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Original Article

Application of correlation coefficients and principal components analysis in stability of quantitative and qualitative traits on rice improvement cultivation

Aplicação de coeficientes de correlação e análise de componentes principais na estabilidade de características quantitativas e qualitativas no cultivo de melhoramento de arroz

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Abstract

In order to investigate the stability of qualitative and quantitative traits and choose the most appropriate cultivation method and irrigation regime in rice plants, the experiment was conducted in the form of a split-plot design based on a randomized complete block design in three replications and in two cropping years. The results of compound analysis indicated that the effect of year × irrigation regimes in terms of traits, grain yield, rainfall, productivity 2, number of full grains, number of hollow grains, harvest index, percentage of crushed grains and yield of white rice, the effect of year × Cultivation method characteristics in terms of water consumption, rainfall, productivity 1, number of tillers, plant height, spike length, number of hollow grains, thousand seed weight, small grain percentage and white rice yield and the effect of irrigation regime × cultivation methods in terms of all Traits except traits productivity 2 were significant. The results of the mean comparison of the interaction effect of irrigation regimes and cultivation methods also showed that treatments T1W1, T2W1 and T1W3 are favorable for all evaluated traits. Based on the table of correlation coefficients, correlation diagram and map of the intensity of the correlation in the years of the experiment, it is possible to report the correlation of the grain yield trait with the traits of water consumption, rainfall, plant height, 100- seed weight, full grain number and white rice yield. Also, traits productivity 1, productivity 2 and small grain percentage showed a positive correlation and a negative correlation of these three traits with most of the traits evaluated in the experiment was observed. Based on the analysis of the main components, the first four main components explained the most data variance, and T2W2 and T2W3 treatments were identified as suitable treatments for rice cultivation in terms of the first and second main components.

Keywords: stability, rice, adaptability, irrigation regimes, correlation, PCA.

Resumo

Para investigar a estabilidade dos caracteres qualitativos e quantitativos e escolher o método de cultivo e regime de irrigação mais adequados em plantas de arroz, o experimento foi conduzido em esquema de parcelas subdivididas em blocos completos em três repetições e em dois anos de colheita. Os resultados da análise composta indicaram os seguintes fatores significativos: o efeito dos regimes de irrigação do ano X em termos de características, rendimento de grãos, pluviosidade, produtividade 2, número de grãos cheios, número de grãos ocos, índice de colheita, porcentagem de grãos esmagados e rendimento de arroz branco, o efeito do ano X, características do método de cultivo relativamente ao consumo de água, precipitação, produtividade 1, número de perfilhos, altura da planta, comprimento da espiga, número de grãos ocos, peso de 1000 sementes, porcentagem de grãos pequenos e rendimento de arroz branco e o efeito da irrigação no regime X, métodos de cultivo em relação a todos os caracteres, exceto os caracteres produtividade 2. Já os resultados da comparação média do efeito de interação entre regimes de irrigação e métodos de cultivo também mostraram que os tratamentos T1W1, T2W1 e T1W3 são favoráveis para todas as características avaliadas. Com base na tabela de coeficientes de correlação, diagrama de correlação e mapa da intensidade da correlação nos anos do experimento, é possível relatar a correlação da característica produtividade de grãos com as características consumo de água, pluviosidade, altura de planta, 100 - peso da semente, número de grãos cheios e rendimento do arroz branco. Além disso, os caracteres produtividade 1, produtividade 2 e porcentagem de grãos pequenos apresentaram correlação positiva e foi observada correlação negativa desses 3 caracteres com a maioria dos caracteres avaliados no experimento. Por fim, com base na análise dos componentes principais, os quatro primeiros componentes principais explicaram a maior variância dos dados,

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e os tratamentos T2W2 e T2W3 foram identificados como tratamentos adequados para o cultivo de arroz quanto aos primeiro e segundo componentes principais.

Palavras-chave: estabilidade, arroz, adaptabilidade, regimes de irrigação, correlação, PCA.

1. Introduction

Rice (*Oryza sativa L.*) is one of the world's most important crops; after wheat, it has taken second place in annual production. With a global production of more than 700 million tons per year and a harvest area of nearly 165 million hectares, rice constitutes the main food of more than half of the world's population, and in large part of the Asian continent, it provides more than 80% of calories and 75% of the protein consumed by people (Ben Hassen et al., 2017). With the increase in the world population, the increase in food is inevitable in order to meet the nutritional needs of the people. Solving such inconsistency requires increasing the yield of crops per unit area, which is the most important solution to save humanity from poverty and hunger (Pourgholam-Amiji et al., 2020). Water shortage in many countries, including Iran is one of the main challenges of governments. In such countries, more than 70% of renewable water resources are used in the agricultural sector (Heydari, 2019). In Iran, the agricultural sector's share of renewable water during statistical periods of 7 and 50 years is 52 and 71 percent, respectively (Kohzad et al., 2020). Population growth, changes in the standard of living and a decrease in rainfall are among the factors that cause the balance between water supply and demand (Duvvada et al., 2020), hence increasing productivity to feed the growing population using Efficient water management practices and water saving technologies are essential (Zhang et al., 2006). In terms of water consumption, rice requires the most water among all agricultural products, so to produce one kilogram of rice, farmers have to use 2 to 3 times more water than other grains (Ghoddosi et al., 2018). Iran has 0.57 million hectares of paddy fields, and irrigation is carried out in almost all paddy fields using flood irrigation regime and keeping 35 cm of water on the soil for the growing season (Ye et al., 2013). However, much of the total water used at the farm level is lost by evaporation, transpiration, seepage, and water infiltration. In addition, rice cultivation is threatened by climate change and is the most important challenge that irrigated agriculture will face worldwide. The effect of climate change makes it necessary to optimize water consumption in areas with rice irrigation. Considering the serious problems of lack of water during rice cultivation, limited resources and increasing water demand for urban and industrial uses, using the traditional method of permanent flooding to irrigate paddy fields is not justified in terms of water management (Kumar and Ladha, 2011). Investigating alternative rice production methods using less water is extremely important for food security. Therefore, in new agricultural research, one of the important approaches is saving water in rice production systems. Sedaghat et al. (2013) in research compared and investigated the possibility of using different irrigation methods compared to the traditional method and evaluated different irrigation methods. The results showed that the plant cultivars used as well as different irrigation methods were significantly different in terms of water consumption. The findings of Xu et al. (2019) showed various advantages of direct cultivation, including performance similar to the conventional method, savings in consumption and costs of irrigation, labor and production, and reducing methane gas emissions. Xu et al. (2019) reported that the yield in direct cultivation was about 12% less than in transplanting. In a study, Pourgholam-Amiji et al. (2020) Manual weeding leads to a reduction of the labor required for rice cultivation and there is no significant difference in terms of paddy yield with paddy cultivation. The results of Chauhan and Johnson's (2010) studies showed that in direct cultivation of rice, weed intensity is higher than that of seed cultivation because in this system, weeds grow at the same time as rice, and there is no water height necessary to suppress weeds as in the seed method, and the risk of re-ducing Rice yield is very serious due to weed competition. Devkota et al. (2020) reported that direct cultivation of rice can improve soil productivity, minimize costs, increase household income, increase yield, and reduce fertilizer and land preparation costs. Singh et al. (2019) during a, research on rice water management under drip irrigation in India concluded that the water requirement of rice irrigation in the drip method is in the range of 1838-938 liters/kg, while this amount was 4250-5508 liters/kg in flood irrigation. The importance of irrigation management in increasing crop yields confirms that any attempt to optimize rice cultivation without special attention to water management will not be successful. The studies conducted by the above researchers showed that changing the method of rice cultivation and irrigation greatly affects water consumption, yield and water efficiency in the production of this plant. Hassan and Behzad (2011) compared the difference between direct and conventional rice cultivation methods. According to the results, the difference in yield of cultivars in different cultivation methods was significant and the highest and lowest yields were observed in conventional and direct seed method. Sidhu et al. (2014) also showed that the yield in conventional cultivation was significantly higher than the yield in the direct method. The results of studies, Liu et al. (2015), showed that the seed yield of direct rice cultivation was the same as the seed yield of conventional rice cultivation, but direct rice cultivation consumed 15.3% less water than conventional cultivation. According to Kaur and Singh (2017), direct cultivation of rice seeds offers certain advantages due to the low input demand, which saves water and labor, early harvest, low production cost, suitable physical soil conditions for the next crops and propagation. Less methane gas is produced and hence it is a suitable option in different rice cultivation systems. In some reports, the use of direct rice cultivation method leads to a decrease in yield, and some reported no decrease in yield in this method of cultivation (Puramir et al., 2019), and regarding the preparation of the cultivation. In order to reduce water consumption and increase water productivity, the traditional cultivation method was introduced as a suitable method of cultivation in a non-polluting substrate (Hossen et al., 2018; Illes et al., 2021). Kruzhilin et al. (2017) investigated the drip irrigation method on rice. According to the results, using drip irrigation of rice, the yield of 5, 6 and 7 tons per hectare of grain was observed. The results showed the possibility of rice cultivation under the drip irrigation system with a significant reduction in the amount of irrigation water and high profitability. Considering the importance of rice cultivation, it is necessary to plan carefully for the optimal use of available water resources in the agricultural sector, especially rice, so that the water demand for rice production is reduced and while maintaining optimal performance, by reducing water consumption, it increases profit. Considering water problems, which is the most important threatening factor in the production of agricultural products, especially rice and the importance of reviewing the traditional methods of water consumption and providing appropriate solutions, this research aims to determine the effect of different cultivation and irrigation methods on Morphological, biological and physiological characteristics of Fajr variety were done. The purpose of this research: 1) Selecting and identify the most suitable cultivation method and irrigation regime in rice cultivation, 2) Investigate cultivation methods and irrigation regimes in rice cultivation in the experimental years, 3) Investigating the correlation between grain yield and other quantitative traits and also evaluating the correlation between traits, 4) evaluation of the most appropriate irrigation regime in order to reduce water consumption..

2. Materials and Methods

In order to investigate the stability of qualitative and quantitative traits, as well as to investigate yield and yield components in rice plants, an experiment was conducted in the form of a split plot based on a randomized complete block design in three replications and two cropping years. The experiment area had a longitude of 51° 18' 2.0016" E and a latitude of 36° 27' 11.0016" N, an altitude of 400 meters and an average rainfall of 665 mm per year. The main factor in three levels was continuous irrigation throughout the day (T1), irrigation two days after the water disappeared from the ground surface (T2) and permanent soil saturation (T3). The secondary factor also included three cultivation levels without plowing (W1), 60 cm stack (W2) and 80 cm stack (W3). Table 1 shows the characteristics of treatments and traits evaluated in the experiment. The preparation of the field was done before the test components and the applied fertilizer was used in the same way for all treatments. The 21-day-old seed-lings of Fajr variety were planted on the ridges with a distance of 20 cm, and the dimensions of the irrigation plots were designed as 3 x 7 meters. The water consumption was measured by a volume meter, and to prevent side leakage losses, the borders of the plots were completely covered with plastic cover. Figure 1 shows the meteorological characteristics of the experimental years. In order to determine traits such as plant height and number of tiller per plant, 10 plants

Table 1. Characteristics of the treatments and traits evaluated in the experiment.

Treat Code.	Treatment	Traits Code.	Traits
T1	Permanent irrigation throughout the period	YLD	Grain Yield
T2	Irrigation after two days of water disappearing from the ground	CW	Consuming Water
T3	Permanent soil saturation throughout the growing season	RF	Rainfall
W1	Cultivation without plowing	PR1	Productivity 1
W2	Ridge Size 60cm	PR2	Productivity 2
W3	Ridge Size 80cm	NT	Number of Tiller
T1W1	Permanent irrigation throughout the period and Cultivation without plowing	PH	Plant Height
T1W2	Permanent irrigation throughout the period and Ridge Size 60cm	SL	Spike Length
T1W3	Permanent irrigation throughout the period and Ridge Size 80cm	NFS	Number of full Seeds
T2W1	Irrigation after two days of water disappearing from the ground and Cultivation without plowing	NES	Number of empty Seeds
T2W2	Irrigation after two days of water disappearing from the ground and Ridge Size 60cm	WTS	Weight of 1000 Seeds
T2W3	Irrigation after two days of water disappearing from the ground and Ridge Size 80cm	HI	Harvest Index
T3W1	Permanent soil saturation throughout the growing season and Cultivation without plowing	PCS	Percentage of Crushed Seeds
T3W2	Permanent soil saturation throughout the growing season and Ridge Size 60cm	WHS	Weight of 100 Seeds
T3W3	Permanent soil saturation throughout the growing season and Ridge Size 80cm	WRY	White Rice Yield

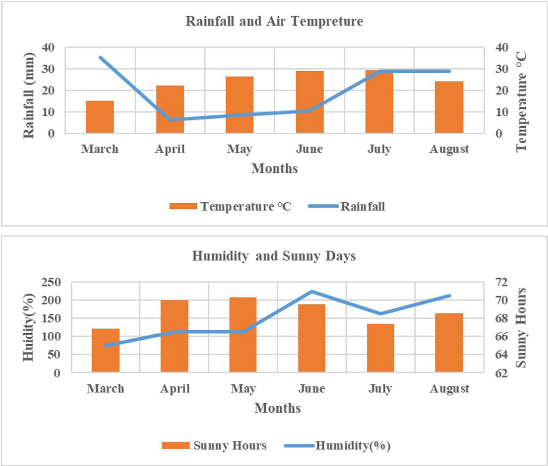

Figure 1. Average meteorological characteristics during the plant growth period in the experimental years.

were randomly selected from each experimental plot and these traits were measured in them. To determine the number of seeds in a spike, 30 spikes from 10 plants were randomly selected and this trait was calculated in them. Also, the amount of water consumed and irrigation water + rain was evaluated. Irrigation water efficiency (CW) and irrigation water efficiency + rainfall (RF) were also used to determine the best irrigation treatment using the following relationships (Equations 1 and 2).

$$CW \quad \frac{\text{Rice Paddy Yield}}{\text{Irrigation Water amount}} \tag{1}$$

$$RF = \frac{\text{Rice Paddy Yield}}{\text{Irrigation Water amount} + \text{Rainfall}} \tag{2}$$

In order to perform data analysis, from compound analysis, mean comparison by LSD method, correlation analysis including analysis of correlation coefficients, correlation diagram and correlation intensity map, analysis into principal components including vector eigenvalue diagram, analysis tables into principal components Based on the traits and treatments evaluated in the experiment, the distribution diagram of the treatments and traits based on the first and second principal components and cluster analysis in the first and second years and the average data of the first and second years of the experiment were used. In order to analyze the data, software were used Excel, XLstat 2015, SAS.V9 and Genstat.V12.1.

3. Results and Discussion

3.1. Variance analysis and mean comparison

Based on the compound analysis, the effect of year was significant in terms of rainfall traits, productivity 2, number of tillers, number of hollow seeds, weight of 1000 seeds, percentage of crushed seeds and yield of white rice at the confidence level of 0.01. Block effect also showed a significant difference in grain yield, water consumption, rainfall, productivity 2, plant height and yield of white rice. The effect of irrigation regimes in all traits except traits productivity 1, plant height, the effect of year × irrigation regimes in terms of traits, grain yield, rainfall, productivity 2, number of full seeds, number of hollow seeds, harvest index, percentage of crushed seeds and The yield of white rice, the effect of cultivation methods in terms of all traits except the number of full grains, the effect of year × cultivation methods in terms of traits of water consumption, rainfall, productivity 1, number of tillers, plant height, spike length, number of hollow seeds, 1000 grain weight, crushed grain percentage and white rice yield and the effect of irrigation regimes × cultivation methods were significant in terms of all traits except productivity 2 trait. The highest percentage of the coefficient of variation was related to the trait of the number of full seeds (17.5) and the lowest percentage of the coefficient of variation was related to the trait of spike length (1.79) (Table 2). Based on the comparison of the mean using the LSD method at the probability level of 0.01 in terms of irrigation regimes (T1), grain yield traits, productivity 1, productivity 2, number of tillers, plant height, harvest index, 100- grain weight and rice grain yield took the top rank. The investigation of T2 irrigation regime also showed that the characteristics of grain yield, water consumption, rainfall, productivity 1, productivity 2, number of full grains, number of hollow grains, weight of 1000 grains, harvest index, percentage of crushed grains, weight of 100 grains and rice yield White has a favorable rank. Based on the T3 irrigation regime, the characteristics of water consumption, rainfall, spike length, number of full seeds, number of hollow seeds, weight of 1000 seeds and weight of 100 seeds had more favourable ratings. In other words, the traits of seed yield based on irrigation regime T1 and T2, traits of water consumption, rainfall, number of full seeds, number of hollow seeds, the weight of 1000 seeds and weight of 100 seeds based on irrigation regime of T2 and T3 had favorable rank and high yield. In the investigation of cultivation methods based on W1, W2 and W3, in terms of grain yield trait in W1 and W2, water consumption trait in W1, rainfall trait in W1, productivity 1 trait in W3, productivity 2 trait in W2 and W3, Number of tillers trait in W2, plant height trait in W1, spike length trait in W2, full grain number trait in W1 and W2, number of hollow seeds trait in W1, harvest index and 1000- seed weight traits in all three cultivation methods, percentage pf crushed grains trait in W3, 100- grain weight trait in W1 and W2, and white rice yield trait in W1 and W2 had the highest desirability and rank. The comparison of the average effect of irrigation regime x cultivation methods also indicated that in terms of all the traits evaluated, treatments T1W1, T2W1 and T1W3 were identified as appropriate treatments with the highest rating and treatments T3W2 and T3W3 as treatments with an unfavorable rating. The order of the treatments from favourable to unfavorable rank is as follows (Table 3):

$$T1W1 > T2W1 > T1W3 > T2W3 > T3W1 > T1W2 > T2W2 > T3W3 > T3W2$$

Table 2. The mean square effect of irrigation regimes and planting systems in terms of the studied quantitative traits in two years of the experiment.

S.O.V	Df	YLD	CW	RF	PR1	PR2	NT	PH	SL	NFS	NES	WTS	HI	PCS	WHS	WRY
Year	1	26268.1^{ns}	9733.8^{ns}	96.36*	0.00002^{ns}	0.0001*	18.25**	1.85^{ns}	0.007^{ns}	728.2^{ns}	0.11*	0.13*	0.0003^{ns}	0.001*	0.001^{ns}	11791*
Block	2	8910342.2**	22097933.8**	2265.42**	0.07^{ns}	0.03*	0.47^{ns}	13.6*	0.18^{ns}	699.1^{ns}	0.03^{ns}	1.22^{ns}	0.0007^{ns}	0.93^{ns}	0.002^{ns}	399985*
Irrigation	2	31495.5*	52278.2*	3665.36*	0.004^{ns}	0.003*	8.21**	5.57^{ns}	2.75**	862.03*	38.7**	8.9**	0.007**	16.1**	0.001*	14138*
Year × Irri	2	351.5*	56519.9^{ns}	5469.2*	0.001^{ns}	0.0007*	0.23^{ns}	0.79^{ns}	0.4^{ns}	745.5*	0.86*	0.06^{ns}	0.0004*	1.05*	0.004^{ns}	157.7*
Error1	4	92851.9	32865.7	2364.1	0.002	0.001	0.77	3.62	0.37	701.7	1.5	0.97	0.0004	1.37	0.0003	41681.2
Cultivation	2	1084856.6**	6783483.8**	12642.1**	0.06*	0.03*	22.6**	301.2*	2.03**	616.5^{ns}	10.6**	0.06*	0.0007^{ns}	48.2**	0.003*	486992*
Year × Plant	2	0.41^{ns}	35517.1*	45365.1*	0.0002*	0.001^{ns}	0.001*	5.12*	0.61*	247.9^{ns}	2.99**	0.18*	0.0001^{ns}	0.02*	0.001^{ns}	7650.6*
Irrigaton × Cultivatiom	4	37914.3*	16013.6*	1215.3*	0.001*	0.001^{ns}	5.25**	16.9*	0.39*	205.7*	6.14**	1.89*	0.001*	6.005*	0.008*	17019*
Error 2	30	42053.3	47597.3	41232.2	0.002	0.0001	0.59	3.8	0.25	314.2	0.58	0.83	0.0003	0.67	0.0008	18877.7
CV%	-	3.2	3.44	3.08	4.63	4.46	2.91	1.99	1.79	17.5	1.83	3.49	3.7	7.3	1.59	2.23

S.O.V = source of variation; CV = coefficient of variation;*, **, and ns: Significant at 5%, 1% and not-significant. Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

Table 3. Comparison of the means effect of different irrigation regimes and culti-vation methods in terms of the studied traits.

Irrigation	YLD	CW	RF	PR1	PR2	NT	PH	SL	NFS	NES	WTS	HI	PCS	WHS	WRY
T1	6370.3^{a}	6276.6^{b}	7016.6^{b}	1.02^{a}	0.91^{a}	27.1^{a}	98.2^{a}	28.01^{b}	92.9^{b}	39.9^{b}	25.3^{b}	0.51^{a}	10.2^{b}	1.88^{a}	4268.09^{a}
T2	6337.4^{a}	6351.9^{a}	7091.9^{a}	1.008^{a}	0.9^{a}	26.2^{b}	97.7^{b}	27.9^{b}	104.9^{a}	42.7^{a}	36.7^{a}	0.52^{a}	12.12^{a}	1.87^{a}	4246.09^{a}
T3	6287.2^{b}	6381.1^{a}	7121.1^{a}	0.99^{b}	0.88^{b}	25.8^{b}	97.1^{b}	28.6^{a}	104.8^{a}	42.15^{a}	26.2^{a}	0.48^{b}	11.14^{ab}	1.87^{a}	4212.4^{b}
LSD	180.5	26	21	0.02	0.03	1.8	2	2.8	2.9	0.6	3	1	0.03	0.04	121
Cultivation	YLD	CW	RF	PR1	PR2	NT	PH	SL	NFS	NES	WTS	HI	PCS	WHS	WRY
W1	6556.9^{a}	6950^{a}	7690^{a}	0.94^{c}	0.85^{b}	25.3^{c}	102.2^{a}	28.2^{ab}	107.2^{a}	42.4^{a}	26.1^{a}	0.51^{a}	10.2^{b}	1.89^{a}	4393.1^{a}
W2	6368^{a}	6337.5^{b}	7077^{b}	1.01^{b}	0.9^{a}	27.5^{a}	96.6^{b}	28.5^{a}	99.7^{a}	40.9^{b}	26.1^{a}	0.5^{a}	10.2^{b}	1.87^{a}	4266.5^{a}
W3	6070^{b}	5722.2^{c}	6462^{c}	1.06^{a}	0.94^{a}	26.3^{b}	94.3^{c}	27.8^{b}	95.7^{b}	41.4^{ab}	26^{a}	0.5^{a}	13.05^{a}	1.86^{b}	4066.9^{b}
LSD	124.8	21	22	0.03	0.04	1.5	1.4	1.6	2.1	0.4	0.8	0.9	0.01	0.9	82.6
Irrigation × Cultivation	YLD	CW	RF	PR1	PR2	NT	PH	SL	NFS	NES	WTS	HI	PCS	WHS	WRY
T1W1	7255^{a}	8174^{a}	8914^{a}	0.88^{b}	0.81^{b}	25.4^{b}	103.5^{a}	28.3^{a}	108.4^{a}	42.8^{a}	26.5^{a}	0.51^{a}	9.7^{c}	1.9^{a}	4861^{a}
T1W2	5974^{b}	6284^{bc}	7024^{b}	0.95^{b}	0.85^{b}	25.1^{b}	101.3^{a}	28.06^{a}	106.8^{a}	42^{a}	26.2^{a}	0.51^{a}	10.3^{b}	1.8^{a}	4003^{a}
T1W3	6442^{ab}	6392^{bc}	7132^{b}	1.07^{a}	0.9^{a}	25.4^{b}	102^{a}	28.1^{a}	106.5^{a}	42.2^{a}	25^{b}	0.5^{a}	10.5^{b}	1.8^{a}	4316^{a}
T2W1	7028^{a}	7752^{b}	8492^{a}	0.91^{b}	0.83^{b}	27.5^{a}	97.5^{b}	28.5^{a}	87.9^{b}	40.9^{b}	26.4^{a}	0.51^{a}	9.8^{c}	1.8^{a}	4708^{a}
T2W2	5862^{b}	5491^{bc}	6231^{b}	1.06^{a}	0.94^{a}	27.3^{a}	96^{b}	28.6^{a}	105.8^{a}	40.8^{b}	26.3^{a}	0.5^{a}	10.4^{b}	1.8^{a}	3928^{b}
T2W3	6214^{ab}	5769^{bc}	6509^{b}	1.07^{a}	0.95^{a}	27.8^{a}	96.3^{b}	28.4^{a}	105.6^{a}	41.1^{a}	25^{b}	0.51^{a}	10.3^{b}	1.8^{a}	4163^{a}
T3W1	7051^{a}	6898^{b}	7638^{b}	1.02^{a}	0.92^{a}	26^{ab}	95.1^{b}	27.9^{b}	84.8^{b}	41.2^{a}	26.2^{a}	0.5^{a}	13.1^{a}	1.8^{a}	4724^{a}
T3W2	5394^{c}	4964^{c}	5704^{c}	1.08^{a}	0.94^{a}	26^{ab}	93.8^{b}	27.9^{b}	100.9^{a}	41.6^{a}	25^{b}	0.5^{a}	13.2^{a}	1.8^{a}	3616^{c}
T3W3	5765^{b}	5304^{bc}	6044^{b}	1.08^{a}	0.95^{a}	26^{ab}	94^{b}	27.7^{b}	101.3^{a}	41.5^{a}	26.3^{a}	0.51^{a}	12.8^{a}	1.8^{a}	3863^{b}
LSD	160.5	24.5	25	0.06	0.05	1.2	1.6	2	2.5	0.5	2.3	1	0.06	0.5	101

Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

3.2. Correlation between traits

3.2.1. The first year of the experiment

According to the table of correlation coefficients between traits in the first year of the experiment, the positive and significant correlation between the traits of grain yield with the traits of water consumption, rainfall, plant height and white rice yield, and negative and significant correlation with the traits of productivity 1 and productivity 2 were observed. The trait of water consumption had a positive and significant correlation with the traits of rainfall, white rice yield and plant height, and there was a negative and significant correlation with the traits of productivity 1, productivity 2 and the percentage of crushed grains. Rainfall trait showed positive and significant correlation with productivity traits 2 and plant height, and negative and significant correlation with productivity trait 1. Also, productivity 1 trait had a positive correlation with productivity 2 trait and the percentage of crushed seeds, and there was a negative and significant correlation with plant height trait. Productivity 2 trait also had a positive correlation with the crushed grain percentage trait and a negative correlation with plant height and white rice yield traits. A positive and significant correlation was observed between the trait number of tillers and the trait of spike length, and a negative and significant correlation was observed with the traits of plant height and the number of full seeds. The trait of plant height had a positive correlation with the yield of white rice trait and had a negative and significant correlation with the trait of crushed grain percentage. The trait of the number of hollow seeds showed a positive and significant correlation with the traits of weight of 1000- seeds and percentage of crushed seeds (Table 4). Based on the correlation diagram drawn in the first year of the experiment, positive correlation between the traits of 100- grain weight, white rice yield, grain yield, plant height, rainfall and water consumption together, the traits of the number of hollow seeds and the weight of a 1000- seeds together, the traits productivity 1, productivity 2 and the percentage of crushed seeds together and the traits of the number of tillers, length of the spike, harvest index and the number of full seeds were observed together. Also, the correlation between the two traits of 100- seeds weight and percentage of crushed seeds and the correlation between the two traits of the number of hollow seeds and the number of spike according to the angle of 180 degrees between the two vectors of these traits were reported as negative (Figure 2A).

3.2.2. The second year of the experiment

Based on the analysis of the correlation coefficients performed on the data obtained in the second year of the experiment, there is a positive and significant correlation between the traits of grain yield with the traits of water consumed, rainfall, the number of full grains, the weight of 100- seeds and the yield of white rice and with the traits Productivity 1, productivity 2 and the percentage of crushed seeds were observed to have a negative and significant correlation. The trait of water consumed with the traits of rainfall, plant height, number of full grains, weight of 1000- seeds, weight of 100- seeds and yield of white rice has a positive correlation and with the traits of productivity 1, productivity 2 and crushed grain percentage, has a negative and significant correlation. Rainfall trait showed a positive and significant correlation with plant height, number of full grains, 100- seeds weight and white rice yield traits, and productivity 1 trait showed a positive and significant correlation with productivity 2 and number of tillers traits. Productivity 1 trait had a negative and significant correlation with traits of plant height, number of full seeds, number of hollow seeds, weight of 1000- seeds and yield of white rice. In the examination of productivity 2 trait, positive correlation with number of tillers and negative correlation with plant height, number of full seeds, number of hollow seeds, weight of 1000- seeds, weight of 100- seeds and yield of white rice were evident. The trait of number of tillers had a positive correlation with the trait of weight of 1000- seeds and a negative correlation with the trait of plant height. Plant height and spike length traits positively and significantly correlated with the number of full seeds. There was a positive and significant correlation between the trait of the number of full grains with the traits of the number of hollow grains, the weight of 100- seeds and the yield of white rice, and a negative correlation with the trait of percentage of crushed grains was evident. The crushed grain percentage trait also had a positive and significant correlation with the 100- seeds weight and white rice yield traits (Table 4). In the examination of the correlation diagram of the second year of the experiment, the traits of

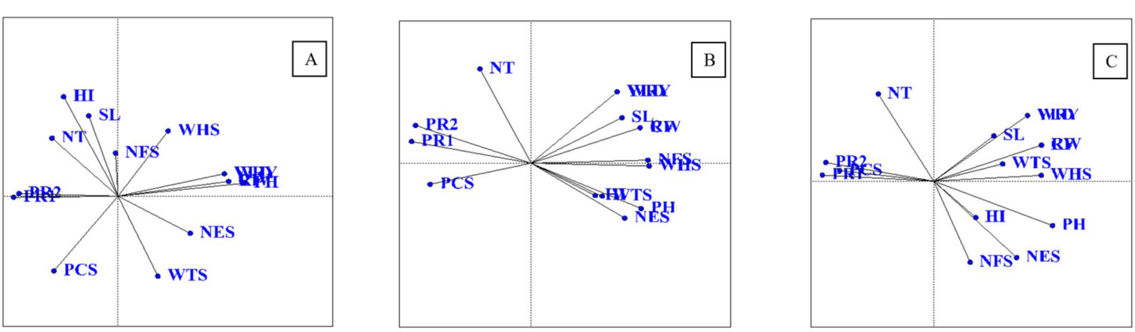

Figure 2. Correlation diagram between traits in the years of experiment. (A) the first year of the experiment; (B) the second year of the experiment; (C) the average of the first and second year of the experiment.

Table 4. Correlation coefficients between the traits evaluated in the first, second and average years of the experiment.

	Traits	YLD	CW	RF	PR1	PR2	NT	PH	SL	NFS	NES	WTS	HI	PCS	WHS
Year 1	CW	0.92**													
	RF	0.92**	0.9**												
	PR1	-0.6**	-0.9**	-0.4**											
	PR2	-0.5**	-0.8**	0.6**	0.9**										
	NT	0.1	-0.03	0.02	0.22	0.25									
	PH	0.62**	0.75**	0.55**	-0.7**	-0.76**	-0.3*								
	SL	0.07	0.05	0.03	-0.01	-0.006	0.47**	-0.14							
	NFS	-0.31	-0.2	-0.17	0.16	0.13	-0.4*	-0.14	-0.03						
	NES	0.11	0.09	0.01	-0.09	-0.08	-0.3	0.15	-0.17	0.16					
	WTS	0.05	0.04	0.05	-0.04	-0.03	-0.04	-0.13	0.08	0.19	0.52**				
	HI	0.004	-0.1	0.1	0.23	0.25	0.07	-0.1	-0.09	0.07	-0.04	-0.2			
	PCS	-0.21	-0.3*	0.3	0.4*	0.4*	-0.1	-0.4*	-0.03	-0.1	0.35*	0.2	-0.04		
	WHS	0.24	0.12	0.12	0.03	0.07	-0.2	0.3	-0.05	0.01	0.05	0.4	0.29	0.03	
	WRY	0.9**	0.9**	0.8	-0.67**	-0.58**	0.1	0.6**	0.07	-0.3	0.11	0.05	0.004	-0.22	0.24
Year 2	CW	0.89**													
	RF	0.89**	0.9**												
	PR1	-0.4*	-0.81**	0.65											
	PR2	-0.3*	-0.7**	-0.5	0.98**										
	NT	0.08	-0.15	0.12	0.43*	0.47*									
	PH	0.18	0.37*	0.44*	-0.52**	-0.5**	-0.43*								
	SL	0.25	0.26	0.36	-0.18	-0.15	0.11	0.21							
	NFS	0.37*	0.46*	0.51*	-0.46*	-0.4*	-0.1	0.69**	0.4*						
	NES	0.09	0.25	0.2	-0.3*	-0.3*	-0.3	0.21	0.13	0.42*					
	WTS	0.16	0.32*	0.16	-0.3*	-0.4*	0.3*	-0.03	-0.05	0.03	0.5				
	HI	0.22	0.21	0.39	-0.14	-0.11	-0.09	0.13	-0.41*	0.04	-0.12	0.12			
	PCS	-0.3*	-0.3*	-0.56	0.28	0.24	-0.18	-0.4*	-0.43	-0.4*	0.3	0.2	-0.15		
	WHS	0.44*	0.48**	0.12*	-0.4*	-0.37*	0.16	0.5**	0.13	0.43*	-0.09	0.12	0.3	-0.4*	
	WRY	0.9**	0.89**	0.63**	-0.4*	-0.34*	0.08	0.19	0.25	0.37*	0.09	0.16	0.22	-0.3*	0.44
Average of year 1 and 2	CW	0.92**													
	RF	0.92**	0.9**												
	PR1	-0.6**	-0.88*	-0.88**											
	PR2	-0.55*	-0.82**	-0.82**	0.99*										
	NT	0.09	-0.1	-0.1	0.3*	0.4**									
	PH	0.4*	0.58**	0.58**	-0.6**	-0.6**	-0.4*								
	SL	0.2	0.23	0.23	-0.2	-0.18	0.2	0.13							
	NFS	-0.27	-0.13	-0.13	-0.05	-0.1	-0.3*	0.14	-0.02						
	NES	0.11	0.17	0.17	-0.22	-0.2	-0.3*	0.2	0.07	0.34*					
	WTS	0.18	0.23	0.23	-0.22	-0.2	-0.18	-0.1	0.14	0.23	0.6*				
	HI	0.13	0.08	0.08	0.007	0.02	-0.01	0.08	-0.44*	-0.1	-0.04	-0.2			
	PCS	-0.2	-0.3*	-0.3*	0.4	0.3*	-0.18	-0.5**	-0.47*	-0.07	0.3*	0.2	-0.1		
	WHS	0.45*	0.4*	0.43*	-0.3	-0.2	-0.07	0.6**	-0.003	-0.04	-0.01	-0.18	0.2	-0.36	
	WRY	0.9**	0.9**	0.92	-0.65**	-0.55*	0.09	0.43	0.21	-0.2	0.11	0.18	0.13	-0.28	0.45*

*, **, and ns: Significant at 5%, 1% and not-significant; Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

grain yield, white rice yield, spike length, rainfall, water consumption, the number of full grains and the weight of one 100- seeds together, the traits of number of full grains, weight of 100- seeds, weight of 1000- seeds, Harvest index, plant height together and the number of hollow seeds and traits of percentage of crushed seeds, productivity 1 and productivity 2 together, had a positive correlation with each other (Figure 2B).

3.2.3. The average of the first and second year of the experiment

In the analysis of the correlation coefficients between the traits in the average data of the first and second year of the experiment, the grain yield trait with the traits of water consumption, rainfall, plant height, 100- seeds weight and white rice yield has a positive significant correlation and with productivity 1 and productivity 2 traits had a negative and significant correlation. The trait of water consumption also had a positive and significant correlation with the traits of rainfall, plant height, 100- seeds weight and yield of white rice, and a negative correlation with the traits of productivity 1, productivity 2 and crushed grain percentage. Rainfall trait had a positive correlation with plant height and 100- seed weight traits, and negative and significant correlation with productivity 1, productivity 2 and percentage of crushed seeds traits. Productivity 1 trait had a positive correlation with productivity 2 and the number of tillers traits and had a negative correlation with plant height and yield of white rice traits. In the study of productivity 2 trait, a positive and significant correlation was observed with the number of tillers and the percentage of crushed grains, and a negative and significant correlation was observed with the traits of plant height and yield of white rice. A negative and significant correlation was observed between the trait number of tillers and the traits of plant height, number of full seeds and number of hollow seeds. Also, a positive correlation was observed between plant height trait and 100- seeds weight trait, and a negative and significant correlation was observed with crushed seed percentage trait. Spike length trait had a negative and significant correlation with the harvest index trait and percentage of crushed seeds traits, and the number of full seeds trait had a positive and significant correlation with the number of empty seeds trait. The number of hollow seeds had a positive and significant correlation with the traits of weight of 1000- seeds and percentage of crushed seeds and weight of 100- seeds with yield of white rice showed a positive and significant correlation (Table 4). In examining the correlation diagram on the average data of the two years of the experiment, the traits of white rice yield, spike length, grain yield, rainfall, water consumption, weight of 1000- seeds, weight of 100- seeds together, traits of plant height, harvest index, number of hollow seeds together and productivity 1, productivity 2, percentage of crushed seeds and number of tillers together, showed a positive correlation. There was a negative correlation between the number of full seeds and the number of tillers, According to the angle of 180 degrees between the vector of these two traits (Figure 2C). Various researchers used correlation diagram to determine the degree of correlation between traits in their research on different plants, which can be mentioned in corn (Shojaei et al., 2020; Mousavi et al., 2022), sunflower (Ansarifard et al., 2020), canola (Shojaei et al., 2011).

3.2.4. The intensity of the correlation in the years of the experiment

Based on the correlation intensity map drawn on the experimental data, the highest intensity of positive correlation was related to white rice yield trait with grain yield, water consumption and rainfall traits. Also, a high positive correlation was observed between the trait of rainfall with the traits of water consumed and grain yield and between the trait of water consumed with grain yield intensity (Figure 3). Based on the table of correlation coefficients, correlation diagram and correlation intensity map in the years of the experiment, it is possible to report the correlation of the grain yield trait with the traits of water consumption, rainfall, plant height, 100- seeds weight, full grain number and white rice yield. Also, the traits of productivity 1, productivity 2 and the percentage of crushed seeds showed a positive correlation, the negative correlation of these three traits with most of the traits evaluated in the experiment.

3.3. Principal components analysis

3.3.1. The first year of the experiment

According to the eigenvalue diagram in the first year of the experiment, the first four components explained

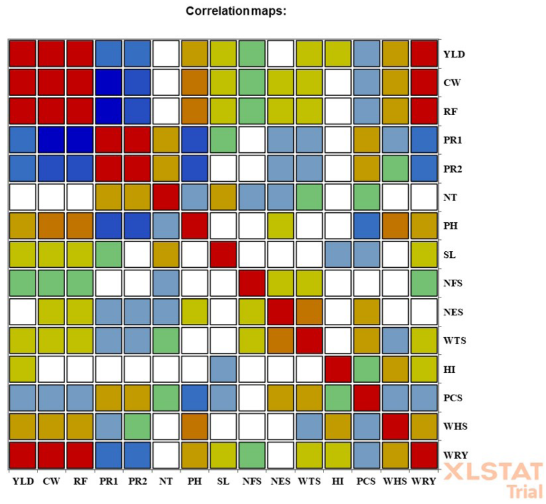

Figure 3. The map of the intensity of correlation between the studied traits in the years of the experiment (Red color: high correlation intensity, green color: medium correlation intensity, blue color: low correlation intensity, white color: absence of correlation). Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

more than 78% of the total variance of the data (Figure 4A). The first component covered more than 41%, the second component 14%, the third component 12% and the fourth component 10% of the data variance. According to the analysis table into the main components, in the first component, grain yield, water consumption, rainfall, plant height, spike length, number of hollow grains, weight of 100- seeds, the weight of 1000- seeds and yield of white rice traits had a positive effect and the most positive impact was related to the traits of the water consumed (0.4) and the rainfall (0.4). The traits of plant height, number of full seeds, number of empty seeds, the weight of 1000 seeds, percentage of small seeds and weight of 1000 seeds also had a positive effect on the second component, and the most positive effect was related to the trait of number of full seeds (0.52). The traits of plant height, number of full seeds, number of hollow seeds, weight of 1000- seeds and percentage of crushed seeds also had a positive effect on the second component, and the most positive effect was related to the trait of number of full seeds (0.52). In the third component, grain yield, productivity 1, productivity 2, plant height, full grain number, harvest index, 100- seeds weight, and white rice yield traits had a positive effect, and the most positive effect was related to 100- seeds weight (0.56) and the harvest index (0.41) traits. All the traits except plant height, spike length and the number of full seeds had a positive effect on the fourth component, and the most positive effect on this component was related to the harvest index trait (0.49) (Table 5). The traits were grouped into four groups based on the trait distribution diagram, the first and second principal components, which covered 56.58% of the total data variance. The first group included traits such as the number of hollow seeds, weight of one 100- seeds, plant height, which had a positive coefficient in terms of both the first and second main components. The second group included traits of grain yield, rainfall, water consumed, yield of white rice and weight of 1000- seeds, which had a positive coefficient in the first principal component and a negative coefficient in the second principal component. The third group included the traits of spike length and number of tillers, which had a negative coefficient in both the first and second principal components. The fourth group included the traits of productivity 1, productivity 2, harvest index, percentage of crushed seeds and number of full seeds, which had a negative coefficient in terms of the first component and a positive coefficient in terms of the second component (Figure 5A).

In the examination of the analysis into main components in terms of experimental treatments, T1W1, T1W2, T1W3, T2W1 and T3W1 treatments had a positive effect on the first component, and the most positive effect on this component was related to T1W1 (4.4) and T2W1(1/3) treatments. The treatments T1W1, T1W2, T1W3, T3W2 and T3W3 also positively affected the second component. The most positive effect was related to T1W1 (2.36) and T1W2 (1.18) treatments. In examining the third main component, the treatments T1W1, T1W2, T2W3 and T3W3 had a positive effect on this component, and the most positive effect was related to the treatment T2W3 (3.37). T2W3, T3W1 and T3W3 treatments also had a positive effect on the fourth component, and the most positive effect on this component was related to T3W1 (2.63) and T3W3 (1.1) treatments (Table 6). The treatments were grouped into four groups in examining the distribution diagram of the treatments based on the first and second main components. The first group includes T1W1, T1W3 and T1W2 treatments, which had a positive coefficient in both the first and second main components. T3W1 and T2W1 treatments were placed in the second group and had a positive coefficient in the first component and a negative coefficient in the second component. In the third group, T2W3 and T2W2 treatments were grouped and had negative coefficients in both the first and second components. In the fourth group, T3W2 and T3W3 treatments were grouped with negative coefficients in the first component and positive coefficients in the second component (Figure 6A).

3.3.2. The second year of the experiment

Based on the eigenvalue diagram, the first four components explained more than 79% of the total variance of the test data (Figure 4B). More than 41% was related to the first component, 16% to the second component, more than 11% to the third component, and 10% to the fourth component. All the traits except productivity 1, productivity 2, the number of tillers and the percentage of crushed grains have a positive effect on the first component and the most positive effect on this component is related to the rainfall traits (0.38) and the water consumed (0.38). In the second component, except for plant height, number

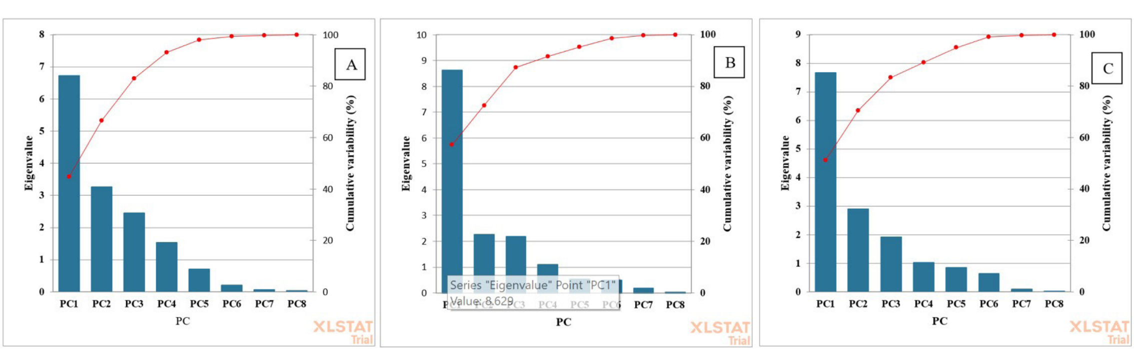

Figure 4. The eigenvalue of the vector for the traits evaluated in the years of the experiment. (A) first year of experiment; (B) second year of experiment; (C) average of first and second year of experiment.

Table 5. Principal components (PC) analysis based on the traits evaluated in the years of testing.

		PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15
Year 1	YLD	0.36	-0.08	0.01	0.29	0.13	0.01	0.28	0.07	0.03	-0.27	0.03	-0.30	-0.14	0.001	0.71
	CW	0.40	-0.02	-0.03	0.06	0.03	-0.05	0.11	-0.08	0.05	0.04	-0.13	0.52	0.16	0.71	0.0003
	RF	0.40	-0.02	-0.03	0.06	0.03	-0.05	0.11	-0.08	0.05	0.04	-0.13	0.52	0.16	-0.71	0.0001
	PR1	-0.37	-0.08	0.07	0.20	0.10	0.09	0.09	0.24	-0.03	-0.27	0.05	0.51	-0.62	0.001	0.002
	PR2	-0.35	-0.10	0.08	0.25	0.14	0.10	0.14	0.28	-0.04	-0.36	0.09	0.09	0.72	0.0003	0.005
	NT	-0.04	-0.53	-0.27	0.26	0.08	-0.07	-0.07	0.28	0.45	0.50	0.19	-0.02	0.001	0.0001	0.001
	PH	0.34	0.11	0.19	-0.16	-0.05	0.11	-0.32	0.29	-0.07	-0.08	0.77	0.11	0.01	-0.003	-0.002
	SL	0.02	-0.36	-0.34	-0.10	0.44	0.45	-0.25	-0.47	-0.16	-0.18	0.11	0.02	0.003	0.001	-0.003
	NFS	-0.11	0.52	0.06	-0.38	0.55	0.03	0.47	-0.06	0.40	0.13	0.21	0.02	0.002	0.002	0.0001
	NES	0.04	0.30	-0.12	0.31	0.24	0.06	-0.56	0.07	0.43	-0.15	-0.22	-0.02	0.002	0.0005	-0.0002
	WTS	0.00	0.34	-0.51	0.17	0.26	-0.10	0.09	0.28	-0.58	0.31	0.05	0.00	0.001	0.0001	0.001
	HI	-0.06	-0.14	0.41	0.49	0.44	-0.65	-0.23	-0.25	-0.19	0.06	0.09	0.00	0.001	0.0002	0.002
	PCS	-0.16	0.27	-0.03	0.23	-0.28	0.09	0.18	-0.55	0.07	0.15	0.41	0.06	0.01	0.0002	0.001
	WHS	0.06	0.01	0.56	0.21	0.18	0.56	-0.01	0.09	-0.18	0.45	-0.20	-0.05	0.0003	-0.005	0.001
	WRY	0.36	-0.08	0.01	0.29	0.13	0.01	0.28	0.07	0.03	-0.27	0.03	-0.30	-0.14	0.0001	-0.71
	Proportion	0.41	0.14	0.12	0.1	0.07	0.04	0.03	0.02	0.01	0.01	0.007	0.0002	0.0001	0.0001	0.00001
	Cumulative	0.41	0.55	0.68	0.78	0.85	0.9	0.93	0.96	0.98	0.99	0.999	0.9998	0.9999	0.9999	1
Year 2	YLD	0.32	0.20	0.31	0.17	0.10	-0.18	0.19	0.09	-0.08	-0.04	-0.02	-0.34	-0.15	0.71	0.0002
	CW	0.38	0.02	0.18	0.08	-0.08	-0.09	0.00	-0.08	0.01	-0.01	0.08	0.51	0.14	0.0001	0.71
	RF	0.38	0.02	0.18	0.08	-0.08	-0.09	0.00	-0.08	0.01	-0.01	0.08	0.51	0.14	0.0002	-0.71
	PR1	-0.35	0.21	0.05	0.08	0.29	0.01	0.25	0.20	-0.09	-0.12	0.00	0.47	-0.63	0.0001	0.0003
	PR2	-0.32	0.26	0.09	0.11	0.33	-0.03	0.30	0.24	-0.12	-0.11	-0.04	0.07	0.72	0.0001	0.0001
	NT	-0.09	0.46	0.12	0.22	0.25	0.26	-0.52	-0.28	-0.07	0.14	0.45	-0.05	0.001	0.0001	0.0001
	PH	0.24	-0.04	-0.46	-0.29	0.15	-0.17	0.16	0.22	-0.24	-0.07	0.68	-0.05	0.002	0.0001	0.001
	SL	0.13	0.17	-0.36	0.49	-0.17	0.27	0.21	0.28	0.57	0.13	0.11	-0.01	0.01	0.001	-0.004
	NFS	0.26	0.02	-0.39	0.04	0.48	0.02	0.11	-0.25	-0.18	0.54	-0.38	0.06	-0.01	0.002	0.0001
	NES	0.13	-0.42	-0.10	0.28	0.51	0.05	-0.13	-0.18	0.20	-0.60	-0.03	-0.04	0.0002	-0.004	0.0002
	WTS	0.13	-0.41	0.26	0.12	0.04	0.63	0.00	0.39	-0.38	0.17	0.06	-0.01	0.003	0.0002	-0.0001
	HI	0.09	0.05	0.30	-0.59	0.28	0.34	0.26	-0.13	0.51	0.08	0.11	-0.02	0.001	0.0001	0.0002
	PCS	-0.19	-0.38	0.24	0.12	0.25	-0.47	-0.22	0.27	0.31	0.47	0.20	0.02	0.01	0.0001	0.0001
	WHS	0.24	0.27	-0.11	-0.29	0.15	0.00	-0.53	0.57	0.10	-0.14	-0.33	0.05	0.002	-0.001	-0.001
	WRY	0.32	0.20	0.31	0.17	0.10	-0.18	0.19	0.09	-0.08	-0.04	-0.02	-0.34	-0.15	-0.71	0.0002
	Proportion	0.41	0.16	0.11	0.1	0.05	0.04	0.04	0.02	0.01	0.01	0.009	0.0003	0.0001	0.0001	0.00001
	Cumulative	0.41	0.57	0.69	0.79	0.85	0.89	0.93	0.96	0.97	0.99	0.999	0.999	0.9999	0.9999	1

Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

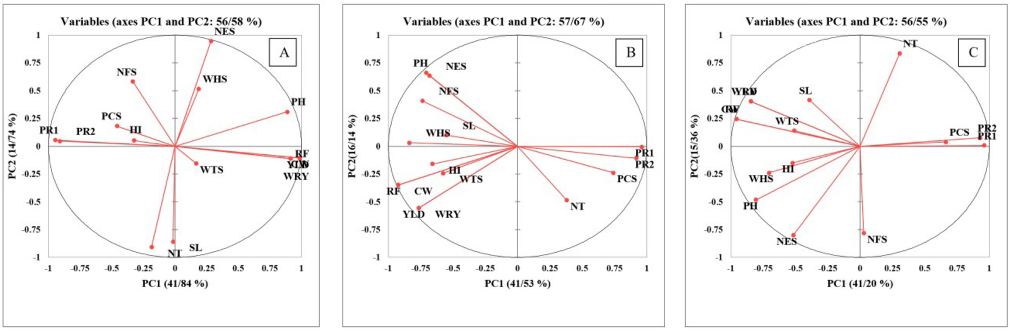

Figure 5. Traits distribution diagram based on the first and second main components in the years of the experiment. (A) the first year of the experiment; (B) the second year of the experiment; (C) the average of the first and second year of the experiment. Caption: YLD: Grain Yield; CW: Consuming Water; RF: Rainfall; PR1: Productivity 1; PR2: Productivity 2; NT: Number of Tiller; PH: Plant Height; SL: Spike Length; NFS: Number of Full seeds; NES: Number of Hollow seeds; WTS: Weight of 1000 seeds; HI: Harvest Index; PCS: Percentage of Crushed Seeds; WHS: Weight of 100 Seeds; WRY: White Rice Yield.

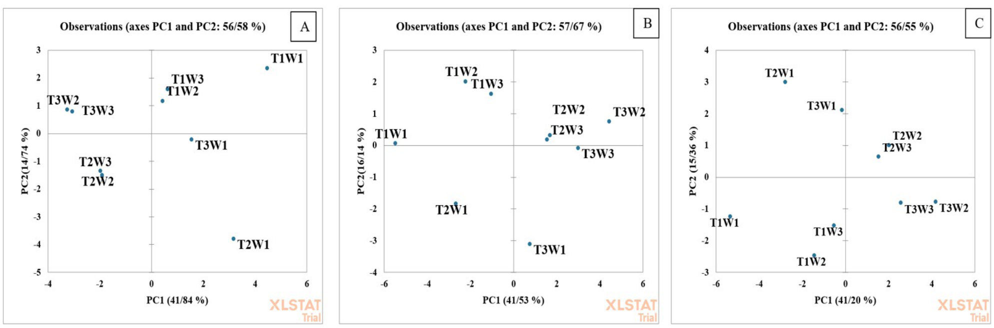

Figure 6. Distribution diagram of the evaluated treatments in the experimental years. (A) the first year of the experiment; (B) the second year of the experiment; (C) the average of the first and second year of the experiment.

Table 6. Principal components (PC) analysis based on the treatments evaluated in the experiment.

	Treatments	PC1	PC2	PC3	PC4
Year 1	T1W1	4.46	2.36	1.31	-0.05
	T1W2	0.42	1.18	0.36	-1.49
	T1W3	0.62	1.61	-0.94	-0.85
	T2W1	3.17	-3.78	-0.45	-0.36
	T2W2	-1.92	-1.50	-0.94	-1.51
	T2W3	-1.97	-1.34	3.37	0.52
	T3W1	1.54	-0.21	-1.70	2.63
	T3W2	-3.26	0.87	-1.83	-0.02
	T3W3	-3.07	0.79	0.81	1.13
Year 2	T1W1	-5.48	0.07	-0.06	-0.05
	T1W2	-2.22	2.02	-1.96	0.43
	T1W3	-1.03	1.63	1.21	-1.10
	T2W1	-2.68	-1.83	0.12	-0.09
	T2W2	1.68	0.33	1.89	1.59
	T2W3	1.55	0.19	2.10	0.08
	T3W1	0.76	-3.10	-0.42	-0.38
	T3W2	4.44	0.76	-0.42	-1.17
	T3W3	2.99	-0.07	-2.46	0.67
Average of year 1 and 2	T1W1	-5.34	-1.23	0.05	-0.57
	T1W2	-1.45	-2.46	-0.16	1.41
	T1W3	-0.54	-1.52	0.61	-1.49
	T2W1	-2.79	3.00	0.04	1.23
	T2W2	2.01	1.02	2.12	-0.50
	T2W3	1.53	0.65	2.00	0.34
	T3W1	-0.16	2.12	-2.30	-1.11
	T3W2	4.18	-0.77	-0.75	0.11
	T3W3	2.56	-0.81	-1.61	0.58

of hollow seeds, 1000- seed weight and percentage of crushed seeds traits, the rest of the traits had a positive effect and the most positive effect was the number of tillers (0.46). In the third component, the traits of grain yield, water consumption, rainfall, productivity 1, productivity 2, number of tillers, weight of 1000- seeds, harvest index, crushed grain percentage and white rice yield had a positive effect, and the most positive effect was related to the traits grain yield (0.31), harvest index (0.3) and 1000- seeds weight (0.26). All the traits except plant height, harvest index and 100- seeds weight had a positive effect on the fourth component, and the most positive effect on this component was related to the spike length trait (0.49), (Table 5). Based on the trait distribution diagram, the evaluated traits were grouped into three groups. The first group includes the traits of productivity 1, productivity 2, percentage of crushed grains and number of tillers, which had a positive coefficient in the first component and a negative coefficient in the second component. The second group included grain yield traits, white rice yield, rainfall, water consumption and harvest index, which had a negative coefficient in terms of both the first and second components. The third group included the traits of the weight of 100- seeds, spike length, number of full seeds, plant height and number of hollow seeds, which had negative coefficients in the first component and positive coefficients in the second component (Figure 5B). The results of analyzing the main components of experimental treatments in the second year also showed the positive effect of T2W2, T2W3, T3W1, T3W2 and T3W3 treatments on the first component, the most positive effect was related to T3W2 (4.4) and T3W3 (2.9) treatments. All treatments except T2W1, T3W1 and T3W3 treatments had a positive effect on the second component, of which T1W2 (2.02) and T1W3 (1.6) treatments had the most positive effect on this component. In the third component, T1W3, T2W1, T2W2 and T2W3 treatments had a positive effect and the most positive effect on this component was related to T2W3 (2.09) and T2W2 (1.89) treatments. T1W2, T2W2, T2W3 and T3W3 treatments also positively affected the fourth component, and T2W2 treatment (1.59) had the greatest effect on this component (Table 6). Four groups were identified in examining the distribution chart of the treatments based on the first and second main components. The first group included T3W2, T2W3 and T2W2 treatments which had positive coefficients in the first and second components, the second group included T3W3 and T3W1 treatments which had a positive coefficient in the first component and a negative coefficient in the second component, the third group included T2W1 treatment which had a negative coefficient in both components. The fourth group included treatments T1W3, T1W2 and T1W1, which had a negative coefficient in the first component and a positive coefficient in the second component (Figure 6B).

3.3.3. The average of the first and second year of the experiment

Based on the drawn vector eigenvalue diagram, the four main components explained more than 80% of the total data variance (Figure 4C). The first component covered 41%, the second component 15%, the third component more than 11% and the fourth component covered 10% of the data variance. Based on the analysis of the first main component, the traits of grain yield, water consumption, rainfall, plant height, spike length, number of hollow seeds, weight of 100- seeds, harvest index, weight of one 1000- seeds and yield of white rice had a positive effect on this component. The most positive effect was related to the traits of water consumed (0.39) and the rainfall (0.39). In the second component, the traits of plant height, number of full seeds, number of hollow seeds and percentage of crushed seeds positively affected this component. The most positive effect on this component was the number of full seeds (0.5) and the weight of 1000- seeds (0.40) traits. All the traits except plant height, number of full seeds, harvest index and weight of 100- seeds had a positive effect on the third component, and the traits of spike length (0.37) and number of tillers (0.35) had the most positive effect. In the examination of the fourth component, except for the traits of the number of tillers, length of the spike, height of the plant, number of full grains, the rest of the traits had a positive effect on this component, and the most positive effect was related to the trait of harvest index (0.49) (Table 5). Traits distribution diagram based on the first and second main components showed that, the traits were grouped into four groups. The first group included the traits of the number of tillers, productivity 1, productivity 2, and crushed grain percentage, which had a positive coefficient in terms of both the first and second components. The second group included the trait number of tillers, which had a positive coefficient in the first component and a negative coefficient in the second component. The third group included traits of harvest index, 100- seed weight, plant height, number of hollow seeds, and this group had a negative coefficient in both the first and second components. The fourth group included traits of spike length, 1000- seed weight, grain yield, white rice yield, rainfall and water consumption, which had a negative coefficient in the first component and a positive coefficient in the second component (Figure 5C). Analysis of the main components in terms of the experimental treatments indicated that the T2W2, T2W3, T3W2 and T3W3 treatments had a positive effect on these components and the T3W2 treatment (1.4) had the most positive effect. In examining the second component, T2W1, T2W2, T2W3 and T3W1 treatments had a positive effect on this component, and the most positive effect was related to T2W1 (3.00) and T3W1 (2.12) treatments. All treatments except T1W2, T3W1, T3W2 and T3W3 treatments had a positive effect on the third component, Among these treatments, the most positive effect was related to T2W2 (2.12) and T2W3 (1.99) treatments. The fourth component also showed that the treatments T1W2, T2W1, T2W3, T3W2 and T3W3 had a positive effect on this component and the treatments T1W2 (1.41) and T2W1 (1.23) had the most positive effect on this component (Table 6). In examining the distribution of treatments in terms of the first and second components, the treatments were grouped into four groups. The first group includes T2W3 and T2W2 treatments, which had

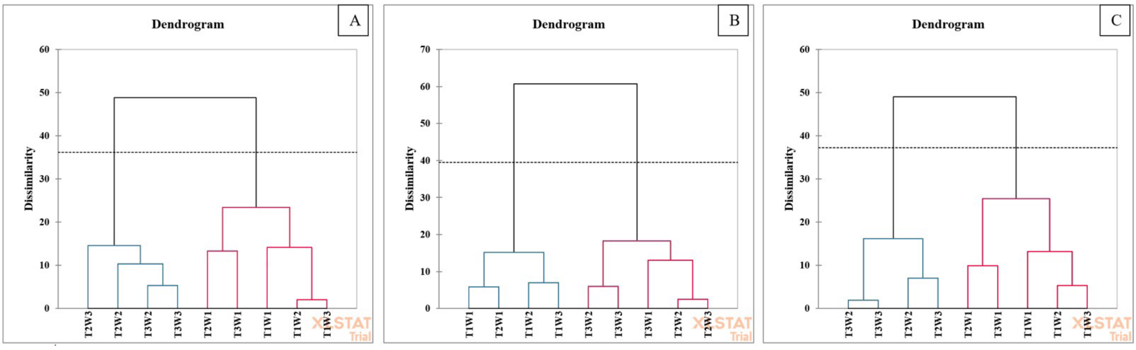

Figure 7. Cluster analysis of evaluated treatments based on traits in the years of experiment. (A) the first year of the experiment; (B) the second year of the experiment; (C) the average of the first and second year of the experiment.

positive coefficients in terms of both the first and second main components. The second group included T3W2 and T3W3 treatments, which had positive coefficients in the first component and negative coefficients in the second component. The third group included T1W3, T1W2 and T1W1 treatments, which had a negative coefficient in terms of both the first and second components. The fourth group included T3W1 and T2W1 treatments, which had negative coefficients in the first component and positive coefficients in the second component (Figure 6C).

Based on analysis into main components in different years of the experiment, four main components were named based on the positive effect of traits on these components. The first component was named as the characteristic of the amount of water consumed, the second component was named as the characteristics of the rice plant, the third component was named as the yield characteristics and the fourth component was named as the harvest index component. In examining the effect of the treatments on the four main components, the most positive effect was related to T2W1 and T3W2 treatments on the first component, T1W2 treatment on the second component, T2W3 treatment on the third component and T2W2, T2W1 and T3W1 treatments on the fourth component. In the grouping of treatments based on the first and second main components during the years of experiment, T2W2 and T2W3 treatments were identified as treatments that had positive coefficients in terms of the first and second main components and were identified as suitable treatments in terms of cultivation and irrigation regime in the rice plant.

3.4. Cluster analysis

3.4.1. The first year of the experiment

Based on the graph obtained from the cluster analysis, the treatments were grouped into two main groups in terms of the traits evaluated in the first year of the experiment. The first group was divided into two subgroups. The first subgroup included T2W3 and the second subgroup included T2W2, T3W2 and T3W3 treatments. The second group was divided into two subgroups. The first subgroup included T2W1 and T3W1 and the second subgroup included T1W1, T1W2 and T1W3 treatments (Figure 7A).

3.4.2. The second year of the experiment

Based on the diagram drawn in the second year of the experiment, the treatments were grouped into two main groups in terms of traits. The first group included two subgroups. The first subgroup included T1W1 and T2W1 treatments and the second subgroup included T1W3 and T1W2 treatments. The second group included two subgroups, T3W2 and T3W3 treatments were placed in the first subgroup and T3W1, T2W2 and T2W3 treatments were placed in the second subgroup (Figure 7B).

3.4.3. The average of the first and second year of the experiment

Based on the graph obtained from the cluster analysis in the average data of the first and second years of the experiment, the treatments were grouped into two groups. The first group included two subgroups; the first included T3W2 and T3W3 treatments and the second included T2W2 and T2W3 treatments. The second group was divided into two subgroups. The first subgroup included T2W1 and T3W1 treatments and the second subgroup included T1W1, T1W2 and T1W3 treatments (Figure 7C).

4. Conclusion

The present research results showed that the effects of irrigation regimes and cultivation methods were significant in terms of all traits except productivity 2 trait. Also, based on the mean comparison results of T1W1, T2W1 and T1W3 treatments and the principal components analysis, T2W2 and T2W3 treatments were identified as appropriate treatments for rice cultivation. The application of non-submerged irrigation treatments increases the economic productivity of water with a very small decrease in the performance of traits compared to the traditional method.

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