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EVALUATION OF QUANTITATIVE, QUALITATIVE TRAITS AND COMPATIBILITY OF RICE GENOTYPES IN TWO REGIONS OF IRAN

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Abstract

In order to evaluate quantitative and qualitative traits and compatibility of rice cultivars, an experiment was conducted with 30 rice genotypes in a randomized complete block design with four replications in two regions of Mazandaran Province (Amol and Sari) in 2018–2019. The results of composite variance analysis of data showed that the interaction between genotype and location on all quantitative and qualitative traits was significant except for grain yield. A significant difference was found between the studied genotypes in terms of grain yield, indicating genetic diversity of the studied genotypes. The results showed that Amol II, Dasht and Keshvari cultivars had acceptable grain yield and desirable quality characteristics. The grain yield had a positive and direct correlation with traits of the plant height, panicle length, number of fertile tillers per hill and Thousand grain weight, but this correlation was not significant.

Introduction

Rice is the staple food of more than 2 billion people in Asia, providing about 80% of energy needs from rice. Rice contains 80% carbohydrates, 7–8% protein, 3% fiber and 3% fat (KADAM et al. 2018). The interaction between genotype and locations refers to the relative yield of cultivars among different locations, which indicates differences in the ranking of genotypes, or in other words, differences in the level of expression of genetic differences between locations (LI et al. 2017). In order to identify rice genotypes with relatively wide compatibility, studies on the amount and patterns of interaction between genotype and locations are of great importance (SHARIFI et al. 2017). In order to select genotypes to increase grain yield, yield-related traits should be considered due to the complexity

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and relationship between yield and yield components (OLADOSU et al. 2018). Yield is a complex trait that is controlled by many factors such as polygenesis, locations, and genetic diversity (USMAN et al. 2017).

The yield of rice genotypes will fluctuate significantly with changing environmental conditions (BOSE et al. 2014). The choice of genotype is necessary based on the evaluation of yield stability from the mean yield under different environmental conditions (ISLAM et al. 2016). Determining the yield of a genotype is determined by the effects of the genotype and locations and their interaction (YAN et al. 2007). By evaluating the compatibility of 30 rice genotypes to the climatic conditions of West Gilan during the two years of cultivation, Saeedzadeh reported that a significant difference was found between the genotypes in terms of most of the studied traits. Among the studied genotypes, the traits of the number of tillers per plant, the yield of each plant and harvest index showed a positive and significant correlation with grain yield (SAEEDZADEH 2010).

Other researchers studied improved rice genotypes in different parts of Indonesia and found that grain yield was affected by the effects of genotype, location, and interaction between genotype and location (TARIKU 2017). MOMENIZADEH et al. (2015) in the study of the interaction between rice genotype and locations in Mazandaran reported that the interaction between genotype and locations for the traits of the number of hollow grains per ear, the capacity of hollow grain, total number of grains, total grain capacity and harvest index was significant, indicating different reactions of genotypes from one place to another.

The researchers by evaluating the interaction between genotype and locations on grain yield of promising rice improved lines in different regions of Mazandaran Province during three years reported that a significant difference was found between genotypes in terms of studied traits such as the plant height, number of ears per plant, number of grains per ear and grain yield in most places (MOMENI et al. 2018). By examining the compatibility of different rice genotypes to different locations in southern China and Laos, ZHANG et al. (2017) reported that PR23 genotype with the highest yield and compatibility to the locations was selected as the top genotype for cultivation in humid and semi-humid areas as well as for grain production and forage in intercropping systems. In general, identifying high and stable yield genotypes in different locations, locations, seasons, and years can be of great help to breeders in recommending identified genotypes to farmers for cultivation. Therefore, this experiment was performed with the aim of evaluating the compatibility of 30 rice genotypes in two regions of Mazandaran Province to identify the best genotypes in terms of grain yield and quality.

Material and Methods

Experimental characteristics

In order to evaluate quantitative and qualitative traits and compatibility of rice genotypes, we compared 30 rice genotypes in the form of complete randomized design with four replications in two regions of Mazandaran Province (Field of the Department of Rice Research Institute of the country-Amol and Research Field of the Institute of Genetics and Biotechnology, University of Agricultural Sciences and Natural Resources of Sari) in 2018–2019 (Figure 1 and Figure 2). Amol Rice Research Institute is located between (36°28'N, 52°23'E), and at an altitude of 23 m above sea level. Sari University of Agricultural Sciences and Natural Resources is located between (36°39′ N, 53°4′E) and at an altitude of 11 m above sea level.

Fig 1. Cultivation of genotypes in University of Agricultural Sciences and Natural Resources

Fig 2. Cultivation of genotypes in Amol Rice Research Institute

Before performing the experiment, the soil of the experimental regions was sampled, the results of which were presented in Table 1. The profile of the genotypes examined in this experiment is also shown in Table 2.

Table 1

The names of the rice cultivars studied in the experiment

No	Genotypes	No	Genotypes
16	Doiar	1	Amol 1
17	IR42	2	Sepidrud
18	Fuji Minori	3	Khazar
19	Onda	4	pnd160-2-1
20	1-2-299-13429	5	Amol 2
21	IR36	6	Amol 3
22	Tabesh	7	Fajr
23	IR24	8	Usen
24	Pouya	9	Line 101
25	Keshvari	10	Nemat
26	Taichung 65	11	346
27	Senyu-285	12	Dasht
28	Neda	13	Bijar
29	Champa	14	BA370
30	IR56	15	Tetep

Table 2

Physico-chemical properties of soil Experimental areas at a depth of 0 to 30 cm soil

Parameter	Location	
–	Amol	Sari
Soil texture	Lum-Silti	Clay-Silti
[%]		
Clay	27	35
Silt	45	49
Sand	28	16
[mg kg^{-1}]		
P	8.5	8.7
K	100	109.7
([%]		
Organic matter	2.8	2. 1
[pH]		
Acidity total saturation	7	1.44
EC [dS m^{-1}]		
Electrical conductivity	7.2	1.84

During physiological maturity, 12 plants were randomly selected from each experimental plot and traits such as the plant height, panicle length, number of effective tillers per hill, number of filled grains, 1000 grain weight and grain yield were measured. Grain yield was calculated by harvesting an area of 4 square meters from each experimental unit after removing the marginal effects and based on 14% humidity. Some physical and chemical quality traits were also measured in the laboratory. The conversion efficiency was calculated using the ratio of the amount of white rice to the total initial rough rice. In order to measure the determinant traits of grain quality, such as amylose content, the methods of Juliano (JULIANO 1971), gelatinization temperature by LITTLE et al. (1958) and gel consistency, CAGAMPANG et al. (1973) were used. Data analysis of compound variance was performed using software MSTATC and mean comparison (LSD) based on the test of the least significant difference at the probability level of 5%. The correlation coefficient of the traits as well as the cluster analysis of the studied genotypes were performed using software SPSS.

Results

Plant height

The results showed that in general, the genotypes in Sari had a higher plant height compared to Amol, which indicates a different reaction of the genotypes studied in the two experimental sites. It seems that the better condition of the soil in Sari in terms of percentage of nutrients and organic matter has led to improved plant growth compared to Amol. The minimum plant height in Amol and Sari was observed with means of 65.75 and 97.75 cm, respectively, in genotypes 26 and 1 (Table 3). Long-legged varieties are more sensitive to weeds, so in addition to problems with crop harvesting, yield of these varieties is reduced. Diversity in plant height of rice is considered as one of the most important basic factors due to the interaction between genotype and location (NASSIR ARIYO 2011, SANDHU et al. 2019).

Panicle length

The length of the panicle in Sari was higher than in Amol (Table 3). The significant interaction between genotype and location for the length of the panicle indicates different reactions of genotypes to factors such as soil physical and chemical properties, latitude and longitude and altitude, which caused differences in the length of the panicle in the studied genotypes.

Table 3

Comparison of average quantitative traits of rice cultivars in two regions of Mazandaran province

No	Plant height		Panicle length		Number of effective tillers		Number of filled grains		Thousand grain weight		Grain yield		Average grain yield
	Amol	Sari	Amol	Sari	Amol	Sari	Amol	Sari	Amol	Sari	Amol	Sari	Amol and Sari
1	114.5^{k-n}	97.75^{q-v}	28.50^{hij}	19.50^{z}	18.50^{h-n}	12.50^{st}	174.3^{b}	78.50^{wx}	24.09^{a-i}	24.41^{a-h}	7260^{b-g}	6971^{b-j}	7116^{bc}
2	108.5^{m-p}	109.0^{m-p}	25.13^{o-r}	26.00^{l-q}	22.00^{c-g}	8.250^{u}	157.3^{cd}	141.5^{efg}	24.08^{a-i}	18.23^{p}	6024^{i-r}	5766^{l-v}	5895^{e-j}
3	108.0^{m-q}	175.3^{ab}	26.25^{l-p}	32.25^{de}	22.25^{c-f}	16.00^{m-r}	169.0^{bc}	143.0^{efg}	25.00^{a-g}	18.66^{op}	5804^{l-u}	5572^{n-w}	5688^{f-k}
4	115.0^{k-n}	119.5^{jkl}	25.63^{m-q}	35.75^{a}	17.75^{i-p}	17.75^{i-p}	149.8^{def}	95.25^{s-v}	27.05^{a}	20.44^{l-p}	6987^{b-i}	6680^{c-m}	6834^{b-e}
5	121.3^{jk}	127.0^{ij}	26.38^{l-o}	35.00^{ab}	17.25^{j-p}	17.00^{k-q}	114.5^{k-o}	138.8^{fgh}	24.75^{a-g}	21.16^{h-p}	7553^{abc}	7335^{a-f}	7444^{ab}
6	112.3^{k-o}	177.0^{a}	27.50^{i-l}	28.25^{ij}	25.50^{ab}	26.25^{ab}	98.75^{r-u}	119.8^{j-n}	25.24^{a-e}	25.75^{abc}	7026b–i	6755^{c-l}	6890^{b-e}
7	122.0^{jk}	134.3^{hi}	24.50^{q-t}	32.25^{de}	19.00^{g-m}	13.50^{rst}	79.50^{wx}	121.0^{i-m}	24.75^{a-g}	23.10^{c-m}	7235^{b-g}	6890^{c-k}	7063^{bcd}
8	97.0^{r-w}	121.3^{jk}	26.38^{l-o}	30.00^{gh}	16.50^{l-r}	17.50^{i-p}	88.00^{uvw}	117.5^{j-o}	23.86^{a-k}	20.35^{l-p}	6926^{c-j}	6723^{c-l}	6825^{b-e}
9	105.3^{n-s}	155.3^{c-f}	23.88^{r-u}	28.50^{hij}	16.00^{m-r}	27.00^{a}	115.0^{k-o}	111.5^{m-q}	24.25^{a-h}	20.60^{k-p}	5829^{k-t}	5568^{n-w}	5699^{f-k}
10	133.5^{hi}	154.5^{def}	23.38^{s-v}	32.50^{cde}	22.00^{c-g}	21.00^{d-h}	74.00^{x}	127.0^{hij}	23.88^{a-j}	22.02^{e-o}	7265^{b-g}	6960^{c-j}	7112^{bc}
11	137.5^{gh}	148.0^{ef}	27.13^{j-m}	32.50^{cde}	25.75^{ab}	17.00^{k-q}	97.75^{r-u}	158.5^{cd}	24.00^{a-j}	20.92^{i-p}	6117^{i-q}	5906^{j-s}	6011^{d-i}
12	128.8^{hij}	134.5^{hi}	26.13^{l-p}	27.50^{i-l}	19.75^{f-k}	15.25^{o-s}	119.3^{j-n}	140.8^{efg}	21.88^{f-o}	24.67^{a-g}	7482^{a-d}	7198^{b-h}	7340^{ab}
13	88.75^{vw}	149.8^{ef}	21.00^{xyz}	30.50^{fg}	18.00^{h-o}	14.75^{p-t}	138.0^{fgh}	121.8^{i-m}	25.63^{a-d}	24.38^{a-h}	5780^{l-v}	5605^{m-w}	5693^{f-k}
14	106.5^{m-r}	105.0^{n-s}	24.50^{q-t}	34.00^{bc}	17.50^{h-p}	20.50^{d-i}	147.3^{def}	144.5^{ef}	24.75^{a-g}	23.90^{a-j}	6326^{e-o}	6191^{g-p}	6259^{c-g}
15	102.8^{o-t}	157.0^{cde}	24.80^{p-s}	27.25^{i-l}	18.00^{h-o}	19.50^{f-l}	93.25^{tuv}	97.00^{r-v}	24.99^{a-g}	23.39^{c-m}	4959^{r-w}	4721^{vw}	4840^{jk}
16	113.0^{k-o}	122.0^{jk}	23.88^{r-u}	34.25^{ab}	17.50^{i-p}	17.75^{i-p}	128.8^{hij}	120.0^{i-m}	21.75^{g-o}	23.39^{c-m}	4825^{t-w}	4713^{vw}	4769^{k}
17	96.75^{r-w}	145.0^{fg}	21.50^{wxy}	26.00^{l-q}	16.50^{l-r}	21.75^{c-g}	102.3^{p-t}	100.8^{q-t}	22.00^{e-o}	22.42^{d-n}	5709^{l-v}	5483^{n-w}	5596^{f-k}
18	93.75^{t-w}	110.3^{l-p}	23.13^{tuv}	31.25^{efg}	16.50^{l-r}	15.75^{n-r}	92.25^{tuv}	120.8^{i-m}	22.62^{c-n}	23.00^{c-m}	5104^{q-w}	4969^{r-w}	5036^{ijk}
19	92.25^{uvw}	165.5^{bc}	22.38^{u-x}	26.00^{l-q}	15.75^{n-r}	20.25^{e-j}	119.8^{j-n}	108.0^{n-r}	24.25^{a-h}	23.28^{c-m}	5286^{o-w}	5146^{p-w}	5216^{g-k}
20	104.0^{o-t}	115.8^{klm}	22.88^{uvw}	25.00^{o-r}	18.00^{h-o}	12.5^{0st}	120.3^{i-m}	85.50^{vwx}	25.66^{a-d}	21.91^{f-o}	5764^{l-v}	5614^{m-w}	5689^{f-k}
21	90.0^{vw}	149.0^{ef}	23.38^{s-v}	27.00^{j-n}	24.25^{abc}	17.50^{i-p}	131.8^{ghi}	100.5^{q-t}	27.00^{ab}	23.40^{c-l}	6356^{e-o}	6125^{h-q}	6240^{c-g}
22	95.0^{s-w}	183.8^{a}	22.88^{uvw}	33.75^{bcd}	22.00^{c-g}	16.25^{m-r}	177.3^{ab}	127.3^{hij}	23.75^{b-k}	23.12^{c-m}	6304^{f-o}	6071^{i-q}	6188^{c-h}
23	103.3^{o-t}	101.5^{p-u}	26.50^{k-o}	27.50^{i-l}	16.50^{l-r}	11.75^{t}	125.5^{ijk}	138.8^{fgh}	24.65^{a-g}	23.31^{c-m}	6656^{c-m}	6425^{d-n}	6540^{b-f}
24	87.0^{w}	103.0^{o-t}	22.00^{vwx}	25.50^{n-q}	24.75^{abc}	14.00^{q-t}	125.0^{i-l}	96.50^{r-v}	25.13^{a-f}	20.14^{m-p}	5343^{o-w}	5211^{p-w}	5277^{g-k}
25	90.0^{vw}	156.8^{cde}	22.13^{vwx}	33.50^{bcd}	27.25^{a}	13.75^{rst}	148.3^{def}	188.8^{a}	24.75^{a-g}	20.80^{j-p}	7648^{abc}	7396^{a-e}	7522^{ab}
26	65.75^{x}	161.8^{cd}	20.25^{yz}	28.75^{hi}	23.25^{b-e}	15.75^{n-r}	93.00^{tuv}	101.3^{q-t}	24.75^{a-g}	21.76^{g-o}	5197^{p-w}	5056^{q-w}	5126^{h-k}
27	89.50^{vw}	175.0^{ab}	19.00^{z}	31.75^{ef}	21.00^{d-h}	17.25^{j-p}	99.50^{r-u}	113.3^{l-p}	23.71^{c-k}	19.68^{nop}	5371^{n-w}	5150^{p-w}	5260^{g-k}
28	101.0^{p-u}	154.3^{def}	25.63^{m-q}	26.50^{k-o}	23.50^{bcd}	24.50^{abc}	91.50^{tuv}	79.25^{wx}	23.91^{a-j}	23.42^{c-l}	8353^{a}	8043^{ab}	8198^{a}
29	101.8^{p-u}	112.5^{k-o}	25.63^{m-q}	24.50^{q-t}	24.25^{abc}	26.00^{ab}	172.8^{b}	150.8^{de}	23.60^{c-l}	22.92^{c-n}	4738^{uvw}	4583^{w}	4660^{k}
30	105.0^{n-s}	151.5^{def}	28.00^{ijk}	31.75^{ef}	24.25^{abc}	17.75^{i-p}	174.8^{b}	106.5^{o-s}	24.65^{a-g}	23.54^{c-l}	5175^{p-w}	4912^{s-w}	5043^{ijk}

Similar letters in each column shows non- significant difference according to Duncan test at 5% level

Increasing the length of the panicle alone cannot be an important advantage unless it is accompanied by an increase in the number of florets and grains in the panicle (MENG et al. 2015). Studies by ZHANG et al. (2017) also show that a statistically significant difference was found in the length of rice panicle between the different genotypes studied and different experiment sites.

Number of effective tillers

The results showed that different experimental sites had different effects on the studied genotypes in terms of the number of effective tillers per hill, so that genotype 2, which had the lowest number of tillers among genotypes in Sari, had increased number of tillers by about 62.5% in Amol (Table 3). This diversity may be due to changes in topography (PENG et al. 2006), soil type, fertility and soil organic matter (GAO et al. 2006), as well as irrigation regimens, nutrient rounds, accessibility and nutrient uptake (KREYE et al. 2009). The researchers stated that the interaction between genotype and location was significant for the number of tillers, and that different genotypes had different numbers of tillers in experimental sites, which was consistent with the results of this experiment (POLI et al. 2018). The number of tillers per hill is directly related to grain yield per hectare, so that breeders focused on increasing the number of tillers per hill to increase grain yield of early matured genotypes in rainfed and irrigated regions (OLADOSU et al. 2018).

Number of filled grains

The results of mean comparison of the interaction between genotype and location showed that the highest number of filled grains with a mean of 188.8 grains related to genotype 25 (Keshvari cultivar) in Sari with genotype 22 (Tabesh cultivar) in Amol had no statistically significant difference (Table 3). The researchers reported that the effects of the genotypes under study, the environment and the interaction of the genotype and the environment on the number of feathers in the cluster were significant at the 1% probability level (OLADOSU et al. 2018). The researchers added that the number of filled grains is one of the criteria for selecting a genotype to improve rice grain yield. In similar results to the present study, SHARIFI and AMINPANAH (2017) reported that a significant difference was found between the studied genotypes in terms of the number of filled grains. The researchers stated that among 9 genotypes studied, genotype 6 was selected as the best genotype with a mean of 139.89 number of filled grains. High genetic diversity coefficients have been reported by researchers for the number of filled grains (BITEW 2016, RUKMINI DEVI et al. 2016).

Thousand grain weight

The results of mean comparison of the interaction between genotype and location showed that the maximum Thousand grain weight with a mean of 27.05 g belonged to genotype 4 (pnd160-2-1) in Amol, which with other genotypes in this region except genotypes 12, 16, 17, 18, 22, 27 and 29 showed no statistically significant difference (Table 3). The highest 1000 grain weight in Sari (25.75 grams) was related to genotype 6 (Amol III) which was grouped with statistical genotypes in this region. The minimum 1000 grain weight with a mean of 18.23 g belonged to genotype 2 (Sepidroud) in Sari (Table 4). ZHANG et al. (2017) and OLADOSU et al. (2018) reported similar results with this study on the significant difference in 1000-grain weight between different genotypes and experimental sites. 1000 grain weight is a trait that has a lot to do with grain yield (BALAKRISHNAN et al. 2016).

Grain yield

The results of mean comparison of data showed that the maximum mean grain yield with a mean of 8198 kg/ha belonged to genotype 28 (Neda cultivar) which was not statistically different from genotypes 5 (Amol II cultivar), 12 (Dasht cultivar) and 25 (Keshvari cultivar). Neda cultivar produced a high number of fertile tillers in both Amol and Sari, which could be a reason for the increase in grain yield in this genotype (Table 3). The number of fertile tillers per hill is one of the important components determining grain yield, and paying attention to this functional component is one of the basic issues before successful breeding plans (OLADOSU et al. 2018). A significant difference was found in yield between the studied genotypes, which indicates high genetic diversity for the selection of genotypes. Other researchers also found that a statistically significant difference was found between different genotypes studied in terms of grain yield (ZHANG et al. 2017), which was consistent with the study results. Different genotypes have high diversity in terms of mean production yield (NASSIR ARIYO 2011, POLI et al. 2018). Significant differences between genotypes in terms of the amount of crop produced have also been reported in the results of other researchers (NASSIR ARIYO 2011, POLI et al. 2018).

Table 4

Comparison of average quality characteristics of rice cultivars in two regions of Mazandaran province

No	Amylose content		Consistency gel		Gelatinization temperature	
–	location					
	Amol	Sari	Amol	Sari	Amol	Sari
1	23.00^{l-q}	21.35^{s-w}	60.38^{rst}	59.00st	3.685^{n-t}	2.670^{z}
2	24.63^{d-i}	22.88^{m-q}	60.50^{rst}	60.25^{rst}	2.883^{xyz}	3.200^{t-y}
3	20.25^{x}	20.40^{wx}	69.25^{ij}	72.00^{gh}	2.543^{z}	3.415^{o-w}
4	25.17^{b-e}	25.73^{bc}	56.00^{u}	55.25^{u}	3.050^{w-z}	3.000^{w-z}
5	23.55^{k-p}	25.00^{c-f}	70.75^{hi}	62.50^{m-q}	3.105^{v-z}	3.365^{p-x}
6	22.70^{o-r}	22.80^{m-r}	38.50^{z}	42.50^{z}	3.152^{u-z}	3.315^{q-y}
7	21.83^{r-u}	23.02^{l-q}	82.35^{c}	72.95^{fg}	5.925^{de}	4.520^{g-j}
8	21.20^{t-x}	22.85^{m-r}	63.50^{lm}	65.50^{k}	3.890^{l-o}	3.822^{l-p}
9	23.95^{g-l}	24.30^{e-k}	61.00^{o-r}	63.00^{mn}	3.780^{m-r}	4.250^{i-m}
10	25.13^{b-f}	24.88^{c-g}	45.00^{y}	48.75^{wx}	3.250^{s-y}	3.625^{n-u}
11	22.10^{q-t}	22.25^{qrs}	50.50^{vw}	50.25^{vw}	6.150^{cd}	5.970^{d}
12	24.13^{f-k}	23.77^{h-n}	89.13^{a}	81.50^{c}	3.188^{u-y}	3.307^{r-y}
13	21.20^{t-x}	23.38^{k-p}	87.15^{b}	74.25^{ef}	6.550^{abc}	6.088^{cd}
14	20.83^{u-x}	21.20^{t-x}	72.25^{gh}	70.75^{hi}	6.673^{ab}	6.963^{a}
15	20.55^{vwx}	20.70^{vwx}	65.50^{k}	62.50^{m-q}	6.250^{bcd}	5.963^{d}
16	21.52^{s-v}	22.67^{pqr}	68.80^{j}	68.25^{j}	2.638^{z}	3.370^{p-w}
17	20.92^{u-x}	20.23^{x}	28.75^{z}	35.25^{z}	3.273^{s-y}	3.017^{w-z}
18	26.13^{b}	24.60^{d-j}	34.65^{z}	36.60^{z}	6.368^{bcd}	4.787^{gh}
19	20.98^{u-x}	27.17^{a}	65.50^{k}	66.03^{j}	5.000^{fg}	4.505^{hij}
20	23.73^{i-o}	24.67^{d-i}	44.75^{y}	50.00^{vw}	4.000^{k-n}	4.050^{j-n}
21	23.58^{j-p}	20.55^{vwx}	48.03^{x}	51.30^{v}	3.175^{u-y}	3.800^{m-q}
22	24.75^{c-i}	23.83^{h-m}	60.50^{rst}	62.55^{m-p}	3.410^{o-w}	3.705^{n-s}
23	20.48^{wx}	20.77^{vwx}	58.70^{t}	60.65^{qrs}	4.550^{ghi}	4.000^{k-n}
24	25.13^{b-f}	20.98^{u-x}	60.75^{p-s}	60.55^{rst}	2.832^{yz}	3.080^{w-z}
25	25.05^{c-f}	24.73^{c-i}	86.15^{b}	81.57^{c}	3.938^{k-n}	3.585^{n-v}
26	23.02^{l-q}	23.75^{i-n}	63.70^{klm}	65.30^{kl}	4.050^{j-n}	4.052^{j-n}
27	21.20^{t-x}	23.00^{l-q}	34.50^{z}	30.75^{z}	3.210^{t-y}	3.938^{k-n}
28	24.80^{c-h}	25.45^{bcd}	77.35^{d}	75.32^{e}	6.700^{ab}	6.875^{a}
29	22.77^{n-r}	23.73^{i-o}	62.70^{mno}	61.38^{n-r}	5.300^{f}	5.450^{ef}
30	24.60^{d-j}	25.20^{b-e}	41.70^{z}	47.30^{x}	4.300^{i-l}	4.400^{h-k}

Qualitative characteristics

The highest amylose content with a mean of 27.17% was related to genotype 19 (Onda cultivar) in Sari, which had a significant difference with other genotypes in both studied locations. The maximum content of amylose in Amol (26.13%) was observed in genotype 18 (Fuji Minori cultivar) – Table 4. According to the method of Juliano (JULIANO 1971), rice varieties based on the content of amylose are classified as waxy (0 to 2%), very low in amylose (3 to 9%), low in amylose (10 to 19%), moderate amylose (20 to 25%) and high amylose (more than 25%). According to this classification, in addition to genotypes 4, 18, 24 and 25 in Amol and genotypes 4, 19 and 28 in Sari which were in the category of high amylose rice, other genotypes studied in two locations were classified as moderate amylose.

Moderate-amylose cultivars are separated after cooking and remain soft for a long time, while high-amylose cultivars are dry (RAY and HILLER-ISLAMBERS 1989) and low-amylose cultivars are glazed and sticky (JULIANO 1971).The researchers examined the interaction between genotype and locations on the quality of rice grain and stated that in multi location experiments, the stability of grain quality is considered as a criterion for selecting the best genotype (PADMAVATHI et al. 2013). The results showed that the maximum gel consistency with a mean of 89.13 mm belonged to genotype 12 (Dasht cultivar) in Amol and the lowest gel consistency in this region with about 67.7% reduction was related to genotype 17. The maximum gel consistency in Sari with a mean of 81.57 mm was related to genotype 25 (Keshvari cultivar) – Table 4. The highest gelatinization temperatures, with means of 6.963 and 6.875º C, were related to genotypes 14 (BA370) and 28 (Neda cultivar) in Sari, which did not have a statistically significant difference with genotypes 13, 14 and 28 in Amol (Table 4). The results showed that BA370 and Neda cultivar genotypes had high gelatinization temperature in both locations (Table 4). The minimum gelatinization temperature with about 63.4% reduction was related to genotype 3 in Amol. In rice quality evaluations, scores of 3 to 5 were desired for rice gelatinization, the most native and high-quality Iranian genotypes are in this range. High gelatinization temperature causes cooked rice to harden and dry, and low gelatinization temperature causes rice to soften and stick after cooking. The low and medium rice gelatinization temperatures compared to high rice gelatinization temperature need less water and time to cook, which is a good feature (KASAI et al. 2001).

The study results showed that in Sari, apart from genotypes, other genotypes studied had a good gelatinization score. Also in Amol, with the exception of genotypes, other genotypes had a desired range in terms of gelatinization temperature. The results of the present study showed that genotypes in both experimental sites had similar degrees of gelatinization temperature, which were in the range of high rice gelatinization temperature. By investigating cooking quality of grains of different rice genotypes in Mazandaran to select the best genotypes, the researchers reported that among the studied genotypes, genotypes 7302 and 7304 were suitable for planting in northern Iran due to good cooking quality and were selected as the best genotypes (RAHIM SOUROSH et al. 2007).

Correlation coefficient

In the present experiment, the correlation between grain yield and traits of plant height, ear length, number of fertile tillers per hill and 1000 grain weight was positive but not significant. Grain yield showed a positive and significant correlation at the probability level of 1% with the qualitative traits of amylose content and gel consistency. The plant height and ear length were very strongly correlated. Also, the length of the ear and the number of fertile tillers per hill were positively correlated with amylose content, especially the number of tillers, which was significant at the probability level of 1% (Table 5). By examining the interaction between genotypes in the locations, ZHANG et al. (2017) reported that a positive and significant correlation was found between grain yield and number of grains per square meter for the studied genotypes. Other researchers also found that grain yield was positively correlated with traits such as the plant height, panicle length, and 100-grain weight (SHARIFI and EBADI 2018), which was consistent with the study results.

Table 5

Correlation coefficients of the studied traits in two test sites (Amol and Sari)

Plant height	Panicle length	Effective Tillers	Total number of grains	Tho-usand grain weigh	Grian yield	Amylose content	Con-sistency gel
1	–	–	–	–	–	–	–
0.579	1	–	–	–	–	–	–
-0.090	-0.169	1	–	–	–	–	–
-0.059	0.190	0.048	1	–	–	–	–
-0.246	-0.283	0.251	0.015	1	–	–	–
0.004	0.070	0.070	-0.011	0.107	1	–	–
0.090	0.144	0.212	0.037	0.008	0.183	1	–
-0.015	0.044	-0.059	0.206	0.033	0.280	-0.002	1
-0.010	0.031	0.100	-0.105	0.091	-0.051	-0.037	0.218

Discussion

In the present experiment, the correlation between grain yield and traits of plant height, ear length, number of fertile tillers per hill and 1000 grain weight was positive but not significant. Grain yield showed a positive and significant correlation at the probability level of 1% with the qualitative traits of amylose content and gel consistency. The plant height and ear length were very strongly correlated. Also, the length of the ear and the number of fertile tillers per hill were positively correlated with amylose content, especially the number of tillers, which was significant at the probability level of 1% (Table 5). By examining the interaction between genotypes in the locations, ZHANG et al. (2017) reported that a positive and significant correlation was found between grain yield and number of grains per square meter for the studied genotypes. Other researchers also found that grain yield was positively correlated with traits such as the plant height, panicle length, and 100-grain weight (SHARIFI and EBADI 2018), which was consistent with the study results. The results showed that a significant difference was found between the experiment sites only in terms of the plant height, ear length, number of fertile tillers and thousand grain weigh. A significant difference was found between the genotypes in terms of all quantitative and qualitative traits. The interaction between genotype and location was significant except for grain yield on other studied traits. The genotypes of Amol II, Dasht, and Keshvari had good physical and chemical quality properties, although the yield of Neda cultivar was higher than the mentioned cultivars. Grain yield had a positive and direct correlation with traits of the plant height, ear length, number of fertile tillers per hill and Thousand grain weight, but this correlation was not significant.

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