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MAXIMIZING RICE PRODUCTIVITY BY ALGALIZATION UNDER WATER DEFICIENCY

Abdel-Fattah, G. A. ; M. M. Shehab ; W. M. El Khoby and A. M. El-Ekhtyar

Rice Res. and Training Center, Field Crops Res. Inst., Agric. Res. Center, 33717 Sakha-Kafr El-Sheikh, Egypt

ABSTRACT

Two field experiments were conducted at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during 2009and 2010 summer seasons to investigate the effect of irrigation intervals,3-days "T1",6-days "T2" and 9-days "T3" on three rice cultivars; namely, Giza 177, "V1", Giza 178 "V2" and Sakha 104 "V3" with Algalization (cyanobacteria) rates; namely, control (without Algalization, C0), 1000 g/fed "C1" and 1500 g/fed "C2 ". The data showed that Giza 178 gave the highest values, while, Giza 177 had the lowest for plant height, number of tillers/m^2 and number of roots/hill. Also, Giza 177 had the superiority over the other two cultivars in grain yield and water utilization. This efficiency could be attributed to its higher number of filled grains/panicle, sterility(%) and 1000-grain weight. On the other side, the gel consistency and gelatinization temperature of all rice cultivars were soft and low, respectively. Data clarified that increasing irrigation intervals decreased plant height, number of tillers/m2 DMA, panicles length, number of panicles/ m^2, number of filled gains/panicle, 1000-grain weight and grain yield. However, the opposite was true for sterility percentage and WUE. In addition, rice quality was not significantly affected by irrigation intervals. All growth characters were significantly increased due to Algalization compared to the non-algalized plots. Also, grain yield, grain yield components, WUE and rice quality were significantly increased due to algalization, compared to the non-algalized plots. Generally, it could be concluded that, from the study, rice might be irrigated every six days and save water without deleterious effects, on its production, under Algalization with cyanobacteria with the rate ranged from 1000 to 1500 g/fed.

Keywords: Irrigation intervals, Algalization, Cyanobacteria, rice cultivars,

INTRODUCTION

Rice (Oryza sativa L.) is one of the most important grains in the world and it is the most important cereal crop after wheat in Egypt. Rice is not only a stable food, but also contributes the major economic activity and a key source of income and employment for the rural population. The area, planted with rice in Egypt in the year of 2009, was about 1.6 million feddan (about 0.67 million hectares) mostly located in the northern part of the Nile Delta. This area is grown under flooded conditions throughout the season. Rice is a simi-aquatic plant and does not need standing water for a successful crop. In Egypt, the dominant practice in rice production is flooding irrigation, which consumes large amounts of water, as being, approximately, 18 % of the total water resources (Badawi *et al.* 2002). Water is a critical factor at any growth stage of the rice plant. It is needed for growth and transport of nutrients from soil to different plant parts. In rice fields, the purpose of water management is to insure a proper growing condition near the roots and a better use the supply of soil nutrient. With limited water resources, future increases in of production require the development of water saving technologies. In Egypt, water of the River Nile is not sufficient for irrigation of both old and reclaimed new lands. So saving of water is a necessity demand to face this problem through, either, increasing irrigation intervals without any drastic effect on grain yield, or growing drought tolerant cultivars, which have a capability to grow under shortage of water (Nour, 1989). Therefore, efforts are needed to develop improved rice cultivars with early maturity and higher grain yield potential. The lower water requirement is a set of characteristics that should be incorporated into future rice cultivars to meet the needs of various environmental and water regimes. For example, reducing growth duration of rice cultivars from 130 to 100 days can save between 200 and 350 mm of water (Wiekham, 1977).El-Mowafy (1994) and Shehata (1995) obtained significant differences among rice cultivars and lines in grain yield and components. The waterlogged rice field offer a proper habitat for the growth of photoautotrophic Blue-green algae, such as Nostoc, Anabaena and Aulosira. The results of several field traits IRRI, at India, have shown savings of 20-30 Kg N/ha in rice planting and increased grain and straw yields for rice (Subbo Rao,1982). Sawashe *et al.* (1985) showed that rice crop increased when a culture of blue-green algae (BGA) was inoculated in the soil 10 days after transplanting even in the absence of N. Combined application with 25, 50,75 or 100 kg N/ha indicated that inoculation gave grain yield increases equivalent to about 25 kg N. Also, the effect of Azolla and blue-green algae on rice was studied by Dixit *et al.* (1987). They concluded that application of six of A. pinnata or ten kg BGA/ha (equivalent to 25 kg N/ha) increased rice growth and grain yield.

While, the use of 60 kg Azospirillum/ ha in combination with 0-75kg N/ha, resulted in increasing tillers number/plant and plant DM, irrespective to the level of N fertilizer. The highest grain yield increase (25.9 %) due to Azospirillum inoculation was at 20 kg N/ha, whiles the largest straw yield increase was obtained without applied N.

On the other hand, the highest grain yield was obtained when 60 kg N/ha was applied and inoculated with azotobacter for roots of rice. Krishna-Chandra, *et al.* (1995) obtained a similar result.

Also, the use of blue-green algae (BGA) may reduce the cost of inorganic N fertilizer. Therefore, algalization has become an appropriate tool for reducing cost and reducing environmental pollution and earning a good economic return (Hammad, 1995).

Hammad *et al.* (1997) evaluated the combination effect of Algalization and chemical N and P fertilization on rice grain yield and its components. The results showed that algalization (with BGA) increased the 1000-grain weight and grain and straw yields. The highest grain yields were obtained with BGA + 20 kg N/fed + 15 kg P_2O_5/fed. They, also, showed that BGA alone could not supply rice crop with its N requirement. Faiza Abd El-Fattah *et al.* (1998) indicated that inoculation of rice, under field conditions with BGA, including the algal-symbiont of azolla; i.e., Anataena spp., had benefited rice grain yields (increases ranging from 20 to 30% over the control).

The present study aimed to find out the best irrigation intervals or irrigation termination and to maximize the productivity of some rice cultivars through optimum irrigation intervals and Algalization with blue-green algae (Cyanobacteria) to avoid the problem of water shortage and N deficit.

MATERIALS AND METHODS

In two successive summer seasons, 2009 and 2010, two field experiments were conducted at the Rice Research and Training Center Farm, Sakha, Kafr El-Sheikh, Egypt. The investigation was carried out to study the effects of three various irrigation intervals (3-days"T1", 6-days "T2" and 9-days "T3") on productivity of three rice cultivars(Giza 177, "V1", Giza 178 "V2" and Sakha 104 "V3") and algalization (cyanobacteria) rates, control (without cyanobacteria, C0), 1000 g/fed "b1," and 1500 g/fed "b2" were applied to all plots ten days after transplanting.

A split-split plot design, with four replicates was used. The irrigation intervals were randomly assigned to the main plots while, the cultivars were assigned to the sub-plots and the algalization treatments were assigned to the sub-sub plots.

Therefore, the main plot size was 10x20 m and surrounded by double canals to prevent lateral movement of irrigation water. The physical and chemical properties of soil, for the two experiments, were determined, according to FAO (1976) and Black (1965) and presented in Table (1)

Rice grains, at a rate of 50 kg/fed, was used as recommended, phosphorus fertilizer was added to all plots during land preparation at the rate of 15 kg P 2O5/fed. In addition, nitrogen fertilizer was applied in the form of urea (46.5 N %) at the rate of 40 kg/fed. The nursery was planted after barley on 15 May in both seasons. Twenty-five days old, seedlings were transplanted (four seedlings/hill)at 20x20cm spacing among rows and hills. Recommended cultural practices for growing rice except the studied factors, were normally conducted.

The two outer rows were excluded to eliminate the border effect and growth attributes random samples were taken from inner three rows of each plot at panicle initiation for estimating plant height, number of tillers/m , dry matter accumulation (kg/m2), flag leaf area "cm2length, number of roots/hill and root volume (cm).

At harvest, plants of ten guarded hills were taken at random from the fifth inner row in each sub-sub plot, for determination at the following characters: panicle length, number of panicles/ m2, number of filled grains/panicle, sterility percentage and 1000-grain weight (g). In addition, the five central rows of each sub-sub plot were harvested and left for air-drying about three days. Grain yield "kg/ m2" was determined (at a grain moisture content of about 15%), then, converted to estimate grain yield in ton/fed.

The quality characteristics studied included grain length, grain width, grain shape, gel consistency, gelatinization temperature and grain nitrogen percentage.Grain length was determined as an average of fifteen, random grains of rough rice per genotype. Grain shape was estimated according to Khush et al. (1979). Gel consistency was measured, as described by Cagampang et al. (1973). Moreover, gelatinization temperature was measured in terms of ' alkali disintegration, six uniformly milled grains/replicate were placed in small Petri plate containing 1.7% KOH solution at 30±1 °C for 14 hours.

Discharge measurements, by using fixed crested weir, were calculated by the following equation (Masoud, 1967)

Q = C L H312

Where:

Q = Discharge in cubic meter per minute.

L =Length of the crest in meter.

H =Water head in meter.

C =Discharge coefficient.

The amount of water needed for land preparation either for nursery or permanent field , was recorded, beside the amount of water needed for raising the nursery or through the first nine days after transplanting (seedling establishment period), as well as the amount of water used for replenish the sub-sub plots. Water depth at every irrigation was kept at 7 cm height.

- **Water relations:**

Total water applied;i.e., the amount of water delivered to each sub-sub plot plus the amount of water applied in both nursery and permanent field for applying the water treatments, was measured for each cultivar. Water utilization efficiency (WUE) was calculated according to the following equation (Nour *et al.* 1994) .

WUE= Grain yield (kg/fed) / Water applied (m^3 /fed).

Data were statistically analyzed, using IRRISTAT computer program, IRRI, (1991), and the treatment means were compared according to Duncan's Multiple Range Test (Duncan,D.B. 1955).Whereas, the interaction mean values were compared ,according to the L.S.D.test significance at the 0.05 levels.

Table 1: Mechanical and chemical analysis of the experiment soil.

Soil analysis	2009	2010
Mechanical analysis:		
Clay (%)	44.06	55.80
Silt (%)	28.64	32.00
Sand (%)	27.30	13.2
Texture class	Clay	Clay
Chemical analysis:		
Organic matter(%)	1.65	1.60
E.C. Ds/m	3.00	3.10
pH	8.10	8.19

RESULTS AND DISCUSSION

Growth characters:

Data in Table 2 indicted that decreasing irrigation intervals significantly increased the plant height and number of tillers/ m2 but decreased root length, while, no significant effect was found for DMAkg/ m2, flag leaf area, number of root/hill and root volume in both seasons. Also, data showed that plant height, number of tillers/ m2 and root length of all cultivars were significantly reduced as the irrigation intervals increased from three and six days to nine days. Hence, plants under the third irrigation interval, were stunted and showed abnormal growth.

Also, data showed that cultivars significantly varied in their plant growth characters , Giza 177 had the lowest values for plant height, number of tillers/m 2 and number of roots/hill. On the other hand, Giza 178 gave the highest number of tillers/m2and number of root/hill. However, no significant differences among all cultivars in their DMA kg/m2 , flag leaf area and root volume in both seasons.

Most of these growth characters significantly responded to algalization with cyanobacteria (BGA) in both seasons. Where, the (BGA) realized slight increase in growth characters, as compared with those obtained by the non-algalized plots. Most of growth characters were significantly increased due to algalizations (cyanobacteria) compared to the non-algalized plots in the two seasons. These results are similar to those obtained by Dixit et al. (1987), Krishna Chandra et al. (1995) and Hammad et al. (1997).

As shown in Table 3a, it is evident that significant interactions between irrigation intervals and cultivars in the two seasons wee obtained. The highest values of growth characters, of all rice cultivars, were obtained under the first and the second irrigation treatments in both seasons, while, the third ones recorded the lowest values.

Also, data, shown in Table 3b revealed that the interaction between irrigation intervals and algalization were significant for root length, number of roots/hill and root volume only. So; T1and T2 recorded the highest values with C2 treatment, while, the lowest values were recorded byT3 with C0 treatment.

In addition, Table 3c showed that the interaction between cultivars and algalization was significant for plant height, flag leaf area and root length only in both seasons. The highest values were recorded by all cultivars with C2, while, the lowest values were recorded by V3 with C0 treatment.

II .Grain yield, grain yield components and water utilization efficiency "WUE":

Data presented in Table 4, indicated that these characters significantly responded to irrigation intervals in the two seasons. Decreasing irrigation intervals significantly increased panicle length, number of panicles/m^2 in 2009 and 2010, number of filled grains/panicle in 2009, 1000-grain weight in 2009 and grain yield in 2009. WUE increased only in 2009. Irrigation every 3days gave the highest values, while irrigation every 9days had the lowest. Similar findings have been reported by Nour (1989) and Nour *et al.* 1994).

Moreover, in 2009, statistical analysis showed that cultivars had a significant effect (p= 0.05) on grain yield, grain yield components and WUE in 2009 (Table 4). Giza178 produced a significantly highly panicle length, number of panicles/ m^2, and number of filled grain/panicles. Whereas, Sakha 104 produced the highest 000-grain weight.

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While, data in 2010 showed that no significant differences among all cultivars for grain yield and number of filled grain/panicle.. This slightly superiority of Giza 178 in grain yield and WUE over the other two cultivars could be attributed to its relatively higher number of filled grains/panicle and 1000-grain weight, while, the opposite was true for Giza 177in both seasons. Table (4) furthen indicated that grain yield, grain yield components and WUE were significantly increased due to algalizations, compared to the non-algalized plots (Table 4). The beneficial effect of inoculation of rice soils with cyanobacteria might not be attributed, solely, to N2-fixing activity, but also to its growth promoting substances synthesized and liberated by these organisms. These results were similar to those obtained by Alaa El-Din (1978), Ghosh and Saha (1993), Yanni and Hegazy (1990) and Faiza Abd EL –Fattah *et al*. (1998). According the results are of great importance since algalization could give the chancely, for reducing chemical nitrogen fertilizer and to face its expensive prices nowadays. Another benefit could be added due to algalization, that is, it keeps the environment away from pollution caused by mineral fertilizers. Islam *et al.* (1984) have reported similar results Table (5a) shows that the interaction was significant between irrigation intervals and cultivars for all studied traits, except for grain yield in two seasons. Irrigation every 3days (T1), with V2, gave the highest values for panicle length, number of panicles/m2 and number of filled grains/panicle, while, the treatment T3 with V1 had the lowest values. On the other hand, T3V2 gave the highest values for all characters except for 1000-grain weight in both season and WUE in the first season.

Also, the interaction was significant between irrigation intervals and algalization for all characters in the two seasons (Table 5b). The highest values were recorded by T1C2 treatment but the lowest values were recorded by T3Co treatment, except for WUE in both seasons.

Data in Table 5c showed that highest values for panicle length and number of panicles/m2 were recorded by V1 with C2 treatment.

III- Rice quality:

Table 6 reveals that rice characters were not significantly affected by irrigation intervals except for grain nitrogen percentage in both seasons, while, these characters were significantly affected by algalization in the two seasons, except for grain shape. These results are in harmony with those obtained by Cagampang *et al.* (1973) and Khush *et al.* (1979).

Also, data in Table 6 showed that the differences among rice cultivars, for all these characters, were not significant except grain nitrogen percentage, where, Giza 178 gave the highest value for this character in both seasons. Also, the results showed that the rice cultivars were in soft gel consistency and had low gelatinization temperature indicating less resistance and shorter cooking time.

Furthermore, Table 7a show, that no significant interaction between irrigation intervals and cultivars for all characters except grain shape and gel consistency in both seasons.

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In addition, no significant interactions were detected between irrigation intervals and algalization for studied traits, except grain width, grain shape and grain nitrogen percentage in both seasons. The highest values for grain nitrogen percentage were recorded by the treatment, T3with C2 while, T3 with Co had the lowest in both seasons.

Besides, the interaction between cultivars and algalization was not significant for all traits except, grain nitrogen percentage in the two seasons. V3C2 recorded the highest values, while V 1 and V2 with Co had the lowest in both seasons.

IV-Water applied:

Table 8a illustrates the irrigation water applied before treatments along the two seasons including water used for land preparation of nursery, permanent field and period of 9days before treatment. The amount of water applied was 1363.30 m3 and 1308.40 m3 in 2009and 2010seasons, respectively. Moreover Table 8b reveals that the number of irrigation ranged from 32 to 9 irrigated due to replacing Giza 178and Sakha 104(long duration cultivars) with Giza 177 (short duration variety). The mean water applied ranged from 7446.40 to 7323.07 m3/fed with irrigation every 3-days treatment, 4825.50 and 4719.73 m3/fed with irrigation every 6-days treatment and 3720.90 and 3843.93 m3/fed with irrigation every 9-days treatment. These data confirmed in Tables 4 and 5.

Table 8a: Water applied before treatments.

Period of irrigation	Water applied(m^3/fed.)	
	2009	2010
Land preparation of the nursery	75.50	79.60
Raising nursery for 25 days.	134.90	127.30
Land preparation of permanent field.	896.00	855.00
Period of 9 days before treatment.	256.90	246.50
Total	1363.3	1308.4

Table 8b: Water relation of rice cultivars with the irrigation intervals during 2009 and 2010 summer seasons.

Treatments	Cultivars "V"	No. of Irrigations		Water applied through treatments (m^3/fed.)		Total water applied (m^3/fed.)		Water utilization efficiency (Kg/m^3)	
		2009	2010	2009	2010	2009	2010	2009	2010
Irrigation	Giza 177 "V1"	27	27		5123.78	6545.20	6432.18	0.65	0.69
every 3days	Giza 178 "V2"	30	30		6014.73	7446.40	7323.13	0.69	0.72
"T_1"	Sakha 104 "V3"	32	32		6905.80	8347.60	8214.20	0.56	0.58
Mean					6014.67	7446.40	7323.07	0.63	0.66
Irrigation	Giza 177 "V1"	13	13		2923.92	4330.90	4232.32	0.79	0.80
every 6days	Giza 178 "V2"	15	15		3411.36	4825.50	4719.76	0.97	1.04
"T_2"	Sakha 104 "V3"	16	16		3898.70	5320.10	5207.10	0.79	0.81
Mean					3411.33	4825.50	4719.73	0.85	0.89
Irrigation	Giza 177 "V1"	9	9			3384.10	3481.71	0.86	0.82
every 9days	Giza 178 "V2"	10	10			3636.70	3753.37	1.09	1.06
"T_3"	Sakha 104 "V3"	11	11			4141.90	4296.70	0.91	0.88
Mean						3720.90	3843.93	0.95	0.92

In view of present study, it was concluded that irrigation every 6day might be the maximum interval that could be used in rice culture and it might water in the same time without any dangerous effect on rice production.

Besides, algalization, with cyanobacteria, could give the chance for decreasing chemical nitrogen fertilizer without any dangerous affect on rice plant performance.

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تعظيم إنتاجة الأرز تحت ظروف نقص المياه باستخدام الطحالب

عبدالفتاح جابر عبدالفتاح ،محمد محمد شهلب،وليد محمدالخبى و أحمد محمد الأختيار
مركز البحوث والتدريب فى الأرز – سخا –كفر الشيخ، معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية -مصر

أقيمت تجربتان حقليتان خلال موسمي صيف 2009 و2010 فى مزرعة مركز البحوث والتدريب في الأرز بسخا كفر الشيخ مصر لدراسة تأثير فترات الري كل ثلاثة وستة وتسعة أيام وكذلك تأثير معدلات التسميد الطحلبي باستخدام الطحالب الخضراء المزرقه بالمعدلات : 1- بدون معاملة ، 2- إضافة1000جرام للفدان و 3- إضافة 1500جرام للفدان، على النمو الخضري ومحصول الحبوب للأرز ومكوناته وكفاءة الانتفاع المائي وكذلك صفات جودة المحصول لثلاثة أصناف من الأرز (جيزة177،جيزة178و سخا104) .

وأوضحت النتائج ما يلي:

1- أدت زيادة فترات الري عن ثلاثة أيام إلى نقص في صفات ارتفاع النبات وعدد الأشطاء/م 2 والوزن الكلى الجاف وطول الدالية وعدد الداليات/م2 وعدد الحبوب الممتلئة/الدالية ووزن الألف حبة ومحصول الحبوب (طن/الفدان). وكانت صفة نقص محصول الحبوب غير معنوية فى الري كل ستة أيام و صفتي النسبة المئوية للعقم وكفاءة الانتفاع المائي ،ولم تتأثر صفات الجودة بطول فترات الري.

2- فوق الصنف "جيزة 178" عن بقية الأصناف فى الصفات الخضرية وكذلك تفوق في صفات عدد الحبوب الممتلئة /الدالية ومحصول الحبوب (طن/الفدان) وكفاءة الانتفاع المائي ، ولم تظهر النتائج فروق معنوية بين الأصناف في صفات جودة حبوب المحصول .

3- أدى استخدام الطحالب إلى زيادة معنوية في صفات النمو الخضري ومحصول الحبوب (طن/الفدان) ومكوناته وكفاءة الانتفاع المائي وكذلك جودة الحبوب مقارنة بالنباتات غير المعاملة.

4- أظهر التفاعل أن أفضل المعاملات هو الري كل ثلاثة أيام مع معاملة استخدام الطحالب بمعدل 1500جرام/الفدان لكل الأصناف وكذلك الري كل ستة أيام مع نفس المعاملة.

وفى ضوء هذه الدراسة يمكن التوصية بإمكانية استخدام الطحالب بمعدل 1500جرام/الفدان مع الري كل ستة أيام بما لا يؤثر تأثيرا سيئا على محصول الحبوب.

قام بتحكيم البحث

أ.د / محمد حسين غنيمه	**كلية الزراعة – جامعة المنصورة**
أ.د / محمد ابراهيم شعلان	**كلية الزراعة – جامعة الاسكندريه**

Table 2: Mean values of growth characters of rice cultivars as influenced by irrigation intervals and algalization rates in 2009 and 2010summer seasons.

Treatments / Variables	F test	Irrigation intervals (T)			F test	Cultivars (V)			F test	Algalization (C)		
		Irrig. every 3 days T1	Irrig. every 6 days T2	Irrig. every 9 days T3		Giza177 V1	Giza178 V2	Sakha104 V3		Control 0 C0	Recom. dose 1 C 1	Recom. dose 2 C 2
2009												
Plant height(cm)	*	100.01	95.88	91.22	*	91.11	93.88	102.11	NS	93.55	96.11	97.44
No. of tillers/ m^2	*	583.11	536.29	447.00	*	451.81	583.31	531.27	*	480.74	530.33	555.33
DMA (Kg/ m^2)	NS	5.82	5.50	4.05	NS	4.32	5.74	5.30	NS	4.90	5.21	5.25
L.A. of flag (cm2)	NS	23.93	23.68	22.47	NS	22.52	24.37	23.19	*	21.86	23.20	25.02
Root length (cm)	*	35.80	34.42	32.57	NS	33.28	35.51	34.00	*	32.71	34.01	36.07
No. of roots/ hill	NS	281.38	267.28	245.49	*	249.09	276.63	268.42	*	249.82	265.26	279.07
Root volume (cm^3)	NS	38.21	36.37	35.01	NS	35.79	37.07	36.73	*	36.02	36.21	37.36
2010												
Plant height (cm)	*	103.27	98.14	93.61	*	93.62	94.44	106.96	NS	96.28	98.94	99.80
No. of tillers/ m^2	*	597.36	550.62	460.13	*	471.56	593.64	542.92	*	496.38	542.62	569.11
DMA (Kg/ m^2)	NS	5.91	5.61	4.13	NS	4.42	5.82	5.40	NS	4.98	5.30	5.34
L.A .of flag (cm^2)	NS	24.41	23.89	22.88	NS	22.88	24.75	23.55	*	22.19	23.57	25.42
Root length (cm)	*	35.75	35.03	33.61	NS	33.88	36.25	34.26	*	33.15	34.46	36.78
No. of roots/ hill	NS	291.64	274.65	249.07	*	255.57	283.93	275.86	*	256.60	272.34	286.43
Root volume(cm^3)	NS	38.26	37.55	35.98	NS	36.46	37.81	37.52	*	36.72	36.98	38.09

***and Ns are significant at 5% level and not significant, respectively, according to DMET.**

Table 3a: The interaction between irrigation intervals and rice cultivars on growth characters in 2009 and 2010 summer seasons.

Cultivars (V) Intervals "T"	Plant height (cm)						No. of tillers/m2						Flag leaf area(cm2)					
	2009			2010			2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
T1	96.60	96.45	106.64	97.10	96.71	110.68	525.10	641.71	591.73	546.84	652.61	605.94	23.07	25.03	23.70	23.51	25.44	24.29
T2	91.56	93.33	102.26	93.84	94.47	107.71	460.66	591.69	541.50	478.16	600.72	552.27	23.03	24.73	23.28	23.35	25.12	23.21
T3	85.18	91.86	97.42	89.91	92.14	102.48	369.67	516.52	460.58	389.67	527.60	470.56	21.46	23.36	22.58	21.78	23.70	23.15
F.test	*			*			*			*			*			*		
LSD at5%	2.95			3,10			75,10			76.60			2.23			2.27		

Cultivars Intervals	Root length (cm)						No. of roots/hill						Root volume (cm3)					
	2009			2010			2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
T1	35.39	36.60	35.42	34.88	37.10	35.26	271.67	287.20	285.26	281.12	299.70	294.10	37.62	38.57	38.45	37.85	38.74	38.20
T2	33.30	35.98	33.98	34.25	36.53	34.30	254.83	277.00	270.00	264.45	283.25	276.25	35.88	36.82	36.40	37.09	37.87	37.69
T3	31.15	33.95	32.60	32.51	35.12	33.21	220.78	265.70	250.00	221.15	268.84	257.23	33.88	35.82	35.34	34.44	36.83	36.66
F.test	*			*			*			*			*			*		
LSD at5%	2.25			2.40			18.69			19.06			3.10			3.16		

*** significant at 0.05 level.**

Table 3b: The interaction between irrigation intervals and algalization rates on growth characters in 2009 and 2010summer seasons.

Algalizations (C) Intervals "T"	Root length (cm)						No. of roots/hill						Root volume (cm^2)					
	2009			2010			2009			2010			2009			2010		
	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2
T1	34.30	35.55	37.55	34.10	35.44	37.71	274.43	278.84	290.88	286.08	290.67	298.16	37.77	38.34	38.52	37.78	38.45	38.55
T2	32.75	34.12	36.38	33.09	34.40	37.59	250.59	265.70	285.56	255.01	273.45	295.49	35.54	35.62	37.95	36.73	36.77	39.15
T3	31.08	32.36	34.27	32.26	33.54	35.04	224.45	251.25	260.78	228.70	252.89	265.63	34.75	34.67	35.61	35.64	35.72	36.57
F.test	*			*			*			*			*			*		
LSD at5%	2.92			2.98			29.44			30.03			3.28			3.35		

*** significant at 0.05 level.**

Table 3C: The interaction between algalization rates and rice cultivars on growth characters in 2009 and 2010 summer seasons.

Cultivars (V) Algalizations "c"	Plant height (cm)						Flag leaf area(cm^2)						Root length (cm)					
	2009			2010			2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
C0	88.17	91.49	100.02	89.41	91.55	105.20	20.91	23.02	21.64	21.23	23.37	21.97	32.18	33.01	32.93	32.69	34.18	32.58
C1	92.11	94.65	102.23	94.81	95.28	107.07	22.53	24.24	22.84	22.89	24.62	23.19	32.55	35.83	33.64	33.16	36.15	34.07
C2	93.05	95.50	104.08	96.64	96.50	108.60	24.13	25.85	25.08	24.51	26.26	25.48	35.10	37.69	35.43	35.79	38.42	36.13
F.test	*			*			*			*			*			*		
LSD at5%	3.19			3.35			3.74			3.81			3.50			3.57		

*** significant at 0.05 level.**

Table 4: Mean values of rice grain yield, grain yield components of rice cultivars as influenced by irrigation intervals and algalization rates in 2009 and 2010 summer seasons.

Treatments / variables	F test	Irrigation intervals (T) Irrig. every 3 days T1	Irrig. every 6 days T2	Irrig. every 9 days T3	F test	Cultivars (V) G. 177 V1	G.178 V2	S.104 V3	F test	Algalization (b) Control C 0	Recom. dose 1 C 1	Recom. dose 2 C 2
2009												
Panicle length(cm)	*	22.12	20.20	19.47	*	19.89	21.29	20.61	*	20.12	20.66	21.01
No. of panicles/ m^2	*	507.85	453.95	375.59	*	378.81	504.64	453.94	*	416.14	450.65	470.59
No. of filled grains/panicle	*	121.41	117.01	109.47	*	112.22	118.97	116.70	*	112.94	115.92	119.02
Sterility %	*	5.33	8.67	10.00	*	7.00	10.00	7.00	*	10.00	8.00	6.00
1000 grain- weight(g)	*	26.03	25.06	24.23	*	25.89	22.57	26.86	*	24.22	25.18	25.92
Grain yield (t/fed)	*	4.70	4.09	3.55	*	3.51	4.60	4.23	*	3.51	4.23	4.60
WUE	*	0.55	0.83	0.94	*	0.74	0.87	0.71	*	0.73	0.78	0.82
2010												
Panicle length(cm)	*	24.85	23.37	22.56	*	23.56	23.95	23.27	NS	23.08	23.52	24.19
No. of panicles/ m^2	*	526.80	468.05	387.28	*	396.89	518.64	466.59	*	430.00	465.51	486.61
No. of filled grains/panicle	NS	123.58	120.04	113.06	NS	115.52	123.16	118.00	NS	115.95	119.12	121.61
Sterility %	NS	5.67	8.67	10.67	NS	7.00	10.00	8.00	*	10.33	8.00	6.67
1000 grain- weight(g)	*	26.10	25.13	24.57	*	26.35	22.18	27.27	*	24.20	25.07	26.54
Grain yield (t/fed)	NS	4.81	4.18	3.54	NS	3.57	4.72	4.25	*	3.57	4.25	4.72
WUE	NS	0.57	0.86	0.94	NS	0.76	0.90	0.72	*	0.73	0.78	0.82

***and NS are significant at 5% level and not significant, respectively, according to DMRT.**

Table 5a: The interaction between irrigation intervals and rice cultivars on grain yield, grain yield components and water utilization efficiency Kg/m3 in 2009 and 2010 seasons.

Cultivars (V) Intervals "T"	Panicle length (cm)						No. of panicles/m^2						No of filled grains/panicle					
	2009			2010			2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
T1	21.78	22.57	22.00	25.50	25.29	23.77	450.10	560.71	512.73	474.84	574.61	530.94	121.54	121.20	121.50	124.77	125.35	120.63
T2	19.10	21.11	20.40	22.75	23.78	23.57	389.66	506.69	465.50	403.16	525.72	475.27	114.32	119.12	117.58	118.22	123.20	118.69
T3	18.79	20.19	19.43	22.43	22.79	22.47	296.67	446.52	383.58	312.67	455.60	393.56	100.80	116.59	111.02	103.57	120.93	114.68
F.test	*			*			*			*			*			*		
LSD (at5%)	0.55			0.57			58.42			6.76			11.31			11.54		

Cultivars(V) Intervals "T"	Sterility(%)						1000-grain weight (g)						Water utilization efficiency (WUE)					
	2009			2010			2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
T1	4.00	6.00	6.00	5.00	7.00	6.00	27.23	22.92	27.93	27.87	22.43	28.00	0.51	0.60	0.54	0.52	0.63	0.55
T2	7.00	12.00	7.00	8.00	12.00	8.00	26.00	22.64	26.55	26.20	22.10	27.10	0.83	0.94	0.73	0.86	0.99	0.74
T3	10.00	12.00	8.00	11.00	14.00	10.00	24.44	22.15	26.10	24.98	22.01	26.71	0.88	1.07	0.87	0.89	1.07	0.87
F.test	*			*			*			ns			*			*		
LSD at 5%	0.03			0.03			4.01			4.10			0.71			0.74		

*** significant at 0.05 level.**

Table 5b: The interaction between irrigation intervals and algalization on grain yield, grain yield components and water utilization efficiency Kg/m3in 2009 and 2010 seasons.

Algalization"c" Intervals (T)	Panicle length (cm)						No. of panicles/m^3					
	2009			2010			2009			2010		
	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2
T_1	21.21	24.33	24.91	23.89	25.04	25.63	452.67	514.31	525.98	476.08	485.38	552.96
T_2	20.47	22.73	22.90	23.13	23.40	23.57	405.97	449.33	492.66	406.48	440.28	530.44
T_3	19.61	21.97	22.18	22.25	22.63	22.83	373.50	392.76	405.00	388.84	426.44	439.45
F.test	*			*			*			*		
LSDat5%	0.84			0.87			63.19			65.72		

Algalization"c" Intervals (T)	Grain yield (t/fed)						Water use efficiency (WUE)kg/ m^3					
	2009			2010			2009			2010		
	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2
T_1	4.24	4.70	5.16	4.44	4.75	5.25	0.57	0.63	0.69	0.61	0.65	0.72
T_2	3.40	4.20	4.68	3.40	4.24	4.91	0.72	0.87	0.97	0.72	0.90	1.04
T_3	2.90	3.78	3.96	2.86	3.76	3.99	0.78	1.04	1.06	0.74	0.98	1.04
F.test	*			*			*			*		
LSD at5%	0.90			0.91			0.34			0.38		

Table 5c: the interaction between algalization and rice cultivars on grain yield, grain yield components and water utilization efficiency Kg/m3in 2009 and 2010 summer seasons.

Cultivars (V)	Panicle length (cm)						No. of panicles/ m^2						Sterility %					
	2009			2010			2009			2010			2009			2010		
Algalizations "c"	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
C_0	21.43	21.69	21.18	23.23	21.83	21.83	440.66	419.01	378.15	459.15	436.61	394.15	0.12	0.10	0.09	0.10	0.08	0.07
C_1	22.45	21.83	21.65	23.54	22.36	22.31	467.33	459.18	414.84	486.85	477.34	432.25	0.09	0.07	0.07	0.08	0.06	0.06
C_2	22.84	22.15	21.98	25.09	22.49	22.65	480.67	470.66	449.85	500.75	490.35	468.65	0.08	0.05	0.05	0.07	0.04	0.05
F.test	*			*			*			*			*			*		
LSD at5%	0.84			0.87			70.16			72.79			0.04			0.03		

*** significant at 0.05 level, according to LSD test of significant.**

Table 6: Mean values of grain rice quality as influenced by irrigation intervals, rice cultivars and algalization rates in 2009 and 2010 summer seasons.

Treatments / Variables	F test	Irrigation intervals (T) Irrig. Every 3 ays T1	Irrig. Every 6days T2	Irrig. Every 9 days T3	F test	Cultivars (V) G. 177 V1	G.178 V2	S.104 V3	F test	Algalization (b) Control C 0	Recom. dose 1 C 1	Recom. dose 2 C 2
2009												
Grain length	NS	7.78	7.77	7.76	NS	7.77	7.74	7.83	*	7.63	7.76	7.85
Grain width	NS	3.04	3.02	3.01	NS	3.05	2.98	3.26	*	2.95	3.10	3.20
Grain shape	NS	2.65	2.65	2.63	NS	2.55	2.60	2.40	NS	2.59	2.50	2.45
Gel consistency	NS	91.75	94.73	94.39	NS	94.59	93.40	94.88	*	91.43	94.40	94.03
Gelatinization temp.	NS	6.08	6.09	5.96	NS	6.05	5.88	6.19	*	5.66	5.88	5.58
Grain nitrogen %	*	1.32	1.38	1.10	*	1.20	1.24	1.58	*	1.24	1.48	1.59
2010												
Grain length	NS	7.79	7.78	7.75	NS	7.78	7.76	7.85	*	7.64	7.77	7.86
Grain width	NS	3.05	3.02	2.99	NS	2.98	2.91	3.01	*	2.93	2.99	3.07
Grain shape	NS	2.68	2.67	2.64	NS	2.56	2.59	2.41	NS	3.60	2.51	2.44
Gel consistency	NS	92.63	95.68	95.33	NS	94.44	93.72	95.83	*	90.32	95.34	98.09
Gelatinization temp.	NS	6.13	6.13	6.00	NS	6.10	5.93	6.24	*	5.71	5.93	6.64
Grain nitrogen %	*	1.33	1.39	1.11	*	1.21	1.25	1.61	*	1.25	1.49	1.61

***and NS are significant at 5% level and not significant, respectively, according to L.S.D. test of significant.**

Table 7a: The interaction between irrigation intervals and rice cultivars on grain quality in 2009 and 2010 summer seasons.

Cultivars (V) / Intervals "T"	Grain shape						Gel consistency					
	2009			2010			2009			2010		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
T1	2.51	2.56	2.39	2.53	2.54	2.36	95.81	94.94	96.02	95.69	95.11	96.54
T2	2.56	2.57	2.40	2.57	2.58	2.38	94.26	93.81	95.06	94.1	94.35	96.19
T3	2.58	2.67	2.41	2.58	2.65	2.49	93.70	91.45	93.56	93.53	91.70	94.76
F.test	*			*			*			*		
LSD at5%	0.10			0.09			5.25			5.36		

*** significant at 0.05 level**

Table 7b:The interaction between irrigation intervals and algalization rates on grain quality in 2009 and 2010 summer seasons.

Algalizations"c" / Intervals "T"	Grain shape						Grain nitrogen(%)					
	2009			2010			2009			2010		
	C0	C1	C2	C0	C1	C2	C0	C1	C2	C0	C1	C2
T1	2.62	2.62	2.6	2.65	2.65	2.58	0.96	1.17	1.42	0.98	1.18	1.43
T2	2.64	2.64	2.63	2.67	2.66	2.63	1.34	1.57	1.63	1.3	1.55	1.64
T3	2.70	2.68	2.67	2.73	2.71	2.70	1.42	1.70	1.72	1.47	1.74	1.76
F.test	*			*			*			*		
LSD at5%	0.12			0.11			0.31			0.33		

*** significant at 0.05 level**

Table 7c: The interaction between irrigation intervals and rice cultivars on grain quality in 2009 and 2010 summer seasons.

Cultivars (V) / Algalizations "c"	Grain nitrogen (%)					
	2009			2010		
	V1	V2	V3	V1	V2	V3
C0	1.01	1.02	1.28	1.05	1.05	1.29
C1	1.14	1.15	1.32	1.15	1.18	1.36
C2	1.45	1.55	2.15	1.43	1.52	2.17
F.test	*			*		
LSD at5%	0.26			0.29		

*** significant at 0.05 level**