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ECONOMICAL OPERATION OF DRIP

IRRIGATION SYSTEM WITH

RICE STRAW MULCHING

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ABSTRACT

A field experiment has taken place in Wahet El-Nagah farm, Khatatba village, Menoufia governorate, Egypt in the year 2005, in order to use the ability of rice-straw mulching as cheap farm residue, to reduce the effect of deficit irrigation on highly sensitive crop for water deficit. Split plot design consisted of soil surface covering case (rice straw mulching ($500g/m^2$) and no-mulch) as main plot with four amounts of applied water 70, 80, 90, and 100% of ET_c as sub-plot. Cucumber crop was irrigated by drip irrigation system under sandy soil conditions. Using rice straw mulch led to decrease the soil moisture reduction by 66, 57, 48.9, and 38 % compared with no-mulch treatments for the 70, 80, 90, and 100% of ET_c respectively. All rice straw mulch treatments showed a productivity increase compared to no-mulch. The maximum crop yield 8.24 Mg/fed was obtained under rice straw mulching and 100% of ET_c percentage causing a 29.6% increase in productivity compared with the crop productivity obtained at the treatment of same amount of applied water under traditional conditions. Rice straw mulch led to increase water use efficiency (WUE) the maximum value of WUE under rice straw mulch was 6.55 kg/m^3 with 90% of ET_c while it was 4.37 kg/m^3 under the same conditions with no-mulch. Maximum benefit-cost ratio, 2.92 was obtained under rice straw mulch with 90% while it was 2.86 for no-mulch with 100%. The study recommended using rice straw mulch with 90% of ET_c to obtain the maximum product of unit of water and maximum economic benefit.

INTRODUCTION

Water problem all over the world will lead to try to maximize the benefits of unit of water. Modern irrigation systems such as drip irrigation have a high efficiency and help to save water and increasing crop production. We should try to use any addition techniques that may help the irrigation system to reduce water losses and gives the most high possible crop productivity in addition to caring and viewing of economic side.

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Drip irrigation system is widely used under Egyptian sandy soil conditions due to it has low initial costs, increased beneficial use of available water, enhanced plant growth and yield, decreased energy requirements. Organic mulch helps to preserve water in soil by reducing evaporation losses, moderates temperature of the root zone. Drip irrigation is compatible with mulching, because the grower can maintain optimum moisture under the mulch **Olson, (1995)**.

Al-Wahaibi *et al.* (2007) found that mulching with date palm residues was superior in terms of tomato fruit yield and controlling increase in soil salinity and temperature as compared to black plastic mulch and control. **Yang *et al.* (2007)** found that surface mulch had significant effect in reducing water evaporation and reducing soil salinity level of the desalinized plots planted with winter wheat. **Kar and Kumara (2007)** found that soil moisture depletion from potato plots decreased with straw surface mulching thus increasing plant growth and tuber production as compared to non-mulched plots that indicated higher soil moisture depletion. In their study of seven soil management practices In their study with corn, **Bu *et al.* (2002)** found that surface applied mulches resulted in reduced soil water loss by evaporation and in reduced salt accumulation on surface in addition to controlling weeds. **Abd El-Kader *et al.* (2010)** concluded that, mulching with rice straw for cowpea with a mixture of some micro-nutrients (600ppm) under clay soils lead to increased soil moisture content, soil temperature, root length, root dry weight, growth and yield measurements. Rice straw (as organic mulch) is inexpensive, available under Egyptian conditions, insulates well, and conserves moisture. In addition, it acts an environmental problem during the last five years in Egypt resulting from the harm way of its disposition (burning) because of the difficulties of using it as a commercial product for normal farmers so using it for mulching could offer a solution for this problem in addition to its benefits as an organic cheap mulch. **Rahaman *et al.* (2004)** revealed that rice straw mulch increased potato yield average of two years than water hyacinth mulch. Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied **Kirda *et al.*, (1999)**, it decreases irrigation system operation time that may give help to face water and fuel problem, but it needs to be managed well to avoid its effect on crop productivity which will be affected negatively with water reduction. **Narayan *et al.* (1994)** found

that water use efficiency had increased from 2.23 to 2.63 kg/m^3 as a result of decreasing the irrigation level from 0.8 to 0.4 of cumulative pan evaporation of sweet pepper. The objectives of this work under sandy soil conditions were as follows:

1- Reduce system operation time via deficit irrigation.
2- Using rice straw mulching to avoid the effect of deficit irrigation without any highly costive treatments.
3- Study the expected productivity reduction significance.
4- Evaluate the effect of deficit irrigation on benefits-cost ratio for recommending an economic management method for drip irrigation system

MATERIALS AND METHODS

1. Preparation of the experimental area

A 30m laterals containing built- in emitters 50 cm spacing along lateral and 150 cm between rows were used to irrigate cucumber crop (F1-Faris) during the successive summer season 2005 in sandy soil (Table 1).

Table.1: Some physical properties of the experimental soil.

Depth, cm	Soil physical and hydro-physical Characteristics					
	Particle size distribution			Texture	F.C, %.	P.W.P, %.
	Sand, %	Clay, %.	Silt, %			
0-15	89.69	0.47	9.84	Sandy	9.8	4.8
15-30	89.71	0.47	9.82	Sandy	10.2	5.0
30-45	88.54	3.21	8.25	Sandy	10.9	5.1

F.C = Field capacity, and P.W.P= Permanent wilting point.

Table.2 shows emitter some emitter characteristics. The field work was carried out in a 60 x 42 m^2 experimental area. The final cultivated area slope was zero level.

Table.2: Used emitter characteristics

Manufacturer name	Classification	Country of made	Flow rate at experimental operating head
Euro drip	Built-in	Egypt	4.41 l/h

The soil and water chemical analysis showed that soil pH was 7.85, therefore 40 kg/fed of sulfur were added to control alkalinity of soil. Electrical conductivity of water was 0.8 dS/m while SAR (Sodium absorption ratio) was 2.55 so irrigation water can be used with out any expected problems for salinity or infiltration (FAO, 1980). Chisel plow (5 shares) hitched by a

33.58 kW (45 hp) tractor was used to remove residues of previous crop (Zea maize) and weeds. Before planting amounts of 20 – 75-100 kg/ fed of N-P-K, respectively, were added during plowing operation. Cucumber crop was planted in 22/7/2005 with 3 seeds per pore (50 cm spacing) at 5 cm depth and after germination it was thinned to one plant / pore. A pesticide 2.5% Mefenoxam, and 40% Copper was used 150g/100 litres to defend plants against fungus infections. A pesticide contains active ingredient diethyl – trichloro- pyridyl phosphoriothioate 480 g/l were used to defend insects (Pachnoda fasciata) that attacked cucumber fruits. Primary tests were carried out to choose a suitable mulching density for rice straw .The compared thickness' were 2.5, 3.8 and 5 cm (1, 1.5 and 2 inches). Every thickness was one meter length. Mulching over 5 cm thickness was avoid to reduce mulching costs and over mulching problems. A soil moisture meter 2 % accuracy was used to measure the soil moisture content after 6, 12, and 24 hours after reaching soil field capacity. This test was carried out in the field with separated lateral (30 m length) out of the main experiment area. Three positions on the previously mentioned outside lateral acting first, second and last thirds along lateral were chosen randomly to be mulched as replicates. According to the primary study the 5 cm thickness was chosen because it reduced the moisture loss as shown in Figure 1. The Rice straw mulch width was 60 cm with abundance 500 g/m^2.

Fig 1 : Effect of Rice straw mulching thickness on soil moisture reduction, %
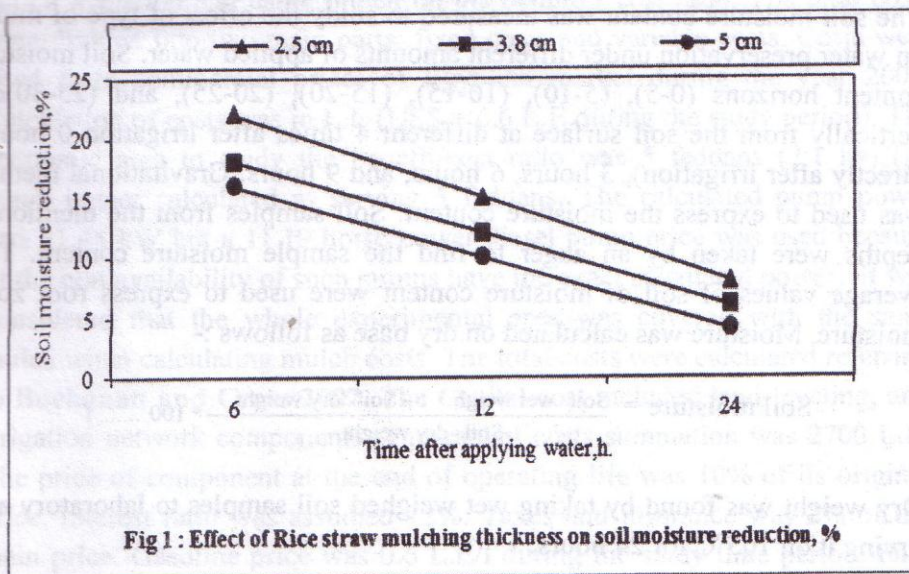
2.Irrigation requirements

Reference evapotranspiration was cited for the experimental area using CLIMWAT computer program **FAO (1993)**. The cucumber crop water requirements (ET_c) was calculated refering to **Vermeiren and Jobling (1980)**. Crop factor values were 0.6, 1 , and 0.75 for the first , second, and last third of growing season respectively **FAO (1998)**.Reduction factor was calculated referring to **Keller and Karmeli (1975)**. The reduction factor value was 1.

3.Experimental design.

Under rice straw mulching and traditional conditions, 72 hs were tested as suitable intervals for sandy soil conditions with drip irrigation laterals. The space between emitters was 50 cm along lateral. Bulb valves (T-shape) were used after 30 cm from the beginning of each lateral to control water entry through the laterals. The main and sub-main pipes were P.V.C 4 and 2 inches diameter respectively. Four quantities of total crop water requirement (ET_c) noted as 70, 80, 90, and 100% were used to study the effect of deficit of irrigation water under mulching conditions on cucumber crop. Split plot design was used to perform statistical analysis and mean comparison. Mulch type act main plot while submain was the amount of applied water.

4.Measurements:

4.1 Soil moisture content preservation:

The soil moisture content was measured to study the effect of type of mulch on water preservation under different amounts of applied water. Soil moisture content horizons (0-5), (5-10), (10-15), (15-20), (20-25), and (25-30)cm vertically from the soil surface at different 4 times after irrigation 0 hours(directly after irrigation), 3 hours, 6 hours, and 9 hours. Gravitational method was used to express the moisture content. Soil samples from the mentioned depths were taken by an auger to find the sample moisture content. The average values of soil of moisture content were used to express root zone moisture. Moisture was calculated on dry base as follows :-

$$\text{Soil moisture} = \frac{\text{Soil wet weigh t - Soil dry weight}}{\text{Soil dry weight}} * 100 \ \ldots\ldots 1$$

Dry weight was found by taking wet weighed soil samples to laboratory and drying it on 105°C for 24 hours.

4.2 Yield productivity and Water use efficiency (WUE):

One meter length (1.5m width) from each treatment were taken to find the crop productivity and replicated four times. Fruits were weighed on 10 g accuracy scale. The average of replicates were calculated , then it was multiplied in 2800 to act the crop yield per feddan (0.42 ha). Picking fruits starts when cucumber fruit reaches 12-14 cm long and/or 2cm diameter.

Crop water productivity expression was used to express water use efficiency, which has been used to describe the relationship between cucumber crop production and the total amount of water used. It was determined by applying the following equation (Jensen, 1983):

$$WUE = \frac{Y}{W_a} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad 2$$

Where:-

WUE = water use efficiency, kg/m^3, Y = total yield kg/fed

W_a = total applied water, m^3/fed.

4.3 Costs.

The total cost of different treatments were calculated to study the effect of deficit irrigation and using mulch on the benefit / cost ratio. The total costs were divided into two main parts, fixed costs and variable costs. Costs were cited from commercial prices of Egyptian market during the year 2005. Calculation of costs was in L.E (US\$ = 6.6 L.E during the study period). The economic area to study the benefit/cost ratio was 5 feddans (2.1 ha).The pump power calculated as serving 5 feddans. The calculated pump power was 11.45 kW but a 11.19 horse power diesel pump price was used because of the non availability of such pumps have the exact calculated power. It was considered that the whole experimental area was covered with the same mulch when calculating mulch costs. The total costs were calculated referring to **Buchanan and Cross 2002**. The Capital cost included land leveling, and irrigation network components. The capital costs summation was 2700 L.E. The price of component at the end of operating life was 10% of its original price. Interest ratio was assumed 12%. Taxes and insurance was 2% of the main price. Gasoline price was 0.6 L.E/l during the study time period. Fuel

consumption(F_c) was calculated Using the following formula (**Kepner et al.,1980**):-

$$F_c= 0.12 * P_E \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where: P_E= Engine brake power, hp

The oil and lubricant costs was assumed to be 15% of fuel costs (**Kepner et al.,1980**). Repairs and maintenance was assumed to be 100% of annual depreciation cost .The price at the end of the expected life, interest ratio, and repairs and maintenance calculation assumptions were referring to (**El-Dnasoury,2001**). The real daily salary of a labor in the study area was 8 pounds/day for 8 hours daily.The benefits of cucumber crop was considered as the price of selling from the farm. It did not include any transport costs .The price was 1.6 L.E/kg (0.24.2 US$/kg) depending on the commercial prices of year 2005. The Benefit- cost ratio (B/C) is the benefit of productivity selling divided by the total production costs.

RESULTS AND DISCUSSION

1.Soil moisture preservation

Table 3 shows the values of soil moisture content reduction for 45 cm depth measured during 9 hours after irrigation. The soil moisture loss increased by increasing amount of applied water, that may happened because of the reversible relationship between soil moisture stress and soil moisture content. Usage of rice straw mulch led to decrease the soil moisture reduction by 66, 57, 48.9, 38 percent compared to No-mulch conditions for the 70, 80, 90, and 100% of ET_c respectively.

Table.3: Soil moisture reduction percentage after 9 hours from the end of irrigation.

Amount of applied water, %ET$_c$	Rice straw	No-Mulch
70	0.88	2.6
80	1.49	3.5
90	2.45	4.8
100	3.4	5.5

2.Crop productivity.

Results listed in Table 4 show that the maximum productivity of crop yield 8.24 Mg/fed was obtained under rice straw mulch with 100% ET_c, while the maximum productivity under traditional conditions was 5.8 Mg/fed for the same amount of applied water. In general, results showed that the rice straw treatments were higher than traditional conditions. Increasing applied water from 70 to 100% will lead to increase the crop productivity by 24% compared with 33% for no-mulch conditions. That may be due to the water preservation by rice straw mulch which decreased the effect of water deficit. Mean comparison showed that there were no significant differences between all amounts of applied water under rice straw mulch.

Table 4: Mean cucumber yield production (Mg/fed) under different irrigation water regime treatments.

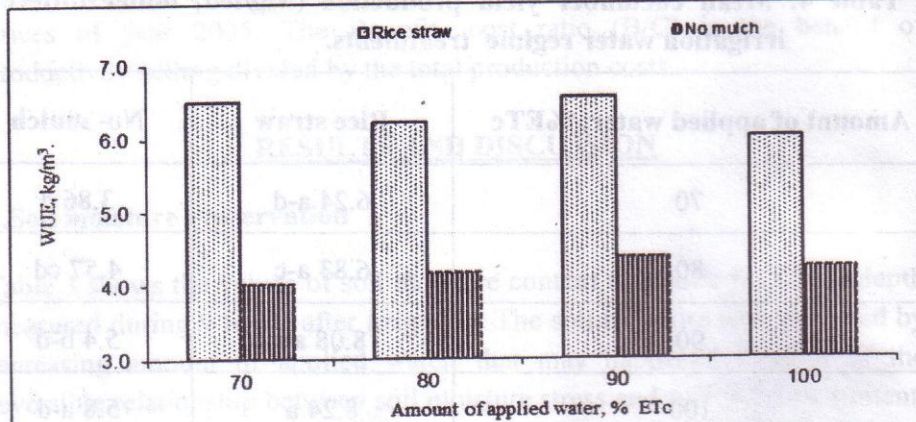| Amount of applied water, %ETc	Rice straw	No- mulch
70	6.24 a-d	3.86 d
80	6.83 a-c	4.57 cd
90	8.08 ab	5.4 b-d
100	8.24 a	5.8 a-d

L.S.D=2.779 at 0.05 level

3. Water use efficiency (WUE):

The resulted data of water use efficiency show that due to the increase in crop productivity under rice straw mulch, water use efficiency for all the amounts of applied water under rice straw mulch were greater than no-mulch amounts. The maximum value under rice straw mulch was 6.55 kg/m^3 with 90% of ET_c while it was 4.37 under the same amount with no-mulch. That may be due to non-significant decrease in crop productivity with the decrease in applied water. Figure 2 shows a histogram to compare the water use efficiency under mulching and traditional conditions.

Table.5: Water use efficiency for experimental treatments.

	Amount of applied water, % ET$_c$.	Crop productivity, Mg/fed	Amount of applied water, m^3/fed	Water use efficiency, kg/m^3
Rice straw	70	6.23	959.7	6.50
	80	6.82	1096.8	6.22
	90	8.07	1233.6	6.55
	100	8.23	1371	6.01
No mulch	70	3.85	959.7	4.01
	80	4.56	1096.8	4.15
	90	5.39	1233.6	4.37
	100	5.80	1371	4.23

Fig.2: WUE for different amounts of applied water under mulch and no-mulch conditions.

3. Costs analysis.

Results illustrated in Table 6 for no-mulch and rice straw mulch show that the maximum B/C ratio under no-mulch was 2.65 with 100% of water requirements while it was 3.59 for rice straw treatment with 90% of ET$_c$. Despite the addition cost of rice straw mulching operation. The treatments under rice straw mulch gave higher values of B/C ratio, That may lead to economically recommend rice straw mulching under experimental variables and conditions.

Table.6: Total costs for 5 feddans under mulch and no-mulch treatments.

	No mulch				Rice straw mulch			
	70	80	90	100	70	80	90	100
Capital costs	2700	2700	2700	2700	2700	2700	2700	2700
Annual fixed costs								
1-Depreciation	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2
2-Interest	325.05	325.05	325.05	325.05	325.05	325.05	325.05	325.05
3-Taxes and insurance	1319.5	1319.5	1319.5	1319.5	1319.5	1319.5	1319.5	1319.5
Total fixed costs	8677.8	8677.8	8677.8	8677.8	8677.8	8677.8	8677.8	8677.8
Variable operating costs								
Labor	268	306	345	383	464	530	597	663
Fuel	230	263.2	296	329	230	263.2	296	329
Repairs and maintenance	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2	4333.2
Lubricants	115	131.6	148	164.5	115	131.6	148	164.5
Mulching	-	-	-	-	346.5	346.5	346.5	346.5
Seeds	700	700	700	700	700	700	700	700
Fertilizers and pesticides	2894	2894	2894	2894	2894	2894	2894	2894
Total variable cost	8540	8628	8716	8804	9083	9199	9315	9430
Total (L.E / season)	17218	17306	17394	17481	17760	17876	17992	18108
Benefits	38720	39440	48960	49920	49520	51520	53840	53920
B/C Ratio	2.25	2.28	2.81	2.86	2.79	2.88	2.99	2.98

CONCLUSION

Rice straw mulching led to increase crop productivity and did not give significant reduction in crop productivity. Crop water productivity showed that the most benefit of unit of water was with 90% of ET_c. The maximum B/C ratio was under the same previously mentioned treatment. That may lead to recommend using rice straw for cucumber crop irrigated by drip irrigation system under sandy soil conditions every 48 hours with 90% of ET_c to obtain an increase in the product of unit of water and B/C ratio.

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الملخص العربى

التشغيل الاقتصادي لنظام الرى بالتنقيط باستخدام التغطية بقش الأرز

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أجريت تجربة بمزرعة واحة النجاه بقرية الخطاطبة ـ مدينة السادات ـ محافظة المنوفية في عام ٢٠٠٥ بغرضالاستفادة من قش الرز كمخلف مزرعي رخيص في تغطية سطح التربة الرملية بغرض تقليل فاقد البخر ودراسة هذا التأثير على امكانية تقليل زمن تشغيل شبكة الرى بالتنقيط مما قد يكون له عائداً اقتصادياً من ناحية تحقيق الربح. تمت التجربة على صنف خيار هجين فارس كنموذج للمحاصيل شديدة الحساسية للنقص المائي. تم استخدام خطوط تنقيط GR بطول ٣٠ م بمسافات ٥٠ سم على طول الخط و ٢م بين الخطوط. شملت المتغيرات استخدام ٤ كميات من مياه الرى٧٠،٨٠،٩٠،١٠٠% من الاحتياجات المائية للمحصول تحت الظروف العادية والتغطية بقش الأرز بكثافة ٥٠٠ج/ م٢. اوضحت النتائج قدرة قش الأرز على الحفاظ على المحتوى الرطوبي للتربة مقارنة بالظروف المفتوحة مما أدى الى زيادة الانتاجية لكل كميات المياه المضافة مقارنة بمثيلتها في الظروف المكشوفة. ووضح زيادة الانتاجية بزيادة كمية المياه المضافة في كل المعاملات وكانت افضل انتاجية ٨،٢٤ طن/فدان تحت ظروف التغطية بقش الأرز ونسبة ١٠٠% من الاحتياجات المائية للمحصول. لم تظهر فروق معنوية بين معاملات قش الأرز الا أن اقصى استفادة من وحدة المياه كانت مع استخدام قش الأرز مع ٩٠% من الاحتياجات المائية للمحصول وبلغت ٦،٥٥ كج/م٣. بينما كَانت أفضل انتاجية لوحدة المياه ٤،٣٧ كج/م٣ تحت الظروف المكشوفة. اوضح التحليل الاقتصادي للمعاملات أن اعلى نسبة عائد ـ التكاليف باستخدام قش الأرز مع ٩٠ % من الاحتياجات المائية الكلية للمحصول وبلغت ٢،٨٦ نظراً لانخفاض زمن التشغيل مما ادى الى وفر في استهلاك الشبكة واستهلاك الوقود مع عدم وجود انخفاض معنوي في الانتاجية مع عدم وجود تكلفة عالية للتغطية. وأوصت الدراسة باستخدام قش الأرز في التغطية تحت الظروف التجريبية مع اضافة ٩٠ % من الاحتياجات المائية للمحصول لتحقيق أقصى استفادة من وحدة المياه وأعلى عائد اقتصادي.

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