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Effect of nitrogen on rice yield, yield components and quality parameters

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Effect of nitrogen (N) fertilizer levels on yield and yield components of rice (Hashemi, Ali kazemi and Khazar) was investigated in an experiment as factorial in randomized complete block design (RCBD) with three replications in a paddy light soil at Guilan province, Iran, in the year 2008 to 2009. In this experiment, four treatments including: N1, control (no N fertilizer); N2, 30 kg N/ha; N3, 60 kg N/ha; N4, 90 kg N/ha were compared. Results show that total biomass (8386 kg/ha), grain yield (3662 kg/ha), plant height (127.9 cm), tillers m^{-2} (250.22), panicles m^{-2} (235.8) and total grain per panicle (103.8) reached the highest value at high nitrogen level. Among the varieties, the highest total biomass (7734 kg/ha), grain yield (3414 kg/ha), unfilled percent (20.16%) and total grain per panicle (78.2) belonged to Khazar. Significantly, tiller m^{-2} (250.83) and panicle m^{-2} (235.91) were obtained from Hashemi. Also 1000-grains weight against various studied varieties revealed that Ali kazemi produced maximum 1000-grains weight (28.99 g). Among the different N application levels, significant difference was observed in all quality parameters except gelatinization temperature (GT); the highest amylose content (AC) was obtained from treatment N1 and significantly highest gel consistency (GC) was obtained from treatment N3. In general, GC was increased with N-fertilizer application and only result was changed from N3 to N4 and was reduced. Whereas AC was reduced from N1 to N3, and the result was reversed from N3 to N4. Meanwhile, the interaction effect of variety × nitrogen fertilizer did not show significant difference between all quality parameters except of GC.

Key words: Nitrogen fertilizer, grain yield, yield components, dry matter production, quality parameters.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic zones. Rice is the staple food for nearly half of the world‘s population, most of whom live in developing countries. The crop occupies one-third of the world‘s total area planted to cereals and provides 35 to 60% of the calories consumed by 2.7 billion people. Nitrogen (N) is the most important nutrient in irrigated rice production (Cassman et al., 1998). Current high yields of irrigated rice are associated with large applications of fertilizer N (Barker and Dawe, 2001; Pingali et al., 1997). Nitrogen (N) is essential for rice, and usually it is the most yield-limiting nutrient in irrigated rice production around the world (Ladha and Reddy, 2003; Samonte et al., 2006). Soil N and biological nitrogen fixation by associated organisms are major sources of N for lowland. Soil organic N is continually lost through plant removal, leaching, denitrification and ammonia volatization. An additional concern is that the capacity of soil to supply N may decline with continuous intensive rice cropping rice cropping under wetland condition. More than 50% of the N used by flooded rice receiving fertilizer N is derived from the combination of soil organic N and biological nitrogen fixation by free-living and rice plant-associated bacteria. The remaining N requirement is normally met with fertilizer (Motior Rahman et al., 2009).

Rice plants require N during vegetative stage to pro-

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Abbreviations: GT, Gelatinization temperature; **AC,** amylose content; **GC,** gel consistency.

Table 1. Soil chemical characteristics (top 20 cm).

Kind	Absorbent K (ppm)	Absorbent P(ppm)	N total (%)	pH (1:2.5 soil:water)	Electrical conductivity (dS m^{-1})	SP%
Si-Ci	280	17.8	0.189	7.4	1.12	75

mote growth and tillering, which in turn determines potential number of panicles. Nitrogen contributes to spikelet production during early panicle formation stage, and contributes to sink size during the late panicle formation stage. Nitrogen also plays a role in grain filling, improving the photo-synthetic capacity, and promoting carbohydrate accumulation in culms and leaf sheaths (Mae, 1997).

Earlier studies reveal that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Place et al., 1970). Given the importance of nitrogen fertilization on the yield in grain from the rice plant, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and other agronomic parameters such as the cycle, plant height, lodging and moisture content of the grain, in order to obtain better knowledge of said productive response. Increased rates of nitrogen fertilizer may increase the yield but reduce the quality of the grain. Some of these fertilizers, like urea, are substantially cheaper than others, and their use may be justified on economic grounds. On the other hand, there are many factors that play a great role in quality of rice. The quality of cooked rice and its taste, which is important for consumers, is a direct result of physical and chemical factors in its production. To a great extent, the quality of taste is dependent on starch that forms 90% of rice and the most important factor that can affect the quality of cooked rice is amylose content (AC), which is part of starch. Other elements such as gel consistency (GC) and gelatinization temperature (GT), which are part of starch properties, also affect the quality of cooking (Damardijati et al., l985, 1988; Juliano, 1993).

Overall, AC in rice grain will determine the softness and hardness of grain after cooking process. GC is the rate of mucilage during cooking. In reality, GT is the water temperature of starch granules at an irreversible expansion (Zamani and Alizade, 2007). Dong et al. (2007) showed that nitrogen amount has a profound effect on cooking quality and nutritious value of rice, with increase in its GC but decrease in AC. Also Young Lee (2006) in his research concludes that there is a negative correlation between the amount of nitrogen and amylase in the grain. In another research done by Chanseok et al. (2005), it was shown that by controlling the amount of nitrogen fertilizer, the control of the amount of amylase, protein and rice taste is attainable. However, there is little information available on the effect of environmental factors especially different level of fertilizer on quality of Iranian rice.

The present investigation was undertaken during 2008 and 2009 to have a detailed account of the effect of commercially-available nitrogenous (N) fertilizers (urea) on the growth, yield and quality of commercial rice varieties in Iran. This information could be useful for genetic improvement programs under development, and to select management practices that increase yield and N use of applied fertilizer. The objectives of this research were to study the response of local rice varieties to N fertilization, determine some yield components, and estimate dry matter production and quality parameters at four N rates.

MATERIALS AND METHODS

Field experiment site

The field experiment was conducted at the Rice Research Institute, Rasht, Guilan, Iran, during the two consecutive (2008 and 2009) growing periods.

Fertilizer treatments

The experiment was laid out factorial in randomized complete block design with three replications of four nitrogen fertilizers levels (N1, without fertilizer; N2, 30 kg/ha in one division during transmission of seedling from nursery to the main field; N3, 60 kg/ha in two divisions during transmission of seedling from nursery to the main field and tillering (30 days after transplanting); N4, 90 kg ha^{-1} in two divisions at the time of transferring seedlings from nursery to the main field and in tillering stage). The N fertilization was applied as single incorporated application of urea (46% N).

Rice cultivar

Date of transmission of seedling from nursery to the main field was 12th May in first year (2007) and 8th June in the second year (2008). Three different varieties were examined (Hashemi, V1; Ali kazemi, V2 and khazar, V3).

Sampling and analysis

Physico-chemical properties of the soil were measured by the standard methods of soil chemical analysis. Soil initial chemical characteristics are presented in Table 1. Three hills in each plot were randomly selected and tagged for recording plant height (cm), tillers m^{-2}, panicle m^{-2}, panicle height (cm), filled grains/panicle, unfilled grain/panicle and unfilled percent at harvest. An area of 2 m^2 of each plots were harvested and dried for two days at 70°C and the total biomass was recorded. Grain weight adjusted to 14% moisture content, was used as estimates of grain yield (kg/ha). Then 1000-grain weight was recorded from plant samples. Also, nitrogen concentration was measured by Kjeldahl method.

Quality control consisted of measuring amylose content (AC), gel consistency (GC) and gelatinization temperature (GT). For determining AC, color rating method was used (Juliano, 1971). GC

Table 2. Results of analysis of variance of studied variable.

Source	df	Yield (kg/ha)	Total biomass (kg/ha)	HI	1000-grains weight	Number of panicles/m²	Number of tillers/m²	Plant height (cm)	Unfilled (%)	Total grains per panicle
Year (y)	1	449826^{ns}	48637740*	0.1568**	38.573472*	14.22*	16714.01*	9.3168^{ns}	868.05*	1050.34**
R	4	116795^{ns}	2645921^{ns}	0.006411^{ns}	3.754027^{ns}	38888.25^{ns}	919.59*	30.5856^{ns}	49.19^{ns}	44.23^{ns}
N	3	7661820**	34357935**	0.004005^{ns}	10.995324^{ns}	1.629^{ns}	15024.1*	735.3727^{ns}	67.88^{ns}	72.93^{ns}
Y*N	3	179768^{ns}	531590^{ns}	0.002925^{ns}	7.072361^{ns}	11.11^{ns}	1414.8^{ns}	137.4423**	38.75^{ns}	74.38^{ns}
V	2	3559318*	20705433**	0.003151^{ns}	72.475416*	3891.72**	50824.5**	394.9429^{ns}	26085.29*	53729.2**
Y*V	2	147185^{ns}	408039^{ns}	0.01024^{ns}	1.0043056^{ns}	3891.72**	359.84^{ns}	892.5451**	815.93^{ns}	439.1^{ns}
N*V	6	235416^{ns}	1866163^{ns}	0.0038^{ns}	2.915601^{ns}	3.54^{ns}	1649.68^{ns}	37.1855^{ns}	218.06^{ns}	246.21**
Y*N*V	6	141670^{ns}	673586^{ns}	0.005835^{ns}	3.088194^{ns}	15.38^{ns}	636.16^{ns}	42.9695^{ns}	129.07^{ns}	180.93**
Cv		17.83	15.99	6.03	6.03	44.79	13.95	4.1	25.44	6.28

**,* and ns Significant at 1, 5% probability level and non-significant, respectively. HI, Harvest index; df, degree of freedom.

was measured according to the rate of movement of gel produced from flour sample. In consideration of changes in endosperm of rice grain, temperature of gelatinization process was distinguished (Little et al., 1958). The amount of rice nitrogen with the usage of Kjeldahl method was measured (Juiliano, 1993).

Statistical analysis

All of the data were analyzed statistically with data processing softwares (MSTATC, SAS and SPSS) and figured with Microsoft Excel 2007.

RESULTS AND DISCUSSION

Grain yield and yield components

Nitrogen fertilization and variety had significant effects on grain yield, but there were no interaction effects among these factors on any of the yield parameters (Table 2). Maximum yield (3662 kg ha^{-1}) was obtained with the higher N rate (90 kgN/kg) (Table 2) (Figure 1), with detecting yield decrease in the range of rates tested. Parma Artacho et al. (2009) illustrated that grain yield showed a significant quadratic response to N fertilization. Conry (1995) showed that proper use of fertilizers can markedly increase the yield too. Grain yield showed a significant quadratic response to N fertilization for three varieties (Table 2; Figure 3). However, mean yields of Khazar were higher than other varieties. Maximum yield was reached with 90 kg N ha^{-1}; maximum yield was obtained with the higher N rate, in spite of increasing panicle number (Table 2) However, mean yield due to Khazar variety were higher than other varieties (3414 kg ha^{-1}) (Figure 2).

In this experiment, the number of panicles m^{-2} increased with N fertilization, and differences between N rates were significant (Table 1). Findings show that N4 (90 kgN/ha) caused higher panicle density (235.8 m^2) (Table 2). Also, variety had significant effects on panicles m^{-2}, as Hashemi variety had the highest panicles m^{-2} (235.9 m^2) (Table 3). Artacho et al. (2009) revealed that number of panicles m^{-2} increased with N fertilization and the relationship was linear. In fact, panicle number m^{-2} significantly increased with N fertilization and regression analysis showed a quadratic response to N in the three varieties (Figure 4). On average, the panicle number m^{-2} was lower in khazar variety. On the other hand, total grains per panicle increased with N fertilization and differences between N rates were significant (Table 1 and Figure 5). Findings show that N4 (90 kgN/ha) caused higher total grains per panicle (108.3) (Table 2). Also, variety had significant effect on total grains per panicle, as Khazar variety had the highest total grains per panicle (78.2) (Table 3).

Experimental findings reveal that nitrogen fertilization and variety had significant effects on tillers m^{-2} (Table 2). Data showed also shows increased number of tillers m^{-2} with applied N. Since the highest number was due to N4, Hashemi variety had the highest number between varieties (Table 3). Rajput et al. (1988) showed that more number of tillers m^2 might be due to the more availability of nitrogen that played a vital role in cell division. According to Yoshida et al. (1981), as the amount of nitrogen absorbed by the crop increases, there is an increase in the number of tillers per square meter. Meanwhile, nitrogen fertilization had no significant effect on plant height (Table 2).

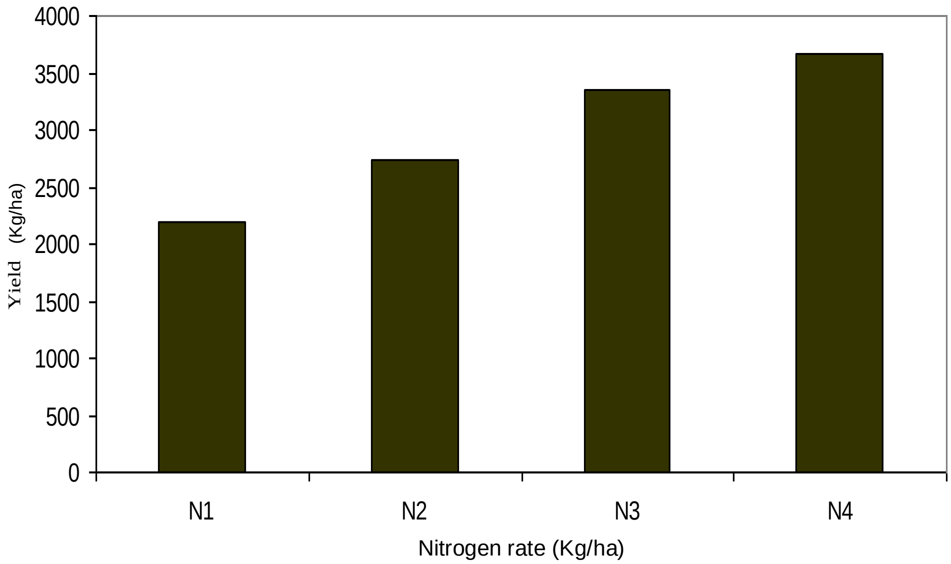

Figure 1. Effect of N fertilization on yield, 2008 to 2009.

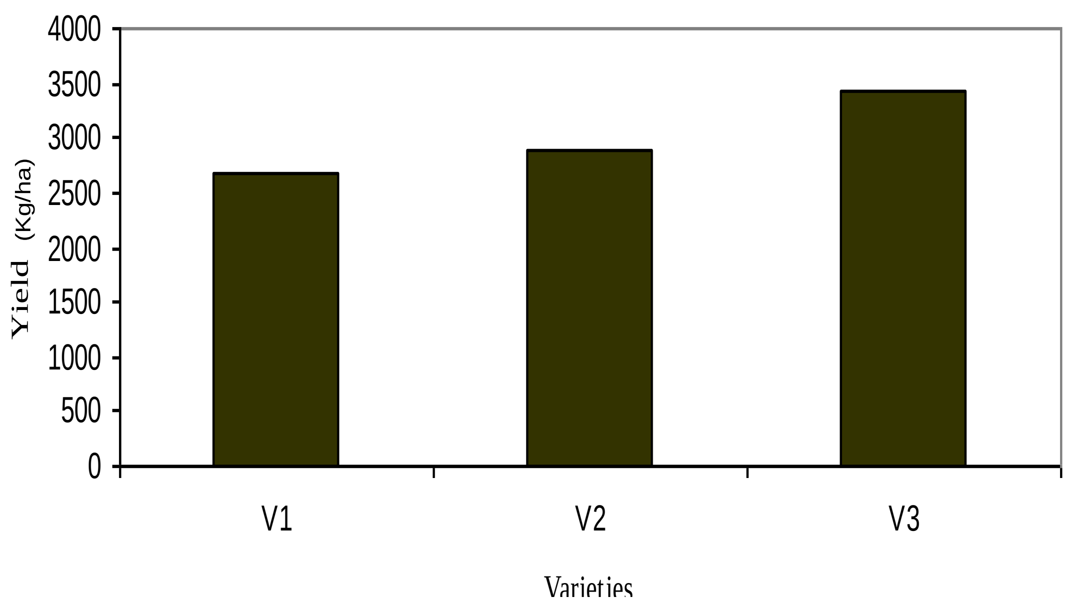

Figure 2. Effect of varieties (V) on yield for 2008 to 2009 (V1, Hashemi; V2, Ali kazemi; V3, Khazar).

Application of different contents of N fertilizer had no significant effect on 1000-grain weight (Table 2), but it was found that application on different varieties affected on 1000-grain weight significantly. The highest 1000-grain weight (28.99 g) was obtained from the plots of Ali kazemi variety, while minimum 1000-grain weight (25.63 g) was produced by Hashemi variety (Table 3). Chaturvedi (2004) in his research also showed the same results. It therefore appears that the application of nitrogen increased the protein percentage, which in turn increased the grain weight. Kausar et al (1993) also reported similar result. It reveals that grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling.

Furthermore, data reveals that nitrogen fertilization had no significant effect on unfilled percent (Table 2), although evaluation of research findings showed significant difference between varieties. The highest unfilled percent was from Khazar variety (20.16%) and the lowest belonged to Hashemi variety (5.915%) (Table 3). In general, Yoshida (1981) believed that grain yield in rice is the product of different yield components. Also, Singh et al. (1998) showed that the relative importance of each component varies with location, season, crop duration

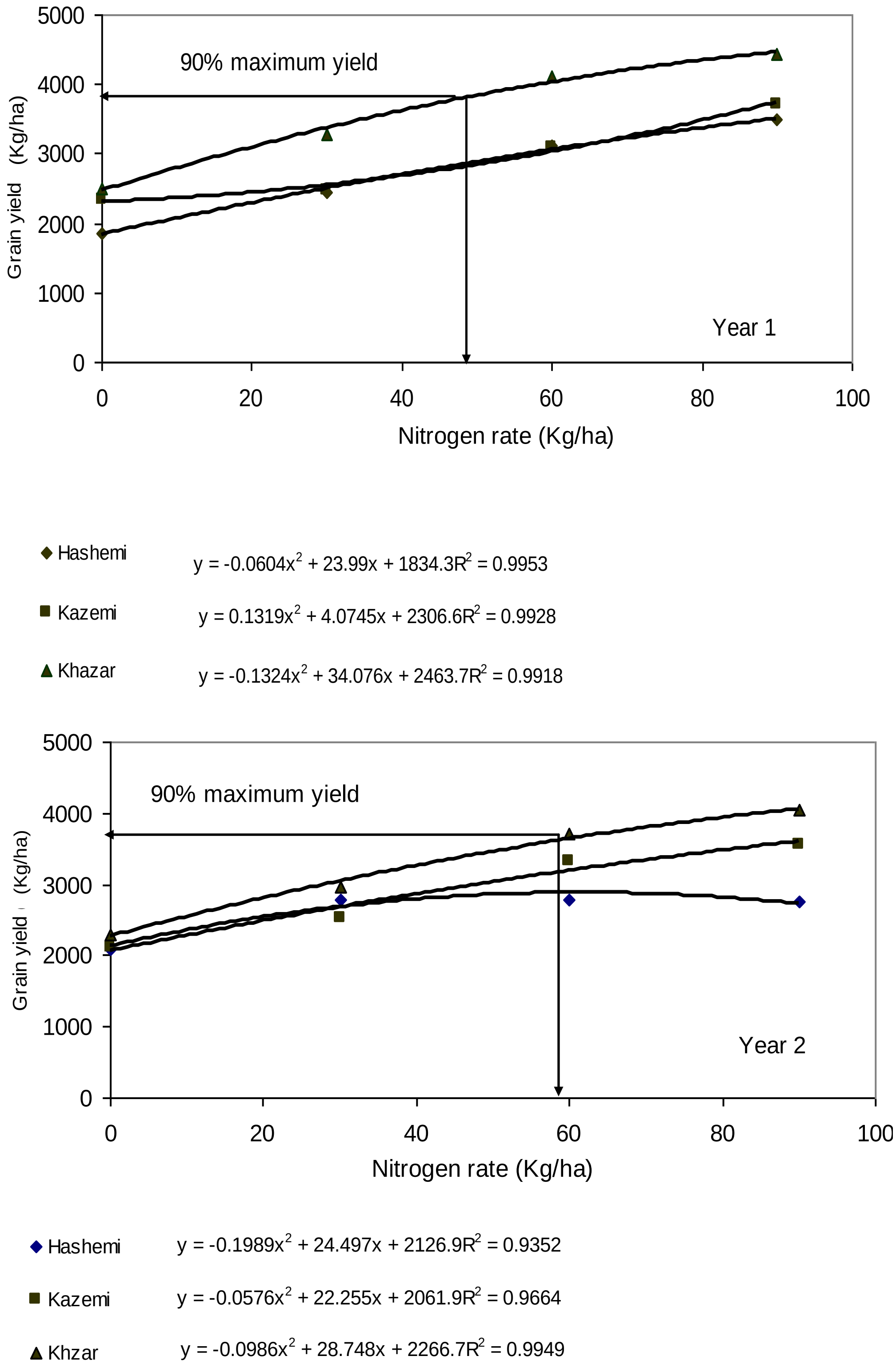

Figure 3. Effect of N fertilization on grain yield (14% moisture) in 2008 to 2009.

and cultural system. There is an agreement that panicle density is the most important factor determining high yields.

Biomass production

Variance analysis showed that effect of different amount

Table 3. Results of comparison of average of studied variables between chemical fertilizer contents in confidence level of 5%.

Variable	Total biomass (kg/ha)	Yield (kg/ha)	HI	Plant height (cm)	Weight of 1000-grain (g)	Tillers/m^2	Panicle/m^2	Total grains per panicle	Unfilled percent
2008	7504[a]	3069[a]	0.41[a]	122.2[a]	27.7861[a]	233[a]	217.66[a]	110.27[a]	12.1667[a]
2009	5860[b]	2911[a]	0.50[b]	121.5[a]	26.3222[b]	2025.528[b]	194.97[a]	102.63[b]	9.8889[b]
N1	5032[d]	2194[c]	0.45[a]	114.2[b]	26.2611[a]	185.72[c]	179.33[c]	108.6[a]	10.555[a]
N2	6241[c]	2749[b]	0.47[a]	119.1[ab]	26.5611[a]	203[bc]	192.722[bc]	107[a]	10.777[a]
N3	7169[b]	3356[a]	0.44[a]	126.3[ab]	27.4389[a]	232.11[ab]	217.333[ab]	106.2[a]	10.888[a]
N4	8386[a]	3662[a]	0.44[a]	127.9[a]	27.9556[a]	250.22[a]	235.889[a]	103.8[a]	11.888[a]
V1	5973[b]	2663[b]	0.44[a]	126.1[a]	25.6333[b]	250.833[a]	235.917[a]	161[a]	7.000[b]
V2	6339[b]	2893[b]	0.47[a]	121.7[a]	28.9917[a]	237.250[a]	224.500[b]	80.04[b]	5.917[b]
V3	7734[a]	3414[a]	0.44[a]	117.9[a]	26.5357[b]	165.20[b]	158.542[c]	78.25[b]	20.167[a]

N1, Without fertilizer; N2, 30 kg/ha in one division during transmission of seedling from nursery to the main field; N3, 60 kg/ha in two divisions during transmission of seedling from nursery to the main field and tillering (30 days after transplanting); N4, 90 kg ha^{-1} in two divisions at the time of transferring seedlings from nursery to the main field and in tillering stage. Hashemi, V1; Ali kazemi, V2; khazar, V3; HI, harvest index.

of nitrogen fertilizer on total biomass was significant (Table 2), and in N4 treatment (90 kg N ha^{-1}) had the highest total biomass (8386 kg ha^{-1}) (Figure 7). Chaturvedi (2005) in his research presented that dry matter accumulation increased significantly with N fertilizer application in rice at all the growth stages of the crop. Also, total biomass due to Khazar variety was higher than other varieties (7734 kg ha^{-1}) (Table 3 and Figure 8). For the three varieties, total (straw plus grain) dry matter production had a significant quadratic response to N fertilization; Hashemi variety had lower straw and total biomass than other varieties (Table 3). These results could also explain the lower yields for Hashemi variety, considering the high correlation between total dry matter production and grain yield (R^2 = 0.73, 0.91 and 0.99 (first year) and R^2 = 0.90, 0.95 and 0.99 (second year) for Khazar, Ali kazemi and Hashemi, respectively) (Figure 6).

Analysis of data revealed that nitrogen fertilization had no significant effect on harvest index (HI) (Table 2). Artacho (2009) believed that HI, which is the ratio of grain yield to total biomass, was not affected by N fertilization. Fageria et al. (2006) and Mae et al. (2006) explained that the HI represents partitioning of photosynthate between grain and vegetative plant parts. Witt et al. (1999) and Hasegawa (2003) illustrated the reasons as its higher sink capacity (higher amount of panicles). The relationship between yield and yield components has been studied extensively in Table 4. Total biomass, plant height, panicle height, 1000-grains weight were having significant and positive correlation with grain yield (0.92). Gravois and McNew, (1993) reported that percent filled grains per panicle and total grains per panicle were the secondary or tertiary important com-ponents of yield associated with rice yield, after number of panicles m^{-2}. Seed weight was typically of minor importance in determining rice yield. Fageria and Baligar (2001) also reported that panicle was the most important component of yield, accounting for 87% of the variation in yield. Moreover, spikelet sterility accounted for a 7% variation in yield, and 1000-grain weights a 3% variation. Although an HI value was having significant correlation with grain yield, efficiency of grain production in crop plants is frequently expressed as HI.

Quality parameters

Review of results of variance analysis of AC show a significant difference between effects of amount of N fertilizer (Table 5). Examination of compare-son of variables in confidence level 5% specified that between contents, N1 (0 kg N ha^{-1}) causes the highest AC (22.75%) and N3 (60 kg N ha^{-1}), the lowest AC (20.99%) (Table 6 and Figure 9). AC was significantly lowered and then increased from N3 to N4. Hence, there is a negative and

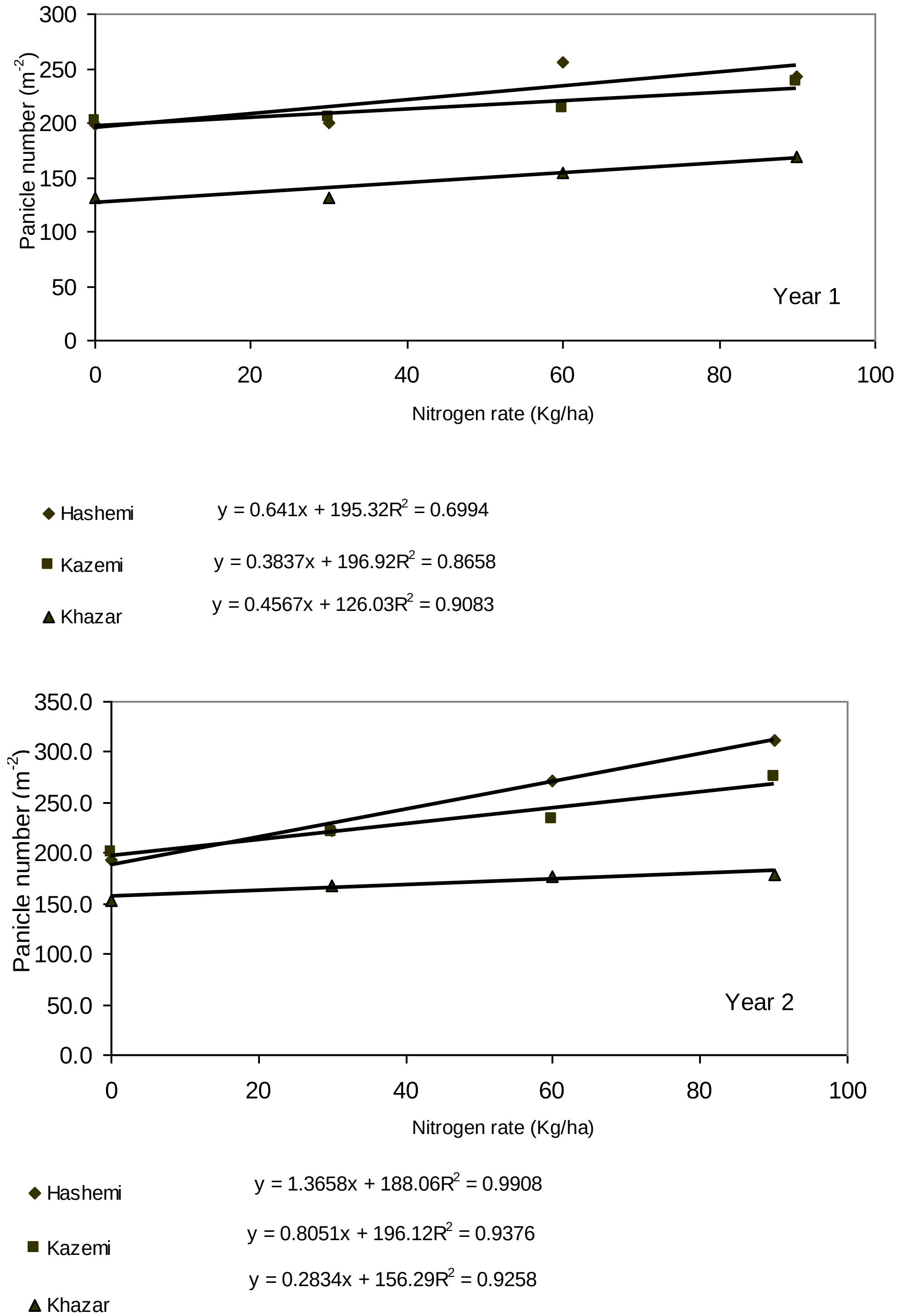

Figure 4. Effect of N fertilization on panicles numbers for 2008 to 2009.

significant correlation between amount of nitrogen and AC. Ju-Young, (2006) showed that there is a negative correlation between nitrogen rate and AC. Dong et al. (2007) confirms with the above results when he showed that with an increase in the amount of nitrogen fertilizer from zero to 120 kg/ha in Japan's varieties under their studies, activation of starch branch-ing enzymes increased and as a result amylopectin percentage increases while in contrast AC decreases. Thus, a significant negative correlation was observed between the activity of these enzymes and AC. Each time the amount of nitrogen fertilizer increases, enzyme

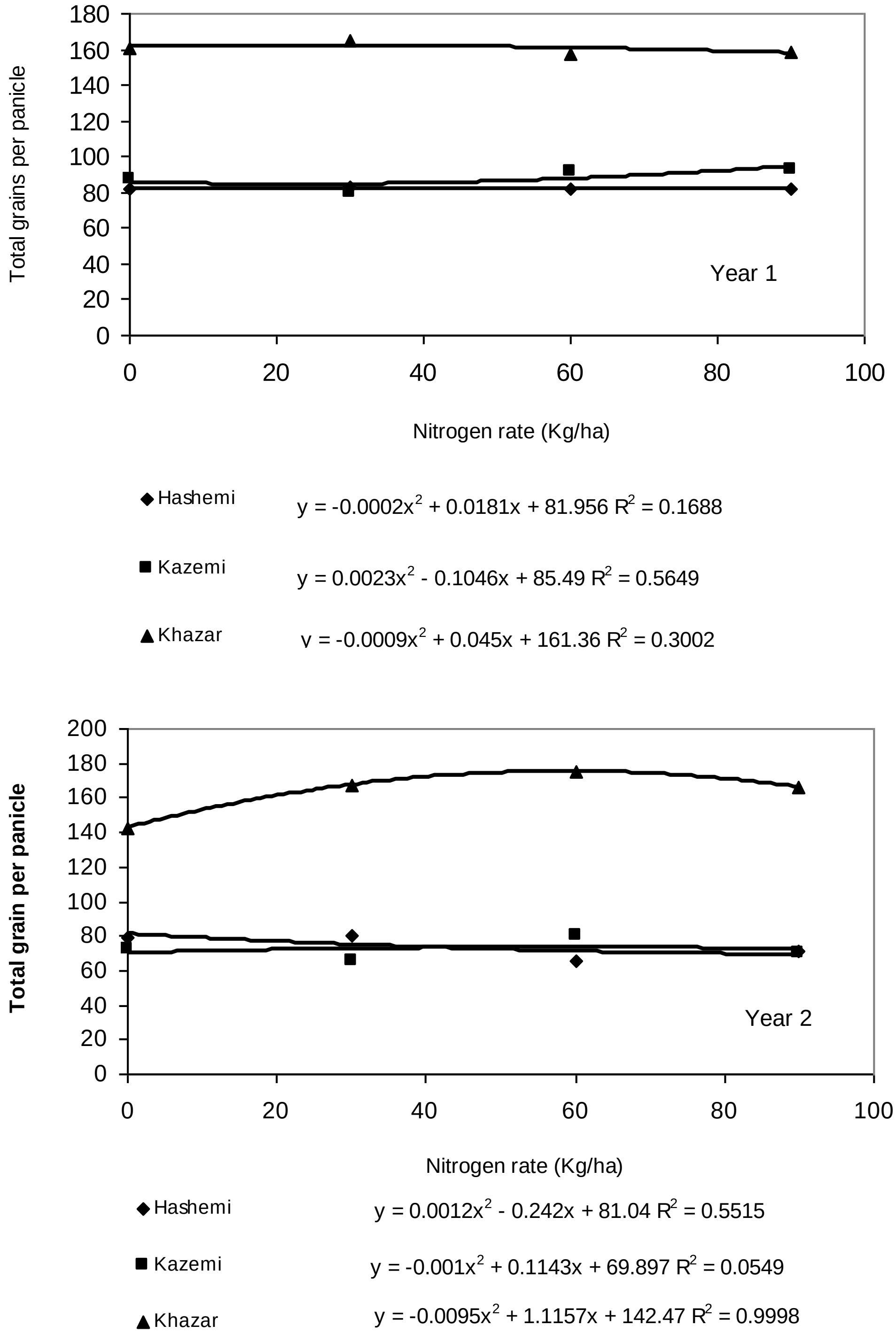

Figure 5. Effect of N fertilization on total grains per panicle for 2008 to 2009.

activity will decrease and as a result AC will increase. In addition Ju-Young, (2006) confirms the existence of negative correlation between nitrogen amount and AC in the grain.

The review of variance analysis showed that effect of different amount of nitrogen fertilizer on GC is significant (Table 5), although between varieties in regard to GC, significant difference in confidence level 1% was not observed (Table 6). Examining the results of comparison of average of N content effect in GC rate from N1 (36.61 mm) to N3 (52.97 mm) show that with an increase in the used amount of nitrogen fertilizer to a certain point, an

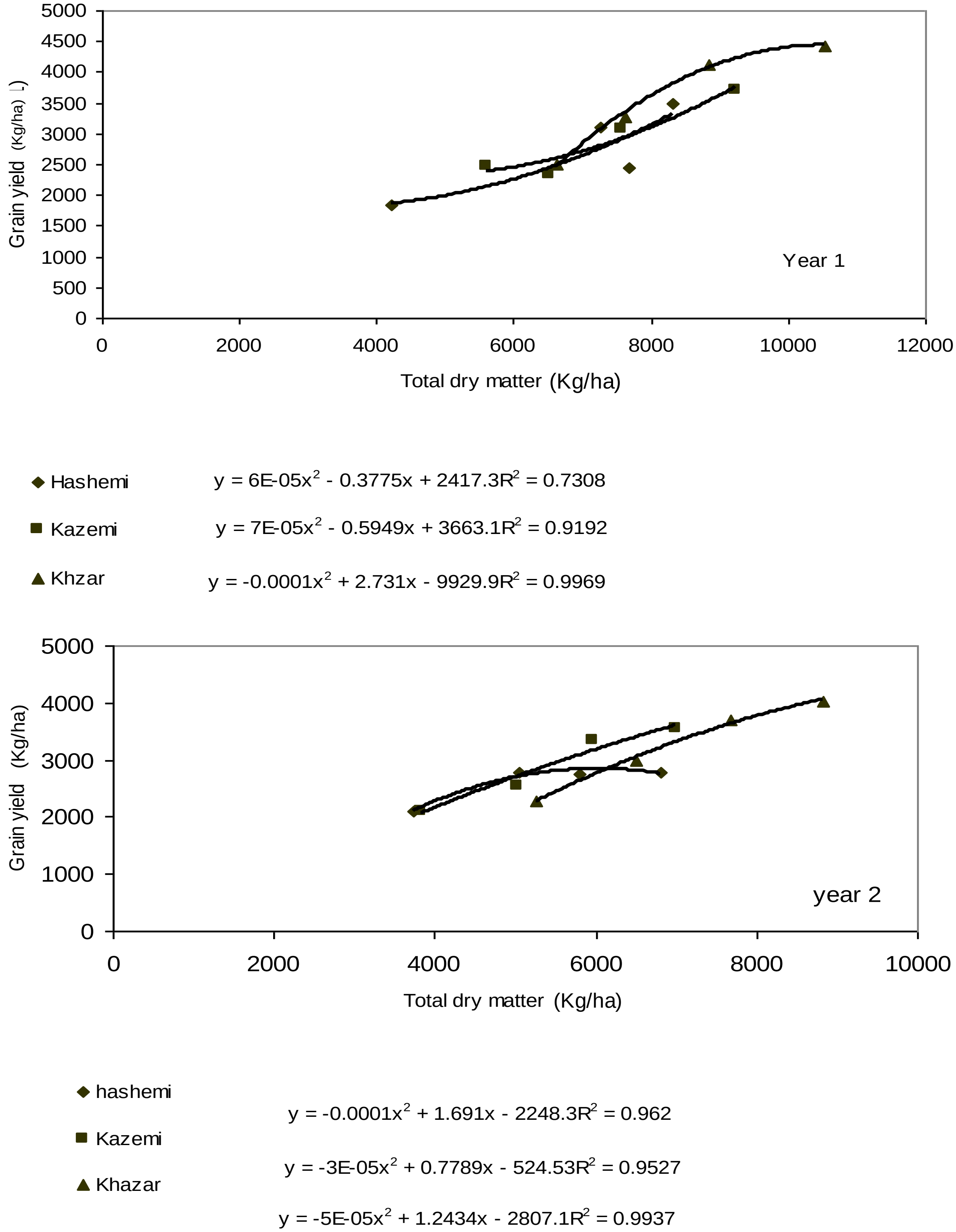

Figure 6. Relationship between total dry matter and grain yield for 2008 to 2009.

increase in GC and then a lowering trend resulted (Table 6 and Figure 10). However, in Ali kazemi, results appeared that there is a negative linkage between N rate and GC (Figure 10). Ju-Young et al. (2006) in results of their research on Japanese rice varieties showed that in the low amount of nitrogen fertilizer, there is a significant and positive correlation between starch branching enzymes activity and GC. Thus, with an increase in those enzymes activity, the amylopectin percentage increased and GC also showed an increase. Ju-Young et al (2006) showed that with an increase in nitrogen fertilizer amount, GC decreased. Of course, environmental conditions such

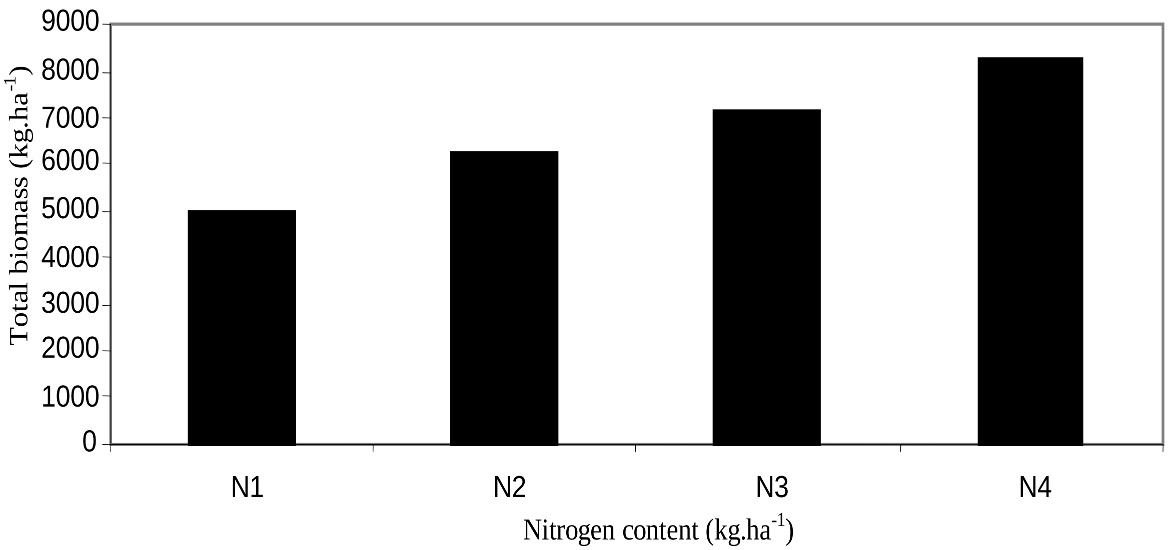

Figure 7. Effect of N fertilization on biomass during 2008 to 2009.

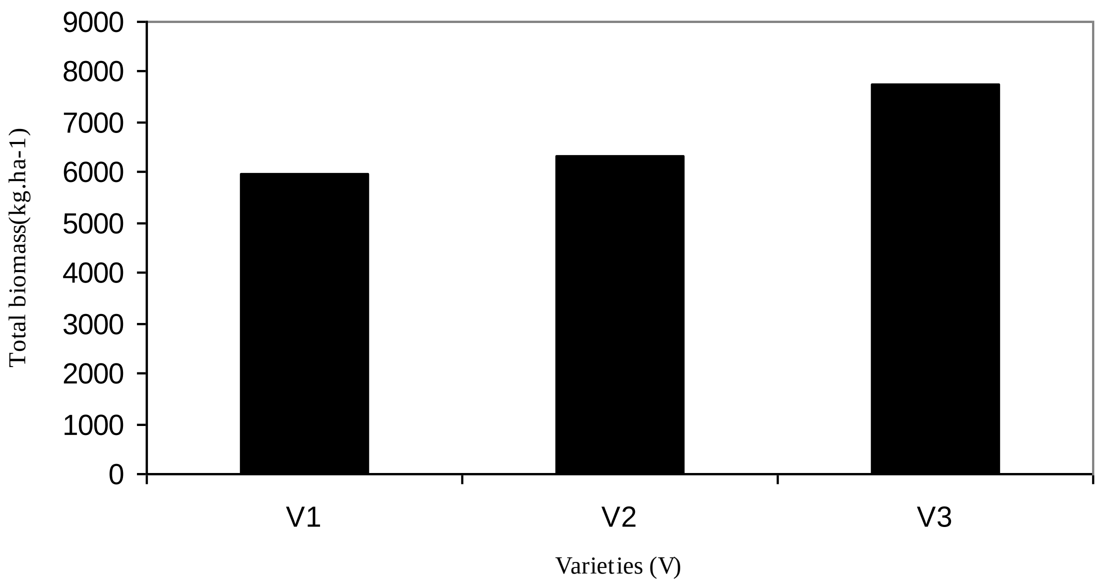

Figure 8. Effect of varieties (V) on biomass, 2008 to 2009 (V1, Hashemi; V2, Ali kazemi; V3, Khazar).

as temperature during rice seed maturity affected on the GT to strongly. The review of variance analysis showed that between different amount of nitrogen fertilizer usage and its influence on GT rating there is no significant difference (Table 5).

The study of results in regard to existence of simple correlation between qualitative properties of examined cases show a very significant positive correlation (0.771) between AC and the GT. In other cases except correlation between AC with GC which was negative, others showed a positive correlation between each other (Table 6). Therefore it appears that there is a linkage between related genes of AC and GT and GC or perhaps caused by the high correlation of these properties. So in choosing genotypes for improving quality of rice, a special attention must be given.

The study of results about simple correlation between nitrogen rates on all qualitative properties show that in each of the three examined varieties, there is a negative correlation between nitrogen amount and GC. In Ali kazemi varieties, correlation between nitrogen amount and AC is positive and in Hashemi variety is negative. In addition Ju-Young, (2006) confirms the existence of negative correlation between nitrogen amount and AC in

Table 4. Correlation between grain yield and yield components.

Plant parameter	Grain yield
Plant height	0.47^{ns}
Number of grain per panicle	0.89*
1000-grains weight	0.42^{ns}
Tillers/m2	0.37^{ns}
Panicles/m2	0.068^{ns}
Biomass	0.92**
Harvest index (HI)	0.165^{ns}
Unfilled percent	0.42^{ns}

*, ** and ns indicate significance at 5%, 1%probability level and non significant, respectively.

Table 5. Results of analysis of variance of studied variable (quality parameters).

Source	AC (%)	GC (cm)	GT (°C)
Year (Y)	24.5**	42.36**	0.56^{ns}
R	4.33**	96.02**	12.54**
V	3.88^{ns}	2.36^{ns}	0.36ns
Y×N	76.13**	11.22**	51.20**
N	154**	41.96**	2.37^{ns}
Y×V	0.19^{ns}	0.29^{ns}	8.23**
N×V	2.24^{ns}	9.46**	0.39^{ns}
Y×N×V	1.75^{ns}	0.19^{ns}	1.52^{ns}
Error	36.68	8.52	11.68
CV	2.69	14.18	4.2

*, ** and ns indicate significant at 5%, 1% probability level and non significant, respectively. AC, Amylose content; GC, gel consistency; GT, gelanization temperature.

Table 6. Results of comparison of average of studied variables between fertilizer contents in confidence level of 5% (quality parameters).

N	AC (%)	GC (cm)	GT(°C)
N1	22.75^{a}	39.61^{c}	4.54^{a}
N2	21.71^{b}	47.33^{b}	4.26^{a}
N3	20.99^{d}	52.97^{a}	4.1^{a}
N4	21.41^{c}	46.91^{b}	4.18^{a}

N1, 0 kg N /ha; N2, 30kg N /ha; N3, 60kgN / ha; N4, 90 kgN /ha. AC, AMYLOSE content; GC, gel consistency; GT, gelanization temperature.

the grain (Table 7). In consideration of produced results from the study of the effect of different tending varieties and observed changing trend in studied properties, it can be perceived that in Hashemi and Khazar varieties anytime amount increases from N1 to N3, AC and GT will decrease but GC will increase. From N3 to N4 (nitrogen amount increase) GC lowers, but AC and GT showed an increase. In Ali kazemi variety with an increase in nitrogen amount, an increase in GC and a decrease in GT and AC were observed. Significant positive correlation between GT and AC was observed (Table 8). These results therefore show that with a proper manage-ment of nitrogen fertilizer amount, chemical and nutritious quality of rice in different varieties can be improved, although suggestion for the best usage amount requires more investigation.

Conclusion

Nitrogen fertilization significantly increased grain yield, plant height, number of tillers, number of panicles and dry

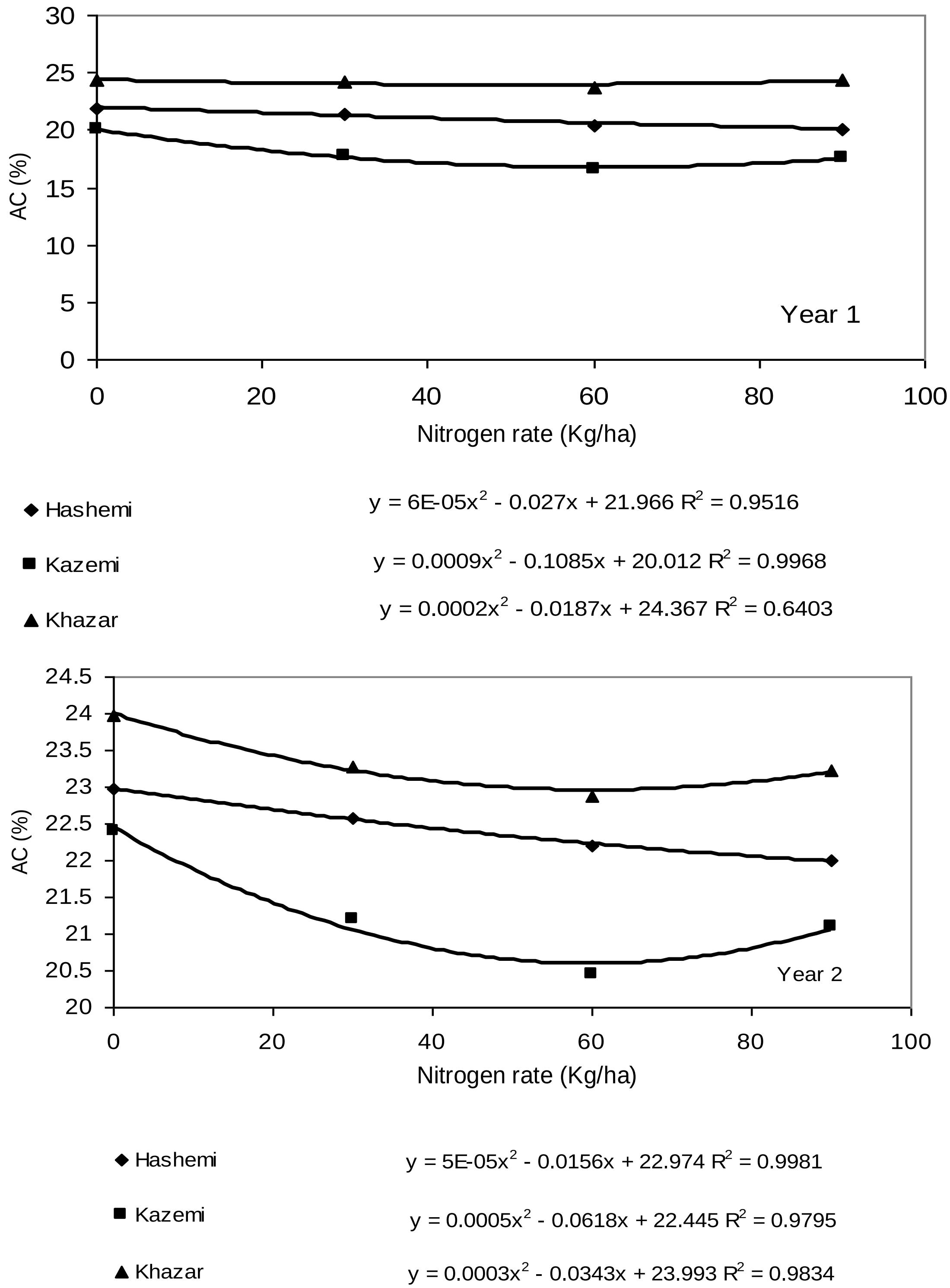

Figure 9. Effect of N fertilization on AC in 2008 to 2009. AC, Amylose content.

matter production. The highest grain yield was 3662 kg ha^{-1} with 90 kg N ha^{-1}. These differences were explained by higher total grains per panicle and the resulting higher dry matter production. Also, N1 (0 Kg N /ha) showed the highest AC (22.75%), whereas N3 (60 kg N ha^{-1}) causes the highest GC (52.97 mm). The above results show that with a proper management of nitrogen fertilizer amount, agricultural, chemical and nutritious parameters of rice in

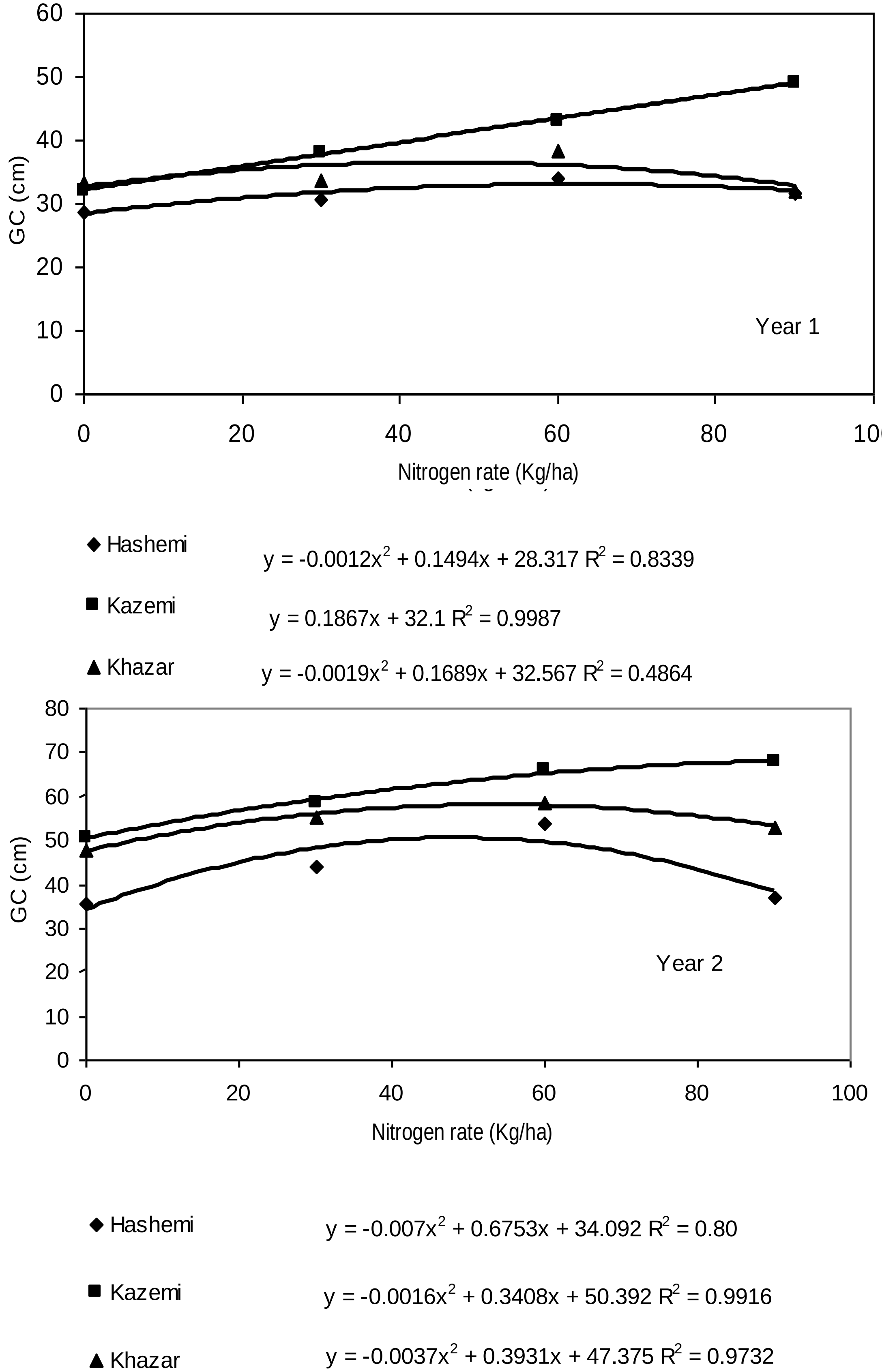

Figure 10. Effect of N fertilization on GC in 2008 to 2009. GC, Gel consistency.

Table 7. Evaluation of correlation between quality parameters.

Parameter	AC	GC	GT
AC	1	-0.078	0.771**
GC		1	0.485
GT			1

*, ** and ns indicate significant at 5%, 1% probability level and non significant, respectively. AC, Amylose content; GC, gel consistency; GT, gelanization temperature.

Table 8. Evaluation of correlation between different contents N fertilizer and quality parameters.

Parameter	N- content		
	Hashemi	Ali kazemi	Khazar
AC	-0.936	0.486	0.486
GC	0.788	0.948	0.948
GT	-0.162	-0.902	-0.881

AC, Amylose content; GC, gel consistency; GT, gelanization temperature.

different varieties can be improved, although suggestion for the best usage amount requires more investigation.

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