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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Use of subsurface drip irrigation and water retention barrier to effective use of water in rice

Çeltik üretiminde suyun etkili kullanımında toprakaltı damla sulama ve su tutma bariyeri kullanımı

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Ö Z E T / A B S T R A C T

Aims: Rice is one of the most applied irrigation waters applied plant among cultivated plants since it is grown in water or in saturated soil conditions in a significant portion of the growing season. This study was aimed to determine the effects of rice grown on water use, development, yield and some yield parameters using of both separately and jointly water retention barriers and subsurface drip irrigation methods in Enez, Edirne, Turkey in 2017.

Methods and Results: Four different treatments were applied: ponding ((control(C)), subsurface drip irrigation system (SDI), ponding + water retention barrier (C+WRB) and SDI+WRB in this study. Subsurface drip irrigation laterals were placed 10 cm deep from the soil surface and the WRB was placed at 30 cm deep. Plants were irrigated with a constant water height of 10-15 cm on the soil in C and C+WRB treatments, 20% ± 5% of the available water retention capacity is consumed without exposure to water stress in SDI and SDI+WRB treatments, the field capacity is completed. WRB and SDI applications significantly affected the irrigation water amount, grain yield and yield components of rice. The yield and irrigation water amount according to the treatments varied between 321-715 kg da^{-1} and 751-2444 mm, respectively.

Conclusions: In comparison to the control treatment, water saving was achieved by 27%, 50%, 69% in C+WRB, SDI and SDI + WRB treatments, respectively. Despite this, when marketable yield values are analysed according to the control treatment, it has increased by 10.8% in C+WRB, and decreased by 48.8% and 40.7% in SDI and SDI + WRB treatments. The water retention barriers and subsurface drip irrigation practices used in the study have been shown to reduce the use of irrigation water in rice production.

Significance and Impact of the Study: It can be said that these methods have the potential to be used especially in arid and semi-arid regions where water is limited or inadequate.

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INTRODUCTION

Rice is the third largest grain produced in the world after wheat and maize. Most of the rice produced in the world is grown in tropical and subtropical regions where water is abundant (Anonymous, 2003). Rice is grown everywhere in Turkey where water is adequate and flat land. The most important limiting factor in paddy farming is the provision and management of irrigation water (Ozgenc and Erdogan, 1988). Rice is a plant with different propensity to other plants in terms of cultural activities and is the only grain plant that uses dissolved oxygen for water. Therefore, the amount of irrigation water and the consumption of plant water of rice and the application of this water are different. The amount of water needed by the rice grown under water varies depending on factors such as climate and length of growing period, varieties, soil type and land structure (Tabbal et al., 2002; Tulucu, 2003).

Ponding irrigation method is generally applied in paddy growing in Turkey or other countries. In this method, the water is kept on the soil surface at a certain depth. Among the advantages of the method, it can be said that it is a good growing eliminating the drought stress and easier to control weed (Surek, 2002). However, in this method water has negative features such as excessive use of irrigation, making tanks and channels for water retention, drainage water's effects on ground water and environment. Another negative effect is the presence of anaerobic conditions in rice cultivation due to the continuous presence of water in the field, which causes methane gas formation. It has been reported that the adverse effects of drip irrigation applications will be reduced (Beser and Surek, 2009). Subsurface drip irrigation systems are defined as the application of water and plant nutrients directly to the plant root zone. Subsurface drip irrigation systems have begun to be part of modern agricultural irrigation since the 1980s, which first appeared in the United States in the early 1960s. The first scientific report on groundwater drip irrigation was published by Blass (1964) in Israel (Lamm and Camp, 2007).

Irrigation is usually made in rice depending on the presence of water at a certain level on the soil surface. There are many studies on this subject in the world (Raju, 1980; Veerara Ghavulu and Reddy, 1985; Surek et al., 1998; Xiaoguang et al., 2002; Meral and Temizel, 2006). In recent years, water has become more valuable day by day. Therefore, it has increased the research on the feasibility of different irrigation methods (sprinkler or drip irrigation), because of the use of too much irrigation water in paddy growing. Muirhead et al. (1989) reported that sprinkler irrigation method resulted 50% reduction in grain yield of rice comparison to traditional method. Similar results were found other researchers (Surek et al., 1996; Cakır et al., 1998). It has been reported by researchers that studies have generally saved irrigation water but have significantly reduced yield.

The use of drip irrigation in the world has been accepted for many years, but subsurface drip irrigation has gained momentum for different plants, melon (Sharma et al., 2014), grassland (Finger et al., 2015), ornamental plant (Elhindi et al., 2016), sugar cane (Silva et al., 2016), broccoli (Oliveira et al., 2016) in recent years. Studies on the use of surface/subsurface drip irrigation for rice have been emphasized in recent years, but research on the subject is still needed. Ottis et al. (2006) reported that subsurface drip irrigation system reduced water use by 80% in 3 different rice varieties. He et al. (2013) examined the performance and water use efficiency in rice production using traditional methods and plastic mulching + drip irrigation. While water use efficiency is highest for drip irrigation, it has been reported that the yield decreases by 31.76-52.19%. Rajwade et al. (2014) reported that subsurface drip irrigation applied in rice increased grain yield compared to conventional irrigation and decreased fertilizer requirement.

From the beginning of 1950, asphalt application (Smucker, 1969; Palta and Blake, 1974), mulching (Garrity et al., 1992), soil treatment (Galvez and Barahona, 2005), and polymer (Boartright et al., 1997; Hayat and Ali, 2004) material was applied to the soil surface and subsurface to hold water in the soil. These applications have not been widely used today due to both application difficulties and economic reasons. The placement of polyethylene (PE) materials used as an impermeable barrier to soil is an approach to reduce both the detrimental effects of rapid percolation and the movement of poor-quality groundwater upwards. The main advantages are that the PE barrier (WRB) is retained for longer than the polymeric materials, the absence of any harmful side effects known, the application of the barrier only once in land conditions, and the more cost-effective. Furthermore, the developed WRB covering methods causes an increase in yield and provide significant savings water resources. The most important disadvantage of the system is about the implementation of the material to the sub-soil. For this purpose, in 2014, a placement machine called SWRT (BRON) was developed in USA). In the coming years, this method will become popular in the world especially in countries experiencing water scarcity. Studies of different plants; turfgrass (Demirel and Kavdir, 2013),

maize (Gong, 2014; Amirpour et al., 2016), pepper (Al-Rawi et al., 2017; Hommadi and Almasraf, 2018), eggplant (Almasraf and Salim, 2018) related to this method have begun to gain speed in recent years. According to the results of these researches done on different plants, WRB/SWRT significantly reduces irrigation requirements and saving up to 50% on irrigation water. At the same time, it was seen that the incomes increased significantly in studies.

In recent years, research has been spreading on the use of subsurface drip irrigation in many crops in the world, work on the use of paddy fields has been limited. In studies on this subject; Dunn et al. (2004) and Ottis et al. (2006) stated that the subsurface drip irrigation method provides significant savings from irrigation water in rice. On the other hand, any other study has been published on application of subsurface drip irrigation and water retention barriers together in rice production. The aim of this study is to determine that combination of subsurface drip irrigation and water retention barriers would be more appropriate in reducing irrigation water use, considering yield and grain quality of rice.

MATERIAL AND METHOD

Study site

The study was carried out in a condition on rice farm field (40° 40' north latitude, 26° 10' east latitude) located in the Edirne/Turkey where rice farming was intensively conducted in 2017. In the study, as a plant material, a sleep-resistant, short-lived, medium-early and high-yielding "Luna" rice variety was used.

The physical properties of the soil were determined before the experiment began. The field capacity, wilting point, bulk density and soil texture values are shown in Table 1. Field capacity and wilting point values were determined at pF at 1/3 and 15 atm, respectively.

Experimental design

The experiment was carried out in 3 replications, 4 different treatments: ponding ((control(C)), subsurface drip irrigation system (SDI), ponding+water retention barrier (control+WRB), and SDI+WRB according to randomized blocks trial design (Figure 1).

Table 1. Soil analysis results of the study area

Depth (cm)	Texture Class	Bulk density (gr cm^{-3})	Field Capacity Pv (%)	Wilting point Pv (%)
0-30	Clay-loam	1.33	46.3	32.63
30-60	Clay-loam	1.35	47.4	34.67

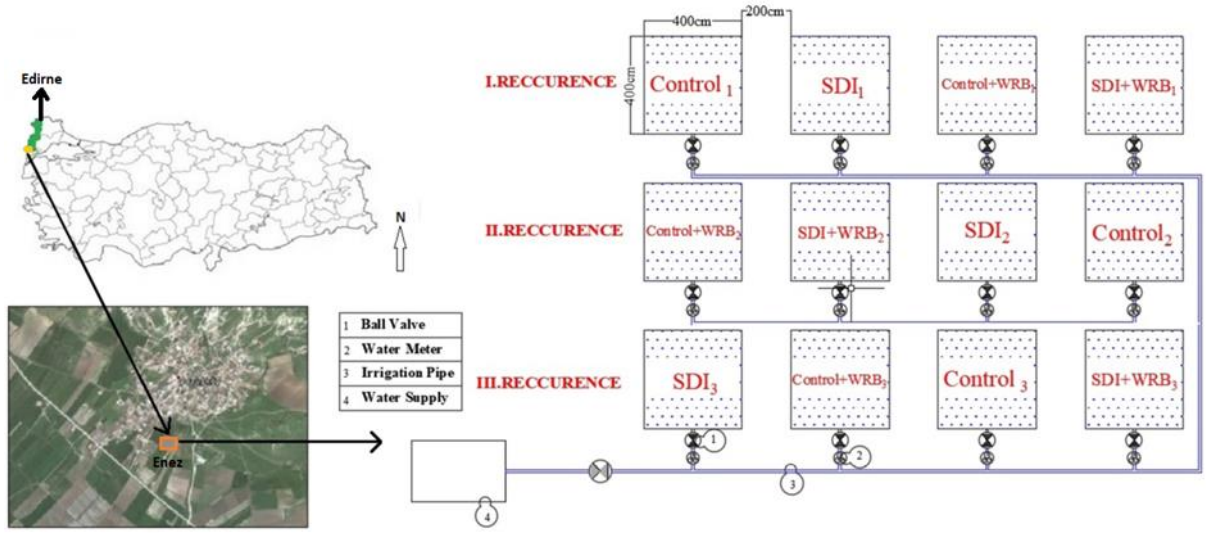


Figure 1. Experimental design and irrigation system

Rice seeds were planted on the field on May 21, 2017 after application of subsurface drip irrigation system and water retention barriers. On 21 June 2017, irrigation practices were started after rice seed were kept in the soil. During the period from sowing to irrigation treatments, SDI and SDI + WRB trial plots were

not allowed to fall below the field capacity.

Seeds were planted with 20 g m^{-2} spreading method. The dimensions of a parcel were arranged as 4 m x 4 m. To prevent interaction between the plots, a space of 2 m was left between the parcels (Figure 1). The electrical conductivity value (EC) of the irrigation water is 420 mmhos cm^{-1} and the pH value are 7.77. A 250 kg ha^{-1} N15P15K15 compose fertilizer was applied as base fertilizer in experimental soils. Additionally, ammonium sulphate fertilization (500 kg ha^{-1}) was performed 2 times (June 28, 2017 and July 28, 2017) after sowing. As the plant nitrogen requirement is high during the sibling period, the second fertilization is applied considering this period. Two different struggles were made in pre-planting and post-seeding, as weed control is especially important in subsurface drip irrigation in rice. Herbicides (Buckstar) with a doses of 25 EC 5 L ha^{-1} against Echinochloa oryzoides, Echinochloa crus-galli, etc. was used prior to sowing. Different herbicides were applied at 3 times (June 14, 2017; 2 kg ha^{-1} Clipper 200 EC, June 28, 2017; 2 kg ha^{-1} Basagran M, 2 kg ha^{-1} Efdal Halo, 0.5 kg ha^{-1} Intervix Pro, July 4, 2017; 2 kg ha^{-1} Basagran M) after sowing.

Soil preparation of all plots was done according to traditional methods. Soil tillage was made by plow in April, 2017. Afterwards, the leveling of the soil was performed by digging machine equipped with laser. Embankments have been made in the control treatments. After these processes in the water retention barrier applications, the plots were excavated to a depth of 30 cm with the aid of the bucket (Figure 2). After the water barrier covering material was laid, the parcels were re-leveled (Figure 3).



Figure 2. The excavation for water retention barriers



Figure 3. Leveling operations after water retention barriers

Treatments

a) Ponding irrigation (Control/C): In the control application, irrigation was done according to the traditional method. The irrigation water in the plot was filled 1 day before planting in order to reach the appropriate germination temperature. 5 days after sowing, the water in the pans was evacuated and thus the seeds were attached to the soil and their development was accelerated. Afterwards, the water depth was 10-15 cm during the trial period. The pans

were emptied and refilled for the water circulation for the development of the plants in the pans throughout the trial. Irrigations were made for a few days during the trial period. Prior to irrigation, the height of the water in the pan was measured and the water was completed up to 15 cm high. The amount of irrigation water to be applied is given in a controlled manner according to water meter. In order to make the harvesting operations easily, water was cut 2 weeks before the harvest.

b) Subsurface drip irrigation (SDI): The subsurface drip irrigation pipes were buried 10 cm below the soil surface. Drip pipes has drippers within pressure regulators, self-cleaning and anti-siphon. These drippers have a flow rate of 1.6 L h^{-1}, an outer diameter of 17 mm and a dripper spacing of 0.50 m and pipes were placed in the soil at 50 cm intervals with a wetting ratio of 1 (Lamm and Camp 2007). One soil moisture sensor was placed to 10 cm deep to determine moisture of the root depth effectively and another sensor was placed to 30 cm depth to monitoring water movement in each plot. Irrigation was carried out so as not to fall below the field capacity during the planting and fertilization times to prevent water stress of plants. After irrigation applications, 20 ± 5% of the available water holding capacity has been made in a way that will bring it back to the field capacity. The amount of irrigation water to be applied is given in a controlled manner according to the water meter.

c) Ponding irrigation + water retention barrier (C+WRB): 1.0 mm thickness polyethylene plastic cover material used as greenhouse cover material was used as water retention barrier. The material used was tested in terms of water permeability in laboratory conditions and it was found to be completely impermeable. The WRBs were placed in a depth of 30 cm of the soil surface after all the edges of the paddy plant were folded up to 20 cm above the effective root depth. Thus, in practice the drainage is partially blocked. Irrigation is similar to the control application.

d) Subsurface drip irrigation + water retention barrier (SDI+WRB): In this treatment, the details of the irrigation practices were carried out under the heading of SDI and the detail of the water retention barrier to be applied was as described under Control + WRB.

Measurements and calculations

Soil moisture

In the monitoring of soil moisture, moisture sensors (DECAGON) working according to the dielectric principle and remote-control systems (DEVINT) were used for computer monitoring of the data to be obtained from the sensors (Figure 4). The placement of the sensors was done prior to seed sowing. 20 days prior to the establishment of the experiment, the soil was saturated by turning a certain area in the experiment area for the calibration process. Then, regression equations were obtained between the soil samples taken at certain intervals and the sensor values and calibration equations were obtained. The sensors are placed in the parcels as described in the experimental part.



Figure 4. Remote monitoring system (DEVINT)

Determination of the amount of irrigation water

Irrigation was carried out as described in the treatments. In the C and C+WRB treatments, the water height was measured continuously and when the water level fell below 10 cm, water was given up to 15 cm level again. In other treatments, the amount of irrigation water to be applied was calculated with the help of Equation 1 (Howell and Meron, 2007). The calculated irrigation water was given via water meter placed at the beginning of all parcels.

$$I=AWHC \times Ry \times P \times A \quad (1)$$

Where; I: Irrigation water amount (mm), AWHC: Available water holding capacity up to 25 cm in depth (determined using moisture sensors) (mm), Ry: Part of AWHC allowed to be consumed (%20±5), P: Wetted area ratio (1.0), A: Parcel area (m^2)

Water use and irrigation water use efficiency

Water usage values for each subject were calculated as seasonal. For this purpose, the amount of irrigation water applied to the treatments was taken into consideration. Irrigation Water Use Efficiency (IWUE) values are calculated according to Equation 2 by using the applied irrigation water quantities and rice grain yield values. (Hillel and Guron, 1973).

$$IWUE = \frac{Y}{I} \quad (2)$$

Where, IWUE: Irrigation Water Use Efficiency (kg m^{-3}), Y: Rice yield (kg da^{-1}), I: Irrigation Water Amount (mm).

Yield and yield parameters

Yield (kg da^{-1}): Each sub-parcel of the applications was harvested and yield per decares was calculated from the grain product cleaned after the blend.

Thousand grain weights (g): In the three separate samples taken from 1 m^2, one thousand grain weight was calculated as the result of multiplying the averages with ten.

Plant height (cm): The length of the plant between the top connection point of the fringe roots and the inflorescence starting point was measured as the plant height.

Panicle length (cm): It was determined by measuring the distance between the top of the panicle and the bunch of the panicle between 10 plants which were taken accidentally from the plots in the maturation stage.

Number of panicle (number m^{-2}): The total number of panicles detected in 1 m^2 was determined.

Grain number per panicle (number $panicle^{-1}$): The average number of total numbers of ten plants selected randomly in 1 m^2 was determined.

Grain length and width (mm): After the separation of the beak of the rice grains from each parcel, 3 specimens were measured using a caliper tool in 100 samples.

Grain-shaped: The length of the grain is calculated by proportioning the grain width.

Unbroken kernel ratios (%): During the processing of the rice, the parts of the grain such as the chunky-fruit shell (embryo) are separated and the remaining brass (solid and broken) remains. The unit is determined by how many units of the whole rice is obtained from the unit.

Marketable yields (kg da^{-1}): This parameter was found by multiplying yields by unbroken kernel ratio

Change in grain yield (kg da^{-1}): ($Yield_{control}$ - $Yield_{treatment}$)/($Yield_{control}$) x 100

Water saving (%): (Irrigation $water_{control}$ - Irrigation $water_{treatment}$)/(Irrigation $water_{control}$) x 100

Statistical analysis

The difference between the data obtained as a result of the experiments (p = 0.05) was determined by one-way analysis of variance (One-Way ANOVA). If the difference is significant, Duncan test is used to determine the difference between the treatments. All statistical evaluations were made by SPSS 20.0 package program. Also, data from the study were analyzed in R program (R Development 2014). Covariant / Correlation analysis was used in BiplotGUI (La Grange et al. 2009) package to demonstrate the change of the properties according to irrigation practices.

RESULTS AND DISCUSSION

Total irrigation water amount and irrigation water use efficiency

Total irrigation water amount (TIWA) and irrigation water usage efficiency (IWUE) values are shown in Figure 5. In the mentioned figures, the mean values and statistical analysis results and the standard error values are given on the graphs.

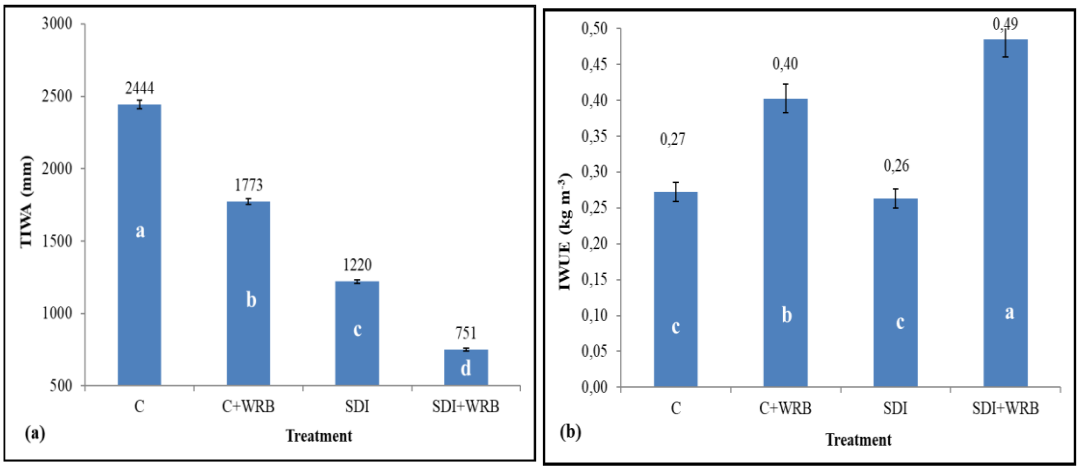


Figure 5. TIWA (a) and IWUE (b) values by treatments

When amount of irrigation water applied to the treatments is examined, it is seen that the highest water application is control treatment (C) and the lowest is SDI+WRB with use of subsurface drip irrigation and water retention barrier. In addition, difference between amount of irrigation water applied on all treatments was statistically significant (Figure 5a). The highest IWUE value was obtained for SDI+WRB. In the treatments of water retention barrier applications (C+WRB and SDI+WRB), irrigation water usage efficiency values were higher than the treatments (C and SDI) in which the application was not performed (Figure 5b). Difference between the treatments was statistically significant. Our results indicated that WRB treatment caused significant increase in water use efficiency of rice.

Yield and yield parameters

Grain yield and yield components (number of panicles, panicle length, grain number per panicle, thousand grains weight, plant height, grain length, grain width, grain-shaped, unbroken kernel ratios) are shown in Figure 6. As a result of the statistical analysis on the yield values, it is seen that the C and C+WRB treatments and SDI and SDI+WRB treatments were in the same group, namely the difference between these treatments is not significant (Figure 6a). However, it was determined that the C treatments were more efficient than the SDI treatments and this difference was important. According to these results, it was found that WRB application increased the efficiency in both treatments, but this increase was not statistically significant. Also, SDI applications significantly reduce rice yield (Figure 6a). It is thought that this is due to weed pressure. At the end of the harvest 1 m^2 obtained in the number of panicles obtained results similar to yield values. The highest number of panicles was in control and the lowest in SDI+WRB (Figure 6b). When the panicle length was compared, the C treatment had the highest value and the difference between the other treatments was significant (Figure 6c). The difference between the treatments in terms of grain number per panicle was not significant (Figure 6d). The highest value in terms of thousand grain weights of SDI+WRB. Nevertheless, there was no difference between the other treatments except for the control treatment (Figure 6e). Our findings indicated that remarkable decrease in gran yield as a result of SDI and SDI+WRB treatments were mostly caused by decrease in number of panicles in a unit area instead of panicle number or grain weight of rice. Reduction in panicle number could be attributed to less tiller number per plant. Since tiller number is determined earlier growth stages of rice, alternative agronomic practices such as lower sowing density and higher nitrogen application could be suggested to examine for those application. It was observed that the highest plant height values were in C+WRB application and the difference between the application and other application treatments was statistically significant (Figure 6f).

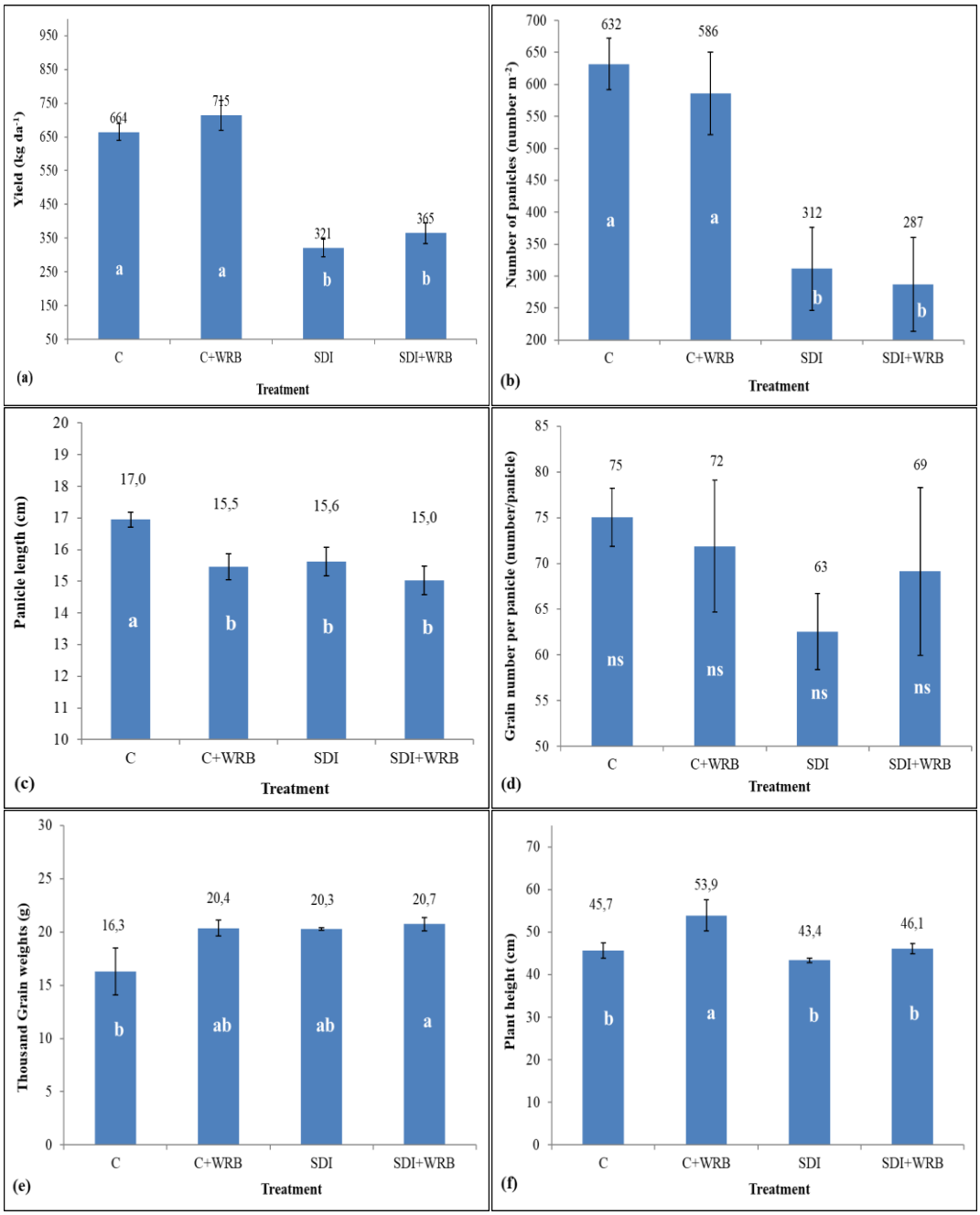


Figure 6. Yield and yield parameters (yield (a), number of panicles (b), panicle length (c), grain number per panicle (d), thousand grain weights (e), plant height (f))

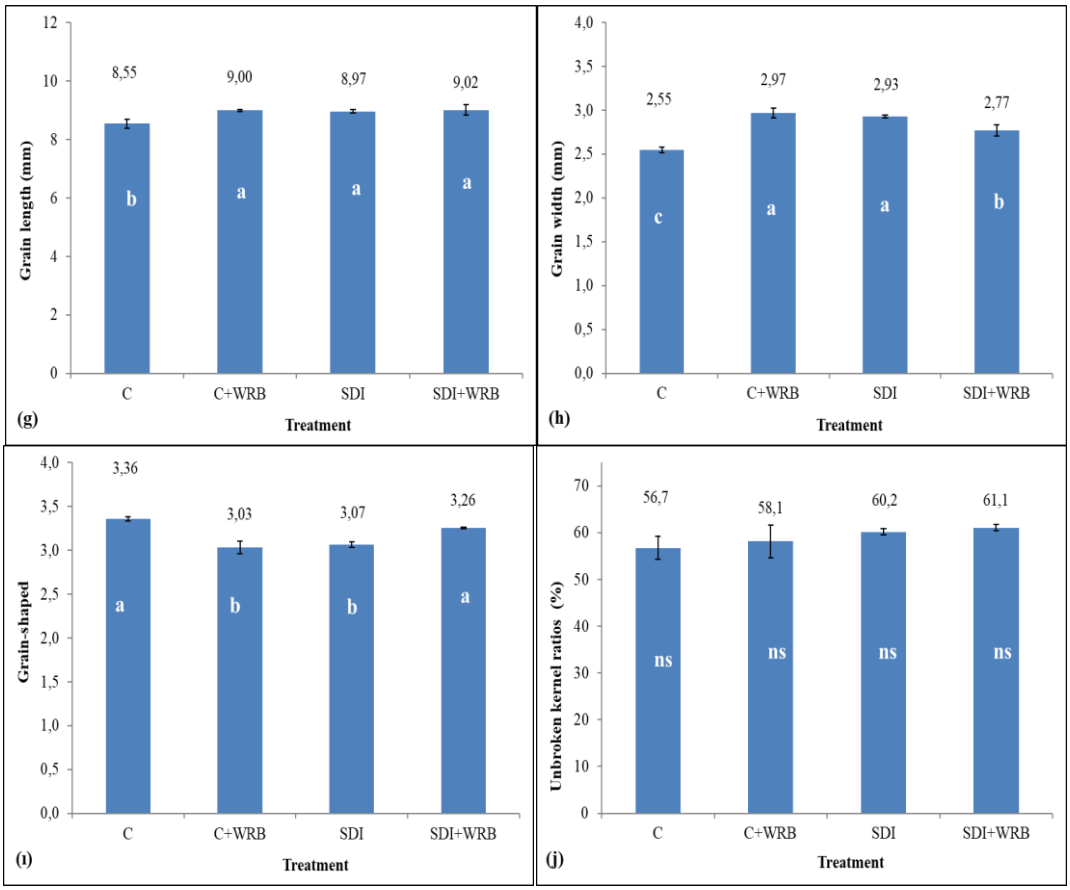


Figure 6. continued (grain lenght (g), grain width (h), grain-shaped (ı), unbroken kernel ratios (j))

When the grain length and width are examined together, it is seen that the lowest values are obtained at control treatment (Figure 6 g, h). It was determined that the difference between the grain length and the other treatments was not statistically significant. In terms of grain width, C+WRB and SDI treatments achieved the highest value (Figure 6 g, h). If the grain-shaped values were inspected, the highest values were obtained from C and SDI+WRB treatments in contrast to grain width and the differences of these treatments were significant compared to other treatments (Figure 6ı). This difference was not statistically significant even if there was a difference between the treatments in unbroken kernel ratios (Figure 6j). Measurements on physical properties of rice grain revealed that although slight changes in all alternative treatments relative to control, grain formation didn't drastically affect by each treatment. Therefore, we may suggest that the treatments which limited water is applied have not discernible changes during grain filling stage then that of earlier growth period of rice.

When all yield parameters are evaluated together, it can be said that C treatments are higher yields compared to SDI subjects as the reason number of panicles and panicle length obtained in harvest. Other yield parameters did not have a clear effect on the overall yield while making differences between the treatments. In addition, the other parameters directly affecting the yield, the grain number per panicle and the unbroken kernel ratios values do not affect the difference between the treatments. As one of the results of the study; in the case of SDI applications with little irrigation water compared to the control subject, although it has a significant effect on the number of panicles, indirectly, it does not significantly affect the quality of rice.

Comparison of irrigation water and yield

The yield obtained per decares in rice cultivation is separated from the shells of the shelled grains as a result of the processing of the rice. As a result of the decomposition process, two different yields are obtained with and without fractures. The 1st and 2nd broken rice are left to the factories in exchange for processing fee. The rice produced by the producer from the factory is the yield value which is found at the rate of breakage. For this purpose, market efficiency was calculated within the scope of the study. The yield value was obtained by multiplying the yield value by the percentage of the broken rate and the yield value obtained from the square meter. In other words, it is the

amount of rice that the producer receives from the factory per kilogram. As the difference between the unbroken kernel ratios values was not statistically significant, market yield values showed a similar trend as in yield values (Figure7a).

As a result of the study, it was observed that SDI applications in rice plant significantly increased water use and affected yield values negatively. On the other hand, although less irrigation water was used for the C+WRB where the water retention barrier was applied, it was seen that it affects the efficiency in a positive way (Figure 5a, 6a). In order to determine the effects to the rice of the applied treatments in this study, it is necessary to compare the decreasing or increasing yield and water use in other treatments compared to the control treatment (Figure 7c, d). When the yield values are examined according to the C, it is seen that the efficiency and market yield values increased by 7.58% and 10.85% in the C+WRB application, respectively (Figure 7b, c). In terms of SDI and SDI+WRB, where subsurface drip irrigation was applied, the yield and market yield values were approximately reduced by 50% and 43%, respectively. Compared to the amount of irrigation water, the situation seems to be reversed. The highest water saving was achieved in SDI+WRB (69%) with the SDI application applied to the water retention barrier (Figure 7d). The effect of water retention barrier on yield values was not statistically significant, but it was seen that it was important in terms of total amount of irrigation water applied. The effect of water retention barrier on water saving is seen clearly in both different applications (Figure 7d).

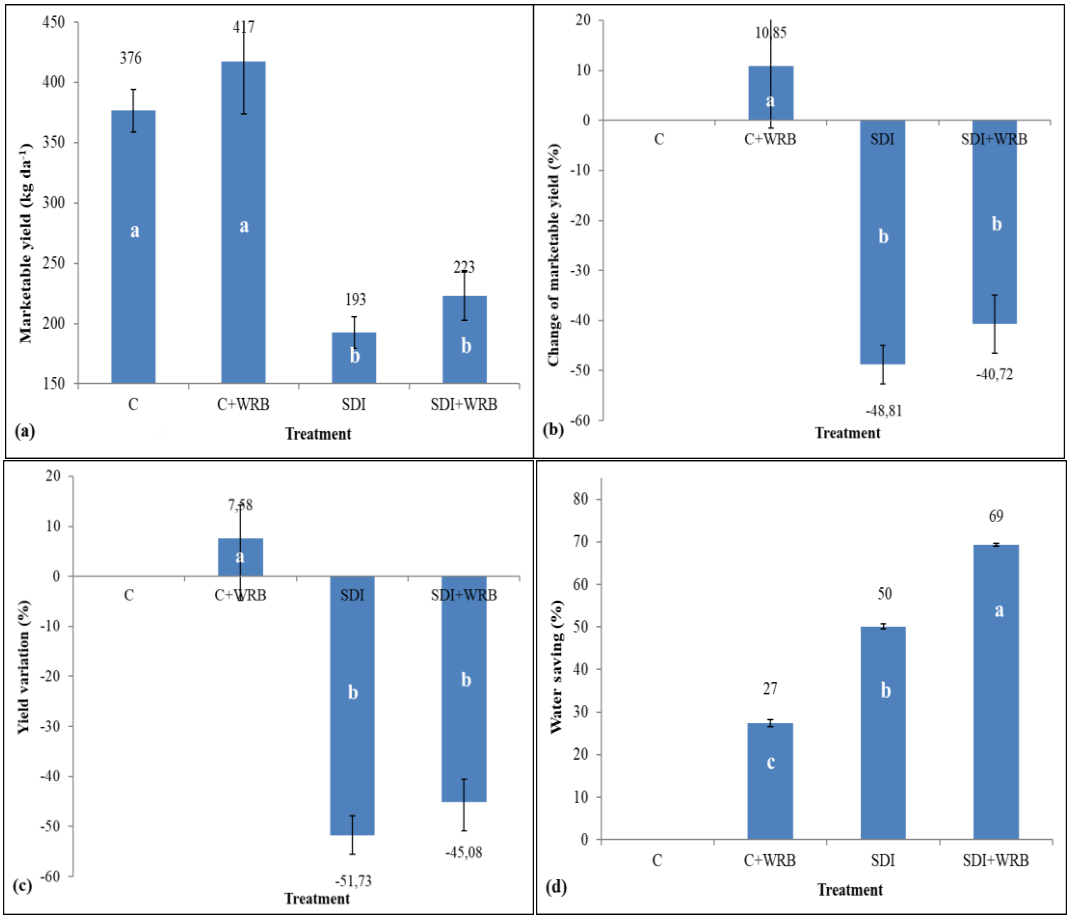


Figure 7. Marketable yield (a), change of marketable yield (b), yield variation (c), water saving (d)

There are many studies conducted in Turkey and in the world about ponding, sprinkler and drip irrigation in rice. In recent years, especially sprinkler and drip irrigation methods were compared with ponding irrigation. Many researchers reported that sprinkler irrigation (Ferguson and Gilmore, 1977; Muirhead et al., 1989; Sürek et al., 1996; Cakir et al., 1998; Gevrek et al., 2009) and drip irrigation systems (Anonymous, 2009; Tuna, 2012) increased the use of water however the yield was significantly reduced. However, there are few studies using subsurface drip irrigation system. In the studies; Dunn et al. (2004) examined the effects of different irrigation methods on rice in Australia. In the study, they applied ponding irrigation, furrow irrigation

and subsurface drip irrigation in rice and reported that the highest yield was obtained in the ponding irrigation and the lowest yield in subsurface drip irrigation was about 35% yield loss. Ottis et al. (2006), applied different doses of nitrogen in 3 different rice cultivars using subsurface drip irrigation system. According to the results of the study, they were found that the subsurface drip irrigation system reduced the water use by 80%. He et al. (2013) studied the effects on the performance of rice and water use efficiency of traditional methods and plastic mulching + drip irrigation methods. They reported that yield decreased by 31.76-52.19% while water use efficiency was highest in drip irrigation. The results obtained in our study were similar to the other studies.

Relationships among plant traits and grain traits

The statistical analysis (covariance/correlation plot) for plant and grain traits examined in the study are presented in Figure 8 and 9, respectively.

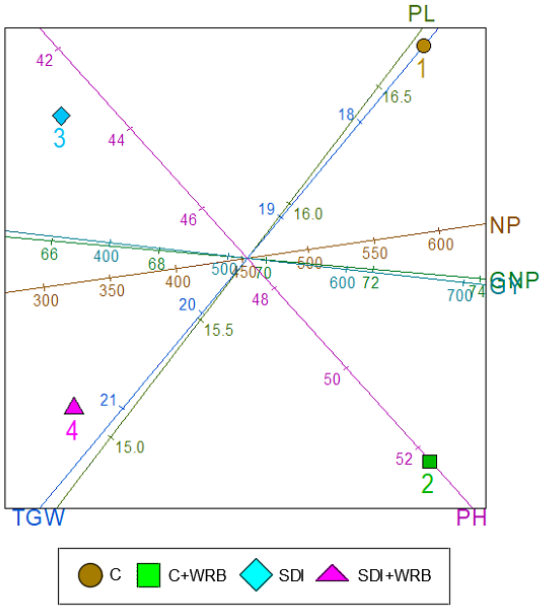


Figure 8. Covariance/correlation plot for plant traits

According to the results of the biplot analysis for plant traits; C + WRB application in terms of plant height (PH) value has the highest average (Figure 8). In the SDI application, the PH value was lower than other applications. Control treatment in terms of panicle length (PL) gave higher value than other treatments. However, thousand grain weight (TGW) in the control treatment was found to be lower than other applications. It was observed that there was a high and negative correlation between panicle length and thousand grain weight according to the covariance/correlation graph (Figure 8). Also, it was found that there was a positive and high correlation between the number of panicles (NP), grain number per panicle (GNP) and the grain yield (GY) in the unit area. In terms of these properties, C and C+WRB applications were found to be higher than SDI and SDI+WRB applications.

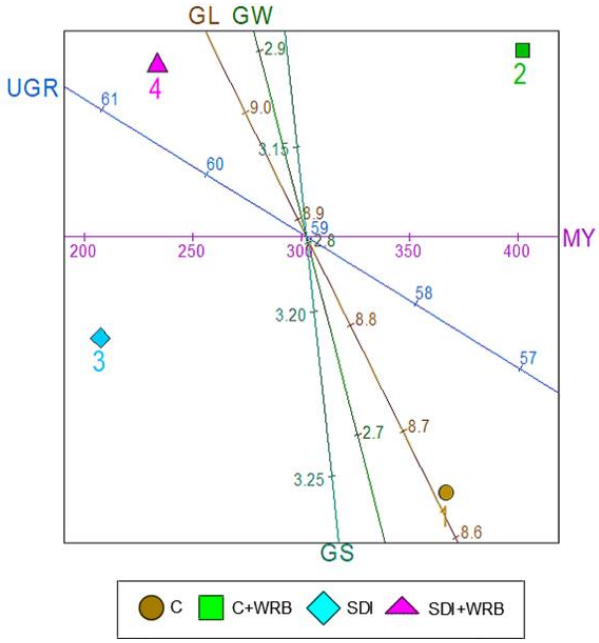


Figure 9. Covariance/Correlation plot for grain traits

According to the results of biplot analysis for grain traits; the highest values for grain length (GL), grain weight (GW) and unbroken kernel ratios (UGR) were obtained from SDI + WRB treatment. There was a negative relationship between the control treatment and the mentioned properties (Figure 9). In the SDI application, the marketable yield (MY) value was lower than other applications. It was observed that the highest grain-shaped (GS) value was obtained in control treatment to the covariance/correlation graph.

CONCLUSION

It has been observed that water retention barriers and subsurface drip irrigation applications significantly affect irrigation water amounts, yield and yield parameters in rice. The highest irrigation water use efficiency has been found in SDI+WRB. The C+WRB, SDI and SDI+WRB treatments were 27%, 50% and 69% water saving to control treatment, respectively. As a result of the study, when the irrigation water amount, irrigation water use efficiency, yield and yield parameters are evaluated together; we concluded that C+WRB application is the best application among the treatments because it provides 27% water saving,

causes an increase in yield although not statistically significant and positively affects the yield parameters. However, due to meteorological drought in the coming years, it is foreseen that the reduction of water resources and especially cultivation of rice, where water use is high, will be significantly reduced by prohibitions. In most of these areas, it is estimated that only cultivation will be allowed with the use of alternative methods which can save a considerable amount of water instead of the method of ponding irrigation. Therefore, even if subsurface drip irrigation system causes a decrease in efficiency, it can be used in rice fields due to significant water savings.

Considering the features such as the subsurface drip irrigation and water retention barriers to be applied in rice fields for long years in the soil, saving water from irrigation water, increasing yield and cost, it is thought that the use of these methods will increase in arid and semi-arid regions. In addition, it is believed that high amounts paid for irrigation work will be minimized by the methods used in this study. Also, it will be saved in terms of workmanship, fuel-oil and time since there will be no need to tillage deeply before the season. On the other hand, studies on new agronomic approaches such as better sowing density or fertilizer management and selecting or developing suitable rice varieties should be performed in order to minimize yield reduction for this kind of water saving rice production systems.

ÖZET

***Amaç*:** Çeltik, büyüme döneminin önemli bir bölümünde sürekli su altında veya doygun toprak koşullarında yetiştirildiğinden kültür bitkileri arasında en çok sulama suyu uygulanan bitkilerden birisidir. Bu çalışmada, 2017 yılında Edirne İli, Enez İlçesinde su tutma bariyeri ve toprakaltı damla sulama yöntemlerinin hem ayrı ayrı hem de birlikte kullanımının; çeltik bitkisinde su kullanımına, gelişimine, verime ve bazı verim parametrelerine etkilerinin belirlenmesi amaçlanmıştır.

***Yöntemler ve Bulgular*:** Çalışmada; Göllendirme (kontrol), toprakaltı damla sulama sistemi (SDI), göllendirme+su tutma bariyeri (kontrol+STB) ve SDI+STB olmak üzere 4 farklı konu oluşturulmuştur. SDI toprak yüzeyinden 10 cm, STB ise 30 cm derinliğe yerleştirilmiştir. Sulamalar kontrol ve kontrol+STB konularında toprak üzerinde sürekli 10-15 cm su yüksekliği bulunacak şekilde, SDI ve SDI+STB konularında ise su stresine maruz bırakmadan toprakta kullanılabilir su tutma kapasitesinin %20±5'i tüketildiğinde, tarla kapasitesine tamamlanması şeklinde yapılmıştır. STB ve SDI uygulamalarının çeltik bitkisinde sulama suyu, verim ve verim parametrelerini önemli düzeyde etkilediği görülmüştür. Konulara göre verim ve sulama suyu miktarları sırasıyla 321-715 kg da^{-1} ve 751-2444 mm arasında değişmiştir.

***Genel Yorum*:** Kontrol konularına oranla kontrol+STB, SDI ve SDI+STB konularında sırasıyla %27, %50, %69 oranında su tasarrufu sağlanmıştır. Buna rağmen, kontrol konusuna göre verim değerleri incelendiğinde, kontrol+STB konusunda pazarlanabilir verimi değerinin %10.8 artmış, SDI ve SDI+STB konularında ise sırasıyla %48.8 ve %40.7 azalmıştır. Çalışmada kullanılan su tutma bariyeri ve toprak altı damla sulama uygulamalarının, çeltik alanlarında sulama suyu kullanımını azalttığını göstermiştir.

***Çalışmanın Önemi ve Etkisi*:** Bu yöntemlerin, özellikle suyun sınırlı veya yetersiz olduğu kurak ve yarı kurak bölgelerde kullanılma potansiyeli olduğu söylenebilir.

***Anahtar kelimeler*:** Toprakaltı damla sulama, su tutma bariyeri, su tasarrufu, çeltik, verim

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest in the study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

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