0 t/ha
T6	(GYP) 0% and (FYM) 10 t/ha
T7	(GYP) 25% and (FYM) 10 t/ha
T8	(GYP) 50% and (FYM) 10 t/ha
T9	(GYP) 75 % and (FYM) 10 t/ha
T10	(GYP) 100 % and (FYM) 10t/ha
T11	(GYP) 0% and (FYM) 20t/ha
T12	(GYP) 25% and (FYM) 20 t/ha
T13	(GYP) 50 % and (FYM) 20t/ha
T14	(GYP) 75% and (FYM) 20t/ha
T15	(GYP) 100 % and (FYM) 20t/ha

Data Collection

Meteorological data were obtained from Werer Agricultural Research Center. Agronomy and physiological, rice growth and yield and nutrient use efficiency data were collected as indicated below.

Plant tissue sampling and analysis

Ten non-boarder rice plants per plot were randomly selected from each plot for straw and seed analysis at maturity. After washed with distilled water, the samples were dried in oven at 70°C for 24 hours. After drying, the plant tissue samples were ground and passed through 0.5 mm sieve for laboratory analysis. Wet acid digestion for N was used for determination of concentration in the samples at laboratory (FAO, 2008).

After the concentration is determined the uptake of the nutrient is calculated as

$$\frac{N\%\ ingrain\ or\ straw * Dray\ matter\ of\ grain\ or\ straw\ in\ \frac{kg}{ha}}{100}$$

Nutrient use efficiency indices

Determination of NUE in cereal based ecosystems enabled broad assessment of management and environmental factors related to N use, grain yield and N accumulation, N in aboveground, N harvest index, and grain N accumulation are the key indicators of NUE (Huggins and Pan, 2003). As described by Doberman (2007) the following four common nutrient use efficiency formulas were used to calculate NUE.

Agronomic Efficiency (AE): The agronomic efficiency is defined as the economic production obtained per unit of nutrient applied. It was calculated by:

$$\text{Agronomic Efficiency(AE)}\left(\frac{\text{kg}}{\text{kg}}\right) = \frac{\text{Gf} - \text{Gu}}{\text{Na}}$$

Where;

Gf = is the grain yield of the fertilized plot (kg)

GU = is the grain yield of the unfertilized plot (kg)

Na = is the quantity of nutrient applied (kg)

Physiological Efficiency (PE): Physiological efficiency is defined as the biological yield obtained per unit of nutrient uptake. It was calculated as:

$$\text{Physiological efficiency (PE)}\left(\frac{\text{kg}}{\text{kg}}\right) = \frac{\text{BYf} - \text{BYu}}{\text{Nf - Nu}}$$

Where;

BYf = is the biological yield (grain plus straw) of the fertilized plot (kg)

BYu = is the biological yield of the unfertilized plot (kg)

NF = is the nutrient uptake (grain plus straw) of the fertilized plot, and Nu is the nutrient uptake (grain plus straw) of the unfertilized plot (kg)

Agro physiological efficiency (APE): Agro physiological efficiency is defined as the economic production (grain yield in case of annual crops) obtained per unit of nutrient uptake. It was calculated as:

$$\text{Agro physiological Efficiency (APE)}\left(\frac{\text{kg}}{\text{kg}}\right) = \frac{\text{Gf} - \text{Gu}}{\text{Nuf - Nuu}}$$

Where;

Gf = is the grain yield of fertilized plot (kg)

GU = is the grain yield of the unfertilized plot (kg)

Nuf = is the nutrient uptake (grain plus straw) of the fertilized plot (kg)

Nuu = is the nutrient uptake (grain plus straw) of unfertilized plot (kg)

Apparent Recovery Efficiency (ARE): Apparent recovery efficiency is defined as the quantity of nutrient uptake per unit of nutrient applied. It was calculated as:

$$\text{Apparent recovery efficiency (ARE)} \left(\frac{kg}{kg}\right) = \frac{Nf - Nu}{Na}$$

Where;

NF = is the nutrient uptake (grain plus straw) of the fertilized plot (kg)

Nu = is the nutrient uptake (grain plus straw) of the unfertilized plot (kg)

Na = is the quantity of nutrient applied (kg).

Data Analysis

The collected data was subjected to statistical analysis. Analysis of variance (ANOVA) on grain yield, biomass, and agronomical parameters of rice were carried out using Genstat and SAS version 9.4 statistical software program (SAS, 2016). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

Initial Soil Physicochemical Properties

Selected properties of the untreated composite saline sodic soil.

Parameter	value
Texture (%)	Clay loam
Clay (%)	32
Silt (%)	40
Sand (%)	28
Bulk density(g cm^{-3})	1.5
Particle density(g cm^{-3})	2.5
Total porosity (%)	40
ECe (ds/m)	4.12
pH	8.41
OC (%)	0.2
OM (%)	0.34
Av.P(mg kg-1)	16
TN (%)	0.05
CEC (cmol (+)/ kg-1)	39
Exchangeable base	
Na (cmol (+) kg-1)	8
Ca (cmol (+) kg-1)	29
Mg (cmol (+) kg-1)	4
K (cmol (+) kg-1)	2.5
ESP (%)	20.5
Soluble base	
Na (meq/l)	38.13
Ca (meq/l)	8.4
Mg (meq/l)	6
k (meq/l)	0.4
SAR	14.49

The data showed that the nutrient content of farmyard manure is more readily available for immediate use because it had low C: N ratio (13.5 %)

Selected chemical properties of farmyard manure used for amendments.

Parameters	Value
pH	6.5
C	16.3 %
N	1.2%
P	14 mg/kg
Ca	49 mg/kg
Mg	7 mg/kg
C:N	13.5

Where, OC= organic carbon; C: N =Carbon to nitrogen ratio

Effect of Gypsum and Farmyard Manure on Rice Nutrient Use Efficiency

Agronomic efficiency (AE)

Agronomic efficiency is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. Agronomic efficiency of nitrogen was significantly ($P \leq 0.05$) affected by the interaction effect of gypsum and farmyard manure. The maximum nitrogen agronomic efficiency (34.98 kg grain kg^{-1}N applied) was obtained in the treatment to which 75% of gypsum requirement +20 t ha^{-1} farmyard manure applied followed by treatments where 50% gypsum requirement +20 t/ha farmyard manure (23.67 kg/kg) . Bronick and Lal (2005) reported the high agronomic efficiency might be due to the reason that organic manure change the soil quality, which is linked to the effects of OM content on soil structure and biological activity. The smallest nitrogen agronomy efficiency (1.11 kg grain kg^{-1} nutrient applied) was obtained at 25% gypsum requirement + 0t/ha farmyard manures This may be due to availability and absorption of plant nutrients is severely limited to sustain high crop production due to ion interactions, especially low nitrogen (N) because of its leaching as NO_3, volatilization and de-nitrification losses .

Physiological efficiency (PE)

Physiological efficiency is a yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant. Like AE and RE, it needs a plot without application of the nutrient of interest to be implemented on the site. It also requires measurement of nutrient concentrations in the crop and is mainly measured and used in research. Physiological efficiency of nitrogen was affected by the interaction and the main effect of gypsum and farmyard manure. The highest PE (301 kg kg^{1}) was observed at a combined application of 20t ha^{-1} farmyard manure + 100% gypsum requirement and the smallest PE (104.9 kg kg^{-1}) was recorded at treatment containing 25% soil gypsum requirement. Nitrogen uptake in plant organs increased with increasing organic manure application (Beah *et al*., 2015). Khatun *et al*. (2015) reported managing the N application to rice is an essential to reduce N losses, improve N use efficiency and obtain higher yield. This author reported that application of organic and inorganic source conjunctionally can improve nutrient use efficiency.

Agro physiological efficiency (APE)

Nutrient APE was computed from kg grain produced per kg of N accumulated in the grain and straw across N rates. Interaction and main effect of gypsum and farmyard manure significantly ($P \leq 0.05$) affected Agro physiological efficiency .The highest nitrogen APE (61.33 $kg.kg^{-1}$) was observed at treatment 20 t/ha farmyard manure+ 75% gypsum requirement. followed by 10 t ha^{-1} farmyard manure +100% gypsum requirement (60 $kg.kg^{-1}$) .This might be due to N loss could be reduced if the ammonia pool resulting from urea hydrolysis was partly substituted by organic matter, since the uptake of nitrogen inhibited under salt affected soils. The lowest (20.11 $kg.kg^{-1}$) was obtained at treatment of 10t/ha farmyard manure alone application.

Apparent recovery efficiency (ARE)

Apparent recovery efficiency is one of the more complex forms of nitrogene use efficiency (NUE) expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. It is often the preferred to NUE expression by scientists studying the nutrient response of the crop. The percentage of apparent N recovery efficiency varied with different application of gypsum and farmyard manure rates. Statistical analysis revealed that interaction effect of farmyard manure and gypsum highly significantly ($P \leq 0.01$) affected nitrogen ARE .The maximum N recovery (77%) was achieved at treatment with 20 t ha^{-1} farmyard manure + 75% soil gypsum requirement followed by combined application of 10 t ha^{-1} Farmyard manure + 75% gypsum requirement that gave 51.21% from kg quantity of nitrogen uptake per unit of kg nutrient applied. But, the minimum N recovery efficiency (8.1 %) was obtained at 0 t ha^{-1} Farmyard manure + 25% soil gypsum requirement . The reason for low recovery efficiency may be associated with losses by volatilization, leaching, denitrification. Application of organic manures stimulates nutrient uptake and ultimately influenced the nutrient recovery due to supply of additional amount of nutrients and also improved soil properties (Yaduvanshi, 2003).

Nitrogen harvest index

Nitrogen harvest index (NHI) is a ratio between N accumulated in grain to N accumulated in grain plus straw. The NHI is an important index in determining crop yields because it is positively associated with grain yield. This index is very useful in measuring N partitioning in crop plants, which provides an indication of how efficiently the plant utilized acquired N for grain production (Fageria and Baligar, 2003a,) . Significant ($P \leq 0.05$) difference was observed for nitrogen harvest index (NHI) due to applied interaction effect of gypsum and farmyard manure. The highest nitrogen harvest index (51.97%) was obtained from application 20 t ha^{-1} farmyard manure +75% gypsum requirement while the lowest NHI (39.45%) was obtained from combined Application of 0 t ha^{-1} farmyard manure + 0% gypsum requirement .

Total nitrogen uptake

Analysis of variance showed that statistically significantly ($P \leq 0.05$) on total nitrogene uptake by the main effect of gypsum and highly significantly ($P \leq 0.01$) affected by the main effect of farmyardmanure.The maximum N uptake (61.06 kg/ha) was achieved at treatment with 20 t ha^{-1} farmyard manure.

But, the minimum Total N uptake (32.03 kg/ha) was obtained from 0t/ha farmyard manure. This may be due to uptake of N by rice was inhibited under high sodium chloride (NaCl) and sodium sulfate (Na_2SO_4) concentration in the roots, and the excess amount of absorbed Na^+ depressed NH^{4+} absorption (Britt *et al*. 2004) .Fisher (2011) reported that Application of organic matter with amendment significantly improved the NUE.

Effect of gypsum and farmyard manure on rice nitrogen use efficiency parameters

Treatments	AE ($kg \cdot kg^{-1}$)	PE ($kg \cdot kg^{-1}$)	APE ($kg \cdot kg^{-1}$)	ARE %	NHI %
G0F0	_	_	_	_	39.45^{a}
G25F0	1.11^{a}	104.9^{b}	22.0^{bc}	8.1^{a}	44.46^{abcd}
G50F0	1.83^{ab}	111.0^{bcd}	47.9^{efgh}	10.1^{ab}	44.75^{abcd}
G75F0	3.96^{ab}	120.0^{bcd}	38.0^{cdef}	9.5^{ab}	47.18^{bcd}
G100F0	6.43^{abc}	200.0^{def}	48.0^{efg}	20.1^{bc}	48.4^{bcd}
G0F10	3.96^{ab}	166.1^{bcde}	20.1^{b}	19.5^{bc}	51.09^{cd}
G25F10	14.01^{cde}	244.6^{efg}	40.0^{defg}	23.1^{c}	46.43^{abcd}
G50F10	18.21^{ef}	153.0^{bcd}	53.9^{fgh}	39.4^{d}	46.22^{abcd}
G75F10	19.18^{ef}	133.2^{bcd}	42.1^{efg}	51.2^{e}	42.44^{ab}
G100F10	20.63^{ef}	192.0^{cdef}	60.0^{h}	36.0^{d}	50.16^{cd}
G0F20	9.18^{bcd}	112.0^{bc}	24.6^{bcd}	38.5^{d}	39.47^{a}
G25F20	21.98^{f}	147.2^{bcd}	41.0^{efg}	51.0^{e}	44.24^{abc}
G50F20	23.67^{f}	155.5^{bcd}	55.0^{gh}	44.0^{de}	44.46^{abcd}
G75F20	34.98^{g}	252.0^{g}	61.3^{h}	77.0^{f}	51.97^{d}
G100F20	16.52^{def}	301.0^{g}	36.7^{cde}	42.6^{de}	43.92^{abc}
LSD(0.05)	7.64	85.7	16.3	11.46	7.51
CV%	35	32	24.8	21.8	9.9

Similar letters or no letters with column indicate that there is no significant difference Among Treatment levels, α= 0.05, based on LSD test. Where, G (gypsum), F (farmyard Manure) AE (Agronomic Efficiency), PE (Physiological Efficiency), APE (Agro Physiological Efficiency), ARE (Apparent Recovery Efficiency) and NHI (Nitrogen Harvest Index).

4. SUMMARY AND CONCLUSION

Nutrient use efficiency indices, agronomic efficiency, agro physiological efficiency and apparent recovery efficiency, physiological efficiency and Nitrogen Harvest index of nitrogen were significantly affected by the interaction Effect of gypsum and farmyard manure. However, total nitrogen uptake did not show significant difference among the treatments. The maximum agronomic efficiency (34.98 $kg{\cdot}kg^{-1}$) , The maximum agro physiological (61.33 $kg{\cdot}kg^{-1}$), maximum apparent recovery Efficiency (77%) ,maximum Nutrient Harvest index (51.9%) were obtained at treatment from 20 t ha^{-1} farmyard manure + 75% gypsum requirement .

Therefore, based on the results of the study and the above summary, it can be concluded that;

- Nitrogen use efficiency of rice can be also improved through combine application of 20 t ha^{-1} farmyard manure + 75% soil gypsum requirement.
- However, where salt affected soils is a problem similar further studies are warranted at various locations using different varieties of rice and different rates of gypsum and farmyard manure to provide conclusive recommendation.

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