Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Evaluation of seedling cultivation and irrigation regimes on yield and yield components in rice plant

Avaliação do cultivo de mudas e regimes de irrigação sobre o rendimento e os componentes do rendimento em planta de arroz

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Abstract

A split-plot experiment was conducted in a randomized complete block design with three replications in two cropping years at Mazandaran Rice Research Institute to study cultivation and irrigation regimes. The main factor is three-level irrigation regimes, permanent irrigation throughout the day (T1), irrigation two days after water disappears from the soil (T2) and permanent soil saturation (T3) the second factor is three-level cultivation methods., Plowless cultivation (W1), stack 60 cm (W2), and stack 80 cm (W3). Based on the results obtained from the combined analysis, the effect of the year was significant in terms of rainfall, productivity 2, number of tillers, number of empty grains, 1000-grain weight, percentage of the crushed grain, and white rice yield. The effect of the main factor was significant for all traits except productivity 1 and plant height. Based on the results of comparing the mean effect of year × treatment, four treatments, without plowing with permanent irrigation throughout the day in the first and second year of the experiment, cultivation without plowing with irrigation two days after water disappears from the soil in the second year of experiment and cultivation without Plowing with permanent saturated irrigation in the first and second years of the experiment was identified in terms of grain yield as suitable planting methods with appropriate irrigation regimes. Based on the results obtained from the polygon view in different years of the experiment, T3W1, T3W2, and T1W1 treatments can be suggested as desirable treatments in terms of irrigation regimes and cultivation methods in this rice cultivar. According to the ranking diagram of treatments based on traits in the years of experimentation, T1W1, T2W2 and T1W3 were introduced as the most desirable treatments for cultivating this rice cultivar.

Keywords: rice, graphic analysis, cultivation methods, irrigation regimes, correlation.

Resumo

Um experimento de parcelas subdivididas foi conduzido em um delineamento de blocos completos casualizados com três repetições em dois anos de cultivo no Mazandaran Rice Research Institute para estudar os regimes de cultivo e irrigação. O principal fator são os regimes de irrigação em três níveis, irrigação permanente ao longo do dia (T1), irrigação dois dias após o desaparecimento da água do solo (T2) e saturação permanente do solo (T3); o segundo fator são os métodos de cultivo em três níveis: cultivo sem arado (W1), empilhar 60 cm (W2) e empilhar 80 cm (W3). Com base nos resultados obtidos na análise combinada, o efeito do ano foi significativo em termos de precipitação pluviométrica, produtividade 2, número de perfilhos, número de grãos vazios, peso de 1.000 grãos, porcentagem de grãos triturados e rendimento de arroz branco. O efeito do fator principal foi significativo para todas as características, exceto produtividade 1 e altura de planta. Com base nos resultados da comparação do efeito médio ano x tratamento, quatro tratamentos, sem aração com irrigação permanente ao longo do dia no primeiro e segundo ano do experimento, cultivo sem aração com irrigação dois dias após o desaparecimento da água do solo no segundo ano de experimento e cultivo sem aração com irrigação saturada permanente no primeiro e segundo ano do experimento, foi identificado em termos de produtividade de grãos como métodos de plantio adequados com regimes de irrigação adequados. Com base nos resultados obtidos na visão poligonal em diferentes anos do experimento, os tratamentos T3W1, T3W2 e T1W1 podem ser sugeridos como tratamentos desejáveis em termos de regimes de irrigação e métodos de cultivo nessa cultivar de arroz. De acordo com o diagrama de classificação dos tratamentos baseados em características nos anos de experimentação, T1W1, T2W2 e T1W3 foram introduzidos como os tratamentos mais desejáveis para o cultivo dessa cultivar de arroz.

Palavras-chave: arroz, análise gráfica, métodos de cultivo, regimes de irrigação, correlação.

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Received: July 23, 2022 – Accepted: September 13, 2022

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important food products for more than 50% of the world's population (Atera et al., 2018). Globally, about 160 million hectares of land are devoted to rice cultivation, which is estimated to produce 500 million tons per year (Kirby et al., 2017). Environmental stresses have negatively affected the production of crops, especially cereals, worldwide. Drought is one of the most important abiotic stresses that causes great economic losses to crop production in arid and semi-arid regions (Sarshad et al., 2021; Panda et al., 2021). Due to climate change, global warming has occurred, leading to changes in precipitation patterns in different regions (Schultze-Kraft et al., 2018). On the other hand, rice demand is steadily increasing. Therefore, in strategic planning, rice seems to play an important role in food security (Kaloi et al., 2020). Rice cultivation is one of the largest users of the world's freshwater resources. Because the most common rice production system is seedling cultivation in plowless fields that require a lot of water for irrigation (Ishfaq et al., 2020). It is estimated that to meet global demand by 2035, rice production will need to increase by 26% (Elshayb et al., 2021). As a result, any factor associated with performance losses is a major threat to food security (Kim et al., 2020). Rice is cultivated as a main crop in some provinces of Iran. The usual method of rice irrigation in Iran is interval waterlogging periods during the growing season. Since drought is a major problem in Iran, water is the most important factor in sustainable rice production (Pirmoradian et al., 2020). Attention to new methods of cultivation and irrigation will reduce water consumption and the sustainability of rice production (Kaloi et al., 2020). Diagne et al. (2012) The acceptance report of new agricultural technologies by farmers depends on their knowledge of that technology, so that farmers will use it if they fully understand modern technology. One of these modern technologies is the SIR method, which was developed to increase rice yield and reduce hunger and poverty by 2025 (Kadigi et al., 2020).

Rice cultivation in ridges was introduced in the mid-1990s. This method was first tested for rice cultivation in 2000 in India and Nepal in 2001 (sain et al., 2019). This Water-Saving Technology helps diversify agricultural systems, as well as Improving soil's physical properties soil degradation by Conventional rice cultivation and Excessive use of water and labor, reduced farm profitability (Naresh et al., 2012). Increasing water productivity by using new irrigation technologies (Singh et al., 2013; Siyal and Skaggs, 2009) as well as using low irrigation method (Rezaei et al., 2010) and new cultivation methods (Boojang and Fukai, 2002; Bouman et al., 2005) have been proposed by various researchers. ShamsAli et al., conducted an experiment in two-time phases with two irrigation treatments and concluded that submerged irrigation compared to subsurface irrigation on both planting dates, did not show a significant increase in yield and suggested that with the help of near-saturated soil moisture supply technique, rice cultivation can be started without reducing yield (ShamsAli et al., 2018). In another study to evaluate the effect of irrigation on grain yield and some quantitative traits, the results showed that irrigation regimes could affect grain yield (Mousavi et al., 2021). The purpose of this study was: 1) to select and introduce the most desirable cultivation method and irrigation regimes in rice plants, 2) to study the relationships between traits in different cultivation methods and irrigation regimes, 3) to study water use efficiency in different methods Rice cultivation to save water consumption and maximum use of water volume unit, 4) Investigate changes in grain yield in different cultivation methods and irrigation regimes

2. Material and Method

2.1. Experiment and specifications of the area

To study different cultivation methods and irrigation regimes on yield and yield components and also to select the best cultivation method and irrigation regime for the Shiroodi rice cultivar, a split plot experiment in a randomized complete block design with three replications and two cropping years was carried out in the research farm of Mazandaran Rice Research Institute. 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 at three levels included continuous irrigation throughout the day (T1), irrigation two days after the disappearance of water from the ground (T2), and permanent soil saturation (T3). Second factor sctor also included three levels of plow less cultivation (W1), 60 cm stack (W2), and 80 cm stack (W3). Table 1 shows the names and characteristics of treatments, irrigation regimes, planting methods, and traits evaluated in the experiment. Figure 1 also shows the experimental area's region and geographical and climatic characteristics. Field preparation was performed before the experiment components and fertilizer application was applied equally to all treatments. 21-day-old seedlings of the Shiroodi cultivar were planted on the ridges at a distance of 20 cm and the dimensions of irrigation plots were designed to be 3×7 m. Water consumption was measured by a volume meter and to prevent lateral leakage losses, the boundaries of the plots were completely covered with plastic cover. After planting, propanil herbicide in the amount of four liters per hectare and mechanical control (manual weeding) for weeds were used. To control pests, Swine venom in the amount of two per thousand was used to control leaf-eating green worms, and once diazinon

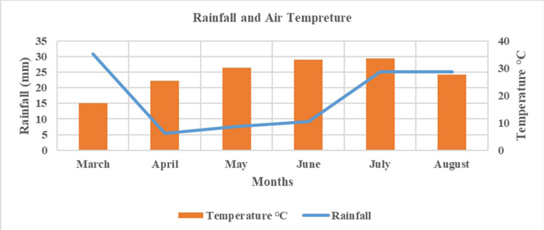

Figure 1. Average meteorological of the area under experiment 2019-2020.

Table 1. Code and name and characteristics of the treatment, cultivation methods, irrigation regimes, and studied traits in the first and second-year experiment.

Treat Code.	Treatment	Traits Code.	Traits
T1	Permanent irrigation throughout the period	YLD	GraYIELDYield
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
Y1	The first year of experiment		
Y2	The second year of the experiment		

poison was applied simultaneously with irrigating the plots to fight tapeworms.

2.2. Data collection

After ripening and harvesting from each treatment, plant height was measured, the number of tillers per plant and cluster sample was prepared to measure yield components (number of clusters, cluster length, number of seeds per spike, 1000-seed weight). In order to determine traits such as plant height, number of tillers per plant, and number of spikes per plant, 10 plants were randomly selected from each experimental plot and these traits were measured. To determine the number of seeds per spike, 30 spikes of 10 plants were randomly selected and this trait was calculated in them. Also, the amount of irrigation water used and irrigation water + rainfall were evaluated. Irrigation water efficiency (CW) and irrigation water efficiency + rainfall (RF) were also used to determine the superior irrigation treatment using the following equations (Equations 1-2).

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

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

2.3. Data analysis

Combined analysis and mean comparison by LSD method were performed on the data obtained from two years of experiment. Atoer to evaluate the treatments in terms of perform traits in the experimental years, the mean effect of the year × treatment was compared. To investigate and select the most suitable crops and irrigation regimes, as well as examine the correlation between traits and grain yield trait, graphical analysis including polygon diagram, ranking of treatments based on its, correlation between, traits and grouping of treatments in terms of traits were used. Data standardization was used to analyze the data obtained from two years of experimentation graphically. Due to the existence of different units of traits, standardization of traits eliminates the units (Equation 3).

$$Z = \frac{X - \mu}{\sigma} \tag{3}$$

In this equation, Z: standard score, X: initial data of the trait, μ: mean of the trait, σ: standard deviation of the trait.

Cluster analysis was used to group the treatments in the first and second years of the experiment. SAS.V9, Genstat. V12.1, Excel, and, SPSS software were used for analysis in this experiment.

3. Results and Discussion

3.1. Analysis of variance and mean comparison

Based on the combined analysis performed at the probability level of 0.01, the effect of the year was significant in terms of rainfall traits, productivity 2, number of tillers, number of empty grains, 1000-grain weight, percentage of crushed grain and white rice yield. The effect of irrigation regimes was significant in terms of all studied traits except productivity 1 and plant height. Also, the effect of year × irrigation regimes on grain yield, rainfall, productivity 2, Number of full grains, number of empty grains, harvest index, percentage of crushe grain and white rice yield showed significant differences. Also, the effect of planting methods was significant for all traits except the number of filled seeds and harvest index. The effect of year × planting methods was also significant in water consumption, rainfall, productivity 1, number of tillers, plant height, spike length, number of empty seeds, 1000-,seed weight, percentage significancegrain, and white rice yield. Significance of the interaction of year and irrigation regimes and the interaction of year and planting methods indicate changes in irrigation regimes and planting methods in different years of the experiment. The effect of irrigation regimes × planting methods was also significant in all studied traits except productivity 2. The highest percentage of coefficient of variation was related to productivity 1 trait (4.63) and the lowest percentage of the the the the coefficient of variation was related to trait of 100-grain weight (1.59) (Table 2). Based on the mean by LSD method at the probability level of 0.01 in terms of irrigation regimes (T1), grain yield, productivity 1, productivity 2, tiller number, plant height, harvest index, 100-grain weight, and rice grain the yield had favorable score. Examination of T2 irrigation regime also showed that grain yield, water consumption, rainfall, productivity 1, productivity 2, number of full grains, number of empty grains, 1000-grain weight, harvest index, percentage of crushed grain, 100-grain weight and white rice yield traits have a favorable rating. According to the T3 irrigation regime, the traits of water consumption, rainfall, spike length, number of full seeds, number of empty seeds, 1000-seed weight and 100-seed weight had more favorable scores.

In other words, grain yield based on T1 and T2 irrigation regimes, water consumption, rainfall, number of full grains,, number of empty grains, 1000-grain weight and 100-grain weight based on T2 and T3 irrigation regimes had the desired rank and high yield. In the study 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, Trait number of tillers in W2, plant height trait in W1, spike length trait in W2, trait number of full seeds in W1 and W2, number of empty seeds trait in W1, trait harvest index and 1000-seed weight trait in all three cultivation methods, trait seed percentage Crush in W3, 100-grain weight trait in W1 and W2 and white rice yield trait in W1 and W2 were desirable and superior (Table 3). Considering that the grain yield trait is used as an important and widely used trait and due to the significant effect of irrigation regimes, the effect of year × irrigation regime, the effect of cultivation methods, the effect of year × cultivation methods and The effect of irrigation regimes × cultivation methods, comparison of the means effect of the year × treatment was also plotted in terms of grain yield trait (Figure 2). Based on this figure, T1W1, T3W1 treatments in the first and second year and T2W1 treatment in the second year of the experiment were identified as the best cultivation method and irrigation regime compared to other treatments. T3W2 treatment in the first year of the experiment and T2W2 and T2W3 treatments in the second year of the experiment were also identified as undesirable methods and had the worst rank. According to the study of Figure 2, it can be concluded that in terms of economic efficiency and water saving, using T2 irrigation regimes (irrigation two days after the disappearance of water in the ground) can also achieve the desired performance. ShamsAli et al. In the results of their research proposed

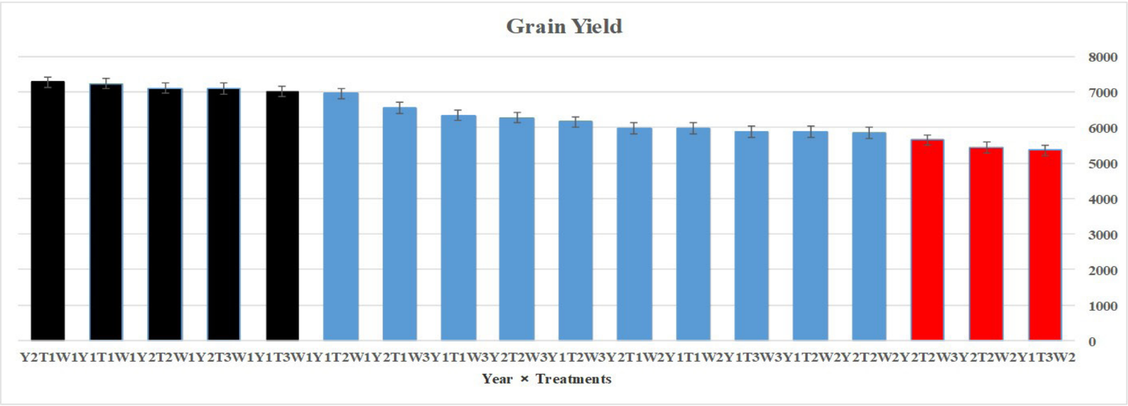

Figure 2. Comparison of means the effect of year × treatment in terms of grain yield in the two years of experiment.

Table 2. Combined analysis based on irrigation regimes and planting methods on the evaluated traits in two years of 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
Planting	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 × Planting	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

*, **, and ns: SignYIELDcant at 5%, 1% and not-significant. 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 mean by LSD (The least significant difference) method on the evaluated traits in two years of experiment.

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	282.1	167.7	167.7	0.04	0.03	0.81	1.7	0.56	24.5	1.13	0.91	0.01	1.06	0.01	188.9
Planting															
W1	6556.9a	6950a	7690a	0.94c	0.85b	25.3c	102.2a	28.2ab	107.2a	42.4a	26.1a	0.51a	10.2b	1.89a	4393.1a
W2	6368a	6337.5b	7077b	1.01b	0.9a	27.5a	96.6b	28.5a	99.7a	40.9b	26.1a	0.5a	10.2b	1.87a	4266.5a
W3	6070b	5722.2c	6462c	1.06a	0.94a	26.3b	94.3c	27.8b	95.7b	41.4ab	26a	0.5a	13.05a	1.86b	4066.9b
LSD	282.01	167.7	167.7	0.04	0.03	0.81	1.7	0.56	24.5	1.13	0.91	0.01	1.06	0.01	188.9

Data followed by the same letter within a column or group of treatments do not differ significantly at the P≤0.05 level.

the technique of providing near-saturated soil moisture in rice cultivation (ShamsAli et al., 2018).

3.2. Polygon view

In order to identify appropriate and desirable treatments to reduce and economic efficiency of water consumption in rice cultivation, a polygon view was used in the experiment (FiguA polygonPolygon diagram is used to identify the best treatments among the studied traits. This diagram is drawn by connecting the treatments farthest from the origin, so the other treatments are inside this polygon. In each section, treatments with specific traits have higher performance and desirability are separated by lines. Based on the graph obtained from the first year's data, the first and second principal components were 47.26 and 20.79%, respectively, and more than 68% of the total variance of the data was explained. Based on this diagram, T2W3, T1W1, T3W1 and T3W2 treatments had the greatest distance from the center of the graph and were selected as suitable irrigation regimes and suitable cultivation methods. In each section, T1W1 treatment was highly desirable in water consumption, plant, height, and white rice yield traits, T3W1 treatment in 1000-grain weight trait, and T3W3 treatment in traits productivity 1 and productivity2 (Figure 3A). In the graph obtained from the second year's data, the first component explained 59.47%, the second component 15.9%, and a total of 75.37% of the variance of the data. Treatments T3W1, T1W1, T1W2, T3W3 and T3W2 had the greatest distance from the center of the graph and were identified as desirable treatments. In each section, T1W1 treatment in terms of 100-seed weight and T3W1 treatment in terms of number of tillers trait were highly desirable (Figure 3B). In the graph drawn on the average of the experiment's first and second year data, the first and second components covered 54.59 and 18.24%, respectively, and 72.83% of the total variance data was explained. Based on this, treatments T3W1, T1W1, T1W2 and T3W2 were identified as treatments with high yield and usefulness, and in each section, T1W1 treatment in terms of 100-grain weight trait and T3W1 treatment in trait number of tillers were highly desirable compared to other treatments (Figure 3C).

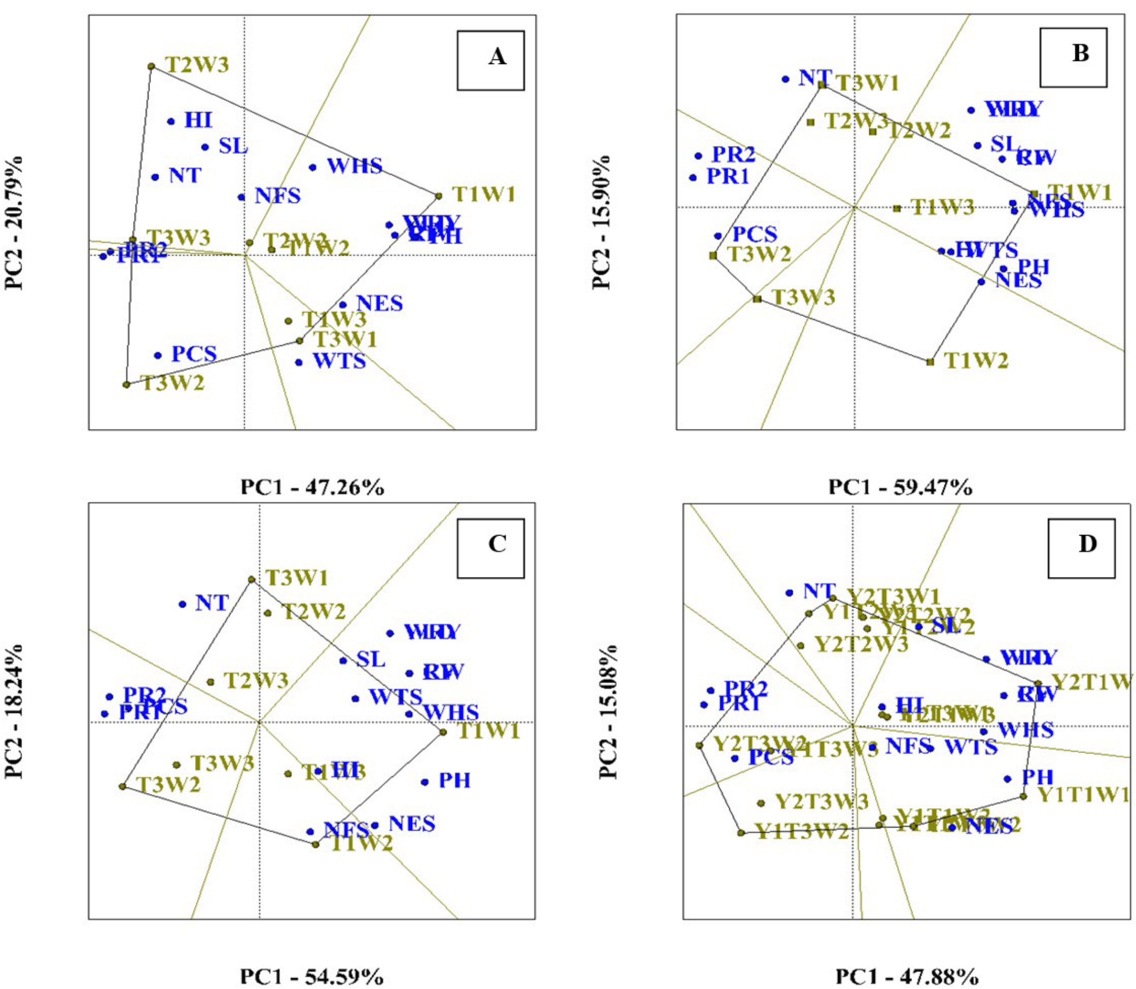

Figure 3. Polygon view of irrigation regimes and cultivation methods based on studied traits in different years of experiment. A: first year of experiment; B: second year of experiment; C: average of two years; D: first and second years of experiment.

In the polygon biplot study based on the first and the second year data simultaneously, the first and second components covered 47.88 and 15.08%, respectively, and more than 62% of the total variance of the total data was explained. Treatments Y1T1W1, Y1T3W2, Y2T3W2 and Y2T3W1 were identified as desirable treatments and in each section, Y2T1W1 treatment in water consumption and rainfall traits, Y1T1W1 treatment in plant height trait and treatment Y1T3W1 in tiller number trait were desirable. (Figure 3D). Various researchers have used this type of diagram to review their experiments (Shojaei et al., 2022a; Adedeji et al., 2020; Akcura and Kokten, 2017).

In general, according to the results obtained from the polygon view in different years of the experiment,, T3W1, T3W2 and T1W1 treatments can be suggested as desirable treatments in terms of irrigation regimes and cultivation methods in this rice cultivar.

3.3. Ranking of treatments based on traits

In this diagram, linear coordinates are connected to the point of averages from the origin and continue to the sides. The best treatment is a treatment that is inclined to the positive end of this axis and its vertical distance from this line is the least value. In this figure, the best point is the center of the concentric circles, which is marked with an arrow, and other treatments are grouped based on this point. Based on the ranking diagram of treatments in the first year of the experiment, T1W1, T2W3, T1W2 and T2W2 treatments were selected as suitable cultivation methods with irrigation regimes to cultivate this cultivar. T3W2 treatment was also introduced as an inappropriate method. The order of treatments from favorable to unfavorable is as follows: (Figure 4A)

T1W1> T1W2> T2W2> T2W3> T1W3> T3W1> T3W3> T3W2.

Based on the graph obtained from the data of the second year of the experiment,, T1W1, T1W3 and T2W1 treatments were identified as the most desirable treatments and T3W3 and T3W2 treatments as the most undesirable treatments. The order of treatments from the most desirable to the most undesirable treatments is as follows: (Figure 4B)

T1W1> T1W3> T2W2> T3W1> T2W3> T1W2> T3W3> T3W2.

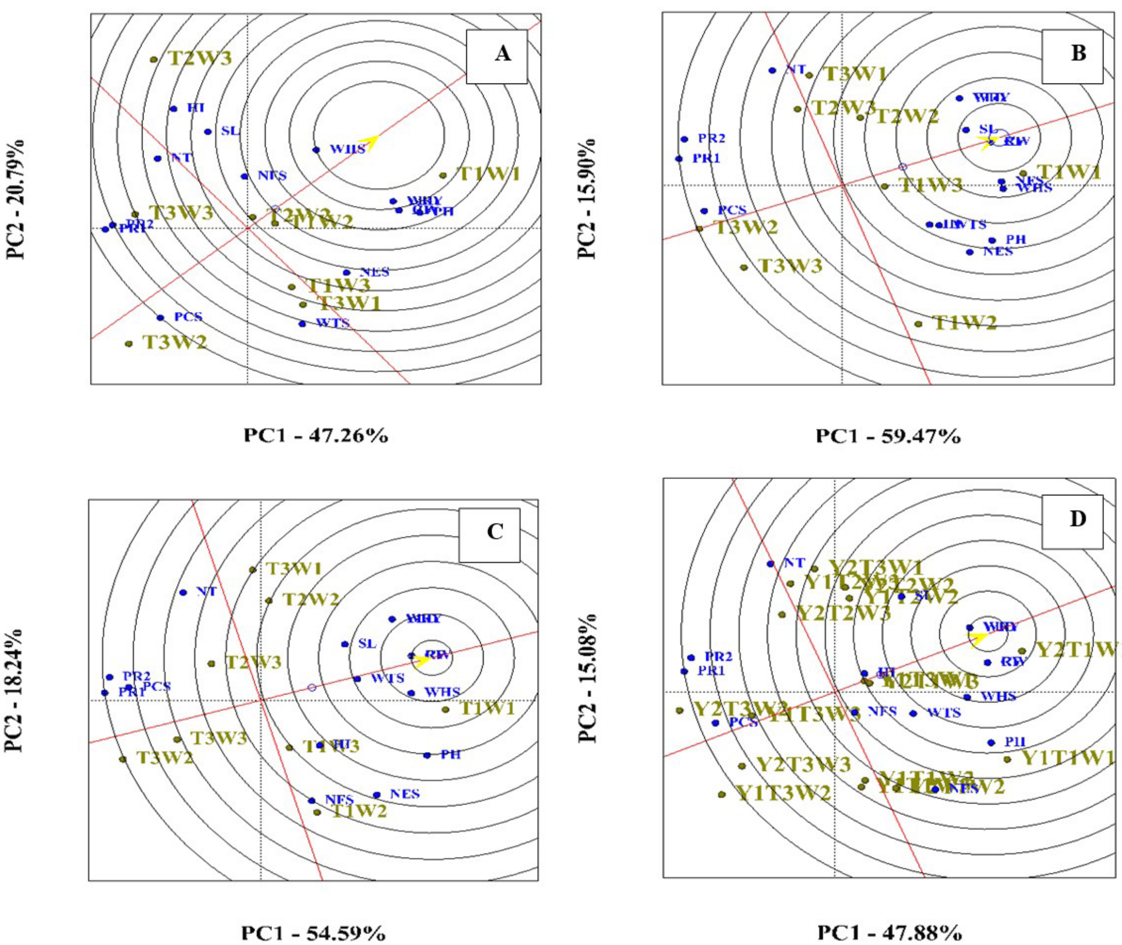

Figure 4. Evaluation of treatment rankings based on the evaluated traits in different years of the experiment. A: first year of experiment; B: second year of experiment; C: average of two years; D: first and second years of experiment.

Based on the graph drawn on the data of the first and second years of the experiment, T1W1,, T2W2, T3W1 and T1W3 treatments were selected as desirable treatments and T3W2 treatment as unfavorable treatments. The order of treatments from optimal to optimal in the data of the average of two years of experiment is as follows: (Figure 4C)

T1W1> T2W2> T1W3> T3W1> T2W3> T1W2> T3W3> T3W2.

Based on the graph drawn on the data of the first and second years of the experiment simultaneously, T1W1 and T3W1 treatments in the second year of the experiment and T1W3 in the first year of the experiment were identified as optimal treatments. Also, T3W3 and T2W2 treatments in the second year of the experiment and T3W2 treatment in the first year of the experiment were identified as the most undesirable treatments. The order of treatments from the most desirable to the most undesirable is as follows: (Figure 4D)

Y2T1W1> Y2T3W1> Y1T1W3> Y1T2W2> Y1T1W1> Y1T2W1> Y2T1W3> Y2T1W2> Y2T2W2> Y2T2W3> Y1T1W2> Y2T2W1 > Y1T3W1> Y1T3W3> Y1T2W3> Y2T3W3> Y1T3W2> Y2T3W2.

In general, by examining different treatments in the years of experiment, T1W1, T2W2 and T1W3 can be introduced as the most desirable treatments for cultivating this rice cultivar. Also, due to the unfavorable treatment of T3W2 and T3W3 in the evaluated reaction in the traits, this type of cultivation and irrigation method is not recommended.

3.4. Correlation between traits

A correlation graph was used to determine the presence or absence of correlation between traits and also to examine the relationships between yield components and grain yield trait (Figure 5). In this cosine biplot diagram, the angle between the trait vectors indicates the correlation intensity between the traits. If the angle between the vectors is less than 90 degrees, the correlation between the traits is equal to +1, if the angle between the vectors of the traits is 90 degrees, the correlation between the vectors of the traits is zero, and if the angle between the vectors is 180 degrees, the correlation is -1. (Yan and Kang, 2003). Based on the graph drawn on the data of the first year of the experiment, grain yield, 100-grain weight, white rice yield, plant height and water consumption traits showed a positive correlation with each other. Also, the number of empty seeds and 1000-seed weight had a positive correlation. Productivity 1, productivity 2 and micrograin percentage were also positively correlated. There was a positive correlation between traits number of full seeds, spike length, harvest index and number of tillers. According to the angle between the two vectors, the percentage of crushed grain percentage – 100 seed weight, harvest index and spike length - 1000seed weight traits were negatively correlated. Also, according to the 90 degree angle between the two traits, the number of full grains and productivity 1 traits were estimated to be zero (Figure 5A). Based on the graph drawn on the data obtained in the second year of the experiment, between

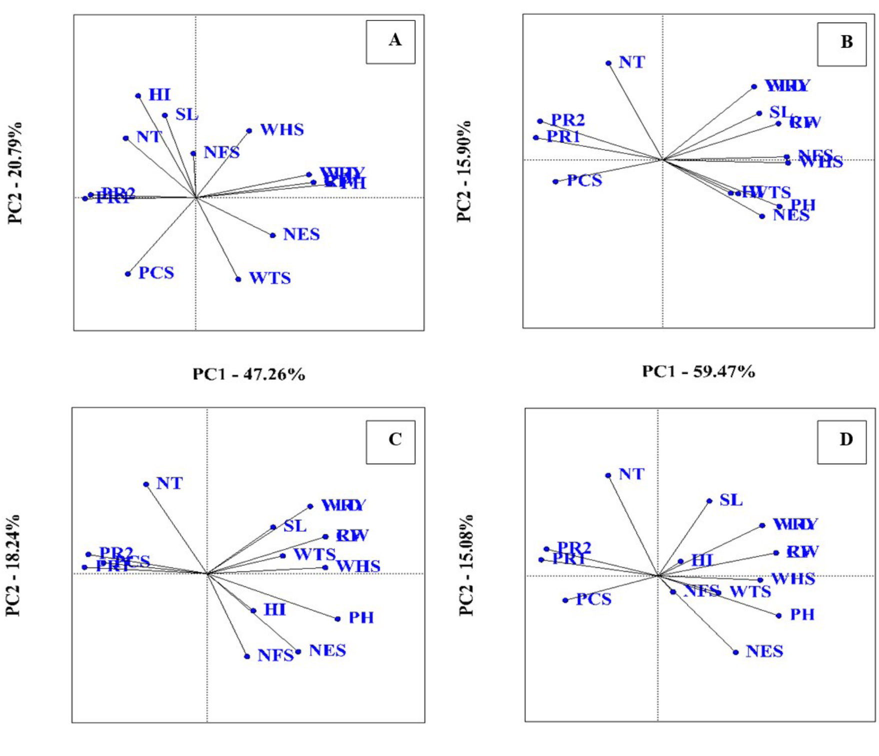

Figure 5. Correlation diagram between the evaluated traits in different years of the experiment. A: first year of experiment; B: second year of experiment; C: average of two years; D: first and second years of experiment.

traits grain yield, white rice yield, spike length, rainfall, water consumption, number of full grains and weight of 100 grains together and also between traits number of full grains, weight One hundred seeds, 1000-seed weight, harvest index, plant height and number of hollow seeds together and a positive correlation was observed between crushed seed percentage, productivity 1, productivity 2 and tiller number. Also, no correlation was reported between the 90 degree angle between the two traits, the number of tillers with water consumption and rainfall (Figure 5B). The results of the correlation diagram drawn on the average data of the two years of the experiment also identified a positive correlation between traits grain yield, white rice yield, panicle length, rainfall, water consumption, 1000-seed weight, 100-seed weight and plant height. There was also a positive correlation between traits 100-seed weight, plant height, harvest index, number of full seeds and number of hollow seeds. The number of tillers, percentage of crushed grain, productivity 1 and productivity 2 traits also had a positive correlation with each other. According to the 180 degree angle between the vectors of the number of full grain traits and the number of tillers traits, the correlation between these negative traits was identified (Figure 5C). The results of the correlation diagram drawn on the data of the first and second years simultaneously, the correlation between traits grain yield, white rice yield, spike length, rainfall, water consumption, harvest index, 100-grain weight and 1000-grain weight were identified as positive. There was also a positive correlation between 100-seed weight, 1000-seed weight, plant height, number of full seeds and number of hollow seeds traits. A positive correlation was also identified between traits crushed grain percentage, productivity 1 and productivity 2. According to the angle between the two vectors, the percentage of crushed grain percentage with water consumption and rainfall traits, as well as between the traits of 1000-grain weight with efficiency 2, a negative correlation was evident (Figure 5D). In another study conducted by Shojaei et al., This type of diagram was used in research (Shojaei et al., 2022b; Shojaei et al., 2020).

In general, by examining the correlation results in different years of the experiment, a positive correlation can be reported between grain yield trait and traits white rice yield, spike length, rainfall, water consumption, 100-grain weight and 1000-grain weight.

3.5. Grouping and cluster analysis of treatments in terms of traits

Based on the grouping of treatments in terms of evaluated traits in different years of the experiment, the grouping diagram of treatments in terms of traits was used (Figure 6). Based on the graph drawn on the data of the first year of the experiment, the treatments were grouped into two groups. The first group included T1W1, T1W2 and T2W3 treatments and the second group included T1W3 and T3W1 treatments (Figure 6A). The graph drawn on the data of the second year of the experiment also

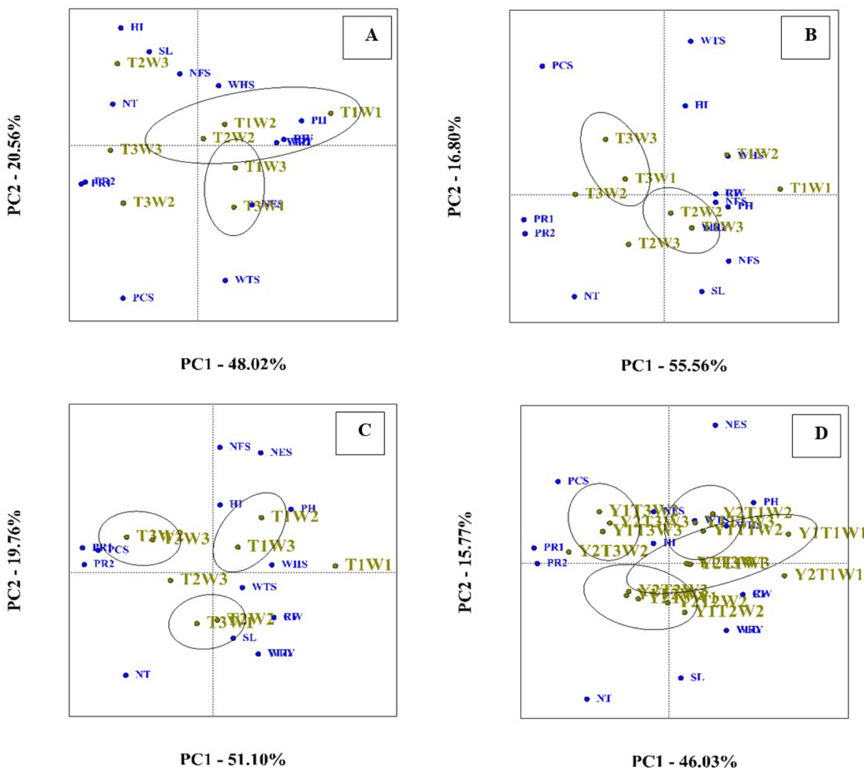

Figure 6. Grouping of evaluated treatments based on the traits measured in different years of the experiment. A: first year of experiment; B: second year of experiment; C: average of two years; D: first and second years of experiment.

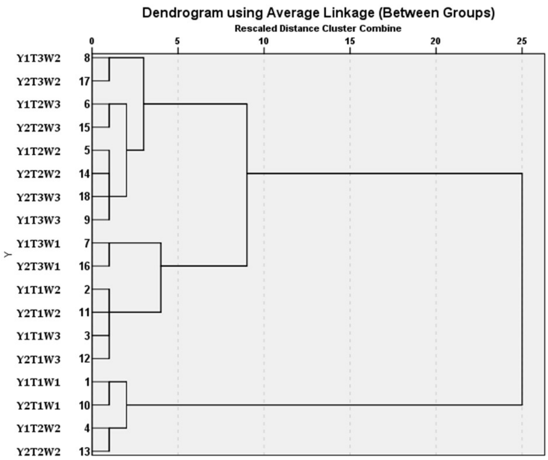

Figure 7. Cluster analysis and grouping of evaluated treatments in terms of traits measured in experimental years.

grouped the treatments into two groups. The first group included T3W3 and T3W1 treatments and the second group included T2W2 and T1W3 treatments (Figure 6B). Based on the graph drawn on the average of the data of the first and second years of the experiment, the treatments were grouped into three groups. The first group included T1W2 and T1W3 treatments, the second group included T3W1 and T2W2 treatments and the third group included T3W2 and T3W3 treatments (Figure 6C). In the obtained diagram on the data of the first and second year of crop simultaneously, four main groups were formed. The first group included treatments Y1T3W2, Y2T3W3, Y1T3W3 and Y2T3W2. The second group included treatments Y2T1W2, Y1T1W3 and Y1T1W2. The third group consisted of Y1T1W1, Y1T1W2, Y1T2W3 and Y2T2W3 treatments.

Y1T1W2 treatment was present in both the second and third groups and was similar to the treatments of these two groups in terms of trait response. The rest of the treatments were in the fourth group except Y2T1W1 and Y2T1W1 was not in any group (Figure 6D). Based on the results obtained from cluster analysis drawn on two years of experiment data, the treatments were grouped into three main groups in terms of traits. The first group was divided into two subgroups. In the first subgroup were Y1T3W2 and Y2T3W2 treatments and in the second subgroup were Y1T2W3, Y2T2W3, Y1T2W2, Y2T2W2, Y2T3W3 and Y1T3W3 treatments. The second group also divided into two subgroups. The first subgroup included Y1T3W1, Y2T3W1 and the second subgroup included Y1T1W2, Y2T1W2, Y1T1W3 and Y2T1W3 treatments. The third group included treatments Y1T1W1, Y2T1W1, Y1T2W2 and Y2T2W2 (Figure 7).

4. Conclusion

Based on the results of the present study, combined analysis of the studied traits showed that the effect of irrigation regimes on all traits except productivity 1 and plant height were significant. The effect of cultivation method was significant for all traits except the number of filled seeds and harvest index. The interaction of irrigation regimes and cultivation methods was also significant in all traits except productivity 2. Based on the analysis of the treatments and traits evaluated in the two years of experiment, T2W2 and T3W1 treatments can be considered as suitable and cost-effective methods for cultivation and irrigation of rice (Shiroodi cultivar). It can also be concluded that in addition to using non-flooding systems in rice cultivation, modern cultivation management methods can achieve maximum economic efficiency from limited water and soil resources.

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