

IMPROVING WATER PRODUCTIVITY OF BEANS THROUGH DOUBLE RIDGE FURROW IRRIGATION METHOD

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ABSTRACT

Food security and water resources are in danger as a result of water scarcity and there is a need to produce more crop yields with less water. Consequently, adopting new efficient irrigation methods is crucially important to sustain population growth. This study compared the effects of applying two different surface irrigation methods (traditional furrow and double ridge furrow irrigation methods) on yield, water productivity of dry beans in sandy loam soils taking two irrigation intervals into consideration. Different irrigation treatments were compared in terms of beneficial water use and economical water productivity for the two irrigation methods. Comparing the results obtained from different treatments, the double ridge furrow method is advantageous in comparison with traditional furrow irrigation in terms of water saving. It was obvious that double ridge furrow method can at least save 40-50% of water which can directly expand the cultivated area in the Nile Delta and Valley. As a result of saving water, beans water productivity increased by 41 and 34% over the traditional furrow method. The results therefore showed that double ridge furrow method can be a robust irrigation method to increase water productivity by applying less irrigation water while having higher yields.

Keywords: *improving, surface, irrigation, double, ridge, furrow, irrigation, water, productivity and costs*

INTRODUCTION

Continues increase in world's population with limited water resources particularly in arid and semi arid regions requires increasing water productivity. Therefore the progressive need for more food to sustain rapidly population growth with limited water resources forces farmers to use more efficient irrigation systems to maximize crop productivity.

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Water is considered one of the main factors limiting crop production of various crops and therefore water application method is crucial for obtaining maximum grain yield. Availability of water rather than land is the main obstacle on agricultural production in arid and semi arid regions and also the most important factor limiting plant yield and performance worldwide (Sezen et al., 2011). Limited water resources and growing need for water will reduce the availability of water. Additionally, increasing water pumping cost and low efficiency of traditional irrigation systems are among the main reasons that prompt many farmers to apply less water to crops than that required to obtain maximum yield (Craciun and Craciun, 1999). Irrigation water management attempts to increase economic return while using less water or less energy (Sidhu et al., 2008).

Green bean (*Phaseolus Vulgaris L.*) is a major crop cultivated in many countries in arid and semi arid regions. In hot weather conditions large amounts of water are needed to produce beans and other agricultural crops as a result of high evapotranspiration. Accomplishing maximum crop productivity per unit of applied water has become critical since costs for irrigation and limited water resources increase (Hunsaker et al., 1998). Efetha et al. (2011) concluded that available water should be used as efficiently as possible by applying irrigation management practices which enhance increased grain yield and water conservation.

One way to increase traditional surface furrow irrigation efficiency is to develop the furrow irrigation management technique to decrease water losses. Previous studies used different techniques to improve surface furrow irrigation such as surge flow irrigation (Unlu et al., 2007), alternate furrow irrigation (Kang et al., 2000 and Weber et al., 2006 and Thind et al., 2010), cutback flow (Humpherys 1978) and deficit irrigation (Geerts and Raes, 2009 and Okwany et al., 2012).

Surface furrow irrigation is the most commonly used method in the Nile Delta and Valley. The method causes great water losses to deep percolation and surface runoff that lead to low irrigation efficiency. Additionally most farmers in Egypt over irrigate their crops particularly the fields at the beginning of irrigation canal network. Efficient irrigation methods are therefore essential in the Nile Valley and Delta to increase

water productivity and also can be a step forward to expand the cultivated area. Under good management practices, double ridge furrow irrigation method and similar techniques can result in remarkable water saving with less effect on yield production. In this context, this research aimed to enhance water productivity and water use efficiency of beans crop under Egyptian conditions.

MATERIALS AND METHODS

Site description and agronomic practices

A field experiment was undertaken in Elnasr village, Bohaira Province, Egypt (latitude of 30.93 and longitude of 29.92). The average temperature in the study site over spring season is about 26 °C. Rainfall is very low over this period of time. Soil samples were collected prior to the experiment to determine soil physical and chemical analysis. Soil samples were taken from two different depths (0-15 and 15-30). Samples were oven dried, sieved (2mm) and soil paste extract was prepared for various analyses. The soil texture at this site is a sandy loam soil with low nitrogen concentration having 15.8% clay, 4.8% silt and 79.4% sand). Table 1 shows both chemical and physical properties of the experimental soil.

Table (1) Chemical and physical analysis of soil at the experimental site

Depth, cm	EC, dS/m	pH	Cations, meq/l				Anions, meq/l				Texture
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄	
0-30	1.48	7.6	11.7	1.18	7.31	1.94	0.3	8.2	9.5	4.13	Sandy loam
30-60	1.35	7.7	9.7	1.98	6.15	1.11	0.1	7.5	8.2	3.14	Loam

Beans seeds were planted on March 20th over 2016 spring growing at a rate of 120 kg ha⁻¹. All experimental plots were irrigated to ensure high germination percentage, and they irrigated again a week after planting. When soil became dry, plants in all plots were thinned to just one plant per hole to accomplish the recommended plant density. Nitrogen fertilizer in the form of ammonium nitrate was applied as recommended in two equal doses at 45 kg ha⁻¹ each. The first dose of nitrogen fertilizer was applied concurrent with the third irrigation and the second dose was applied at the fourth irrigation for each treatment. Four different treatments with three replicates were assigned for this research study. The

experimental area was divided into small plots with an area of 15*15m. A 2 m buffer was left without planting to avoid overlapping between different treatments. The distance between furrows was 0.60 m in case of using traditional furrow method while the distance was 1.2 m for the double ridge furrow method. When the crop reached the maturation, each plot was harvested manually for threshing. The three replicates of each treatment were taken in consideration to get the mean for means comparison.

The studied treatments were:

F₁₀: traditional furrow method with 10 days irrigation interval

F₁₅: traditional furrow method with 15 days irrigation interval

DF₁₀: double ridge furrow method with 10 days irrigation interval and

DF₁₅: double ridge furrow method with 15 days irrigation interval

Application rate of irrigation water

Water was delivered to different plots through a concrete channel and the discharge rate was measured by the help of a rectangular weir of 0.4 m width. The total amount of irrigation water delivered was calculated using the following formula:

$$Q = \frac{2}{3} C_d \sqrt{2g} B H^{1.5} \dots\dots\dots(1)$$

Where Q is the amount of water (m³ s⁻¹), B is the width of weir (m), C_d is the discharge coefficient of weir (taken 0.95) and H is the water head over the weir. A stop watch was used to estimate the time required to irrigate each plot to identify the total amount of water for every treatment. Care was taken to ensure constant head over the weir base.

Water productivity

Water productivity is defined as the weight of grains produced from one cubic meter of water and can be calculated according to **Rodrigues and Pereira (2009)** as follows:

$$P = \frac{Y}{D} \dots\dots\dots (2)$$

Where P is water productivity in Mg per every cubic meter of water, Y is the total grain yield obtained from one hectare in Mg ha⁻¹, D is the amount of water applied in m³ ha⁻¹.

Cost analysis

The net return of any agricultural production is fundamentally important for countries suffering limited natural resources especially water resources. Inputs and net return of various irrigation treatments was investigated to choose the optimum and efficient irrigation method. The total cost of different irrigation treatment was calculated taking into account the rent of water pumping machine (9hp). In this study the rent was LE15 per hour and irrigation cost (LE Mg⁻¹) was calculated using the following equation

$$\text{Irrigation cost} = \frac{C}{Y} \dots\dots\dots(3)$$

Where C is the total cost for irrigation over the growing season (LE ha⁻¹), Y is the grain yield (Mg ha⁻¹).

Profit cost ratio

Profit cost ratio is an indicator of the return of each pound invested and is based on the net profit and total cost which is calculated as follows:

$$\text{Profit cost ratio} = \text{net profit}/\text{total cost} \dots\dots\dots (4)$$

Where net profit is the difference between total cost and total income of the crop obtained.

Statistical analysis

Data were subjected to statistical analysis using Minitab v15. Data were checked for normality using Anderson-Darling method with a 95% significance level. Different between various treatments were checked through Duncan's multiple range test at 5 % probability level. Additionally, treatment means were compared for statistical significance using a least significant difference (LSD) test. Simple linear regression analysis was used to derive regression equations to predict beans grain yield.

RESULTS AND DISCUSSIONS

Effect of irrigation method and irrigation intervals on beans grain yield

Data listed in Table 2 shows the effect of irrigation technique and irrigation interval on beans grain yield. The highest grain yield of 2269 kg ha⁻¹ was recorded with F₁₀ treatment while the lowest grain yield of 1784 kg ha⁻¹ was recorded with DF₁₅. The statistical analysis showed non significant differences between means of treatments. It is obvious that the traditional furrow method of 10 days irrigation interval produced the

highest grain yield which may have been a result of more available water in the root zone that enhance the metabolic process via healthy root system and makes it easier for plants to uptake water and nutrients. Larger root system enables plants to acquire and fulfill water requirements. DF₁₀ treatment produced more grain yield than F₁₅ (19% more) which can be attributed to supply sufficient available water to plants. From the above mentioned results, it can be concluded that irrigation by double ridge furrow can save more water that leads to enlarge the cultivated land area through the utilization of efficient techniques.

Table (2) Beans productivity as affected by both irrigation method and irrigation interval

Irrigation treatment	Grain yield Mg ha ⁻¹			Mean	Applied water, m ³ ha ⁻¹
	R ₁	R ₂	R ₃		
F ₁₀	2177	2279	2351	2269 _a	7973
F ₁₅	2210	1869	1689	1922 _{ab}	6218
DF ₁₀	1961	2066	2259	2095 _{ab}	4862
DF ₁₅	1763	1875	1716	1784 _{ab}	3667

F₁₀, traditional furrow irrigation with 10 days irrigation intervals; F₁₅, traditional furrow irrigation with 15 days irrigation intervals; DF₁₀, double ridge furrow with 10 days irrigation intervals and DF₁₅, double ridge furrow with 15 days irrigation intervals

Association between amounts of water and water productivity

As a result of using double ridge furrow irrigation the amount of irrigation water decreased as shown in Table 3. The results demonstrated a remarkable significant decrease in the amount of water used in different treatments. The highest percent of water save 54.8 % was recorded with the double ridge method with 15 days interval (DF₁₅) when compared with the traditional furrow method (F₁₅). DF₁₀ also showed a significant decrease in water consumption in comparison to F₁₅ since it saved water by 39%. The results obviously demonstrated that DF technique needs less water to produce more or less the same productivity of traditional furrow method that can lead to expand the cultivated area. Less time was required for both DF₁₀ and DF₁₅ and resultantly less water pumping cost. Double ridge furrow of both investigated irrigation intervals was more advantageous than traditional furrow method in terms of evapotranspiration since the wetted area is smaller.

Water productivity was significantly affected by the method of applying irrigation water (furrow and double furrow methods). Both DF irrigation treatments showed positive significant effects on water productivity values since the highest water productivity value of 0.49 kg m^{-3} was recorded with DF₁₅ followed by DF₁₀ that produced 0.43 kg m^{-3} . Traditional furrow method of both tested intervals produced less water productivity in comparison to double ridge furrow method (Table 3 and Fig. 1). The results showed that DF15 increased water productivity by 41 and 34% over F10 and F15, respectively. These increases in water productivity could be attributed to less applied water. Broadly, double ridge furrow technique can give a step forward to increase utilization efficiency of water and therefore increase water productivity.

Table (3) Water productivity, water applied and water saved as affected by various investigated treatments (irrigation methods and intervals)

Irrigation treatment	Water applied	Water saved		Grain yield, Mg ha ⁻¹	Water productivity, kg/m ³
	m ³ ha ⁻¹	m ³ ha ⁻¹	%		
F ₁₀	7973	-	-	2269	0.29
F ₁₅	6218	1755	22.0	1922	0.31
DF ₁₀	4862	3111	39.0	2095	0.43
DF ₁₅	3667	4306	54.8	1784	0.49

F₁₀, traditional furrow irrigation with 10 days irrigation intervals; F₁₅, traditional furrow irrigation with 15 days irrigation intervals; DF₁₀, double ridge furrow with 10 days irrigation intervals and DF₁₅, double ridge furrow with 15 days irrigation intervals

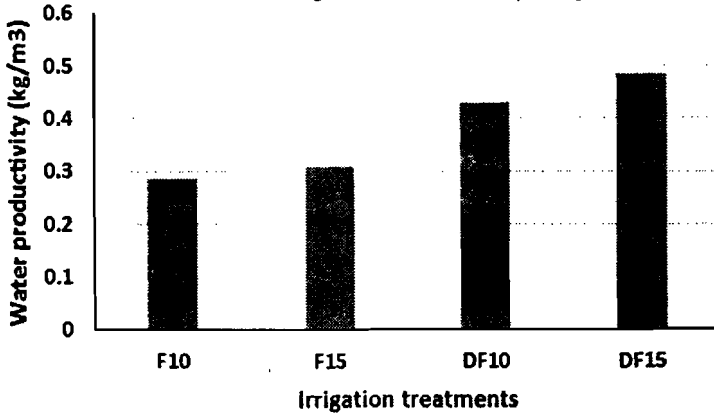


Fig. (1) Beans water productivity under the effect of irrigation water treatments (irrigation method and interval)

Economic evaluation

Green bean production costs were calculated taking into account all production inputs including seeds cost, labor cost, plowing cost, fertilization, thinning, and irrigation cost. The results were evaluated from the economical point of view considering production cost and investment. The results presented in Fig. 2 that pumping less water decreased the total cost of irrigation in the double ridge irrigation treatments particularly DF15 whilst pumping larger amounts of water as in F10 treatment increased the total cost of irrigation over the whole growing season. Table 4 detailed that among different treatments, DF₁₀ produced the second highest total income (18855 LE ha⁻¹) and also produced the second highest net profit of LE 9085 per hectare. Regarding the cost of irrigation per every ton of grains, it is clear that the double ridge method decreased irrigation cost per every ton of bean grains. DF₁₅ and DF₁₀ decreased irrigation cost per every ton by 57 and 43 %, respectively comparing to the traditional furrow method, F₁₀, which can be attributed to less pumping time for double ridge treatments. Profit cost ratio of F₁₀ was recorded the highest value (0.99) followed by DF₁₀ (0.93) as depicted in Fig. 3.

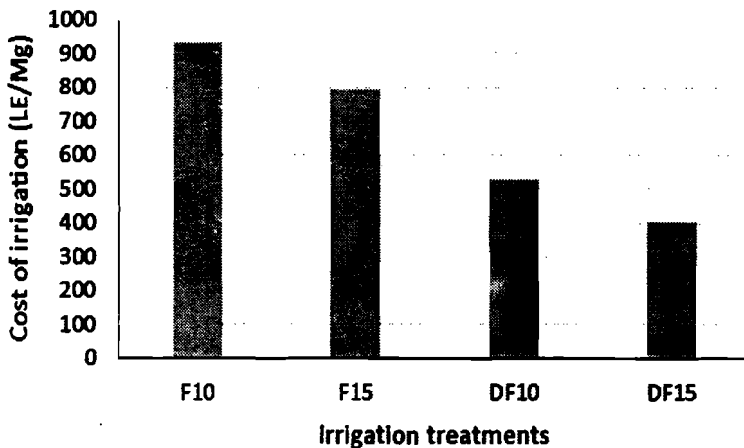


Fig. (2) The effect of irrigation water treatments (irrigation method and interval) on irrigation cost

Table (4) Inputs and outputs costs of beans crop production as influenced by furrow and double ridge furrow irrigation methods and irrigation intervals

Inputs and outputs	Cost, LE	Irrigation treatment			
		F ₁₀	F ₁₅	DF ₁₀	DF ₁₅
Inputs	Land rent	2380	2380	2380	2380
	Plowing	380	380	380	380
	Seed price	1070	1070	1070	1070
	Fertilization	2045	2045	2045	2045
	Pesticides	950	950	950	950
	Labor	1310	1310	1310	1310
	Irrigation cost	990	640	495	320
	Harvesting	665	665	665	665
	Threshing	475	475	475	475
	Total	10265	9915	9770	9595
Outputs	Grain yield, Mg ha ⁻¹	2269	1922	2095	1784
	Total income, LE ha ⁻¹	20421	17298	18855	16056
	Net profit, LE ha ⁻¹	10156	7383	9085	6461
	Cost of irrigation L.Mg ⁻¹	932.2	792	528.5	403
	Profit cost ratio	0.99	0.74	0.93	0.67

F₁₀, traditional furrow irrigation with 10 days irrigation intervals; F₁₅, traditional furrow irrigation with 15 days irrigation intervals; DF₁₀, double ridge furrow with 10 days irrigation intervals and DF₁₅, double ridge furrow with 15 days irrigation intervals

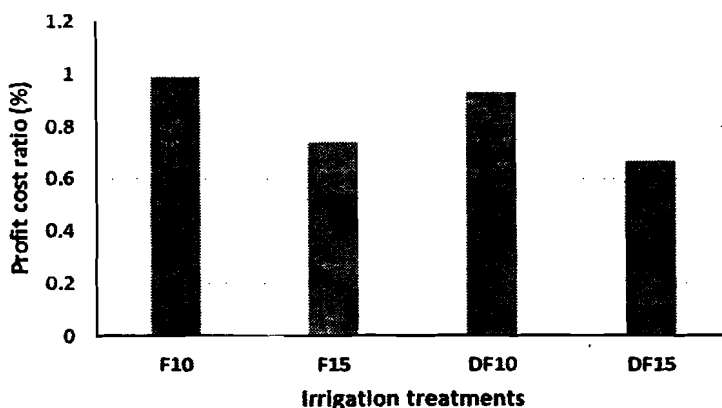


Fig. (3) Profit cost ratio under both irrigation method and interval

CONCLUSION

The effectiveness of double ridge furrow irrigation method for improving surface furrow irrigation efficiency was investigated in the present study. From the obtained results it can be concluded that double ridge furrow

method is a possible way to save water and thus increase water productivity. The results further demonstrated that water was saved by 54.8% when using the double ridge method comparing to the traditional furrow method which can be used to increase the cultivated area in newly reclaimed regions. In conclusion, this research obviously revealed that under limited water resources, the double ridge irrigation method can serve as a reliable irrigation technique to increase water productivity. Additionally, it is strongly recommended that water saving by 40-50% would be advantageous if the strategy is to expand and double the cultivated area. Double ridge furrow method is therefore a reliable irrigation method that can at least double the cultivated area of beans in the Nile Valley and newly reclaimed areas.

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الملخص العربي

تحسين انتاجية المياه لمحصول الفاصوليا من خلال طريقة ري المصاطب
مزبوجة خطوط الزراعة

عدال هلال المتولى* و محمد ماهر ابراهيم**

يعتبر الامن الغذائي وتوافر مصادر المياه العذبة مع زيادة الطلب على المحاصيل المختلفة من اكبر التحديات التي تقابل معظم بلدان العالم في الوقت الراهن. وبناءا عليه فان استحداث واستخدام طرق ري اكثر كفاءة من الطرق التقليدية له اهمية كبيرة خصوصا في المناطق الجافة وشبه الجافة.

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ومن هذا المنظور فإن هذه الدراسة أجريت على محصول الفاصوليا خلال موسم الربيع لعام ٢٠١٦ بمحافظة البحيرة بهدف مقارنة استخدام نوعين من الري السطحي (ري الخطوط التقليدي وري المصاطب مزدوجة خطوط الزراعة) ودراسة تأثيرهما على إنتاجية المياه لمحصول الفاصوليا في الاراضى الخفيفة.
وكانت معاملات الدراسة هي كالتالى:

- رى الخطوط التقليدى مع فترة ١٠ ايام بين الريات
- رى الخطوط التقليدى مع فترة ١٥ يوم بين الريات
- رى المصاطب مزدوجة خطوط الزراعة مع فترة رى ١٠ يوم
- رى المصاطب مزدوجة خطوط الزراعة مع فترة ١٥ يوم بين الريات

لقد تم تقدير كمية المياه المستخدمة طوال موسم الزراعة وتقدير الانتاجية للمعاملات المختلفة ثم حساب انتاجية المياه لكل معاملة وتم عمل تحليل وحساب تكاليف الري وكذلك عائد الجنيه المستمر لكل معاملة واطهرت الدراسة النتائج التالية:

- استخدام طريقة رى المصاطب بخطوط مزدوجة لمحصول الفاصوليا ادى الى توفير كبير فى مياه الري وصل الى ٥٤.٨%.
- الحصول على انتاجية مرتفعة ادى الى زيادة انتاجية المياة فى حالة معاملة رى المصاطب كل ١٥ يوم عن معاملتى رى الخطوط التقليدى لفترات ١٠ ، ١٥ يوم بنسبة ٤١ ، ٣٤ % على الترتيب.
- انخفضت تكاليف الري فى حالة رى المصاطب بمعاملتيه مقارنة بمثيلاتها فى رى الخطوط التقليدى.
- تحقق اعلى عائد متحصل عليه من معاملة رى الخطوط كل ١٠ ايام تلاه معاملة رى المصاطب كل ١٠ ايام بعائد مقداره ١٠١٥٦ ، ٩٠٨٥ جنيه على الترتيب.
- تحققت اعلى تكاليف مع معاملات رى الخطوط بينما اقل تكاليف كنت مع معاملات رى المصاطب مقارنة بمثيلاتها فى رى الخطوط التقليدى.
- بالنسبة لعائد الجنيه المستمر فان اعلى عائد سجل مع رى الخطوط نسبة ٠.٩٩ تلاه رى المصاطب عند ١٠ ايام بنسبة ٠.٩٣.

ومن خلال نتائج هذا البحث نجد أن استخدام رى المصاطب مزدوجة خطوط الزراعة ادى الى زيادة انتاجية المياه مقارنة برى الخطوط التقليدى مم سيساعد فى استخدام الموارد المتاحة من مياه واسمدة بكفاءة عالية. كذلك سيؤدى استخدامها كطريقة لرى المحاصيل التى تزرع على خطوط الى مضاعفة المساحة المنزرعة.