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NITROGEN AFFECTS ON RICE GROWTH AND NITROGEN EFFICIENCY INDICES IN DIFFERENT GEOGRAPHICAL REGIONS IN NORTHERN IRAN

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ABSTRACT

Proper nitrogen management in paddy fields is crucial to achieve benefits of potential yield in northern Iran. To estimate the optimal rates of nitrogen fertilizer to obtained a sustainable rice production in different geographical regions of northern Iran, two-years field trial were performed in three regions using various nitrogen management. The experiment was conducted as factorial based on a randomized complete block design (RCBD) with three replications in Mazandaran province (Bandpay Babol and Babol Plain) and Guilan province (Lahijan region) during 2019 and 2020. Three levels of nitrogen fertilizer including 50, 90 and 130 kg N ha^{-1} from urea sources were used as main plots and three levels of nitrogen splitting in basal applied, initial heading stage and full heading stage were used as sub plots. The findings revealed that grain yield in Lahijan region (6044 kg ha^{-1}) was 6.57% and 5.53% lower than Bandpay region and Babol Plain. With increase of 90 and 130 kg N ha^{-1} compared to 50 kg N ha^{-1}, panicle length, number of panicle per hill, number of spikelet per panicle, filled spikelet percentage, grain nitrogen uptake, protein yield and nitrogen harvest index (0.77% and 2.44%, respectively) were significantly enhanced which resulted in enhance of grain yield (24.87% and 12.71%, respectively). GY with application of 50, 90 and 130 kg N ha^{-1} was 5602, 6314 and 6995 kg ha^{-1}, respectively. In contrast, nitrogen utilization efficiency (108.21% and 30.37%, respectively) and nitrogen uptake efficiency (26.02% and 16.53%, respectively) were significantly decreased. Therefore, nitrogen management in the paddy field could be an effective approach to enhance performance of rice and nitrogen utilization efficiency is a major objective of future.

Keywords: geographical regions, nitrogen harvest index, nitrogen utilization efficiency, nitrogen uptake, nitrogen.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population and has an obvious effect on feeding, income, and job creation of people in the world, especially in Iran (Dastan et al., 2020; Pishgar-Komleh et al., 2011). According to the official statistics released by FAO, the area cultivated with rice in the world during the past years was from 145 million hectares to over 160 million hectares (FAO, 2018). The last global statistics showed that paddy yield and white rice productions were 742 and 492.2 million tons respectively in 2017, respectively (FAO, 2018). The same amount was predicted for 2018. Iran has 550 thousand hectares of paddy field and two million tons of white rice production, has a 0.4% share in rice production and cultivation area in the world, most of which (about 75%) is located in the northern strip, i.e. the provinces of Guilan, Mazandaran and Golestan, and the remaining (25%) of the paddy field is located in other 13 provinces with different climates (Ministry of Jihad-e-Agriculture of Iran, 2019).

Among all fertilizers, nitrogen (N) is the most essential for plant development, growth and grain quality (Kichey et al., 2007). However, in developed economies, N use efficiency (NUE; defined as grain dry matter per unit of N available from the soil, fertilizer included), is very low and estimated to be approximately 33% of the applied N source (Raun and Johnson, 1999). Thus, in Asia, Europe, and northern America, intensive agricultural practices (Singh, 2006) have led to both higher production costs and greater

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risk from environmental hazards, such as ground and surface water pollution by nitrate leaching (Qian et al., 2018). The main challenge for breeders is to minimize the applied amount of fertilizer N to the field without affecting yield, and also in selecting the cultivars that metabolize N more effectively. The average fertilizer N dose in China is roughly 180 kg ha^{-1} for the production of rice, which is 75% higher than the worldwide average (Peng et al., 2002). Application of around 300 kg N ha^{-1} is also practicing in different regions of China (Peng et al., 2011). Over-utilization of N regularly initiates pest destruction and lodging, bringing a decrease in quality and quantity of rice yield (Cassman and Harwood, 1995). Excessive use of N may induce the acidity of the soil (Guo et al., 2010), water contamination (Diaz and Rosenberg, 2008) and encourage nitrous oxide (N_2O) emission (Smil, 1999). Because of the significance of nitrogen as a major nutrient for rice crop to attain high grain yield, it is crucial to determine the ideal amount and timing of N application for each rice cultivars and also the impact on agronomic parameters, for example, moisture content, plant height, lodging and other parameters (Shrawat et al., 2008). Therefore, many researchers have identified different fertilization scheduling techniques to achieve the maximum N use efficiency in rice fields (Deng et al., 2014). Subsequently, nearly each farmer supply N to get high yields (Peng et al., 2011) in one single split or up to four splits during crop growth critical stages neglecting crop N demand and temporal changes (Jing et al., 2007). A basal dose application of N on transplantation day or day before transplantation has been followed (Jing et al., 2007). The N loss likely to be at the basal application as rice take seven days in recovering from transplanting shock and after developing root, rice N requirement is minimized during that period (Fan et al., 2009). However, fertilizer application can increase the rice yield matching the indigenous N supply (Singh et al., 2002). N splits with basal at panicle initiation irrespective of N rates can increase yield (Sathiya and Ramesh, 2009). A study has been conducted by Prasad and Mailapalli (2018), revealed that four split (basal, tillering, panicle initiation and heading) limited the nitrate (NO_3) leaching loss from rice fields. The adjusted splits could result in a reduction of fertilizer N input (Jeong et al., 2014), splitting N can increase spikelets per panicle, 1000-grain weight, ripened grain percentage and N uptake (Pan et al., 2012). However, an increasing trend has been shown in N application doses in rice fields of China (Li et al., 2010). Therefore, the aims of the study were field trial evidence of nitrogen to improve rice growth and nitrogen efficiency indices in different geographical regions in northern Iran.

MATERIAL AND METHODS

Description of the experimental site

Field experiments were conducted in Babol region (in the central part of Mazandaran province) and Lahijan region (in the eastern part of Guilan province) located in north of Iran between the Alborz Mountains and the Caspian Sea during the periods of 2019 and 2020. The most important climatic parameters during the rice growing period are shown in Table 1. The climate of these regions is Mediterranean with different altitude above sea levels. The soil properties and geographical coordinates of three experimental regions are shown in Table 1.

Table 1. Description of the geographical coordinate, soil properties (0-30 cm) and meteorological parameters of three rice production sites prior to rice transplantation

Description	Bandpay, Babol (Mazandaran province)		Babol Plain (Mazandaran province)		Lahijan (Guilan province)	
Geographical coordinate	36°39'22.52"N 53°9'42.55"E		36°23'59.24"N 52°31'37.55"E		37°13'28.78"N 49°38'57.85"E	
Soil properties	Bandpay, Babol (Mazandaran province)		Babol plain (Mazandaran province)		Lahijan (Guilan province)	
Soil texture	Clay loam		Silt loam clay		Clay loam	
EC (ds m^{-1})	0.93		0.91		0.94	
pH	7.3		7.1		6.2	
Organic matter (%)	2.12		2.21		2.24	
Phosphorus (mg kg^{-1})	11.87		13.12		12.11	
Potassium (mg kg^{-1})	187		195		204	
Climatic parameters	Bandpay, Babol (Mazandaran province)		Babol plain (Mazandaran province)		Lahijan (Guilan province)	
	Experiment period	Mean 15 years	Experiment period	Mean 15 years	Experiment period	Mean 15 years
Minimum temperature (°C)	18.4	18.3	18.9	18.5	13.8	17.6
Maximum temperature (°C)	28.4	25.2	27.7	26.9	33.6	26.5
Mean temperature (°C)	23.4	22.8	23.3	32.2	22.3	22.1
Evaporation (mm)	143.7	147.6	109.5	120.8	99.6	121.4
Rain (mm)	52.5	89.0	50.8	93.4	77.7	60.7
Mean humidity (%)	74.7	73.5	75.8	77.5	78.7	78.0
Mean sunshine hours	221.1	208.8	187.6	182.7	186.2	213.9
Solar radiation (MJ m^{-2} d^{-1})	19.3	19.5	17.8	17.9	17.7	18.1

Description of the experiment

The experiment was conducted as factorial based on a randomized complete blocks design (RCBD) with three replications in three regions (Bandpay of Babol in Mazandaran province, Babol Plain in Mazandaran province and Lahijan region in Guilan province). Three levels of nitrogen fertilizer including 50, 90 and 130 kg N ha^{-1} from urea sources were used as main plots and three levels of nitrogen splitting including S_1: 50% as a basal application + 50% in initial heading stage, S_2: 33.33% as a basal application + 66.66% in initial heading stage, and S_3: 66.66% as a basal application + 33.33% in initial heading stage were used as sub plots.

Description of the field practices

Nursery preparation were done in the first and second years in three regions on April 11-15 and on April 12-15, respectively. To prevent nitrogen leaching and weed growth in paddy fields, nylon plastic cover was put at the borders to the depth of 30 centimeters of each plot. The size of main plots was 9×5 m^2 and the size of sub plots was 3×5 m^2.

Considering the regional climates, 'Tarom Hashemi' cultivar was transplanted. Seedlings were prepared by the traditional method (furrow and basin); transplanting (spacing of 20×20 cm^2 equals 25 seedlings per m^2) was done by two young seedlings per hill with 3-4 leaves (25 days old). Transplanting was done during the first and second years in three regions on May 22-26 and on May 24-27, respectively. Flooding + interval irrigation was done with two steps drainage during the maximum of tillering (initial heading stage) and full heading stage in the period of growing season. The depth of irrigation water was set at five centimeters according to agricultural principles of rice farming.

Chemical fertilizers were used in each plot according to the suggestion of Rice Research Institute of Iran (RRII) and by considering the result of soil analysis. Chemical fertilizers were used from urea sources (according to treatment situation) for nitrogen; followed by using the triple super phosphate (100 kg ha^{-1}) for phosphorus; and potassium sulfate (100 kg ha^{-1}) for potassium. Total phosphorus fertilizer and 50% of the potassium fertilizers was used as basal application in the paddy field preparation stage. In addition, 25% of potassium fertilizers were used as top-dressing in panicle initiation stage. To control weed, weedicide was applied once pre-emergence and, hand weeding was done at third steps (28, 40 and 50 days after transplanting). Pesticides were used to control the pests and diseases. Crop protection practices, such as irrigation, weeding, pests and diseases control, and fertilization, were done in the experiment paddy field based on technical instruction of RRII. Other agricultural practices and field management were done according to the Standard Evaluation System (SES) of the International Rice Research Institute (IRRI).

Measurement

During the growth period, after the removal of marginal effect, traits were randomly measured according to SES of IRRI. Thus, 10 tillers per hill were randomly selected from each experimental plot and, their average was analyzed.

Sampling was done 30 days after full heading stage from 12 stems selected from 4 hills per plot in order to determine the morphological traits. The number of tillers per hill was counted using 12 tillers per plant. The number of spikelet per panicle and the number of filled spikelet per panicle were measured by counting from 15 panicles. Paddy yield was measured by harvesting hills from four square meters in the middle part of each plot based on moisture of 12%. Finally, the shoot and grain were separated at the harvesting stage and, the material was dried in an oven at 70°C to a constant weight (Fageria et al., 2014). Total nitrogen content in grain and straw was determined by the micro-Kjeldahl method.

To determine the grain protein content, the percentage of nitrogen calculated in the protein conversion factor (5.95) was multiplied (Firestone, 1997). The protein yield was obtained from the multiplication of the grain protein content to the amount of rice grain yield. Some parameters were evaluated such as nitrogen harvest index (Eq. 1), nitrogen utilization efficiency (Eq. 2), and nitrogen uptake efficiency (Eq. 3), (Fageria et al., 2011; 2014).

$$\text{NHI (\%)} = (\text{uptake of N in grain / uptake of N in grain + uptake of N in grain}) \quad [1]$$

$$\text{NUE (kg kg}^{-1}\text{)} = \text{Wg / Nf} \quad [2]$$

where, Wg is the grain weight (kg) and Nf is the quantity of N applied (kg).

$$\text{NUtE (kg kg}^{-1}\text{)} = \text{Nt / Nf} \quad [3]$$

where, Nt is total N uptake in grain (kg) and Nf is the quantity of N applied (kg).

Statistical analysis

All statistical analyses were performed using the SAS software. A two-way analysis of variance (ANOVA) was used by the GLM procedure and, the least significant difference (LSD) test was used to compare the differences between the treatment means at a 5% of probability level. Standard error ($SE=\sqrt{\Sigma(O-P)^2/n}$, where O, P and n are actual data, predicted data and sample size, respectively) was used to evaluate the confidence interval of the regression coefficients. The coefficient of determination (R^2) and coefficient of variation (CV) were determined for testing the ability of the used mathematical models.

RESULTS AND DISCUSSION

Bartlett's test

To investigate the effect of nitrogen amounts and splitting on rice growth in different geographical regions over the two years, firstly the data were measured using the Bartlett's test for homogeneity of the variance. The results of Bartlett's test revealed significant differences for panicle length (PL), 1000-grain weight (TGW), and nitrogen uptake efficiency (NUtE). Therefore, the analysis and interpretation of these traits was performed by the simple mean square analysis (ANOVA) and, for other traits (shown in Table 2) which did not show any significant differences the combined variance analysis was used (Table 2).

Table 2. Bartlett test results for investigated traits under effect of year

Investigated traits	Unit	Pr>ChiSq	Chi-squares
Panicle length (PL)	cm	<0.0001**	18.93
Number of panicle per hill (PH)	no.	0.634^{ns}	0.23
Number of spikelet per panicle (TSP)	no.	0.498^{ns}	0.46
Filled spikelet percentage (FSP)	%	0.466^{ns}	0.531
1000-grain weight (TGW)	g	0.033**	4.53
Grain yield (GY)	kg ha^{-1}	0.250^{ns}	1.33
Grain nitrogen content (GNC)	%	0.605^{ns}	0.266
Straw nitrogen content (SNC)	%	0.529^{ns}	0.396
Plant nitrogen content (PNC)	%	0.487^{ns}	0.483
Grain nitrogen uptake (GNU)	kg ha^{-1}	0.313^{ns}	1.02
Grain protein content (GPC)	%	0.605^{ns}	0.268
Protein yield (PY)	kg ha^{-1}	0.313^{ns}	1.02
Nitrogen harvest index (NHI)	%	0.994^{ns}	0.0001
Nitrogen utilization efficiency (NUE)	kg kg^{-1}	0.915^{ns}	0.011
Nitrogen uptake efficiency (NUtE)	kg kg^{-1}	0.0377**	4.32

†: ns, * and ** show non-significant and significant at 5% and 1% of probability levels, respectively.

Analysis of variance (ANOVA)

The results of the combined analysis of variance presented in Tables 3 and 4 demonstrated that, panicle length (PL), number of panicle per hill (PH), and number of spikelet per panicle (TSP) were statistically significant under the year effect ($P \leq 0.05$; $P \leq 0.01$). The findings of ANOVA revealed that, all the investigated traits (shown in Tables 3 and 4) except straw nitrogen content (SNC) and nitrogen harvest index (NHI) revealed significant difference under the regions effect ($P \leq 0.05$; $P \leq 0.01$). The results of ANOVA for nitrogen amount showed that PL, PH, TS, TGW, grain yield (GY), SNC, grain nitrogen uptake (GNU), grain protein content (GPC), protein yield (PY), nitrogen harvest index (NHI), nitrogen utilization efficiency (NUE) and nitrogen uptake efficiency (NUtE) were statistically different ($P \leq 0.05$; $P \leq 0.01$). The difference of nitrogen splitting revealed statistically significant in PL, TSP, FSP, TGW, GY, GNU, GPC, PY, NHI, NUE and NUtE ($P \leq 0.05$; $P \leq 0.01$) (Tables 3 and 4). Findings of double interaction of nitrogen amount and splitting demonstrated that, PL, TSP, GY, SNC, GPC, NHI and NUE were statistically significant ($P \leq 0.05$; $P \leq 0.01$) (Tables 3 and 4).

Table 3. Combined analysis of variance (ANOVA) and mean comparison of studied traits of rice related to application of nitrogen amount and splitting in three locations

SOV		DF	PL	PH	TSP	FSP	TGW	GY
Mean square (ANOVA)								
Year (Y)		1	*	**	**	ns	ns	ns
Location (L)			**	**	**	*	*	**
Nitrogen (N)		3	**	**	**	ns	*	*
Splitting (S)		3	**	ns	**	**	**	**
N × S		9	**	ns	**	ns	ns	**
CV (%)		-	16.48	9.55	3.25	7.14	9.25	8.05
Mean comparison								
Year	First year (2017)		28.04 a	17.11 a	155.79 a	77.62 a	28.18 a	6291 a
	Second year (2018)		26.47 b	16.27 b	151.02 b	76.71 a	28.08 a	6316 a
LSD 0.05			1.40	0.50	1.56	1.72	0.81	158.27
Location	Babol		28.30 a	17.37 a	156 a	78.03 a	28.64 a	6469 a
	Babol		28.09 a	17.39 a	154.91 a	77.79 ab	28.39 a	6398 a
	Lahijan		25.38 b	15.33 b	149.30 b	75.75 b	27.36 b	6044 b
LSD 0.05			1.72	0.61	1.91	2.11	0.99	193.84
Nitrogen	50 kg N ha^{-1}		24.85 c	16.20 b	146.70 b	75.98 a	27.29 b	5602 c
	90 kg N ha^{-1}		27.53 b	16.59 b	148.12 b	77.96 a	28.18 ab	6314 b
	130 kg N ha^{-1}		29.39 a	17.30 a	165.39 a	77.62 a	28.93 a	6995 a
LSD 0.05			1.72	0.61	1.91	2.11	0.99	193.84
Splitting	S_1		28.91 a	16.76 ab	150.55 b	75.22 b	26.82 c	5837 b
	S_2		26.94 b	16.97 a	154.29 a	77.01 b	28.14 b	6455 a
	S_3		25.92 b	16.35 b	155.37 a	79.33 a	29.43 a	6619 a
LSD 0.05			1.72	0.61	1.91	2.11	0.99	193.84

†: ns, * and ** show non-significant and significant at $P \geq 0.05$ and $P \geq 0.01$, respectively.

††: Values within a column followed by same letter are not significantly different at least significant differences (LSD) test (0.05). SOV, source of variation; DF, degree of freedom; and CV is the coefficient of variation which was related to overall data.

†††: Refer to Table 2 for description of abbreviation and unit of traits.

††††: Value in the parenthesis indicate percent change in the respective studied traits in comparison with the control condition.

†††††: S_1 is 50% as a basal application + 50% in initial heading stage; S_2 is 33.33% as a basal application + 66.66% in initial heading stage, and S_3 is 66.66% as a basal application + 33.33% in initial heading stage, respectively.

Table 4. Combined analysis of variance (ANOVA) and mean comparison of studied traits of rice related to application of nitrogen amount and splitting in three locations

SOV		DF	SNC	GNU	GPC	PY	NHI	NUE	NUtE
Mean square (ANOVA)									
Year (Y)		1	ns	ns	ns	ns	ns	ns	ns
Location (L)			ns	**	**	**	ns	**	**
Nitrogen (N)		3	**	**	**	**	**	**	**
Splitting (S)		3	ns	**	**	**	**	**	**
N × S		9	**	ns	*	ns	**	**	ns
CV (%)		-	8.66	15.51	9.59	15.51	6.06	8.86	14.08
Mean comparison									
Year	First year (2017)		1.28 a	610.12 a	5.96 a	381.32 a	42.56 a	78.65 a	6.95 a
	Second year (2018)		1.26 a	608.68 a	5.88 a	380.42 a	42.62 a	78.68 a	7.00 a
LSD 0.05			0.03	29.48	0.18	184.28	0.80	2.17	0.31
Location	Babol		1.29 a	636.72 a	6.04 a	397.95 a	42.68 a	80.74 a	7.36 a
	Babol		1.27 ab	628.55 a	6.03 a	392.84 a	42.99 a	79.92 a	7.10 a
	Lahijan		1.24 b	562.93 b	5.69 b	351.83 b	42.09 a	75.34 b	6.47 b
LSD 0.05			0.04	36.11	0.22	22.57	0.99	2.66	0.38
Nitrogen	50 kg N ha^{-1}		0.98 c	393.38 c	4.36 c	245.86 c	41.52 b	112.04 a	7.70 a
	90 kg N ha^{-1}		1.39 b	640.59 b	6.33 b	400.37 b	42.29 b	70.15 b	7.12 b
	130 kg N ha^{-1}		1.44 a	794.22 a	7.07 a	496.39 a	43.96 a	53.81 c	6.11 c
LSD 0.05			0.04	36.11	0.22	22.57	0.99	2.66	0.38
Splitting	S_1		1.25 b	556.84 b	5.84 b	348.03 b	42.60 b	73.11 b	6.32 b
	S_2		1.24 b	645.23 a	6.17 a	403.27 a	44.08 a	81.49 a	7.44 a
	S_3		1.32 a	626.12 a	5.76 b	391.32 a	41.08 c	81.40 a	7.16 a
LSD 0.05			0.04	36.11	0.22	22.57	0.99	2.66	0.38

†: ns, * and ** show non-significant and significant at $P \geq 0.05$ and $P \geq 0.01$, respectively.

††: Values within a column followed by same letter are not significantly different at least significant differences (LSD) test (0.05). SOV, source of variation; DF, degree of freedom; and CV is the coefficient of variation which was related to overall data.

†††: Refer to Table 2 for description of abbreviation and unit of traits.

††††: Value in the parenthesis indicate percent change in the respective studied traits in comparison with the control condition.

†††††: S_1 is 50% as a basal application + 50% in initial heading stage; S_2 is 33.33% as a basal application + 66.66% in initial heading stage, and S_3 is 66.66% as a basal application + 33.33% in initial heading stage, respectively.

Mean comparison

Agronomic traits and grain yield

Findings of agronomic traits revealed that, PL, PH and TSP in first year were 5.93%, 5.16%, and 3.16% higher than second year. Mean comparison of different geographical regions showed that GY in Lahijan region (6044 kg ha^{-1}) was significantly 6.57% and 5.53% lower than Bandpay region and Babol Plain. PL in Bandpay region (28.30 cm) and Babol Plain (28.09 cm) was 11.51% and 10.68% higher than Lahijan region (25.38 cm). According to findings, PH, TSP, FSP and TGW in Lahijan region was statistically lower than Bandpay region and Babol Plain. TSP in Bandpay region (156 spikelets) and Babol Plain (154.91 spikelets) was 4.49% 3.76% higher than Lahijan region (149.30 spikelets). These findings leading to an increase in PY in Bandpay region and Babol Plain compared to Lahijan region (Table 3).

Mean comparison of nitrogen amount demonstrated that all investigated traits enhanced significantly with increase of nitrogen amount. For instance, with increase of 90 and 130 kg N ha^{-1} compared to 50 kg N ha^{-1}, PL (1.18% and 1.11%, respectively), PH (6.19% and 2.41%, respectively), TSP (12.74% and 0.97%, respectively), FSP (1.64% and 1.98%, respectively), and TGW (6.01% and 3.26%, respectively) were significantly enhanced which resulted in enhance of PY (24.87% and 12.71%, respectively). GY with application of 50, 90 and 130 kg N ha^{-1} was 5602, 6314 and 6995 kg ha^{-1}, respectively (Table 3). Mean comparison of nitrogen splitting displayed that the maximum amounts of TSP (154.29 and 155.37 spikelets) and GY (6455 and 6619 kg ha^{-1}) were calculated in S_2[1] and S_3[2]. In contrast, the maximum PL (28.91 cm) was observed in S_1[3], but maximum PH was obtained in S_2. The most amount of FSP (79.33%) and TGW (29.43 g) was calculated in S_3 (Table 3).

Linear regression model for agronomic traits (dependent traits) and GY (independent trait) of rice related to nitrogen amounts and splitting in different geographical regions in two years showed positive correlation between GY with PL, TSP and FSP (Figure 1).

[1] S_2: 33.33% as a basal application + 66.66% in initial heading stage;
[2] S_3: 66.66% as a basal application + 33.33% in initial heading stage;
[3] S_1: 50% as a basal application + 50% in initial heading stage.

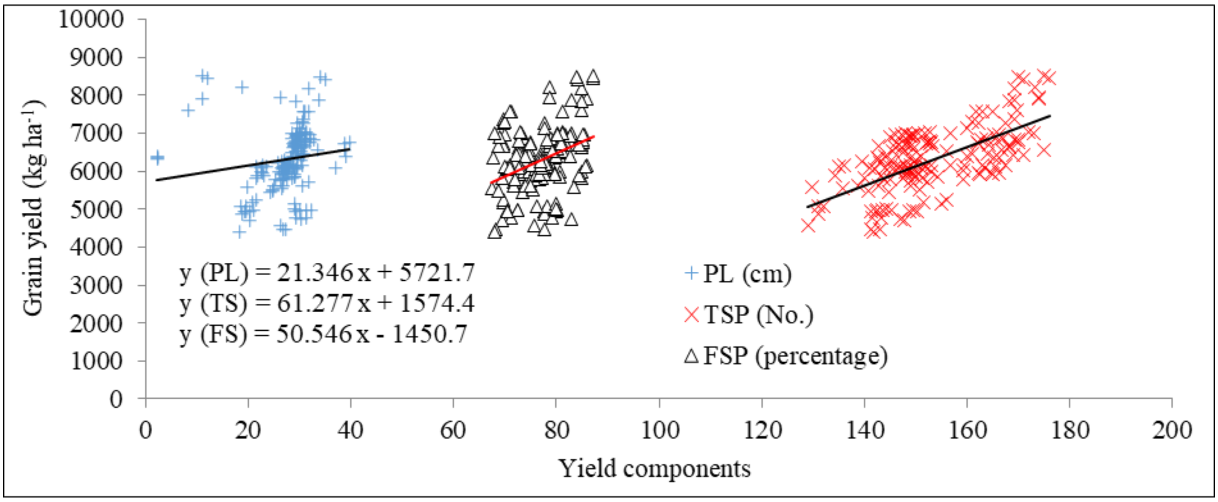

Figure 1. Linear regression model between panicle length (PL), number of spikelet per panicle (TSP) and filled spikelet percentage (FSP) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

Nitrogen efficiency indices

Findings of nitrogen related parameters displayed that, all investigated traits related to nitrogen (SNC, GNU, GPC, PY, NHI, NUE and NUtE) were same under the effect of year (Table 4). Mean comparison of different geographical regions revealed that all investigated traits related to N in Mazandaran province (Bandpay region and Babol Plain) were significantly higher than

Guilan province (Lahjan region). For instance, SNC in Bandpay region and Babol Plain (1.29 cm and 1.27 cm) was 4.03% and 2.42% higher than Lahijan region (1.24 cm). GNU in Bandpay region (636.72 kg ha^{-1}) and Babol Plain (628.55 kg ha^{-1}) was 13.11% and 11.66% higher than Lahijan region (628.55 kg ha^{-1}). In contrast, GPC in Lahijan region (5.69%) was 0.35% and 0.34% less than Bandpay region (6.04%) and Babol Plain (6.03%). According to findings, NUE in Bandpay region (80.74 kg kg^{-1}) and Babol Plain (79.92 kg kg^{-1}) was 7.17% and 6.08% more than Lahijan region (75.34 kg kg^{-1}). In addition, NUtE in Bandpay region and Babol Plain (7.36 and 7.10 kg kg^{-1}, respectively) was 13.76% and 9.74% greater than Lahijan region (6.47 kg kg^{-1}) (Table 4).

Mean comparison of nitrogen amount for N related parameters displayed that with increase of 90 and 130 kg N ha^{-1} compared to 50 kg N ha^{-1}, SNC (0.41% and 0.46%, respectively), GNU (62.84% and 101.90%, respectively), GPC (45.18% and 62.16%, respectively), PY (62.84% and 101.90%, respectively), and NHI (0.77% and 2.44%, respectively) were significantly enhanced. In contrast, NUE (108.21% and 30.37%, respectively) and NUtE (26.02% and 16.53%, respectively) were significantly decreased (Table 4). Mean comparison of nitrogen splitting revealed that the maximum amounts of SNC (1.32%) was observed in S_3. In contrast, the maximum GPC (6.17%) and NHI (44.08%) were calculated in S_2, but maximum GNU (645.23 and 626.12 kg ha^{-1}), PY (403.27 and 391.32 kg ha^{-1}), NUE (81.49 and 81.40 kg kg^{-1}) and NUtE (7.44 and 7.16 kg kg^{-1}) were obtained in S_2 and S_3 (Table 4).

Linear regression model of N related parameters demonstrated that SNC, GPC, NUtE, GNU, PY and NHI had a positive correlation with GY (Figures 2-4), but NUE had a negative correlation with GY (Figure 4). Linear regression model of N related indices showed that, NUE had a negative correlation with NHI, but positive correlation between NUE and NUtE was observed (Figure 5). According to findings of linear regression in Figure 6, correlation between NHI and NUtE was positive, but correlation between NHI and NUE was negative. In contrast, NUtE had a positive correlation with NHI and NUE (Figure 7).

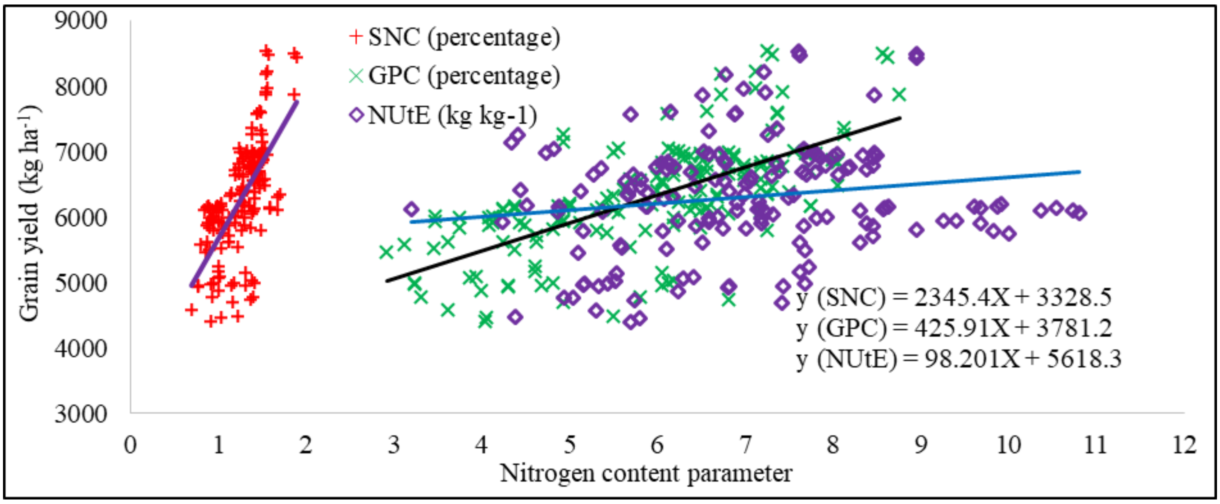

Figure 2. Linear regression model between straw nitrogen content (SNC), grain protein content (GPC) and nitrogen uptake efficiency (NUtE) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

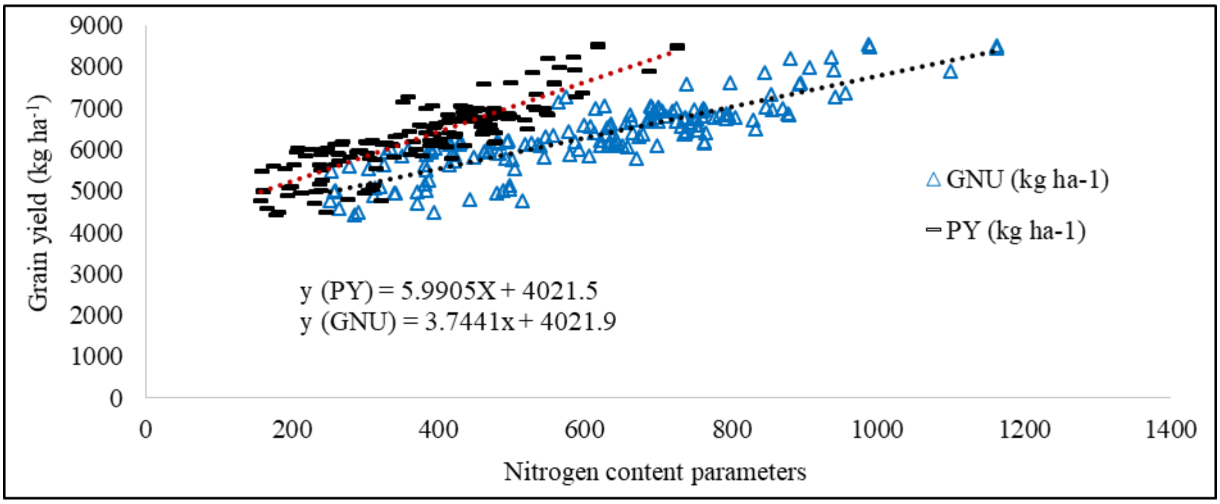

Figure 3. Linear regression model between grain nitrogen uptake (GNU) and protein yield (PY) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

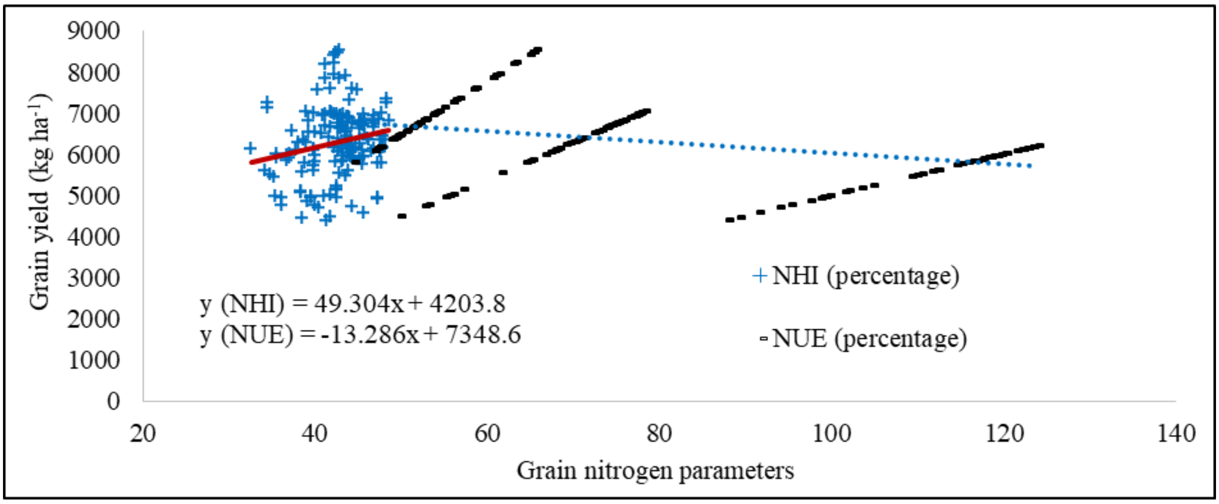

Figure 4. Linear regression model between nitrogen harvest index (NHI) and nitrogen utilization efficiency (NUE) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

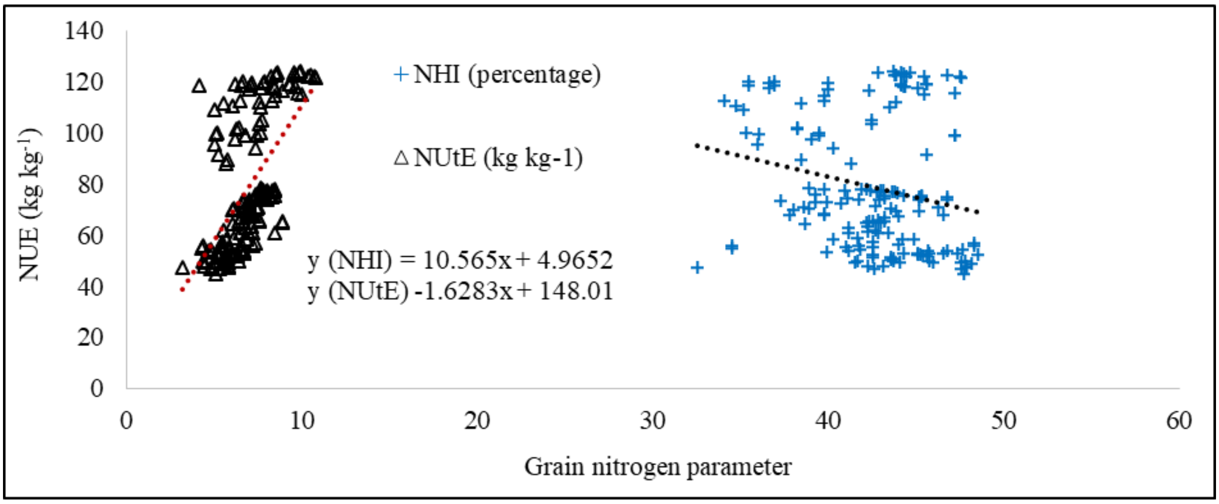

Figure 5. Linear regression model between nitrogen harvest index (NHI) and nitrogen uptake efficiency (NUtE) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

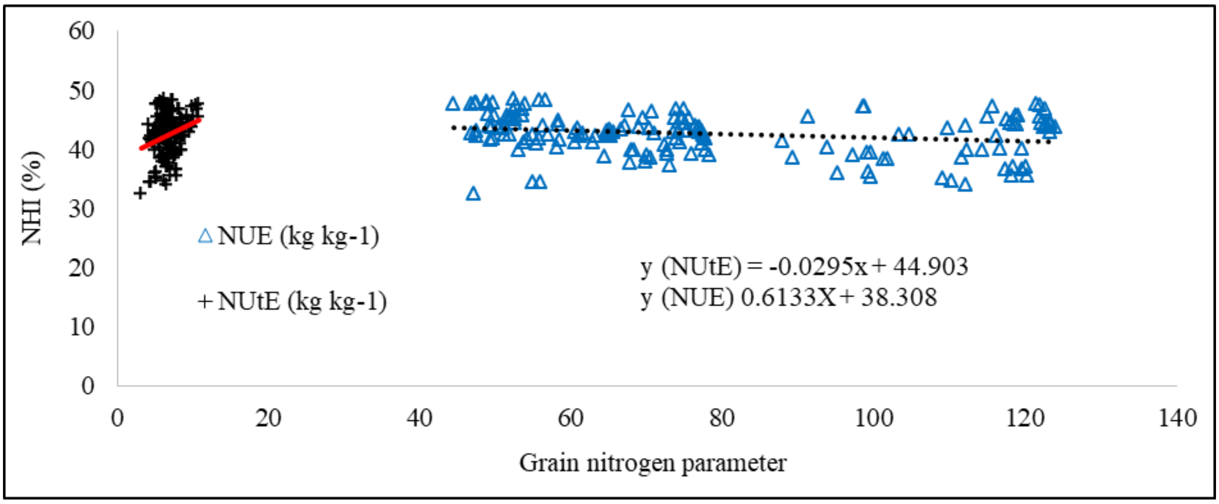

Figure 6. Linear regression model between nitrogen utilization efficiency (NUE) and nitrogen uptake efficiency (NUtE) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

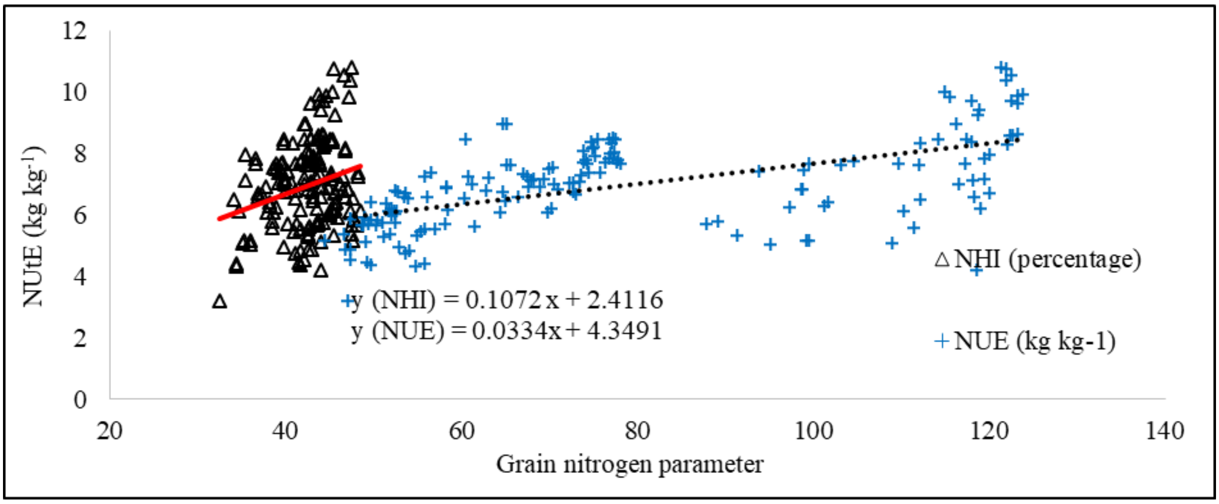

Figure 7. Linear regression model between nitrogen harvest index (NHI) and nitrogen utilization efficiency (NUE) with grain yield (GY) of rice related to nitrogen amount and splitting in different geographical regions

With respect to chemical nitrogen application in paddy fields, current nitrogen application strategies should be improved in paddy field cropping systems. Nitrogen significantly improved plant height, panicle length, grain HI and nitrogen HI which is positively associated with paddy yield. Similar results were found by Fageria (2007) and Fageria et al. (2011). However, without nitrogen fertilization, rapeseed yield in rice-rapeseed rotation was significantly lower than in cotton-rapeseed rotation. Similar findings were reported for other crops (Yamada et al., 2010). Other researchers demonstrated that because of higher nitrogen losses from runoff and ammonia volatilization during the rice season (Zhao et al., 2009), the flooded rice production soil contained significantly lower accumulated mineral nitrogen contents after harvest (Fan et al., 2007). Mohammadi et al. (2011) demonstrated that nitrogen uptake in the green manure utilization was one of the most effective factors in increasing the crop production. Further, crop rotation led to improved soil fertility (Yadvinder-Singh et al., 2004). In addition, many explanations have been stated for yield enhancement in crop plants rotation (Rathke et al., 2005).

Number of panicle per plant is one of the major yield determining factor of rice (Jahan et al., 2019). In this study, PL and PH were significantly enhanced with increase of N amounts. In fact, N contributes to rice panicle formation by stimulating cell division in the reproductive stage of crop growth (Jahan et al., 2019). Gewaily et al. (2018) reported that N fertilization enhanced PL and panicle number of rice. The findings displayed that PH enhanced with increase of nitrogen rates in different geographical regions. Jahan et al. (2019) announced that number of tiller per m^2 had a linear correlation with N application. However, in another study, a quadratic correlation rice tillering to N rates was reported (Contreras et al., 2017). Jahan et al. (2019) revealed that filled grains per panicle were significantly affected by N rates which adopted with our findings. Yesuf and Balcha (2014) reported that enhance of number of filled grain of rice with increase of N application. The results of this study showed that GY enhanced with increase of N rates. Moro et al. (2015) displayed that quadratic response of GY to N fertilization which supports our findings and the results of Jahan et al. (2019). The findings of our study displayed that in three regions GNU of rice crop enhanced with increase of N rates which resulted in PY. Jahan et al. (2019) and Yesuf and Balcha (2014) also demonstrated similar results.

CONCLUSIONS

According on the findings, it can be stated that GY in Lahijan region (6044 kg ha^{-1}) was significantly 6.57% and 5.53% lower than Bandpay region and Babol Plain. TSP in Bandpay region and Babol Plain was 4.49% 3.76% higher than Lahijan region. These findings leading to an increase in PY in Bandpay region and Babol Plain compared to Lahijan region. All investigated traits enhanced significantly with increase of nitrogen amount. For instance, with increase of 90 and 130 kg N ha^{-1} compared to 50 kg N ha^{-1}, PL, PH, TSP, FSP, and TGW were significantly enhanced which resulted in enhance of PY (24.87% and 12.71%, respectively). Findings of nitrogen related parameters displayed that, all investigated traits related to N in Mazandaran province (Bandpay region and Babol Plain) were significantly higher than Guilan province (Lahjan region). With increase of 90 and 130 kg N ha^{-1} compared to 50 kg N ha^{-1}, SNC, GNU, GPC, PY, and NHI (0.77% and 2.44%, respectively) were significantly enhanced. In contrast, NUE (108.21% and 30.37%, respectively) and NUtE (26.02% and 16.53%, respectively) were significantly decreased. Therefore, nitrogen management in the paddy field could be an effective approach to enhance performance of rice and nitrogen utilization efficiency is a major objective of future.

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