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EFFECTS OF INTERVAL IRRIGATION AND NITROGEN FERTILIZER AT DIFFERENT STAGES OF GROWTH ON YIELD AND YIELD COMPONENTS OF RICE

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ABSTRACT

In this study, effects of nitrogen (N) fertilizer at different levels and irrigation interval at different growth stages of Hashemi rice were investigated on the yield and yield components in a factorial experiment based on a randomized complete block design with three replications during the crop years 2017 and 2018 in the Rice Research Institute of Iran, Rasht City. Studied factors were irrigation intervals (permanent waterlogging and irrigation once a week and once every 2 weeks) and different levels of N fertilizer (40, 60, and 80 kg ha^{-1}) in both vegetative and reproductive stages. The studied traits were plant height, panicle length, number of panicles per plant, number of spikelet per main cluster, number of full grains per panicle, panicle fertility percentage, number of empty grains per panicle, 1000-grain weight, and grain yield. Results of the analysis of variance table showed that grain yield (GY) was significantly influenced by simple and interaction effects of the experimental treatments. The interactions of growth period, N fertilizer, and irrigation cycle were significant on this trait at a level of 1% during the two years. Grain yield and yield components increased significantly with N fertilizer application under optimal irrigation conditions. Among the treatments, the highest and lowest GYs belonged to the waterlogged irrigation treatment with 80 kg ha^{-1} of N fertilizer in the vegetative period in 2018 and irrigation treatment of once every 14 days with 40 kg ha^{-1} of N fertilizer in the reproductive period in 2017, respectively. In the presence of sufficient water, nitrogen plays an undeniable role in the yield. Although equal nitrogen use and management of permanent waterlogged irrigation and irrigation intervals have no effects on the yield, higher water use strongly reduces water use efficiency.

Keywords: rice, yield and yield components, irrigation management, nitrogen.

INTRODUCTION

Under natural and agricultural conditions, crops are constantly exposed to various stresses, among which water shortage is the most important factor limiting the yield of crops in Iran and most regions of the world (Akbari et al., 2016). As one of the most important crops worldwide, rice is cultivated in vast areas of the world and is the staple food of more than half of the global population (Pandey et al., 2014). Among crops, rice consumes the highest amount of water that accounts for about 80% of the total fresh water sources in Asia. Irrigated paddies comprise approximately 75% of the global rice fields (Tuong et al., 2005). Irrigations of once every several days provides sufficient oxygen to the plant root system, which accelerates the mineralization of organic matter and fixation of soil nitrogen, all of which increase nutrients and consequently the growth of plants (Tan et al., 2013). Alternative irrigation management can meet the water needs of the plant in critical situations. Saving water consumption and reducing the use of chemical fertilizers in terms of decreasing leaching are the most important advantages of the alternative irrigation of rice with multi-day irrigation intervals (Chowdhury et al., 2014).

Existing evidence indicate that a plant with well nutrition and enough uptake of elements will have better drought resistance and will therefore affect the quantity and quality of the product. Among nutrients,

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nitrogen is the most important and limiting element in the growth of rice plant (Manzoor et al., 2006), so that lack of N uptake at any stage of the plant growth will reduce the yield. Nutrient limitation in the vegetative growth period reduces nutrient storage, prevents filling of grains, and increases the number of empty grains, hence the use of nitrogen at times of the plant requirement increases the yield, even in alternative irrigation (Belder et al., 2005). An increase in nitrogen application was frequently shown to improve water use efficiency (WUE) and mitigate the harmful effects of drought stress on plant growth in arid regions, as it prevents damage to the cell membrane and improves osmoregulation (Saneoka et al., 2004). Obviously, the use of additional nitrogen levels will not always play a positive role in mitigating the effects of stress on the plant growth, but nitrogen plays a very clear role as a moderator of physiological and morphological responses, particularly in relation to WUE and tolerance to drought stress (Tan and Hogan, 1997). Taghizadeh et al. (2008) and Hatamifar et al. (2012) reported that the highest rice grain yield was obtained from permanent waterlogging and using 90 kg ha^{-1} of N. In another study (Mousavi et al. 2016), the number of panicles m^{-2}, number of grains per panicle, GY, and harvest index increased significantly with increasing fertilizer use from zero to 120 kg ha^{-1}. Overall, a 7-day irrigation interval and using 80 kg ha^{-1} of N led to the achievement of maximum GY in the plant. Razavipour et al. (2018) observed that increasing nitrogen use frequency in three splits led to increased percentage of nitrogen uptake in the grain. Their results also showed that the increased yield with the application of additional nitrogen by 30 kg ha^{-1} was equivalent to one step increase in the number of splits. In a study by Manan et al. (2010), the highest plant height, number of tillers m^{-2}, number of panicles m^{-2}, and GY were obtained in a treatment with 100 kg ha^{-1} of N, but 1000-grain weight was not affected by the consumed N and the number of grains per panicle decreased with increasing N application. Significant increases in the panicle length, plant height, number of panicles m^{-2}, number of grains per panicle, 1000-grain weight and GY of millet with increasing nitrogen consumption were reported by Ali (2011). Faraji et al. (2012) reported that the consumption of nitrogen fertilizer at high levels in rice (Caspian cultivar) was associated with increased nitrogen content, leaf chlorophyll, leaf area duration and expansion, photosynthetic activity, and plant growth rate. Moreover, the application of nitrogen fertilizer up to 180 kg ha^{-1} increased GY and yield components, such as number of panicles, number of full grains per panicle, and panicle fertility percentage, in rice (Singh et al., 2017). Some reports indicate that the nitrogen use efficiency (NUE) is lower in low irrigation conditions than permanent irrigation (Timsina et al., 2001). At the same time, some evidence indicates the role of alternative irrigation in increasing NUE compared with permanent irrigation and an increase in WUE by the use of N fertilizer. In addition to the very important role of nitrogen in rice cultivation, N application more than the actual need causes leaching, environmental degradation, and even reduced yield (Cabuslay et al., 2002). Given the need for optimal use and saving of agricultural inputs, the aim of this experiment was to find the best irrigation and fertilizer management and to investigate the interaction between irrigation and nitrogen management in rice cultivation in Guilan province.

MATERIAL AND METHODS

In this study, effects of N fertilizer at different levels and irrigation intervals at different growth stages of Hashemi rice were investigated on yield and yield components in a factorial experiment with a randomized complete block design with three replications during the two crop years of 2017 and 2018 in the Rice Research Institute of Iran, Rasht City. Studied factors were irrigation intervals (permanent waterlogging and irrigation once a week and once every two weeks) and different levels of N fertilizer (40, 60, and 80 kg ha^{-1}) in both vegetative and reproductive stages. The results of soil analysis are presented in Table 1.

Table 1. Physicochemical properties of the soil in the study area

Absorbable K (ppm)	Absorbable P (ppm)	Total soil N (%)	Soil pH	EC (dc/m)	Soil type	Sp
280	17.8	0.184	7.4	1.2	Si-Cl	75

The seeds were first disinfected with 10% commercial sodium hypochlorite and then sown in the nursery. Seedlings were transferred to the field after reaching a height of about 30 cm. The size of plots was 2 m^{-2} (2 × 1) with a density of 25 plants m^{-2}. After random assignment of treatments to the plots, seedlings were transplanted as individual plants. In each plot, 10 plants at a distance of 20 cm were planted in each of five rows with 20 cm spacing. All field operations, such as weeding and the control of pest and diseases, were performed according to the conventional methods.

The traits studied here were plant height (the tallest tiller height in cm from the crown at the soil surface to the panicle tip without considering the awn), panicle length (three random panicles per plant and 10 plants per plot, from the panicle petiole to the end of panicle without considering the awn in cm), number of panicles per plant (panicle-containing harvestable tillers in 10 random plants per plot in the grain dough stage), number of spikelets per panicle (total number of full and empty grains in the main panicles of 10 random plants per plot), number of full grains per panicle (number of full and healthy panicle in the main panicles of 10 random plants per plot after full grain ripening), panicle fertility percentage (the number of full grains per panicle divided by the total number of grains per panicle), the number of empty grains per panicle (the number of empty grains in the main panicles of 10 random plants per plot after full grain ripening), 1000-grain weight or TGW (random TGW in grams per plot), and rice husk yield (of total plants per plot calculated in tons ha^{-1}). All traits were measured according to the standard guidelines of the International Rice Research Institute (IRRI).

At the end of each year, measured data of the studied traits were subjected to simple analysis of variance (ANOVA) according to the statistical design using SAS and SPSS statistical software. Means of data were compared with Duncan's multiple range test at 5% probability level. Curves and tables were drawn using Excel and Word software.

RESULTS AND DISCUSSION

Based on the results of combined ANOVA for the traits, the effect of year was not significant on all the traits except the panicle length and number of panicles per plant. The dual and triple interactions of the experimental treatments were significant on all studied traits. The interactions of growth period, N fertilizer, and irrigation interval on plant height, panicle length, number of panicles per plant, total number of grains per plant, and number of full grains per panicle were significant at 5% level, and on the panicle fertility percentage, number of empty grains per panicle, and 1000-grain weight at 1% level. GY was affected by the interactions of growth period, N fertilizer, and irrigation interval during the two years (Table 2).

Table 2. Results of combined ANOVA for the studied traits

Sources of variation	df	Plant height	Panicle length	Panicle No.	Total grains per plant	Full grains per panicle
Year (Y)	1	66.66^{ns}	128.48**	27.1**	43.22^{ns}	5.81^{ns}
Replication (Y)	4	40.12	5.79	31.74	81.96	66.06
Irrigation interval (II)	2	140.02^{ns}	5.42^{ns}	1.34^{ns}	31.14^{ns}	25.78^{ns}
N fertilizer	2	25.1^{ns}	11.6**	4.15^{ns}	171.3^{ns}	80.81^{ns}
Growth period (GP)	1	4.09^{ns}	0.01^{ns}	1.25^{ns}	203.42^{ns}	130.13
Y × II	2	38.37^{ns}	1.64^{ns}	0.07^{ns}	36.58^{ns}	33.42^{ns}
Y × N	2	131.5^{ns}	0.33^{ns}	0.06^{ns}	15.62^{ns}	55.95^{ns}
Y × GP	1	3.74^{ns}	1.5^{ns}	4.36**	175.87^{ns}	100.4^{ns}
N × II	4	353.32**	10.9^{ns}	9.28**	343.4*	272.4*
GP × II	2	624.11**	37.19^{ns}	21.72**	2185.33**	2060.81**
GP × N	2	242.88*	3.1^{ns}	6.78^{ns}	265.46*	344.16*
Y × II × N	4	36.68^{ns}	2.05^{ns}	0.04^{ns}	19.09^{ns}	73.07^{ns}
Y × II × GP	2	150.87^{ns}	1.35^{ns}	0.33^{ns}	24.5^{ns}	42.55^{ns}
N × GP	2	2.41^{ns}	1.56^{ns}	0.41^{ns}	23.49^{ns}	10.27^{ns}
N × II × GP	4	179.85*	6.07*	16.06*	142.63*	293.07*
Y × II × N × GP	4	67.95^{ns}	1.66^{ns}	0.4^{ns}	72.03^{ns}	40.64^{ns}
Experimental error	68	87.4	2.21	2.79	115.14	118.72
COV	-	7.93	5.22	10.49	13.12	14.17

Sources of variation	df	Fertility (%)	No. of empty grains	TGW	Grain yield
Year (Y)	1	0.004^{ns}	0.6^{ns}	0.28^{ns}	2264565.66^{ns}
Replication (Y)	4	0.001	2.09	0.09	1587447.12
Irrigation interval (II)	2	0.0008^{ns}	5.19^{ns}	1.63**	9667602.55**
N fertilizer	2	0.002^{ns}	0.71^{ns}	0.03^{ns}	1747431.3^{ns}
Growth period (GP)	1	0.0005^{ns}	2.18^{ns}	2.03**	12563286.17**
Y × II	2	0.003^{ns}	3.8^{ns}	0.3^{ns}	10660865.2**
Y × N	2	0.0014^{ns}	0.21^{ns}	0.02^{ns}	952108.84^{ns}
Y × GP	1	0.0006^{ns}	0.01^{ns}	0.12^{ns}	6512899.49**
N × II	4	0.03*	10.8**	0.07^{ns}	2180245.5*
GP × II	2	0.007*	0.74^{ns}	0.03^{ns}	629882.86^{ns}
GP × N	2	0.006*	1.03^{ns}	0.33^{ns}	536939.16^{ns}
Y × II × N	4	0.0058*	1.5^{ns}	0.39*	2940953.28*
Y × II × GP	2	0.001^{ns}	0.19^{ns}	0.05^{ns}	2785278.6*
N × GP	2	0.0002^{ns}	2.2^{ns}	0.08^{ns}	1524362.31^{ns}
Y × N × GP	4	0.006**	7.47**	1.08**	1131765.65^{ns}
Y × N × GP × II	4	0.002^{ns}	1.04^{ns}	0.38^{ns}	3962236.04**
Experimental error	68	0.002	2.25	0.26	872186.6
COV	-	5.1	14.43	1.95	15.17

ns, *, and ** are nonsignificant and significant at the 5 and 1% probability levels, respectively.

Plant height

Among the treatments, the highest plant heights belonged to the treatments of 80 and 60 kg ha^{-1} of N fertilizer (29.28 and 125.17 cm, respectively) in permanent waterlogged irrigation during the vegetative growth (Table 3). The lowest plant heights were recorded in the N fertilizer use of 40 kg ha^{-1} with every 14-day irrigation, N fertilizer use of 40 kg ha^{-1} fertilizer with every 7-day irrigation, and N fertilizer use of 60 kg ha^{-1} with every 14-day irrigation (105.16, 110.88, and 110.89 cm, respectively) during the reproductive growth period (Table 3). According to the results, the plant height increased with decreasing irrigation interval and increasing N fertilizer application. As mentioned above, the use of N fertilizer led to further increases in the plant height and the formation of panicles in Hashemi rice in the vegetative growth stage than the reproductive stage. Hatamifar et al. (2012) observed a significant effect of nitrogen on the plant height. Manan et al. (2010) reported that nitrogen application had positive effects on many of these traits, with the highest plant height in 100 kg ha^{-1} of N treatment. Meena et al. (2003) found that plant height increased by N fertilizer up to a level of 175 kg ha^{-1}. Irrigation treatments were not effective on the plant height in a study by Shokri Vahed et al. (2015). A significant increase in millet plant height with increasing nitrogen consumption was reported by Ali (2011).

Panicle length

Based on the comparison of means of the traits, the highest panicle lengths were related to the N fertilizer treatment of 80 kg ha^{-1} with permanent waterlogging in the vegetative and reproductive growth periods (30.92 and 30.15, respectively) (Table 3). The lowest panicle length (25.87) was observed in the N fertilizer treatment of 40 kg ha^{-1} with every 14-day irrigation during the reproductive growth period (Table 3). Hatamifar et al. (2012) found a significant effect of nitrogen on the panicle length. Meena et al. (2003) showed that panicle length increased by N fertilizer use up to a level of 175 kg ha^{-1}. Irrigation treatments were not effective on the panicle length in a research by Shokri Vahed et al. (2015). A significant increase in millet panicle length with increasing N application was reported by Ali (2011).

Number of panicles

The highest numbers of panicles were observed in the N fertilizer treatment of 80 kg ha^{-1} with waterlogged irrigation in the reproductive (18.93) and vegetative (17.77) growth periods, respectively. The lowest number of full grains per panicle was obtained in the N treatment of 40 kg ha^{-1} with 14-day irrigation in the vegetative (13.98) and reproductive (13.6) growth periods, respectively (Table 3). The effect of water stress was significant on the number of panicles in studies by Aminpanah et al. (2017) and Sabetfar et al. (2013). Sabetfar et al. (2013) reported a significant effect of nitrogen on the number of panicles. Manan et al. (2010) found positive effects of N on most of these traits, with the greatest number of panicles in an N treatment of 100 kg ha^{-1}. Taghizadeh et al. (2008) and Shokri Vahed et al. (2015) reported that the numbers of panicles were affected by irrigation methods. The interaction of irrigation and N treatments showed that an increase in N fertilizer led to an increase in the number of panicles under water shortage conditions. Ali (2011) noticed a significant increase in the number of millet panicles per m^2 with increasing use of nitrogen.

Total number of grains per panicle

Based on the comparison of means of the traits, the highest total numbers of grains per panicle belonged to N fertilizer uses of 60 and 80 kg ha^{-1} (94.34 and 92.96, respectively) with waterlogged irrigation in the reproductive growth period (Table 3). Total number of grains per panicle was lowermost (63.19) in the N fertilizer treatment of 40 kg ha^{-1} with 14-day irrigation in the vegetative growth period (Table 3). Sabetfar et al. (2013) showed that water stress had an effect on the total number of grains per panicle. Since some traits are significantly related to the plant yield and changes in the yield are not the same for all genotypes in different moisture conditions, it is expected that the variations of yield components in this situation are not the same for different genotypes. Meena et al. (2003) showed that the number of grains per panicle increased with using N fertilizer up to a level of 175 kg ha^{-1}, but this trait began to decrease at higher levels (>200 kg ha^{-1}).

Number of full grains per panicle

The results of comparison of means of the traits showed that the highest number of full grains per panicle per panicle belonged to N fertilizer application of 60 and 80 kg ha^{-1} (89.3 and 88.64, respectively) with waterlogged irrigation in the reproductive growth period (Table 3). The lowest number of full grains per panicle was observed in the N fertilizer treatment of 40 kg ha^{-1} with 14-day irrigation in the vegetative and reproductive growth periods (57.14 and 65.61, respectively) (Table 3). The duration and green leaf area decreased due to the drought stress, leading to decreased photosynthate production, which reduces the number of fertile tillers and consequently full grain number due to low photosynthates and elevated intra-plant competition; hence, the drought stress caused a relatively further decrease in the grain number relative to the grain weight. Sabetfar et al. (2013) found that the number of fertile grains was affected by the application of water stress. The application of N fertilizer up to 180 kg ha^{-1} resulted in increased number of full grains per panicle in rice (Singh et al., 2017). Taghizadeh et al. (2008) reported that an increase in N fertilizer level had a significant effect on the number of full grains per panicle. A significant increase in the number of grains per millet panicle was reported with increasing use of nitrogen (Ali 2011).

Panicle fertility percentage

Based on the comparison of means of the traits, panicle fertility percentage was uppermost in the treatment using N fertilizer of 80 kg ha^{-1} with waterlogged irrigation in the vegetative and reproductive growth periods (0.97 and 0.96, respectively) (Table 3). This trait was lowermost in treatments using 60 kg ha^{-1} of N fertilizer with the 14-day irrigation in the reproductive growth period (0.81) and 80 kg ha^{-1} of N fertilizer with 14-day irrigation in the vegetative growth period (0.90) (Table 3). A comparison of panicle fertility percentage between different treatments showed that this trait was also affected by the interactions of different treatments, as with the other traits. Aminpanah et al. (2017) observed that water stress reduced the grain fertility percentage (19.8%) in the reproductive stage. Singh et al. (2017) reported an increase in the rice grain fertility percentage by the application of N fertilizer up to 180 kg ha^{-1}.

Number of empty grains per panicle

The highest numbers of empty grains per panicle belonged to the N fertilizer uses of 60 kg ha^{-1} with 14-day irrigation in the vegetative growth period (5.56), 80 kg ha^{-1} with 14-day irrigation in the vegetative growth period (5.54), and 40 kg ha^{-1} with 14-day irrigation in the vegetative growth period (5.08) (Table 3). The treatments of 40 and 60 kg ha^{-1} of N fertilizer with the waterlogged irrigation presented the lowest number of empty grains (2.59 and 2.76, respectively) in the vegetative growth period (Table 3). The most drought stress-induced damage to the number of empty grains in water stress conditions was reported in other studies (Sabetfar et al. 2013; Ghiasi Oskooie 2013; Aminpanah et al. 2017).

Thousand-grain weight (TGW)

The highest TGW values were observed in N fertilizer treatment of 80 kg ha^{-1} in waterlogged irrigation in the vegetative (28.48) and reproductive (27.11) growth periods, respectively. The lowest values of this trait were recorded in 40 kg ha^{-1} N fertilizer treatment with 14-day irrigation in the vegetative growth period (20.79 g) and N fertilizer use of 80 kg ha^{-1} in 14-day irrigation in the reproductive growth period (21.89 g) (Table 3). Mousavi et al. (2016) found that the highest TGW belonged to an irrigation treatment at 7-day intervals, which was higher than a 14-day treatment. Manan et al. (2010) observed no effect of N application on the TGW. Meena et al. (2003) showed that the TGW increased by N fertilizer use up to a level of 175 kg ha^{-1}, but this trait began to decrease at higher levels (>200 kg ha^{-1}). Excessive use of nitrogen inhibits the growth and spread of roots and consequently carbohydrates decrease sharply in the plant due to insufficient uptake of other nutrients required by the plant. Taghizadeh et al. (2008) and Ali (2011) found significant increases in the TGW with increased use of N fertilizer. Shokri Vahed et al. (2015) noticed that the TGW was affected by irrigation methods. The interaction between the irrigation and N fertilizer treatments showed that an increase in N fertilizer led to an increase in the TGW under water shortage conditions.

Grain yield

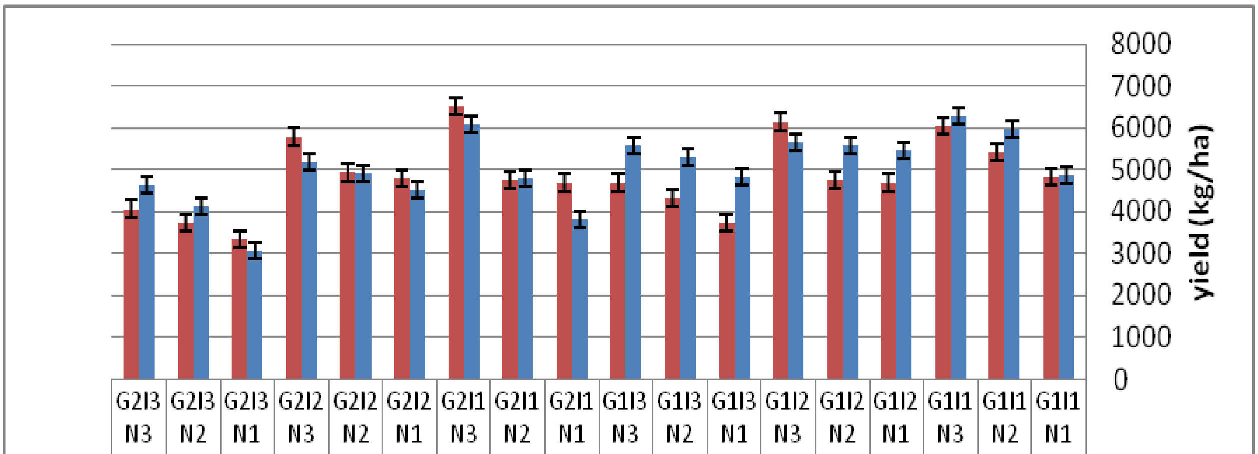
Based on the comparison of means of the traits, the highest GY was found for the N fertilizer application of 80 kg ha^{-1} with waterlogged irrigation during the reproductive growth period in 2018 (6516.3 kg ha^{-1}) and the same N fertilizer use with waterlogged irrigation during the vegetative growth period in 2017 (6289.1 kg ha^{-1}) (Table 3). N fertilizer application at 40 kg ha^{-1} with 14-day irrigation interval during the reproductive growth period in 2017 (3075.7 kg ha^{-1}) and 2018 (3351.2 kg ha^{-1}) resulted in the lowest grain yields (Table 3). This damage resulted from sharp reductions in the number of full grains per panicle, number of spikelets per panicle, number of panicles per plant, and TGW caused by water deficit stress during the grain filling period. Richards et al. (2001) reported that a balance should be exist between pre- and post-pollination growth to achieve a high GY. Less pre-pollination growth reduces biological yield but maximizes harvest index, while higher pre-pollination growth maximizes biomass but decreases harvest index. Mousavi et al. (2016) observed significant effects of irrigation levels and N fertilizer on GY at a level of 1%. The highest GY was obtained in 7-day irrigation interval, which was higher than that of 14-day irrigation treatment. GY increased significantly with increasing fertilizer application from zero to 120 kg ha^{-1}. Overall, 7-day irrigation interval and the application of N at 80 kg ha^{-1} led to the achievement of maximum GY in millet plant. In another study, the effect of N on GY was also significant, with the highest level obtained at 90 kg ha^{-1} of N (Hatamifar et al., 2012). Rezaei and Nahvi (2007) reported that the effect of irrigation treatment was not significant on GY and this trait was more affected by weather conditions and changes in meteorological factors than by applied irrigation treatments.

N application had positive effects on many of these traits and the highest GY was obtained in an N treatment of 100 kg h^{-1} (Manan et al., 2010). Meena et al. (2003) found an increase in the rice husk yield by N fertilizer use up to a level of 175 kg ha^{-1}, after which this trait began to decrease at higher levels (>200 kg). Excessive use of nitrogen inhibits the growth and spread of roots and consequently carbohydrates decrease sharply in the plant due to insufficient uptake of other nutrients required by the plant. Taghizadeh et al. (2008) showed that GY increased significantly with rising levels of N fertilizer. The results of this experiment revealed that the highest rice GY was obtained from permanent waterlogged treatment with N application of 80 kg ha^{-1}, which was significantly different from that of once every 14-day irrigation with N consumption of 60 kg ha^{-1}.

Table 3. Results of comparison of the studied traits

Treatments			Traits							
Growth period	Irrigation interval	N fertilizer	Plant height (cm)	Panicle length (cm)	Panicle No.	Total grains per panicle	Full grains	Panicle fertility (%)	No. of empty grains	TGW (g)
Vegetative stage	Permanent waterlogging	40 kg/ha	118.75	28.2	16.05	87.04	80.53	0.92	2.59	25.64
		60 kg/ha	125.17	28.52	16.15	87.14	84.5	0.95	2.76	26.9
		80 kg/ha	129.28	30.92	17.77	88.53	82.83	0.97	3.76	28.48
	7 d	40 kg/ha	115.11	28.5	14.65	70.24	66.1	0.91	3.24	23.9
		60 kg/ha	114.69	29.07	15.58	79.83	75.91	0.95	3.29	24.17
		80 kg/ha	119.04	29.73	16.11	81.24	85.31	0.94	4.45	25.9
	14 d	40 kg/ha	113.65	25.87	13.98	63.19	57.14	0.93	3.97	20.79
		60 kg/ha	114.25	27.62	14.75	75.74	72.76	0.93	5.56	22.58
		80 kg/ha	115.94	28.55	16.40	80.19	76.99	0.90	3.45	22.66
Reproductive stage	Permanent waterlogging	40 kg/ha	115.03	28.84	15.63	84.25	79.65	0.89	3.69	25.76
		60 kg/ha	116.08	29.67	16.20	94.24	88.64	0.94	2.89	25.86
		80 kg/ha	124.95	30.15	18.93	92.96	89.3	0.96	4.33	27.11
	7 d	40 kg/ha	110.88	27.01	15.58	81.76	77.69	0.94	3.19	23.3
		60 kg/ha	117.79	28.47	15.80	83.7	78.79	0.94	3.66	24.18
		80 kg/ha	122.47	29.7	16.86	89.01	80.35	0.95	3.24	23.52
	14 d	40 kg/ha	105.16	26.84	13.6	69.4	60.61	0.81	5.08	22.91
		60 kg/ha	110.89	29.67	15.4	74.48	70.3	0.93	4.02	23.95
		80 kg/ha	111.83	28.15	16.32	81.06	71.71	0.84	5.54	21.89
$LSD_{5\%}$			14.75	2.03	2.8	11.54	12.01	0.11	0.44	2.17
$HSD_{5\%}$			16.7	2.86	4.09	16.32	15.2	0.16	1.06	3.15

$LSD_{5\%}$ and $HSD_{5\%}$ are respectively LSD and Tukey test values at 5% probability level.



	G2I3 N3	G2I3 N2	G2I3 N1	G2I2 N3	G2I2 N2	G2I2 N1	G2I1 N3	G2I1 N2	G2I1 N1	G1I3 N3	G1I3 N2	G1I3 N1	G1I2 N3	G1I2 N2	G1I2 N1	G1I1 N3	G1I1 N2	G1I1 N1
96	4624	4113	3076	5170	4898	4537	6097	4786	3816	5584	5306	4840	5670	5587	5469	6289	5952	4866
97	4061	3741	3351	5791	4932	4784	6516	4748	4688	4688	4319	3741	6141	4748	4688	6050	5413	4825

Figure 1. Comparison of 2-year average grain yield at interaction levels of growth period × irrigation interval × N fertilizer

N1, N2, and N3 respectively denote N fertilizer amounts of 40, 60, and 80 kg ha^{-1}; G1 and G2, respectively represent vegetative and reproductive growth periods; I1, I2, and I3 indicate waterlogged, once every 7 days, and once every 14 days irrigation intervals, respectively.

CONCLUSIONS

The results demonstrated that the application of N fertilizer at different levels with different soil moisture conditions could significantly affect the growth traits of Hashemi rice. The interaction of irrigation and N fertilizer treatments revealed that increasing N fertilizer led to increased yield, TGW, and number of tillers, even in water deficit conditions. In this experiment, using 80 kg ha^{-1} of pure N with permanent waterlogged irrigation in the reproductive growth stage, followed by the use of the same N level with weekly irrigation in the vegetative growth stage yielded the most appropriate result in increasing GY. It seems that an economical and desirable yield cannot be expected in drought stress conditions without the application of N fertilizer.

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