Drought Tolerance and Nitrogen use Efficiency of Upland Rice (*Oryza Sativa* L.) Genotypes Grown under Varying Water and Nitrogen Regimes

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Abstract**—** *Rice genotypes were grown under different water regimes and nitrogen levels. Sufficient soil moisture content (SMC) and high N level caused optimum growth of the genotypes. Deficient water and N supply both retarded growth of rice. PSB Rc14, P42, and P38 had high number of tillers, number panicles per hill, number of spikelets per panicle, relative growth rate (RGR), water use efficiency (WUE), harvest index (HI), straw yield, grain weight, and grain yield at field capacity (FC). These genotypes also had high values in the aforementioned growth and yield parameters at 120 kg N ha^{-1} treatment. In terms of the efficiency in the use of N as indicated by agronomic efficiency of nitrogen application (AEN), recovery efficiency of nitrogen application (REN), and internal efficiency of nitrogen application, PSB Rc14, P42, and P38 still performed better than the rest of the genotypes tested. Evaluation of the combined effect of water and N application showed that PSB Rc14, P42, and P38 significantly produced high grain yields among the genotypes under SMC at FC with 120 kg N ha^{-1} which suggests that water plays a fundamental role in rice growth in combination with N. P42 showed the less affected by water deficit and low N nitrogen levels, hence, produced the high grain yield.*

Keywords**— Upland rice, nitrogen use efficiency, agronomic use efficiency, recovery use efficiency, rice genotypes.**

I. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food of over half of the world's population. Globally, it ranks third after wheat and maize in terms of production (Bandyopadhay and Roy, 1992). According to International Rice Research Institute (IRRI) 2012, there is about 50,000 ha of upland rice in Cambodia (2-4% of total rice area) with an average grain yield of 2.97 t ha^{-1}, much less compared to potential yield of the newly-developed varieties (MAFF, 2011). At present, upland rice production contributes about 5-6% of Cambodia's national rice production (CRD, 2008), which is one of the potential areas considered in maintaining the country's rice production level.

The major factor for the low productivity in rainfed uplands is the lack of water. Rice is usually subjected to prolonged drought due to less rain as well as erratic rainfall pattern in the certain years (NARC, 1996). This inadequacy and untimely availability of rainwater is a major limitation of rice production resulting to low yield in the rainfed ecosystems (Kamoshita *et al*., 2000). The effect of drought differs with varieties, growth stage, level and duration of drought stress occurrence (Kato, 2004), hence, results to varying yields (Lafitte *et al*., 2007). The reduction in growth and photosynthetic rate in such fragile environment are the major causes of yield reduction (Zlatev and Lidon, 2012). In addition to its direct effect on yield, drought can also reduce the potential beneficial effects of improve crop management practices, such as fertilizer application, pest and disease management.

The use of varieties that are adapted under limited water is one of the strategies to enhance production in rainfed uplands. Different varieties may have varying degrees of drought tolerance (Zeigler *et al*., 1994). Water deficit during the vegetative stage may have lesser effect on grain yield, but have tremendous effect during reproductive and grain filling stages (Fukai and Cooper, 1995). Growing appropriate varieties in rainfed areas that are drought-prone could be a practical strategy to enhance production. Selections of early maturing rice varieties that are adaptable to drought stress could be one of the pragmatic strategies (Juliano *et al*., 2007). Selection of drought tolerant rice varieties with good N efficiency could improve rice production in rainfed upland areas that are gradually becoming water limited.

Okonje *et al*. (2012) reported that application of low N levels results to low yields, considering that N deficiency is a major abiotic stress that limits rice productivity in rainfed upland soils, such as ultisol and alfisol that are acidic in general (Kirk *et al*., 1998). The low yield of upland rice is a consequence of infertile soils and drought conditions, that are adapted to low harvest index (HI) traditional cultivars (George *et al*., 2001).

Among essential plant nutrients, N is one of the most yield-limiting nutrients for upland rice production. Farmers relate the N deficiency in upland rice to low soil organic matter, low soil pH, soil erosion, and low application of N fertilizers. Nitrogen use efficiency in rice production is subjected to N loss by leaching, volatilization, denitrification and erosion (Fageria and Baligar, 2005). Thus, the use of N-efficient varieties in combination with proper fertilizer application is an important complementary strategy in improving rice yield.

II. MATERIALS AND METHODS

Experiment 1 involved two factors, namely: Factor A: six upland rice genotypes that included 4 test genotypes, 1 drought susceptible check genotype and 1 drought tolerant check genotype; and Factor B: 3 water regimes: field capacity (FC), 50% FC and 75% FC. The experiment was laid out in two factorial randomized complete block designs (RCBD) with three replications. The rice genotypes evaluated were: P31, P38, P42 and P44, PSB Rc14 (N responsive check) and Salumpikit (non-responsive to N check).

Experiment 2 was laid out in two factorial RCBD with three replications which involved two experimental variables, namely: 1) six rice genotypes (4 test genotypes, 1 N-responsive check, 1 non-responsive to N check); and 2) three N levels (0, 60, and 120 kg ha^{-1}). The rice genotypes evaluated were: P31, P38, P42, P44, and PSB Rc14 (N responsive check) and Salumpikit (non-responsive to N check).

Three experimental variables were considered in this experiment, namely: 1) three rice genotypes selected from Experiment I, 2) Two water regimes (FC and 50% FC, and 3) two N levels (0 and 120 kg ha^{-1}). The experiment was laid out in 3-factorial RCBD with three replications analyzed by SAS (9.1) to compare mean LSD at 5 % and 1% level.

TABLE 1
CHEMICAL PROPERTIES OF THE SOIL USED IN THE EXPERIMENTS

Chemical Properties	Concentration Value	Description
pH	6.8	Slightly acidic
Total N (%)	0.31	Low N
Available P (ppm)	90	High P
Exchangeable K (me/100 g soil)	0.66	Low K
Organic Matter (%)	3.87	Medium OM

Results analyzed by Soil Laboratory, Agricultural Systems Cluster, UPLB

III. RESULTS AND DISCUSSION

3.1 Genotypes Responses to Varying Soil Moisture

3.1.1 Number of tillers per hill

The number of tillers per hill was significantly influenced by the soil moisture condition and genotypes (Table 2). P38 and P42 had a comparable number of tillers per hill to PSB Rc14 (11.52, 12 and 12.15 tillers per hill, respectively), while Salumpikit had the lowest number of tillers per hill (6.44 tillers per hill) at FC.

TABLE 2
NUMBER OF TILLERS HILL^{-1} OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING WATER REGIMES AT 72 DAS.

GENOTYPE	NUMBER OF TILLERS PER HILL					
	Water Regime			Difference (%)		
	FC	75% FC	50 % FC	FC-75% FC	FC-50%FC	75% FC-50% FC
P31	8.56e	6.11g	5.44h	33.4	44.6	11.6
P38	11.52ab	9.89de	8.92e	15.2	25.4	10.3
P42	12a	10.78cd	9.87de	10.7	19.5	8.8
P44	8.44e	6.21fg	4.84hi	25.8	54.2	24.8
Salumpikit	6.44fg	4.89hi	3.90i	27.4	49.1	22.5
PSB Rc14	12.15a	11bc	10.22cd	9.9	17.3	7.4

CV(%) = 3.27 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety ** W x V **

3.1.2 Water use efficiency (WUE)

Highly significant differences in water use efficiency under varying soil moisture content were observed in six upland rice genotypes (Table 3). PSB Rc14 (2.30) had the highest water use efficiency, which is comparable to the check P42 (2.27) followed by P38 (2.10) at FC. When SMC was reduced to 75% FC, WUE of the genotypes were still significantly different from each other. P42 obtained the highest WUE (1.86) similar with PSB Rc14 (1.84) followed by P38 (1.59).

TABLE 3

WATER USE EFFICIENCY OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING WATER REGIME TREATMENTS.

GENOTYPE	WATER USE EFFICIENCY					
	Water Regime				Difference (%)	
	FC	75 % FC	50 % FC	FC-75% FC	FC- 50% FC	75% FC -50%FC
P31	1.60 d	1.14h	0.78j	34.1	68.9	37.5
P38	2.10b	1.59 d	1.24g	28.4	51.5	24.7
P42	2.27a	1.86c	1.34g	21.7	51.5	32.5
P44	1.53e	1.11hi	0.75j	31.8	68.4	38.7
Salumpikat	1.41g	1.02i	0.70j	33.5	67.3	37.2
PSB Rc14	2.30a	1.84c	1.43hi	22.2	46.7	25.1

CV (%) = 3.40 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety ** W x V *

3.1.3 Harvest index (HI)

HI (ratio of grain yield to above ground biomass) of the six upland rice genotypes was significantly affected by varying water regimes (Table 4). Despite the comparable high number of panicles produced by the test genotypes P38 and P42 to the drought tolerant check, PSB Rc14 significantly had the highest HI (0.32), while Salumpikit and P44 did not differ from each other at FC. Further increased in water deficit up to 50% FC resulted to significant decreased in HI value. Sharmar *et al.* (2003) reported that high HI was attained in well-irrigated genotypes compared to that of the genotypes grown under water stress condition.

TABLE 4

HARVEST INDEX OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING WATER REGIMES.

GENOTYPE	HARVEST INDEX					
	Water Regime			Difference (%)		
	FC	75 % FC	50 % FC	FC -75% FC	FC -50% FC	75 % FC - 50 % FC
P31	0.25c	0.20e	0.18ef	26.1	32.6	10.5
P38	0.28b	0.24cd	0.22de	14.4	24.0	8.7
P42	0.28b	0.27bc	0.25e	3.6	11.3	7.7
P44	0.22de	0.19ef	0.16fg	14.6	31.6	17.1
Salumpikit	0.20e	0.17f	0.13g	16.2	42.4	26.7
PSB Rc14	0.32a	0.29b	0.25c	9.8	24.6	14.8

CV (%)= 4.63 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety ** W x V *

3.1.4 Number of panicles per hill

At FC the drought tolerant check (PSB Rc14) had the highest number of panicles per hill (10 panicles), which is comparable to P38 and P42 (9.78 and 8.67 panicles, respectively) (Table 5). P31 and P44 had the same number of panicles per hill (7.33 and 7.11 panicles) while Salumpikit had the lowest number of panicle produced (5.68 panicles).

TABLE 5
NUMBER OF PANICLES PER HILL IN SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING WATER REGIMES.

GENOTYPE	NUMBER OF PANICLES PER HILL					
	Water Regime			Difference (%)		
	FC	75 % FC	50 % FC	FC -75% FC	FC -50% FC	75 % FC-50% FC
P31	7.33ef	6.78fgh	5.33hij	7.8	31.6	23.9
P38	9.78ab	9.33cde	7.93def	4.7	20.9	16.2
P42	9.67ab	9.21cde	7.83def	4.9	21.0	16.2
P44	7.11fg	6.22gh	4.46ijk	13.4	45.8	26.4
Salumpikit	5.68ghi	4.22jk	3.27k	29.5	53.9	19.2
PSB Rc14	10a	9.56bcd	8.18 de	4.5	20.0	14.1

CV (%) = 6.07 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety * W x V *

3.1.5 Number of filled grains per panicle

The number of filled grains is one of the most important yield attributes in rice. The results showed significant differences in the number of filled grains per panicle among rice genotypes tested under different water regimes (Table 6). PSB Rc14 (77.69) had the higher number of filled grains, which was not significantly different to P42 (74.84) and P38 (74.33), while P44 and Salumpikit both had the lowest number of filled grains per panicle (65.51 and 63.60, respectively) at FC. At 75% FC, the highest percent reduction in the number of filled grains per panicle was observed in P44 (11%) while P38, P42, and PSB Rc14 had the lowest percent reduction (7.3, 7.2 and 7.2%, respectively).

TABLE 6
NUMBER OF FILLED GRAINS PER PANICLE OF SIX RICE GENOTYPES AS AFFECTED BY VARYING WATER REGIMES.

GENOTYPE	NUMBER OF FILLED GRAINS PER PANICLE					
	Water Regime				Difference (%)	
	FC	75 % FC	50 % FC	FC-75% FC	FC-50% FC	75 %FC-50%FC
P31	68.42c	63.11de	51.53hi	8.1	28.2	20.2
P38	74.33ab	69.09bc	60.51fg	7.3	20.5	13.2
P42	74.84ab	69.67bc	60.62fg	7.2	21.0	13.9
P44	65.51d	58.42gh	49.18i	11.0	28.5	11.1
Salumpikit	63.60de	57.71gh	48.33i	9.7	27.3	17.7
PSB Rc14	77.69a	72.29b	63.62de	7.2	19.9	12.8

CV (%) = 1.84 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety ** W x V **

3.1.6 Thousand-grain weight

Thousand-grain weight was significantly differed among genotypes at FC. P42 had the heaviest 1000-grain weight (24.61 g), while Salumpikit(19.69 g) had the lightest (21.13 g). Reducing SMC from 100 % FC to 75% FC and 50% FC resulted to significant reduction in 1000-grain weight. At 75% FC, P42 had the heaviest grain weight (23.82 g) with a percentage difference of 3.3 %, while Salumpikit had the lightest grain weight (18.82 g) with a percentage difference of 4.5% when grown under 100% FC.

3.1.7 Grain yield per hill

Significant differences in grain yield were observed among the values of grain yield of the genotypes (Table 7). At sufficient SMC (FC), PSB Rc14 had the highest grain yield (10.92 g) which was comparable to P42 (10.61 g) followed by P38 (9.60 g). Salumpikit (5.36g) had the lowest grain yield. Significant reduction in grain yield in all genotypes was observed after reducing SMC from 100 % FC to 75% FC and 50% FC. At 75% FC and 50% FC, PSB Rc14 had the highest grain yield (8.96 g and 7.82 g, respectively) which was comparable to P42 (8.54 g and 7.63 g, respectively). Shani *et al.* (2001) reported that drought stress at filling grains period caused acceleration in ripening time, thus reduction growth duration and number of filled grains per panicle. P42, PSB Rc14 and P38 had the number of filled grains was not much affected by water deficit, hence, showed tolerance to drought.

TABLE 7

GRAIN YIELD AS AFFECTED BY VARYING WATER REGIMES OF SIX RICE UPLAND GENOTYPES.

GENOTYPE	GRAIN WEIGHT (g per hill)					
	Water Regime			Difference (%)		
	FC	75 % FC	50 % FC	FC-75% FC	FC-50% FC	75 % FC -50 % FC
P31	7.61cd	4.75fg	3.04hi	46.3	85.8	43.9
P38	9.60b	6.92d	5.88e	32.5	48.1	16.3
P42	10.61a	8.54c	7.63 cd	21.6	32.7	11.3
P44	6.13de	4.05fg	2.98hi	40.9	69.2	30.4
Salumpikit	5.36e	3.91gh	2.56i	31.3	70.7	41.7
PSB Rc14	10.92a	8.96c	7.82 cd	19.7	33.1	13.6

CV (%) = 5.09 (FC: Water at field capacity)

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Water ** Variety ** W x V **

3.2 Genotypes Responses to Varying Nitrogen Levels

3.2.1 Number of tillers per hill

The number of tillers per hill was significantly differed among the genotypes without N treatment at 72 DAS (Table 8). PSB Rc14 had the highest number of tillers (10.38), while Salumpikit had the least number of tillers (3.51). The number of tillers of P42 and P38 did not significantly different (9.48 and 8.87, respectively). Increasing N level from 0 to 60 kg ha^{-1} and 120 kg ha^{-1} significant increased the number of tillers among the genotypes by 1-2 tillers after application of N. PSB Rc14 had the highest number of tillers with medium and high N application (11.83 and 12.9, respectively), while Salumpikit also had the least number of tillers (5.02 and 6.56, respectively). Chaturvedi (2005) reported that higher number of tillers might be due to the more availability of N, which played a vital role in cell division. He also reported that the maximum numbers of tillers were attained at 200 kg N ha^{-1} level while the minimum number of tillers was observed at 0 kg N ha^{-1} level.

TABLE 8

NUMBER OF TILLERS PER HILL OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS AT 72 DAS.

GENOTYPE	NUMBER OF TILLERS PER HILL					
	Nitrogen Level			Difference (%)		
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	7.44ghi	8.89def	11.22bcd	17.8	40.5	23.2
P38	8.87fg	10.33cde	11.78abc	15.2	28.2	13.1
P42	9.48efg	10.89bcd	12.33ab	13.8	26.1	12.4
P44	6.04hi	7.55hg	9.78def	22.2	47.3	25.7
Salumpikit	3.51j	5.02i	6.56hi	35.4	60.6	26.6
PSB Rc14	10.38cde	11.83bc	12.9a	13.1	21.7	8.7

CV(%) = 5.57

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Nitrogen ** Variety ** N x V *

3.2.2 Relative growth rate (RGR)

At 30 DAS without N application, significant differences were observed in RGRs among the genotypes (Table 9). However, there were no significant differences between the RGRs of P38, P42, and PSB Rc14 (0.12, 0.13, and 0.13 g $g^{-1}d^{-1}$, respectively) and between the RGRs of P31, P44, and Salumpikit (0.08, 0.06, and 0.05 g $g^{-1}d^{-1}$, respectively). Application of 60 kg N ha^{-1} and 120 kg N ha^{-1} significantly increased RGR among the genotypes. Tisdale and Nelson (1984) observed that an adequate supply of N to the plant during the early growth period is very important to increase RGR and the initiation of leaves.

TABLE 9

RGR (g $g^{-1}d^{-1}$) OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS

GENOTYPE	RELATIVE GROWTH RATE (g $g^{-1}d^{-1}$)					
	Nitrogen Level				Difference (%)	
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	0.08h	0.11ef	0.15b	31.6	60.9	30.8
P38	0.12e	0.15b	0.18a	22.2	40.0	18.2
P42	0.13e	0.16b	0.19a	20.7	37.5	17.1
P44	0.06hi	0.08g	0.11ef	28.6	58.8	31.6
Salumpikit	0.05hi	0.07g	0.10f	33.3	66.7	35.3
PSB Rc14	0.13e	0.15b	0.18a	14.3	32.3	18.2

CV(%) = 3.37

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

***Nitrogen ** Variety ** N x V ***

3.2.3 Straw yield

Significant differences in the straw yields were observed among the genotypes in control treatment. P42 had the highest straw yield (26.74 g $plant^{-1}$) while Salumpikit had the lowest straw yield (16.09 g $plant^{-1}$). Straw yield significantly increased after application of N in all genotypes. P42 and Salumpikit consistently had the highest and lowest straw yields after applications of 60 kg N ha^{-1} to 120 kg N ha^{-1}. Hence, these genotypes were least affected under N is limiting condition. Dry matter production increased with increasing N levels. Hence, N is an indispensable nutrient to rice production, and its uptake is affected by different factors such as soil condition (Martin *et al.* 2002).

3.2.4 Harvest Index (HI)

Table 10 shows the different HI of the different genotypes as affected by different N levels. The rice genotypes evaluated have significantly varying HI among genotypes in control treatment (0 N). PSB Rc14 had the highest HI (0.25), followed by P38 and P42 (0.22 and 0.21, respectively). Application of 60 kg N ha^{-1} significantly increased HI among the genotypes, wherein PSB Rc14 (0.28) had the highest HI followed by P38 and P42 (0.26 and 0.25, respectively). Further increase in N level to 120 kg ha^{-1}, significant increased HI. Cai *et al. (*2002) when observed that increasing N up to 120 kg ha^{-1} can increase HI in different genotypes.

TABLE 10

HARVEST INDEX OF SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS.

GENOTYPE	HARVEST INDEX					
	Nitrogen Level			Difference (%)		
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	0.18hij	0.22 efg	0.26cd	20.0	36.4	8.3
P38	0.22efg	0.26cd	0.28ab	16.7	24.0	7.4
P42	0.21ghi	0.25de	0.27bc	17.4	25.0	7.7
P44	0.18hij	0.22efg	0.25cd	20.0	32.6	12.8
Salumpikit	0.14k	0.17hij	0.21fg	19.4	40.0	21.1
PSB Rc14	0.25de	0.28ab	0.30a	11.3	18.2	6.9

CV (%) = 4.63

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Nitrogen ** Variety ** N x V *

3.2.5 Agronomic efficiency of nitrogen application (AEN)

AEN significantly differed among the genotypes (Table 11). P38 had the highest AEN (6.99) and was comparable to PSB Rc14 (6.25) and P42 (5.13) at 60 kg N ha^{-1}. Increased N level to 120 kg ha^{-1} significantly increased AEN among the genotypes. P38 had the highest AEN (7.98) but not significantly different with PSB Rc14 (7.21), followed by P42 (6.09) and P31 (5.58). High AEN with the low percentage difference was observed in P38, PSB Rc14 and P42, which suggest that these genotypes were least affected after decreasing the rate of N application. Hence, achieving higher yield. Application of 120 kg N ha^{-1} in these rice genotypes with SMC at field capacity under screen house condition showed significantly higher AEN values than those plants applied with 60 kg N ha^{-1}. Ladha *et al.* (1998) claimed that rice varieties with high NUE should have the higher AEN at low and high N supply.

TABLE 11
AGRONOMIC EFFICIENCY OF NITROGEN IN SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS.

GENOTYPE	AGRONOMIC EFFICIENCY OF NITROGEN APPLICATION		
	Nitrogen Level		Difference (%)
	60 N	120 N	120 N- 60 N
P31	4.58c	5.58bc	19.7
P38	6.99 b	7.98a	13.2
P42	5.13bc	6.09b	17.1
P44	3.51ef	4.63cd	27.5
Salumpikit	2.45 f	3.57de	37.2
PSB Rc14	6.25bc	7.21a	14.3

CV (%) = 7.02

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Nitrogen ** Variety **N x V

3.2.6 Recovery efficiency of nitrogen application (REN)

Significant difference was also observed in REN among genotypes as affected by different N levels (Table 12). At 60 kg N ha^{-1} rate, P42 had the highest REN (0.45), but this value was not significantly different from the REN of P38 (0.44) and PSB Rc14 (0.43). On the hand, Salumpikit had the lowest REN (0.28). At 120 kg N ha^{-1} rate, higher REN values were obtained compared to the other treatment. P42 had the highest REN value (0.82), which was not significantly different in the REN value of P38 (0.77). As observed in this experiment, doubling the rate of N from 60 to 120 kg ha^{-1} also doubled the REN values in each genotype. Since not all of N applied remains in the soil, particularly under aerobic condition, addition of N increases biomass including root biomass, which might contribute to absorb more native N from the soil Cassman *et al.* (2002).

TABLE 12
RECOVERY EFFICIENCY OF NITROGEN IN SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS.

GENOTYPE	RECOVERY EFFICIENCY OF NITROGEN APPLICATION		
	Nitrogen Level		Difference (%)
	60 N	120 N	120 N - 60 N
P31	0.25e	0.50bc	66.7
P38	0.44c	0.77a	54.6
P42	0.45c	0.82a	58.3
P44	0.30de	0.61b	68.1
Salumpikit	0.28e	0.54bc	63.4
PSB Rc14	0.43cde	0.52bc	26.1

CV (%)= 9.67

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly based on LSD at 5 % and 1% level.

Nitrogen **, Variety **, N x V *

3.2.7 Internal efficiency of nitrogen application (IEN)

Like AEN and REN, IEN was significantly differed among genotypes in response to varying N levels (Table 13). P42 had the highest IEN (1.95), but not significantly different with P38 (1.95) and PSB Rc14 (1.92) while Salumpikit had the lowest IEN (1.06). Increasing N level to 60 kg ha^{-1} significantly increased IEN of the test genotypes. The highest IEN was noted in P42 (2.44), which was not significantly different with P38 (2.40) and PSB Rc14 (2.20). Further increase in N level to 120 kg ha^{-1} also resulted to significant increase in IEN among genotypes. P42 remained to have the highest IEN (2.94) but not significantly different with P38 (2.92), P31 (2.72) and PSB Rc14 (2.72).

TABLE 13

INTERNAL EFFICIENCY OF NITROGEN IN SIX UPLAND RICE GENOTYPES AS AFFECTED BY VARYING N LEVELS.

GENOTYPE	INTERNAL EFFICIENCY OF NITROGEN APPLICATION					
	Nitrogen Level			Difference (%)		
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	1.1gh	1.92gf	2.72ab	27.15	84.82	34.48
P38	1.95fg	2.40bc	2.92a	20.69	39.84	19.55
P42	1.96fg	2.44bc	2.94a	21.82	40.00	18.73
P44	1.74gh	1.99fg	3.01a	13.59	53.47	21.14
Salumpikit	1.06h	1.47gh	1.87efg	32.41	55.29	39.52
PSB Rc14	1.92fg	2.20cde	2.72ab	21.84	34.48	31.54

CV (%) = 6.7

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

*Nitrogen ** Variety ** N x V **

3.2.8 Number of panicles per hill

Without N application, P42 had the highest number of panicles (8.87), which was similar with PSB Rc14 (8.65) and P38 (8.48). Increasing N level to 60 kg ha^{-1} and 120 kg ha^{-1} significantly increased the number of panicles among genotypes. P42, PSB Rc14, and P38 consistently have the highest number of panicles (9.66, 9.44, and 9.33, respectively).

3.2.9 Number of filled grains per panicle

Table 14 shows that there are significant differences in the number of filled grains per panicle among the genotypes as affected by N application. At 0 N level, P42 had the significantly highest number of filled grains (71.33) which was comparable to PSB Rc14 (70.09), followed by P38 (66.04), and the lowest value was observed in Salumpikit (56.54). When N level increased to 60 kg ha^{-1}, significant increase in the number of filled grains was observed among the genotypes. P42 (77.51) still had the highest number of filled grains, which was comparable to the values obtained in PSB Rc14 (75.84) and P38 (72.49).

TABLE 14

NUMBER OF FILLED GRAINS PER PANICLE AS AFFECTED BY APPLICATION OF VARYING N LEVELS IN SIX UPLAND RICE GENOTYPES.

GENOTYPE	NUMBER OF FILLED GRAINS PER PANICLE					
	Nitrogen Level			Difference (%)		
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	62.18ijk	69.07ef	72.67bcd	10.5	15.6	5.1
P38	66.04fgh	72.49bcd	75.67bc	9.3	13.6	4.3
P42	71.33de	77.51b	80.42a	8.4	11.9	3.7
P44	59.02jk	65.29fgh	71.84de	10.1	18.7	9.6
Salumpikit	56.54k	63.08ij	67.98fg	10.9	18.4	7.5
PSB Rc14	70.09def	75.84bc	79.20a	7.9	12.2	4.3

CV (%) = 1.54

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

*Nitrogen ** Variety ** N x V ***

3.2.10 Thousand-grain weight

Grain weight among genotypes were significantly differed at 0 N (Table 15). P42 (23.22 g) had the highest grain weight which was not significantly different with P38 (21.91 g). At 60 kg N ha^{-1} level, significant increase in grain weight was observed among genotypes.

TABLE 15
1000-GRAIN WEIGHT OF SIX RICE GENOTYPES AS AFFECTED BY APPLICATION OF VARYING N LEVELS.

GENOTYPE	1000-GRAIN WEIGHT (g)					
	Nitrogen Level				Difference (%)	
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	19.31ij	19.76hi	21.68efg	2.3	11.6	17.7
P38	21.91def	23.23cd	24.89ab	5.8	12.7	6.9
P42	23.22cd	24.38bc	26.12a	4.9	11.8	6.9
P44	20.84ghi	21.49efg	22.72de	5.8	8.6	5.6
Salumpikit	18.25j	19.82hi	20.52ghi	8.2	11.7	7.8
PSB Rc14	19.34ij	19.91hi	20.56ghi	3.1	6.12	3.2

CV (%) = 2.71

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Nitrogen **Variety **N x V *

3.2.11 Grain yield per hill

Significant differences in grain yield per hill were observed among genotypes in all the treatments. At 0 N, P38 had the highest grain yield (7.41 g) comparable to the grain yields of PSB Rc14 (6.88 g) and P42 (6.97 g), while Salumpikit had the lowest grain yield per hill (3.02 g). Application of 60 kg N ha^{-1}, significantly increased grain yield per hill in test genotypes, particularly P38 having the highest grain yield (9.44 g) but not significantly different with P42 and PSB Rc14 (8.78 and 8.37 g, respectively). The result implies that P38, PSB Rc14 and P42 had better response to increasing rates of N application. P38, P42 and PSB Rc14 produced high number of spikelets per panicle, hence, produced high number of filled grains per panicle. Less affected by increasing N rate application.

TABLE 16
GRAIN YIELD PER HILL OF SIX UPLAND RICE GENOTYPES AS AFFECTED APPLICATION OF VARYING N LEVELS.

GENOTYPE	GRAIN WEIGHT (g per hill)					
	Nitrogen Level				Difference (%)	
	0 N	60 N	120 N	60 N - 0 N	120 N - 0 N	120 N - 60 N
P31	4.51gh	6.95def	8.69bc	42.6	63.3	22.3
P38	7.41cd	9.44b	11.11a	24.1	39.9	16.3
P42	6.88def	8.78bc	10.12a	24.3	34.3	14.2
P44	4.25gh	6.32de	8.61bc	39.2	67.8	30.7
Salumpikit	3.02i	4.22gh	6.05def	33.2	66.8	35.6
PSB Rc14	6.97def	8.37bc	10.89a	18.3	43.9	26.9

CV (%) = 6.17

In a column or row (treatment effect) or row by column (if indication effect is significant), means followed by the same letter by the same letter are not significantly different based on LSD at 5 % and 1% level.

Nitrogen **Variety ** N x V *

3.3 Genotypes Responses to Varying Water and Nitrogen Levels:

The result shows that P42 had better RGR than PSB Rc14 and P38. Generally, low application of N and reduced SMC resulted low growth rate due to inaccessibility of nutrients because of limited root growth (Briggs and Shantz, 1993; de Wit, 1988). Stem partitioning coefficients at maturity stage showed that the combined effect of N level and water regime significantly affected the genotypes (Table 17). Yang *et al.* (2001) claimed that N fertilization generally reduce the remobilization of pre-stored carbon from vegetative tissue to the grain.

TABLE 17
STEM PARTITIONING COEFFICIENT AT MATURITY STAGE IN THREE UPLAND RICE GENOTYPES EXPOSED TO VARYING N LEVELS AND WATER REGIMES.

GENOTYPE	STEM PARTITIONING COEFFICIENT			
	Nitrogen Level (Kg ha^{-1})	Water Regime		Mean
		FC	50 FC	
P38	120 N	0.54 b	0.44 d	0.49 B
	0 N	0.46 c	0.41f	0.44 D
P42	120 N	0.52 b	0.47c	0.50 B
	0 N	0.48 c	0.41f	0.45 C
PSB Rc14	120 N	0.61 a	0.48 c	0.55 A
	0 N	0.50 b	0.42e	0.46 C
Mean		0.51 A	0.44 B	

CV (%) = 5.71 G x W *, G x N **, W x N **, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly differentbased on LSD at 5 % and 1% level.

Leaf partitioning coefficient increased from flowering to maturity stage (Table 18). At FC level with 120 kg N ha^{-1} application, PSB Rc14 (0.36) had the highest leaf partitioning coefficient among the genotypes. When SMC was reduced to 50% FC, significant reduction in leaf partitioning coefficient was observed among the genotypes. The lowest reduction in partitioning coefficient was recorded in PSB Rc14 (0.22) when grown under FC level without N application.

TABLE 18
LEAF PARTITIONING COEFFICIENT AT MATURITY STAGE OF THREE UPLAND RICE GENOTYPES EXPOSED TO VARYING N LEVELS AND WATER REGIMES.

LEAF PARTITIONING COEFFICIENT				
GENOTYPE	Nitrogen Level (Kg ha^{-1})	Water Regime		Mean
		FC	50 FC	
P38	120 N	0.34 b	0.27d	0.31 A
	0 N	0.24de	0.23ef	0.23 D
P42	120 N	0.30 c	0.25de	0.28 B
	0 N	0.26 d	0.22ef	0.25 C
PSB Rc14	120 N	0.36 a	0.24e	0.30 A
	0 N	0.28 cd	0.20f	0.24 C
Mean		0.30 A	0.24 B	

CV (%) = 10.51 G x W *, G x N **, W x N **, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly differentbased on LSD at 5 % and 1% level.

At maturity stage, root partitioning coefficients increment was low but still significantly differed among the genotypes (Table 19). Highest coefficient was observed in PSB Rc14 (0.27) when grown under 100% FC and 120 kg ha^{-1}. Lowest value was also obtained in PSB Rc14 (0.23) when grown under 100% FC without N application.

TABLE 19
ROOT PARTITIONING COEFFICIENT AT MATURITY STAGE IN THREE UPLAND RICE GENOTYPES EXPOSED TO VARYING N LEVELS AND WATER REGIMES.

ROOT PARTITIONING COEFFICIENT				
GENOTYPE	**Nitrogen Level (Kg ha^{-1})**	**Water Regime**		**Mean**
		FC	**50 FC**	
P38	120 N	0.25 b	0.21d	0.23 B
	0 N	0.23 c	0.18 e	0.21 C
P42	120 N	0.23 c	0.2d	0.22 B
	0 N	0.21 d	0.19 e	0.20 D
PSB Rc14	120 N	0.27 a	0.23 c	0.25 A
	0 N	0.22cd	0.17ef	0.20 D
Mean		0.24 A	0.2 B	

CV (%) = 3.11 G x W *, G x N *, W x N **, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly differentbased on LSD at 5 % and 1% level.

3.3.1 Water use efficiency (WUE)

Significant interaction was found among the treatment variables in terms of WUE (25). Highest WUE obtained in P42 (2.49) under FC applied with 120 kg N ha^{-1}, followed by PSB Rc14 and P38 (2.33 and 2.30, respectively). Reduction in SMC to 50% FC applied with 120 kg N ha^{-1}, significantly reduce WUE among the genotypes. PSB Rc14 (1.82) had the highest WUE followed by P42 then P38 (1.27 and 1.25, respectively). Zhao *et al.* (2003) reported that WUE increases with water stress because of higher reduction in conductance than the reduction in assimilation, while severe water stress decreases the activity of photosynthetic enzyme that results to decrease in WUE.

TABLE 20
WATER USE EFFICIENCY IN THREE UPLAND RICE GENOTYPES AS AFFECTED BY THE INTERACTION OF VARYING WATER REGIMES AND N LEVELS IN SELECTED RICE GENOTYPES.

WATER USE EFFICIENCY				
GENOTYPE	**Nitrogen Level (Kg ha^{-1})**	**Water Regime**		**Mean**
		FC	**50 FC**	
P38	120 N	2.30 b	1.27 f	1.79 C
	0 N	1.73 d	1.09 g	1.41 E
P42	120 N	2.49 a	1.25 f	1.87 B
	0 N	1.74 cd	1.06 g	1.4 E
PSB Rc14	120 N	2.33 b	1.44 e	1.89 A
	0 N	1.82 c	1.28 f	1.55 D
Mean		2.07 A	1.23 B	

CV (%) = 1.76 G x W *, G x N **, G x N **, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly different based on LSD at 5 % and 1% level.

3.3.2 Total nitrogen uptake (TNU)

P38 (3.15) had the highest TNU was found in but not significantly different with P42 (3.09) under 100% FC applied with 120 kg N ha^{-1} (Table 21). When SMC was reduced to 50% FC applied with the same level of N, the TNU was significantly reduced. PSB Rc14 and P42 had TNU values of 2.78 and 2.70, respectively. According to Yaduvanshi (2003), increases in N fertilizer rates, from 60 to 120 and to 180 kg N ha^{-1}, resulted to decreased NUE by 7 and 27% although the difference among 60 kg N 120 kg N was not significant. Dobermann *et al.* (2005) claimed thatapplication of N at optimum rate of 103 kg ha^{-1} increased aboveground N uptake by 38 kg ha^{-1} or about 37%.

TABLE 21
TNU IN THREE UPLAND RICE GENOTYPES AS AFFECTED BY THE INTERACTION OF VARYING WATER REGIMES AND N LEVELS IN SELECTED RICE GENOTYPES.

TOTAL NITROGEN UPTAKE				
GENOTYPE	Nitrogen Level (Kg ha^{-1})	Water Regime		Mean
		FC	50 FC	
P38	120 N	3.15 a	2.92 c	3.03 A
	0 N	2.64 ef	2.45 gh	2.37 E
P42	120 N	3.09 ab	2.70 de	2.89 B
	0 N	2.57 f	2.35 hi	2.33 F
PSB Rc14	120 N	2.98 bc	2.78 d	2.88 C
	0 N	2.56 fg	2.34 i	2.45 D
Mean		2.83 A	2.59 B	

CV (%) = 1.4 G x W *, G x N ns, W x N *, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly different based on LSD at 5 % level.

3.3.3 Grain yield

Nitrogen level, water regimes, genotypes and their interactions significantly affected grain yield (Table 22). At 100% FC without N application, P42 had the highest grain yield (7.44 g), while P38 had the lowest grain yield (6.79 g). Significant increase in grain yield was observed with the application of 120 kg N ha^{-1}. Miah and Panuallah (1999) had similar tending wherein the rate of yield reduction was higher when higher amount of N was applied in stress-affected rice especially at reproductive stage.

TABLE 22
GRAIN YIELD OF THREE UPLAND RICE GENOTYPES AS AFFECTED BY THE INTERACTION OF VARYING WATER REGIMES AND N LEVELS IN SELECTED RICE GENOTYPES.

GRAIN YIELD (g per hill)				
GENOTYPE	Nitrogen Level (Kg ha^{-1})	Water Regime		Mean
		FC	50 FC	
P38	120 N	10.56 b	5.53 e	8.05 C
	0 N	6.79 cd	3.75 f	5.27 E
P42	120 N	12.61 a	5.75 de	9.18 A
	0 N	7.44 c	4.08 f	5.76 D
PSB Rc14	120 N	11.66 a	5.70 e	8.68 B
	0 N	7.38 c	3.57 f	5.48 F
Mean		9.41 A	4.73 B	

CV (%) = 5.81 G x W *, G x N **, W x N **, G x N x W *

Means followed by a common letter across nitrogen levels x water regimes x rice genotypes are significantly different based on LSD at 5 % level.

IV. CONCLUSION

The first experiment determined the effect of different water regimes in selected upland rice genotypes in terms of agronomic parameters, yield and its components, and water use efficiency. The six upland rice genotypes used in the study were: 1). Salumpikit (susceptible drought check), 2). P31, 3). P38, 4). P42, 5). P44, and 6). PSB Rc14 (drought tolerant check). Water regime treatments were: 1) SMC at FC; 2) SMC at 75% FC, and 3) SMC at 50% FC. Genotypes grown under adequate SMC (at FC) were taller than those grown under water deficit condition. Salumpikit was the tallest plant among the genotypes but it also had high percentage reduction from 100% FC to 75% FC and 50% FC among the genotypes. PSB Rc14, P42 and P38 were among the genotypes that had low percentage reduction when SMC was decreased to 75 % FC and 50 FC %. Indicating that these genotypes were less affected by water deficit. The RGR was significantly affected by the interaction of water regime and rice genotypes. P42 had the highest RGR among the genotypes and result was consistent when exposed to decreasing water regime treatments at 75 % FC and 50 % FC. PSB Rc14, which is a drought-tolerant genotype, had similar performance with P42 in terms of RGR and WUE parameters, which lead to have better grown.

Flowering occurred earlier in genotype the PSB Rc14 while other genotypes had later day to flowering. At reproductive stage, the allocation of photosynthates started to become directed to the production of grains (10.92 g). Shoot weight lower (14.26 g) compared to the previous crop stage as senescence of old shoots started. High values of HI in PSB Rc14, P42, and P38 (0.32 and 0.28, respectively) imply that these genotypes efficiently allocated the photosynthates in the production of grains under different water regimes. Subsequently, the numbers of panicles per hill (10 panicles), number of filled grains per panicle (77.69), number of spikelets per panicle (101.49) and grain weight per hill (10.92 g) were high in these genotypes. Water limitation (50 FC %) is one of the main factors that determinations of rice growth and grain yield, significantly affect grain filling. Among the genotypes evaluated, PSB Rc14, P42, and P38 had good performance under drought condition based on growth and yield parameters, hence can be considered as drought-tolerant genotypes while P44, P31 and Salumpikat were least tolerant to water deficit.

The second experiment revealed the importance of N in upland rice production. N rates applied in the experiment were 60 kg ha^{-1} and 120 kg ha^{-1}. Indicator genotypes were PSB Rc14 as the N-responsive and Salumpikit as the non N-responsive. Application of N significantly increased all the growth and yield parameters measured and significant differences were also observed in all parameters among the genotypes. Moreover, maximum N rate of 120 kg ha^{-1} application resulted to optimum growth of the genotypes. PSB Rc14, P42, and P38 performed well under varying N treatments as indicated by their high RGR values. P42 also had the highest straw yield than other genotypes, although was not significantly different from P38 and PSB Rc14. This means that these genotypes allocated most of their photosynthates in the maintenance of vegetative parts, while the other genotypes concentrated most of their photosynthates for the production of reproductive parts. Thousand-grain weight (23.22 g), number of spikelets per panicle (95.16), number of filled grains (71.33), and grain yield (7.41 g) were also high in PSB Rc14, P42, and P38 suggesting the good grain filling qualities of rice genotypes. The efficiency of N use as calculated in AEN, REN, and IEN showed that with doubled N rate (120 kg N ha^{-1}), P38 and P44, and N-responsive check, PSB Rc14, had high values for the aforementioned parameters. Nitrogen application increased the dry matter partitioning, grain yield and its components. Without N application, reduction in growth parameters, dry matter and grain yield were observed. Further increased N level up to 120 kg N ha^{-1} increased growth parameters and grain yield by 35%.

The effect of combined N levels and water regimes three selected upland genotypes were evaluated in the last experiment. Nitrogen rates applied were 0 kg N ha^{-1} and 120 kg N ha^{-1} under SMC at 100% FC and 50% FC. The genotypes that performed well in experiments 1 and 2 were used: PSB Rc14, P42 and P38. Significant differences were observed in all growth and yield parameters measured among the genotypes. Optimum growth of the genotypes was observed under 100% FC applied with 120 kg N ha^{-1} wherein P42 obtained the highest RGR, WUE, IEN, TNU, straw yield, and grain yield. Therefore, varying water regimes at FC, together with proper N level application up to 120 kg ha^{-1}, can be used as an effective and practical agronomic strategy to get good or high economic yield under water-limited conditions. Apparently, efficiency in rice cultivation can be addressed by providing the necessary and precise inputs of water and nitrogen regimes since the experiment was done in screen house and pot experiments. P42 showed the number of filled grain was not much affected by water deficit, hence showed drought tolerance and produced high yield.

REFERENCES

[1] ABOU-KHALIFA, A.A. 2007. Egypt. J. Plant Breed. 11(2): 681- 691.Special Issue.

[2] CAI C, WANG JY, ZHUYG, SHEN QR, Li B, TONG YP, Li ZS.2002. Gene structure and expression of the high-affinity nitrate transport system in rice roots. Journal of Integrative Plant Biology 50: 443-451.

[3] CHATURVEDI I (2005) Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (Oryza sativa L.) J Central EurAgr. 6:611-618.

[4] COSSAMA, C., DWYER, L. M., ZHOU, X., DUTILLEUL, P. HAMEL, C. REID, L. M. and SMITH, D. L. 2002. Root Morphology of Contrasting Maize Genotypes. Agron. J., 94: 96-101.

[5] DOBERMANN, A., and K.G. CASSMAN. 2005. Cereal area, yield and nitrogen use efficiency are drivers for future nitrogen fertilizer consumption. Science in China (in press).

[6] FAGERIA, N. K., and V. C. BALIGAR. 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy* 88: 97–185.

[7] FAGERIA, N. K. 2007. Yield physiology of rice. Journal of Plant Nutrition 30: 843–879.

[8] FAGERIA, N. K., and V. C. BALIGAR. 2007b. Response of common bean, upland rice, corn, wheat, and soybean to soil fertility of an Oxisol. *Journal of Plant Nutrition* 20: 1279–1289.

[9] FUKAI, S., COOPER, M., 2005. Development of drought-resistant cultivars using physio-morphological traits in rice. Field Crops Research 40, 67–86.

[10] GEORGE, T., MAGBANUA, R., RODER, W., VAN KEER, K., TREBUIL, G., REOMA, V. 2001. Upland rice response to phosphorus fertilization in Asia. Agron. J. 93, pp. 1362–1370.

[11] HOSSAIN ABS, SEARS RG, COX TS, PAULSEN GM (2002) Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. *Crop Science* 30, 622–627.

[12] ISHII, R. 1995. Roles of photosynthesis and respiration in the yield-determining process. In: *Science of the Rice Plant: Physiology*, Vol. 2, eds. T. Matsuo, K. Kumazawa, R. Ishii, K. Ishihara, and H. Hirata, Pp. 691–696. Tokyo: Food and Agriculture Policy Research Center.

[13] JULIANO BO. 2007. Rice chemistry and quality. Philrice, Philippines. pp 402.

[14] KATO, Y., H. SATOSHI, K. AKINIKO, J. ABE, K. URASAKI and J. YAMAGISHI. 2004. Enhancing grain yield of rice (*Oryza sativa* L.) under upland conditions in Japan. 4th International Crop Science Congress, Brisbane, Australia.

[15] KAMOSHITA, A., WADE, L.J., YAMAUCHI, A. 2000. Genotypic variation in response of rainfed lowland rice to drought and rewatering. III. Water extraction during drought period. Plant Production Science 3, 189–196.LADHA, J.K., KIRK, G.J.D.,

[16] BENNETT, J., PENG, S., REDDY, C.K., REDDY and P.M., SINGH, U.2008. Opportunities for increased nitrogen-use efficiency from improved lowland rice germplasm. Field Crops Res. 56, 41–71.

[17] MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES (MAFF). (2012). Annual Report: Summarize Activities in 2011-2012 and Targeting for 2012-2013. Unpublished. Phnom Penh, Cambodia. pp 79.

[18] MASKE. N.S.; BORKAR SL. AD HJ. RUJGIRE. 2007. *J. of Soils and Crops*, 2 (1): 83-86.

[19] MARTIN T, OSWALD O, GRAHAM IA. 2002. Arabidopsis seedling growth, storage lipid mobilization, and photosynthetic gene expression are regulated by carbon: nitrogen availability. Plant Physiology128: 472–481.

[20] MIAH MAM, PANAULLAH GM. 2003. Effect of water regimes and N-levels on soil available N, its uptake and use efficiency by transplanted rice. Bangladesh J Agril Res. 24(2): 343-353

[21] OKONJE C, KEHINDE A, OIKEH SO, SUNDAY G, ADERIBIGBE, FRANCIS E, NWILENE, AJAYI A and AA OYEKAMI. 2012. Rice yield and yield components as influenced by Phosphorus and Nitrogen application rates in moist Savanna West Africa. *J. of Agric Science and Technology*; 1214-1223.

[22] OSAKI, M., T. SHINANO, M. MATSUMOTO, J. USHIKI, M. M. SHINANO, M. URAYAMA, AND T. TADANO. 1995. Productivity of high-yielding crops. V. Root growth and specific absorption rate of nitrogen. *Soil Science Plant Nutrition* 41: 635–647.

[23] SHARMA, K.D., PANNU, R.K., TYAGI, P.K., CHAUDHARY, B.D. and SINGH, D.P. (2003) Effect of Moisture Stress on Plant Water Relations and Yield of Different Wheat Genotypes. Indian Journal of Plant Physiology, 8, 99-102.

[24] SINGH U.P. and SING, K. (2000) IR5178-1-1-4 an Outstanding Drought Tolerant Line. International Rice Research Newsletter, 5, 9.