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EFFECT OF IRRIGATION FLOW RATES, TILLAGE AND MULCHING ON CORN PRODUCTIVITY

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Abstract

The objective of this research is to study the influence of irrigation discharges and tillage systems on corn (*zee mays L.*) grain yield and water efficiency with and without mulching rows by rice straw. The experiments were conducted for one season (autumn) during 2003 at Experimental Farm of Agricultural Research Station at Zarzora (Etay El Baroud, Beherah Governorate). Three irrigation discharges (1.5, 2.0 and 3.0 l/s) and three tillage systems using chisel, moldboard and rotary plows were used. The experimental site is classified as clayey soil. Irrigation discharges and tillage systems and rows mulching show statistically significant difference in their effects on corn grain yield and crop water use efficiency. Generally, the results revealed that the applied water decreased as the irrigation discharge increased at all tillage systems. The plowing with moldboard plow recorded the highest amount of consumed water compared to other plows under rows mulching. On the other hand, plowing with the chisel plow gave highest corn grain yield compared to moldboard and rotary plows with values of 3.66, 3.78 and 2.95 ton/fed under different irrigation discharges 1.5, 2.0 and 3.0 l/s respectively with rows mulching. For the irrigation discharge of 2.0 l/s, the water use efficiency recorded the highest ratio with values of 1.96, 1.51 and 1.67 kg/m^3 for chisel, moldboard, and rotary plows respectively under mulching rows. As a result, the tillage with chisel plow with irrigation discharge 2.0 l/s and mulching rows with rice straw seems to be a promising system for corn production in soil containing high colloids ratio between particles and owning high ability to keep water.

1. Introduction

In Egypt, research efforts need continuos trials in order to increase the food production and to control irrigation water that lead finally to improve living level of Egyptian farmers. Corn crop in Egypt plays a big role for achieving the food security. Corn crop is considered a resource for bread industry in rural area, poultry and animal foods, source for oil and starch extract, it is also considered instead of wheat by a ratio which reaches to 25% in bread industry (Ghonimy, 2003).

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Corn ranks the third crop after wheat and rice in Egypt. On the other hand, irrigation management should be shifted from obtaining maximum grain yield per cultivated area to maximum grain yield per unit of water. In Egypt, corn consumed about 17% of the yearly total amount of water required for the main crops, while its cultivated area represented only 19% of the whole cropped area (Mowelhi and Abou Bakr, 1995).

Abo-Habaga (2003) showed that several researchers have reported that the seedbed preparation systems play an important role in the determination of soil properties, which have a great influence on the crop yield. Traditional irrigation does not control the amount of water application to the field but leaves water flow through a field unit reach to the drain in the tail of the field. In many cases, crop yield actually decreases when excessive water is applied (Yazal et al., 2002), so looking for suitable methods for controlling water is the best way to realize the development in Egypt. One of these methods is rationalization of water use. This could be done through reducing the areas cultivated with high irrigation demand crops. In addition to saving some of irrigation water through applying improved agricultural practices such as seedbed preparation. Water is the limiting factor of agricultural production in Egypt. Surface irrigation is the most widely irrigation method in Egypt, especially in old valley and Delta. Surface irrigated lands faces a number of difficult problems on of the major concerns is the poor efficiency which causes the loss of water recourses (Kassem and El Khatib, 2000).

One practical way to conserve water is to maximize the irrigation application efficiency and uniformity. Several irrigation systems can supply water needs at field application efficiency of 70% - 90%. This high efficiencies could be obtained from a well-designed surface irrigation systems (Walker, 1989). Plastic mulches offer many advantage to growers including earlier and higher over all yields, reduced evaporation, fewer weed problems, reduced fertilizer leaching, cleaner procedure, more effective fumigation, and ability to double / triple crop (Lamont, 1993). The major disadvantages to plastic mulch are initial cost and problems with removal and disposal (Hochmuth, 1996 and Lamont, 1993). Paul (1978) found that water use efficiency of sorghum increased from 55.6 kg/ha.cm for no mulched to 115 kg/ha.cm using 12 tons of wheat straw as mulch per hectare. Lal (1995) stated that crop residue mulches help to conserve the soil, regulate soil temperature and moisture regimes, improve soil physical conditions by enhancing biological activity, increase soil fertility by adding nutrients, and improving soil structure by preventing surface crusting by checking rain drop impact.

Cullum (1993) showed that soil water contents were higher in no-tillage than in conventional tillage systems with differences ranging from 4% to 9% of the mean. These differences were attributed to the presence of surface residue, which showed down run off, reduced surface sealing and allowed more infiltration to occur during storm events. Beily (1995) reported that tillage with moldboard plow in clay soil gave the highest value of basic infiltration rate after plowing operations compared with the chisel and rotary plows. Increasing the plowing depth tends to increase the basic infiltration rate at all plow types. Ali and Abass (1998) showed that the no-tillage system seems to be a promising system for corn production in silt clay loam soil compared to conventional tillage (moldboard plow) for different varieties. Kamel et al. (2003) mentioned that tillage systems (chisel, moldboard, and disk harrow) had significant effect on grain yield of corn planting in clayey soil. Khadr et al. (1998) used different tillage systems (chisel plow, moldboard plow and rotary plow) to prepare clay loam soil for planting corn (Single Cross, S.C. 10). Their results showed that the moldboard plow treatment gave grain yield greater than the other two systems. Ward and Moussa (1997) studied the effect of using no tillage, chiseling twice, disk and moldboard plows followed by disk harrowing and leveling on corn yield in sandy soil. The results showed that the no-tillage treatment recording the least value of corn yield 3.543 ton/fed. Imara and Hamissa (2000) reported that the moldboard plow gave higher grain yield of corn crop planting in clay soil than chisel plow. Helmy et al. (2001a) mentioned that corn yield and its water consumption were influenced by different tillage systems (moldboard plow, chisel plow, and rotary plow) when applied plowing in clayey soil. The results showed that the corn yield, quantity of water, and water use efficiency were 4.88 ton/fed, 2399 m^3/fed and 2.03 kg/m^3 respectively when plowing with moldboard plow followed by disk harrow. Meanwhile, these values were 3.1 ton/fed, 2220 m^3/fed and 1.39 kg/m^3 respectively when plowing with rotary plow. On the other hand, these values were 3.50 ton/fed, 2296 m^3/fed, and 1.52 kg/m^3 respectively when plowing with chisel plow (one pass). Mohamed and El Saadawy (1998) reported that the plowing depth did not have a significant effect on both maize (hybrid maize, 323) yield and water use efficiency, where the soil texture was clay loam. Helmy et al. (2001b) showed that the grain yields of corn crop irrigated by continuos flow were 3.2, 3.8 and 2.7 ton/fed when plowing the clay loam soil using moldboard, chisel and rotary plows respectively.

The objective of this research work is to study the influence of irrigation discharges and tillage systems on corn (*zee mays L.*) grain yield and water efficiency at mulching rows with rice straw.

2. Materials and Methods

The field experiments were conducted for one season (autumn) during 2003 at Experimental Farm of Agricultural Research Station at Zarzora (Etay El Baroud, Beherah Governorate). The soil texture at the experimental site is clay (heavy texture) and it is characterized mainly by averages of pH = 8, organic mater = 0.87%, and EC = 4.8 mmhos/cm. Three irrigation discharges (1.5, 2.0 and 3.0 l/s) and three tillage systems using chisel, moldboard and rotary plows were used. The chisel plow was 7 shares arranged in three rows; the distance between shares was 25 cm. The moldboard plow was locally manufactured with 3 bottoms and had width of 105 cm. The rotary plow had 190 cm width and its blades had L-shape type. Plowing depth for all plows was 20 cm and disk harrow was followed after plowing with chisel and moldboard plows to make the soil more suitable for planting. Average of some soil characteristics and mechanical and chemical analysis are shown in Tables (1) and (2) respectively. Corn crop (*zee mays L.*) was planted on 24 May 2003 and harvested on 12 September 2003.

Table (1): Soil mechanical analysis in experimental site.

Soil depth	$CaCO_3$	Particle size distribution			Soil texture
		Sand	Silt	Clay	
cm	%	%	%	%	
0 – 20	7.0	11.3	28.3	60.4	Clay
20 – 40	6.0	12.4	25.6	62.0	
40 – 75	5.0	11.3	21.4	67.3	

Table (2): Chemical analysis of the soil in experimental site.

Soil depth	O.M*	pH	EC	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
cm	%	----	mmhos/cm	meq/100 g						
0 – 20	1.2	8.10	3.82	5.75	4.58	15.11	0.25	3.65	9.20	12.85
20 – 40	0.8	8.10	3.93	4.39	4.00	18.80	0.26	1.96	12.06	13.03
40 – 75	0.6	7.85	6.65	8.72	6.75	23.79	0.22	1.69	21.20	19.58

* O.M = Organic matter.

Randomized complete block design with three replications was used to study the influence of irrigation discharges and tillage systems and rows covering with straw (54 treatments) on grain yield and water efficiency (water consumptive use, crop and field water use efficiency). Common irrigation intervals in the experimental site approximately (21 days). The amount of irrigation water was measured and controlled using siphon tube. Soil infiltration rate was measured using the double ring infiltrometer. After 48 hours of the second irrigation, the rows surface between plants were covered with rice straw as recommended by Paul (1978) for clayey soil with 5 ton/fed. The soil slope was about 0.1% and cut off the irrigation flow in furrow at 80% of furrow length was achieved.

Soil moisture content was determined before and after each irrigation to calculate consumed water according to Israelson and Hansen (1962) as follows:

$$C_u = \frac{Q_2 - Q_1}{100} \times D \times Bd \qquad (1)$$

Where:

C_u = water consumptive use in each irrigation (cm),
Q_1 = soil moisture before irrigation (%, d.b),
Q_2 = soil moisture after irrigation (%,d.b),
D = soil depth (cm), and
Bd = soil bulk density (g/cm^3).

Crop water use efficiency was expressed as the weight of grain and water consumptive use. It can be obtained according to Vites (1965) as follows:

$$WUE = \frac{GY}{CW} \qquad (2)$$

Where:

WUE = crop water use efficiency (kg/m^3),
GY = grain yield (kg/fed), and
CW = Water consumptive use (m^3/fed).

Field water use efficiency was expressed as the weight of grain and water applied in the field. It can be obtained according to Vites (1965) as follows:

$$FWUE = \frac{GY}{WA} \qquad (3)$$

Where:

$FWUE$ = field water use efficiency (kg/m^3),
WA = Water applied in the field (m^3/fed).

3. Results and Discussion

3.1 Infiltration Rate and Cumulative Infiltration:

The depth of infiltration is the basic functions for evaluation the distribution uniformity and application efficiency. It is therefore an index For selecting the best surface irrigation regime (Guirguis, 1988). Fig. (1) shows accumulative infiltration and infiltration rate at any elapsed time when conducting plowing by moldboard, chisel and rotary plows. It is seen from that figure, the highest values of accumulative infiltration and infiltration rate for moldboard plow. This may be due to the lowest bulk density and the highest total porosity for that plow, while rotary plow caused the highest bulk density and lowest total porosity. Infiltration rate is high at the beginning when the soil was relatively dry and generally after a period of three hours it becomes almost constant.

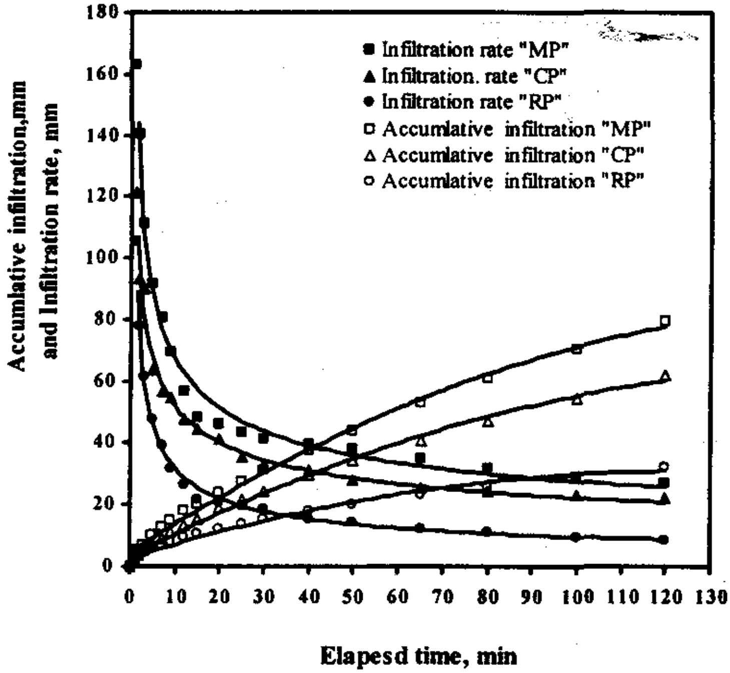

Fig. (1): Accumulative infiltration and infiltration rate vs. elapsed time for continuous flow under three tillage systems (Moldboard plow (MP), Chisel plow (CP), Rotary plow (RP)).

3.2 Water Consumptive Use:

Table (3) shows values of monthly and total water consumptive use by each irrigation treatment with different tillage systems during the growing season with mulching. The high values of total water consumptive use were seen for plowing with moldboard plow compared with plowing with chisel and rotary plows for all irrigation discharges. It is seen from Table (3) that total water consumptive use decreased as the irrigation discharge increased. This phenomenon may be attributed to decreasing the evaporation from the soil surface and increasing the amount of irrigation water leading to leaching of the nutrition of elements, consequently decreasing in water consumptive use. The data in Table (3) revealed that water consumptive use was more available to plants in small amount of irrigation discharge through all tillage systems. On the other hand, the water consumptive uses for the control irrigation treatment (traditional) were 2163.23, 2607.58 and 2052.13 m^3/fed under different tillage systems namely: chisel, moldboard, and rotary plows respectively.

Table (3): Monthly and total water consumptive use for corn crop as affected by irrigation discharges and tillage systems with rows mulching.

Tillage systems	Irrigation discharges (l/s)	Monthly consumptive use (m^3/fed)					
		May*	June	July	August	Septamber	Total
Moldboard Plow	1.5	149.30	416.66	642.38	673.40	362.70	2244.44
	2.0	135.05	404.46	617.40	634.62	284.81	2076.34
	3.0	126.80	402.23	603.83	613.46	186.24	1932.56
Chisel Plow	1.5	99.89	451.66	642.54	650.32	337.75	2182.16
	2.0	95.08	434.96	531.00	542.48	325.78	1929.30
	3.0	90.46	408.83	486.45	488.63	290.58	1764.95
Rotary Plow	1.5	89.18	473.36	545.18	555.68	385.80	2049.20
	2.0	77.68	423.74	490.14	499.89	330.55	1822.00
	3.0	70.82	397.51	478.13	486.22	275.70	1708.38

* Planting started at 24 May.

3.3 Corn Grain Yield:

The effect of irrigation discharge rates 1.5, 2.0 and 3.0 l/s and different tillage systems (moldboard, chisel and rotary plows) on corn yield are shown in Fig. (2), where the rows surface between plants was covered with rice straw as recommended for such soil with 5 ton/fed. Results indicated that the chisel plow recorded the highest grain yield values compared to moldboard and rotary plows for different irrigation discharge rates. Table (4) shows values of corn grain yield as affected by irrigation discharges, tillage systems, and with and without rows mulching.

It is seen from Fig. (2) that the irrigation discharge 1.5 l/s recorded the highest corn grain yield for moldboard and rotary plows, but the highest corn grain for chisel plow was recorded at discharge of 2.0 l/s under rows mulching. This may be attributed to the efficiency of slow irrigation with this kind of soil in this area (heavy soil) which have high ability to keep the water for along time because of it contains colloids between particles.

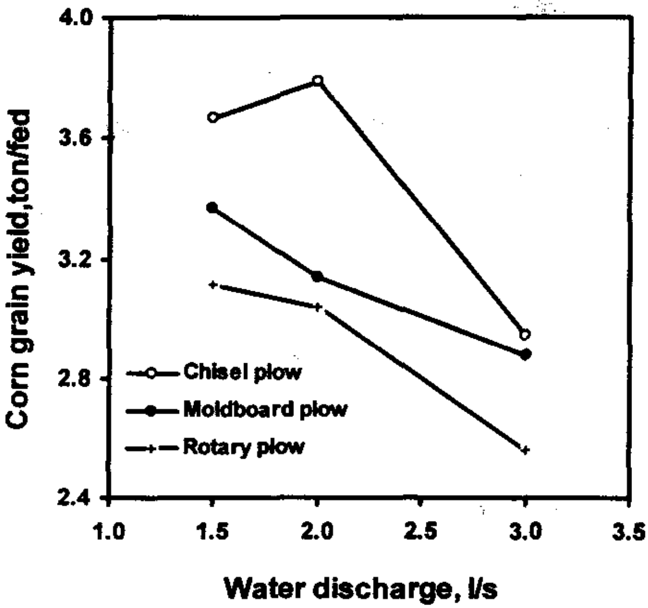

Fig. (2): Effect of tillage systems and irrigation discharge rates on grain yield of corn crop (the rows surface between plants was covered using rice straw).

Table (4): Corn grain yield as affected by irrigation discharge rates, tillage systems, and with and without mulching.

Tillage systems	Irrigation discharge rates	Corn grain yield*	
		With mulching	Without mulching
	l/s	ton/fed	ton/fed
Moldboard plow	1.5	3.37	3.29
	2.0	3.14	3.10
	3.0	2.88	2.75
	Traditional irrigation	3.24	3.18
Chisel plow	1.5	3.66	3.49
	2.0	3.78	3.61
	3.0	2.95	2.88
	Traditional irrigation	3.64	3.51
Rotary plow	1.5	3.11	2.93
	2.0	3.04	2.90
	3.0	2.56	2.42
	Traditional irrigation	2.79	2.68
No-tillage + traditional irrigation + without mulching		2.34	

* Average of three replicates

It is seen from Table (4) that there is obvious difference in corn grain yield between rows with and without mulching. Traditional irrigation under the tillage systems gave different corn grain yield when rows with and without mulching. Also, it gave less corn grain yield compared to irrigation discharge 1.5 l/s. The no-tillage + traditional irrigation + without mulching treatment gave lowest corn crop yield compared to all treatments under rows mulching. Table (5) shows analysis of variance for randomized complete block design with three replications for corn grain yield. It is seen that irrigation discharges and tillage systems and rows mulching show statistically significant difference in their effects on grain yield. All interactions show significant difference in their effects on grain yield expects interaction between irrigation and rows mulching. Meanwhile, Table (6) shows effect of irrigation discharges and tillage systems and rows mulching on corn grain yield. It is seen that chisel plow, irrigation discharge 1.5 l/s and rows mulching gave higher grain yield compared to other treatments.

Table (5): Analysis of variance for corn grain yield.

Source of variation	df	Anova SS	Mean square	F Value
Model	19	7.1	0.374	456.4**
Error	34	0.028	0.0008	
Total	53	7.13		
Blocks	2	0.002	0.0008	1.03
Tillage systems (T)	2	2.91	1.46	1777.04**
Irrigation discharges (I)	2	3.56	1.78	2174.35**
Mulching (M)	1	0.22	0.22	270.74**
T× I	4	0.38	0.096	117.53**
T× M	2	0.009	0.004	5.33**
I × M	2	0.003	0.001	1.54
T × I × M	4	0.009	0.002	2.96*

* Significant (P = 0.05). **Highly significant (P = 0.01). df = degree of freedom

3.4 Field and Crop Water Use Efficiency:

The calculated average water use efficiency values expressed as kilogram of grain yield obtained from one cubic meter of water consumed. Table (7) shows effect of irrigation discharges and different tillage systems on field and crop water use efficiency under rows with and without mulching. Results indicated that the highest crop water use efficiency reached 1.96, 1.51 and 1.67 kg/ m^3 with treatment 2.0 l/s irrigation discharge for chisel, moldboard and rotary plows respectively with rows mulching.

Table (6): Effect of irrigation discharges and tillage systems and rows mulching on corn grain yield.

Treatments	No. of observations	Mean grain yield ton/fed	Significant level*
Irrigation discharges			
1.5 l/s	18	3.31	a
2.0 l/s	18	3.26	b
3.0 l/s	18	2.74	c
LSD+	0.019		
Tillage systems			
Chisel plow	18	3.39	a
Moldboard plow	18	3.08	b
Rotary plow	18	2.83	c
LSD+	0.019		
Mulching			
With mulching	27	3.17	a
Without mulching	27	3.04	b
LSD+	0.016		

* Means in the same column with different letters differ significant (P = 0.05).
+ LSD = Least significant difference.

The highest crop water use efficiency reached 1.72, 1.19 and 1.42 kg/ m^3 with treatment 2.0 l/s irrigation discharge for chisel, moldboard and rotary plows respectively without rows mulching. Data in Table (7) shows that there are differences between water consumptive use and water use efficiency when rows mulching with rice straw compared to no mulching. In the case of rows mulching, the water consumptive use and water use efficiency increase compared to no mulching.

4. Conclusion

The corn (*zee mays L.*) grain yield responded differently to irrigation discharges, tillage systems, and mulching planting rows by rice straw. It seems to conclude that the chisel plow cropping system may become suitable tillage at irrigation discharge of 2.0 l/s under mulching planting rows by rice straw for corn production in soil owing high ability to keep the water for along time and containing colloids between particles. Generally, the applied water decreased as the irrigation discharge increased at all tillage systems. The water consumptive use was more available to plants in small amount of irrigation discharge through all tillage systems. The highest crop water use efficiency reached 1.72, 1.19 and 1.42 kg/ m^3 with treatment 2.0 l/s irrigation discharge for chisel, moldboard and rotary plows respectively without rows mulching.

Table (7): Average* water applied, water consumptive use, and field and crop water use efficiency as affected by irrigation discharges and tillage systems with and without rows mulching.

Tillage systems	Irrigation discharges	Water applied	Water consumptive use	Water use efficiency kg/ m^3	
	l/s	m^3/fed	m^3/fed	Field	Crop
With rows mulching					
Moldboard plow	1.5	2631.44	2244.44	1.28	1.50
	2.0	2395.20	2076.34	1.31	1.51
	3.0	2196.30	1932.56	1.31	1.49
Chisel plow	1.5	2309.70	2180.16	1.58	1.68
	2.0	2100.10	1929.30	1.80	1.96
	3.0	1879.90	1764.95	1.57	1.67
Rotary plow	1.5	2257.40	2049.20	1.38	1.52
	2.0	2039.10	1822.00	1.50	1.67
	3.0	1859.90	1708.38	1.42	1.50
Without rows mulching					
Moldboard plow	1.5	3255.94	2831.25	1.01	1.16
	2.0	2932.58	2595.20	1.06	1.19
	3.0	2683.86	2396.30	1.02	1.15
Chisel plow	1.5	2785.77	2509.70	1.25	1.39
	2.0	2247.11	2100.10	1.61	1.72
	3.0	2049.09	1879.90	1.41	1.53
Rotary plow	1.5	2776.86	2457.40	1.06	1.19
	2.0	2283.79	2039.10	1.27	1.42
	3.0	1942.81	1798.90	1.25	1.35

* Average of three replicates.

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الملخص العربي

تأثير معدلات تدفق الري، الحراثة والتغطية على إنتاجية الذرة

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يهدف البحث إلى دراسة تأثير تصرفات مياه الري المضافة مع نظم حراثة مختلفة على إنتاج الذرة في أرض طينية عند تغطيه وعدم تغطية خطوط الزراعة بقش الأرز، ومقارنة ذلك بالطريقة التقليدية للري وبدون حراثة وعدم تغطية الخطوط خلال الموسم الزراعي ٢٠٠٣ م. تمت تسوية الأرض بميل ٠,١%، وإيقاف سريان المياه عندما تصل إلى ٨٠% من طول الخط. وأظهرت النتائج أن هناك انخفاضًا في قيم الاستهلاك المائي مع زيادة معدلات تصرف المياه لكل نظم الحراثة المستخدمة عند تغطية الخطوط بقش الأرز مقارنة بالطريقة التقليدية في الري وعدم حرث الأرض وعدم تغطية الخطوط، وأن نظام الحراثة بالمحراث الحفار أعطى أعلى إنتاجية للذرة مع تصرفات المياه المختلفة، حيث كانت ٣,٦٦ ، ٣,٧٨ ، ٢,٩٥ طن/فدان لتصرفات المياه ١,٥ ، ٢ ، ٣ لتر/ث على التوالي عند تغطية الخطوط بقش الأرز. وأن قيم كفاءة استعمال المياه للمحصول كانت ١,٩٦ ، ١,٥١ ، ١,٦٧ كجم/م٣ لنظم الحراثة بالحفار والقلاب المطرحى والدوراني على التوالي مع تصرف المياه ٢ لتر/ث عند تغطية الخطوط بقش الأرز مقارنة بالمعاملة التقليدية. وطبقا لنتائج البحث ولطبيعة الأراضي الثقيلة وارتفاع نسبة الغرويات بين حبيباتها وقدرتها العالية على الاحتفاظ بالماء، فإن تغطية خطوط الزراعة بقش الأرز أدى إلى خفض كمية المياه المستهلكة، ووجد أن معدل تصرف الماء ٢ لتر/ث مع ميل ٠,١% مناسب لهذه النوعية من الأراضي مع استعمال المحراث الحفار لتمهيد مرقد البذرة لزراعة الذرة .

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