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Water Saving and Increasing Water Productivity Using New Planting Methods for Wheat Crop

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ABSTRACT

Two field experiments were conducted during two successive winter seasons of 2018/2019 and 2019/2020, to estimate the effect of four planting methods (PM) i.e. traditional method and three treatments as a new technique on growth, yield, and its attributes and some water relations as well as the net return of wheat crop. The study consisted of the following treatments; planting methods: i) flat planting (M_1), ii) raised bed furrows 80 cm (M_2) with three rows of plants, 15 cm apart and 10 cm between hills, iii) narrow beds (M_3) (raised bed furrows 100 cm) with four rows of plants, 15 cm apart and 10 cm between hills, iv) medium beds (M_4) (raised bed furrows 120 cm) with five rows of plants, 15 cm apart and 10 cm between hills (wide beds).The results showed that the highest values of plant height, grain weight/spike, number of spikes/m^2, 1000-grains weight, and grain and straw yield kg ha^{-1} recorded in treatment M_3 and the lowest values were recorded in M_1. Compared with treatment M_1, There was a significant increase of grain yield by 11.77, 13.77, and 9.88% and straw yield by 4.45, 7.79, and 6.68% for treatments M_2, M_3, and M_4, respectively, also, water saving for M_2, M_3 and M_4 were 17.18, 21.53, and 23.19% respectively. The highest values of water productivity were recorded in M_3 (1.53 kg m^{-3}), while the lowest (1.06 kg m^{-3}) was recordrd in M_1. M_3 had the highest values of the total return and net return.

Keywords: New planting methods, raised beds planting, water saving, surface irrigation, water productivity, wheat crop.

INTRODUCTION

In Egypt, crop production is dependent on irrigation. The water use is about 81% from the River Nile in the country (Noaman, 2017). Wheat (Triticum aestivum L.) is the strategic and the most important cereal crop in Egypt. The total production of wheat is not sufficient to meet the local consumption. Irrigation systems management and attention to agricultural water productivity by maximizing the return per unit of water (water productivity) are very important strategies, which are considered an important indicator for measuring the effectiveness of agricultural water management. Irrigation management under old lands conditions which surface irrigation method is a common practice and need to be improved to increase crop production and water saving. Surface irrigation is the traditional irrigation method (about 80% of the irrigated area in Egypt), and it generally has lower application efficiency (about 50%) than other methods mainly because of water loss to deep percolation, which leads to rising groundwater tables and leaching of nutrients. Consequently, deep percolation has a negative effect on crop yield, fertilizer requirements, and efficient water use.

Farmers commonly over-irrigate their fields, so losses of water are often appreciable. Therefore, optimal irrigation application, throughout the growing season, is important for increasing wheat productivity per unit of water applied without additional costs. Improvement of wheat productivity is the most important way to minimize the gap between production and consumption and can be achieved by using high-yielding varieties and new agricultural practices such as planting methods. Raised beds furrow planting is a simple technique that can be easily implemented by farmers. It can lead to an increase in the grains yield of the wheat crop, water productivity, and saving applied water as compared to the traditional method.

The strategy of irrigation policy in Egypt aims to optimize irrigation water. Therefore, it is necessary to find out a new planting method and new surface irrigation technique to be applied to increase the irrigation application efficiency, water saving, field water use efficiency as well as yield and quality of crops. One of the main strategies to overcome this problem is to achieve a better water management policy.

In Egypt , the traditional method for wheat planting is broadcasting of the seed in a large area under flood surface irrigation in the old lands. It is requiring a high seeding rate of about (167 kg ha^{-1}) and more irrigation water although it gives a low yield (Atta and Swelam, 2006). Raised bed planting method is one of the modern methods of planting for many crops with a significant water saving. Singh *et al*, (2002) reported that the average grains yield of wheat increased by 5.5% in bed planting technique compared to conventional sowing.

Yadav *et al*, (2002) found that the yield attributes of wheat, number of effective tillers/m^2, number of grains/spike, and test weight were superior resulting in the grains yield under furrow raised bed system compared to conventional tillage. Several studies showed that water use efficiency was improved under reduced irrigation. Fahong *et al*, (2004) found that changing growing wheat from flat planting with flood irrigation to raised beds technique improved water use efficiency by 21-30% with 17% saving in applied irrigation water.

Many advantages of growing wheat on beds have been reported. Hussein *et al*, (2006) reported that the maximum

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grains yield of wheat was produced from plants sown in ridge 60 cm width which significantly exceeded that of broadcast. Raised bed planting increased wheat grains by 10% yield and water use efficiency by 30%. (Lindwall *et al*, 2005). Mollah *et al*, (2009) reported that wide beds 90 cm increased grains yield of wheat up to 21% over the conventional method. It increases the number of spikes/m^2, the number of grains/spike, and 1000-grains weight of wheat. It saves 41-48% irrigation water. The cost of cultivation was decreased and gross return, gross margin, and benefit ratio were higher in bed planting than the conventional method. The new method to reduce the number of irrigation ditches per area to limit the wetting zone is the strip irrigation method with growing crops on wide planting beds (Maruyama *et al*, 2017).

Abou-Elenein *et al*, (2009) reported that planting wheat using raised bed method (RBM) which the seeds planted in hills or broadcasted on the top of beds gave the highest values of grains and straw yields, water productivity, and water saving compared to farmer traditional method (FTM) or broadcast method. Grains yield was increased from 6.33 t ha^{-1} for treatment FTM to 7.44 t ha^{-1} for treatment RBM and increase straw yield from 16.12 t ha^{-1} for FTM to 17.54 t ha^{-1} for RBM. On the other hand, applied water decreased from 5980.0 m^3 ha^{-1} for FTM to 4680.0 m^3 ha^{-1} for RBM, and water saving value was 27.78% .water productivity increased from 1.057 kg m^{-3} for FTM to 1.524 kg m^{-3} for RBM and increase percentage 44.18%.

Atta and Nassar (2010) reported that for getting the highest values of water saving, water use efficiencies, yield and yield attributes of wheat using planting method (M_3) raised beds 80 cm width) followed by (M_2 furrow width 60 cm) compared to M_1 traditional planting method (broadcasting method). Grains yield was increased by 11.80 and 22.84% and straw yield was increased by 9.26 and 18.24% for treatments M_2 and M_3 respectively compared to treatment M_1 (farmer traditional method). They added that water applied were 5738.0, 4933.0, and 4592.0 m^3 ha^{-1} for M_1, M_2, and M_3 respectively, and water productivity were 1.07, 1.39, and 1.64 kg m^{-3} for treatments M_1, M_2, and M_3 respectively. Also, they found that water saves were 14.0% and 20.0% for treatments M_2 and M_3 compared to treatment M_1. Kumar *et al*, (2013) reported that wheat crop yield, attributing many spikelet's/spikes, the number of grains/spikes, spike weight, grains, and straw yields were higher in raised bed sowing as compared to the conventional method of sowing at both well-drained and poorly drained soils.

Kaur and Dhaliwal (2015) reported that the yield and yield contributing characteristics were a non-significant effect with two planting methods but the higher yield was obtained under bed planted crop than flat planted crop. This study aims to investigate the effect of planting methods on growth, yield, its attributes, and some water relations as well as net return for the wheat crop.

MATERIALS AND METHODS

This study was conducted during two successive winter seasons of years 2018/2019 and 2019/2020 at Zankalon Research Station for Water Requirements, Sharkia Governorate, Water Management Research Institute (WMRI), National Water Research Center (NWRC), Egypt which is located in the East Nile Delta region. The site is located at coordinates 30º 35` N latitude. and 31º 26` E longitude. at elevation of about 7 m above mean sea level. Some soil physical and chemical properties of the experimental site were determined as procedures outlined by (Klute, 1986) and Page *et al.* (1982). The soil is mostly clay, with physical and chemical properties Table (1). The experiments were performed to determine the best method for planting wheat to achieve grains and straw yields increase as well as water productivity and saving.

Table 1. Some soil physical and chemical properties of the experimental site.

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk density (g cm^{-3})	Field Capacity (%)	Wilting Point (%)	Available Water %	E.C (dS m^{-1})	pH
0-15	25.80	29.78	44.42		1.26	43.50	23.60	19.90	1.45	8.13
15-30	25.12	31.38	43.50		1.25	40.60	21.41	19.19	1.25	7.90
30-45	26.70	32.20	41.10	Clay	1.36	37.14	17.04	19.29	1.29	8.15
45-60	26.90	33.00	40.10		1.49	36.28	16.87	19.13	1.13	8.02
Average	26.13	31.59	42.28		1.34	39.38	19.98	19.28	1.28	8.05

1-Experiment design

The treatments were arranged in a complete randomized blocks design for treatments and with three replicates. The total number of plots 12, area of each plot was 600 m^2 (25 m length × 24 m width) surrounded by ditches of 1.5 m width to avoid lateral movement of irrigation water to adjacent plots.

The treatments were as follow:

Traditional planting method

Treatment A: Traditional method (flat planting method, M_1): this method includes one treatment M_1: flat planting method with flood irrigation: In this method, after traditional plowing and land leveling the land is divided into basins. The seeds were manually broadcasting at a seed rate of 167 kg ha-1 as a recommendation of the Atta and Swelam (2006) and ARC (2014) then irrigation directly.

The new planting technique

The new technique of planting namely (raised beds). Raised beds with irrigation in furrows are becoming a new trend in water saving. Seeds were planted manually on the top of beds in rows according to raised beds width, 15 cm between them and 10 cm between hills. The seeds rate used is 110 kg ha^{-1} based on the recommendation of the ARC (2014). The new method of planting including three treatments (M_2, M_3 and M_4) as follows:

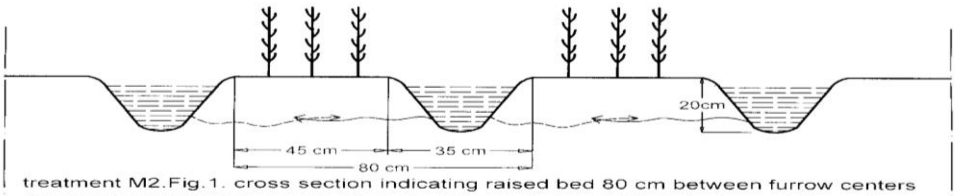
M_2: Narrow raised beds 80 cm between furrows centers with three rows per bed, as shown in Figure 1.

M_3: Medium raised beds 100 cm between furrows centers with four rows per bed, as shown in Figure 2.

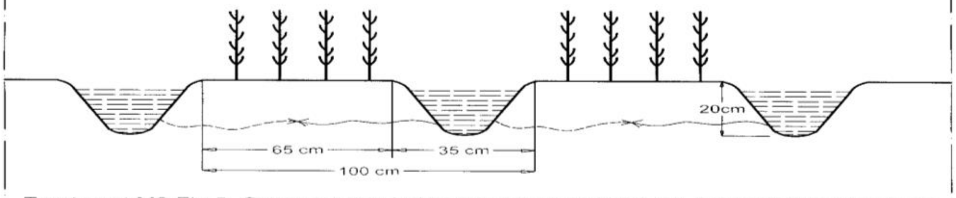
M_4: Wide raised beds 120 cm between furrows centers with five rows per bed as shown in Figure 3.

The previous crop in the two seasons was the maize crop. Traditional land preparation and leveling and dividing to basins were done for one treatment (M_1) flat method (traditional method) and furrowing for raised bed planting methods (M_2, M_3, and M_4 treatments) as a new technique. All these practices were done for each season alone. Seeds of cultivar wheat Sakha 94 were sown on November 23th and 25th and were harvested on April 22nd and 24th in both two winter seasons, respectively. The other recommended practices for wheat plants were followed.

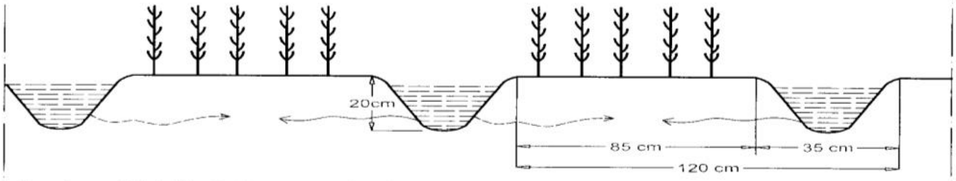
The plots received a constant level of NPK to the bed and flat plots. Fertilizers were applied at 160 kg N, 36 kg P_2O_5, and 60 Kg K_2O ha^{-1} is equal to 476 kg ha^{-1} of ammonium nitrate, 238 kg ha^{-1} of calcium superphosphate, and 119 kg ha^{-1} of potassium sulfate, respectively. The whole amount of P and K and one-third of N were applied at land preparation. The remaining two-thirds of the N was applied with first and second irrigations.



treatment M2.Fig.1. cross section indicating raised bed 80 cm between furrow centers (Narrow beds)with three rows of plants ,15 cm apart and 10 cm between hills on top of the bed.



Treatment M3.Fig.2. Cross section indicating raised bed100 cm between furrow centers (Medium beds)with four rows of plants ,15 cm apart and 10 cm between hills on top top of the bed.



Treatment M4.Fig.3. Cross section indicating raised bed 120 cm between furrow centers (wide beds)with five rows of plants ,15 cm apart and 10 cm between hills on top of the bed.

2- Water relations

Water applied (WA)

The irrigation water used for the experiments had the typical water quality for the region with EC of 0.4 dS m^{-1}. Water applied (WA) was measured using a calibrated flow meter with a reading resolution of 5 decimals of m^3. Irrigation water was transferred to each plot through 0.15 m diameter polyethylene pipes, and the applications were controlled using a valve at the front of each plot. So that, the amount of water delivered to plots is exactly controlled. All treatment plots received irrigation 5 times including the planting irrigation. Planting irrigation was applied to all treatments at equal amounts until puddling occurred. Life or first irrigation was started after 21-25 days from planting in both seasons, and irrigations interval was 25-30 days approximately. Irrigation was stopped after 130 and 135 days from planting in both seasons respectively.

Water productivity (WP)

Water productivity was calculated according to Talha and Aziz (1979) as follows:

WP = grains yield (kg ha^{-1}) / water applied (m^3 ha^{-1}).

3-Crop data

Growth, yield, and some yield attribute data were collected at maturity. To determine grains and straw yields, a central area of 120 m^2 of each plot was harvested to measure the following parameters:

1. plant height (cm).
2. 1000-grain weight (g).
3. grains yield (kg ha^{-1}).
4. grain weight/spike (g).
5. number of spikes/m^2.
6. straw yield (kg ha^{-1}).

In addition to the above net returns for different planting, methods were estimated as well as net. The statistical analyses were conducted for the data according to Steel *et al*, (1997).

RESULTS AND DISCUSSION

1-Water relations:

Water applied (WA)

The amounts of water applied were measured and estimated for all treatments as the average of both seasons as shown in Table (2) and Figure (4). It could be noticed that the amount of water applied was the highest for the traditional method (M_1 treatment) which recorded the maximum amount of 6023.0 m^3 ha^{-1}. On the other hand, the lowest amount of water applied was 4626.0 m^3 ha^{-1} which obtained from the wide raised beds of furrow 120 cm (M_4 treatment), while the amounts of water used for treatments M_3, M_2 were 4726.0 and 4988.0 m^3 ha^{-1}, respectively.

Table 2. Effect of planting methods on some indicators of wheat (as the average of two growing seasons).

Planting methods (M)	Water applied (m^3/ha)	Water saving (m^3 ha^{-1})	Water saving (%)	Water productivity (kg m^{-3})	Increase of water productivity (%)
M_1	6023.0	-	-	1.06	-
M_2	4988.0	1035.0	17.18	1.43	35.42
M_3	4726.0	1297.0	21.53	1.53	44.89
M_4	4626.0	1397.0	23.19	1.51	43.00

Where: M_1, M_2, M_3, and M_4 are the traditional method, narrow beds, medium beds and wide beds, respectively.

In the bed planting, irrigation water was applied only in furrows. The area of furrows in M_4 treatment (wide beds) is lower than treatment M_3 (medium beds) and M_2 treatment (narrow beds). So, M_4 treatment received a lower amount of irrigation water than the average of two growing seasons. It can be seen from the data in Table (2) that applying treatments M_2, M_3 and M_4 saved about 1035.0 m^3 ha^{-1}, (17.18%), 1297.0 m^3 ha^{-1} (21.53%), and 1397.0 m^3 ha^{-1} (23.19%) of water applied respectively, relative to M_1 treatment (traditional method). Similar results were obtained by Mollah *et al*, (2009). Gupta *et al*, (2000) reported

Savings of irrigation water by bed planting of wheat ranged from 18% to 50%.

Generally, this study clearly showed that water applied can be greatly reduced using the bed planting method with increasing grains yield. The higher irrigation requirements for M_1 treatment are likely due to higher water percolation loss and irrigation water advances slower and higher deep percolation than the raised beds method treatments M_2, M_3, and M_4, respectively (Atta and Swelam, 2006). The obvious reasons for higher water saving of applied water can be attributed to the less amount of water required to irrigate relatively less area (only furrows) in bed planting as compared to the M_1 traditional planting method (flat). From the data in Table (2) we can notice that M_4 treatment (wide beds) had the highest value of water saving 23.19% followed by M_3 treatment (medium beds) 21.53%, while the lowest value recorded in M_2 treatment (narrow beds) 17.18% compared to M_1 treatment (traditional method). These results agree with those of Lindwall *et al*, (2005).

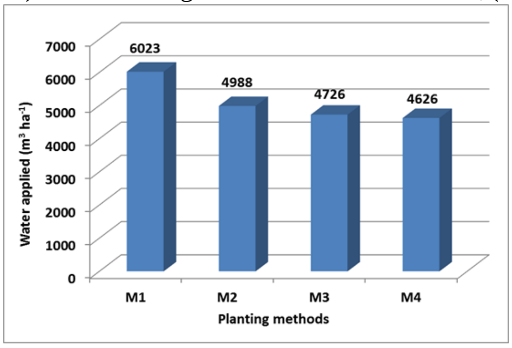


Fig. 4. Effect of planting methods on the water applied (m^3 ha^{-1}) of wheat crop (as mean values of two seasons).

Water productivity (WP)

Water productivity (WP) values as affected by planting methods of wheat as average in the two growing seasons are presented in Table (2) and Fig. (5). The results indicated that M_3 treatment (medium beds) had the highest value of WP 1.53 kg m^{-3} followed by treatment M_4 (wide beds) 1.51 kg m^{-3} and M_2 treatment (narrow beds) which was 1.43 kg m^{-3}, while M_1 treatment (traditional method) recorded the lowest value of WP 1.06 kg m^{-3}. The relative increases in WP were 34.90%, 44.34%, and 42.45% for bed treatments (M_2, M_3, and M_4) compared to M_1 treatment (traditional method), respectively. The least value of WP, for M_1 treatment can be attributed to high amounts of irrigation water applied and may have resulted in greater leaching of nutrients from the roots zone and possibly bad aeration due to excessive irrigation to clay soil which had negative effects on both crop growth and yield. These results agree with those reported by Fahong *et al*, (2003).

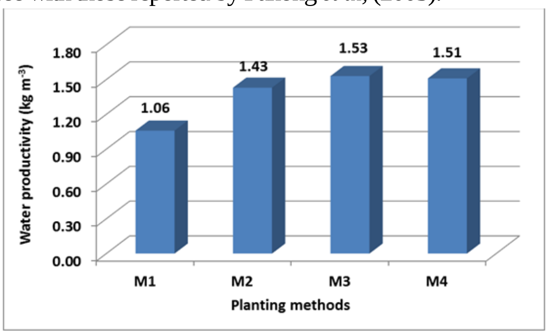


Fig. 5. Effect of planting methods on water productivity (kg m^{-3}) of wheat crop (as mean values of two seasons).

Generally, based on the high water saving and higher production treatments M_3 and M_4 respectively, it seems that planting wheat on raised beds permitted better distribution of irrigation water around the roots and maintained the soil moisture content close to the optimum level. Both treatments M_3 and M_4 had better utilization of irrigation water and nutrients. The highest increase in water productivity for M_3 treatment was the highest grains yield 7237.0 kg ha^{-1}, 13.77% (Table 4) is the first class in grains yield and the second class in water save 21.53% (Table 2). This is due to good water moisture distribution for the area of the bed and consequently more grown of wheat plants in addition to other advantages for raised beds method. Regarding treatment, M_4 had the highest value of water saving 23.19% (the first class and occupied the second class in grains yield. 6995.0 kg ha^{-1}). This result is due to bad water distribution for the area of the beds which leads to the middle rows suffering from the water stress accordingly reducing grains yield and yield components.

Under the condition of the Nile Delta region, it could be recommended that using the sowing wheat using raised beds width 100 cm with four rows of plants with 15 cm apart and 10 cm between hills M_3 treatments (medium beds). In this regard, Fahong *et al*, (2004) reported that improved water use efficiency in wheat due to the reduced quantity of water used as well as water application losses in bed planting. Ahmed *et al*, (2009) found that raised bed technology increases the water productivity by increasing the grains yield of the wheat crop on the bed through better nutrient management and saving water due to lesser area of spreading irrigation water. Similar results were reported by Atta and Nassar (2010).

In this regard, Waraich *et al*, (2010) reported that improved water use efficiency in bed planting may be due to the reduction in soil water loss. Loss of soil water may be reduced in bed planting due to many factors: (1) the bed serves as a windbreak and decreased evaporation from the bottom of the furrows, (2) the water applied to furrows moved rapidly to the soil below the bottom of beds, thereby reducing percolation losses from furrows to the lower soil depths.

2- Crop data

3.2.1. Wheat growth

Plant height is a function of both genetic constitutions as well as environmental factors. The data regarding plant height as affected by planting methods are presented in Table (3). Statistical analysis revealed that different planting methods had a significant effect on wheat plant growth as expressed herein plant height in the combined analysis. The data also indicated that the highest plant height was found under M_3 treatment (medium beds) and M_4 treatment (wide beds) followed by M_2 treatment (narrow beds), while the traditional method (M_1 treatment) gave the lowest value.

Table 3. Effect of planting methods on some growth parameters and yield components of wheat (combined analysis of two growing seasons).

Planting methods	Plant height (cm)	Grains weight / Spike (g)	Number of spikes/m^2	1000-grain weight (g)
M_1	98.93 a	1.86 a	353.00 a	46.20 a
M_2	100.86 b	2.03 b	370.00 b	48.60 b
M_3	102.93 c	2.16 c	381.66 c	51.53 c
M_4	102.63 c	1.98 b	368.66 b	46.80 a
LSD at 5%	1.90	0.11	11.48	1.79

Where: M_1, M_2, M_3, and M_4 are the traditional methods, narrow beds medium beds and wide beds, respectively. This means sharing the same letters in columns does not differ ($P<0.05$).

The difference between treatments M_3 and M_4 is insignificant. Applying M_1 treatment significantly decrease plant height by 3.89% as compared with M_3 treatment such decrease may be attributed to the decrease in the light interception consequently, causing a lower photosynthetic activity. In addition to the treatment, M_1 was irrigated with a large amount of irrigation water and hence more losses of nutrients with leaching. These results are in agreement with those obtained by Atta and Nassar (2010).

Jakhar *et al*, (2005) also reported that plant height was significantly higher in bed planted of wheat crop in comparison to conventionally planted. The decrease in plant height of treatment M_4 with regard to M_2 and M_3 was attributed to the moderate availability of water in beds.

Yield components

Combined analysis of variance for the two growing seasons indicated that planting methods had a significant influence on all studied characters of yield components (Table 3). Results indicated that the highest values for grain weight/spike (g) were recorded for M_3 treatment followed by M_2 and M_4 treatment, while the lowest value was gained from M_1 treatment (traditional method). The difference between M_4 and M_2 treatments was insignificant. Generally, we can say that the beds planting produced a higher grains weight/spike. Applying M_1 treatment significantly decrease grain weight/spike by 16.13% as compared with M_3 treatment. Hussein *et al*, (2006) reported that bed planting increased grain weight/spike, 1000-grain weight, number of spikes/m^2, and grain and straw yields of wheat.

On the other hand, as indicated from Table (3), the number of spikes/m^2 was significantly affected by planting methods (combined analysis). The highest number of spikes/m^2 was obtained from M_3 treatment then M_4 treatment followed by M_2 treatment. The difference between treatment M_4 and M_2 was insignificant for the number of spikes/m^2. M_1 treatment (traditional method) had the lowest value of the number of spikes/m^2. The data also indicated that the number of spikes/m^2 was increased by 4.82 and 8.12% for M_2 and M_3 treatment compared with M_1 treatment. Similar results were obtained by Vijay *et al* (2013).

Data in Table (3) also showed that the mean values of 1000-grain weight were significantly affected by the planting methods. The difference between M_4 and M_1 treatments was insignificant. Bed planting methods (M_2 and M_3) produced higher 1000-grain weight values as compared to the traditional method (M_1 treatment). Dhillon *et al*, (2005) reported that bed planting led to tillers, the number of effective tillers, a higher 1000-grain weight, and a higher yield as compared to conventional planting.

Mollah *et al*, (2009) reported that bed planting increased the 1000-grain weight of wheat because the sterility percentage was lower in bed than the conventional method. Kaur and Dhaliwal (2015) reported that bed planting produced a higher 1000-grain weight as compared to flat planting because the number of tillers and number of effective tillers was more under bed planting which results in higher 1000-grain weight as compared to flat planting. These results are also supported by Atta and Nassar (2010).

Grain and straw yield

Grain and straw yield as affected by planting methods for the combined analysis of variance of the two growing seasons are presented in Table (4) and Figure (6). The results indicated that grains and straw yields were highly significantly affected by planting methods. Among planting methods bed planting (raised bed methods) gave gradually, increasing for grains yield treatments M_4, M_2, and M_3 compared to M_1 treatment (traditional method). The increasing percentage in grains yield were 11.77, 13.77, and 9.88 % for M_2, M_3, and M_4 treatments, respectively, and for straw yield were 4.45, 7.79, and 6.68% for treatments M_2, M_3, and M_4, respectively compared to M_1 traditional method (flat).

Table 4. Effect of planting methods on grains and straw yields of wheat crop (combined analysis of two growing seasons).

Planting methods	Grain yield (Kg ha^{-1})	Increase of grains yield (%)	Straw yield (Kg ha^{-1})	Increase in straw yield %
M_1	6361.0 a	-	9880.0 a	-
M_2	7110.0 c	11.77	10320.0 b	4.45
M_3	7237.0 c	13.77	10650.0 c	7.79
M_4	6995.0 b	9.88	10240.0 b	6.68
L.S.D at 5%	220.15	--	170.28	--

Where: M_1, M_2, M_3, and M_4 are the traditional methods, narrow beds medium beds and wide beds, respectively. This means sharing the same letters in columns does not differ ($P<0.05$).

The decrease in grain and straw yield in M_1 treatments (traditional method) may be due to the excess of applied water which occur partial aeration deficiency in the upper part of the roots zone. Also, the excess of applied water may have resulted in leaching out of some nutrients from the roots zone as a result of using large amounts of irrigation water. Similar results were obtained by Singh *et al*, (2002) Hussein *et al*, (2006).

Bed planting methods (especially M_2 and M_3 treatments) produced higher grain and straw yield due to better crop stand, better radiation interception, more number of tillers, more number of spikes/m^2, higher weight for 1000-grain and grain weight/spike, good distribution of irrigation water around the roots, good plant distribution, and increasing fertilization use efficiency.

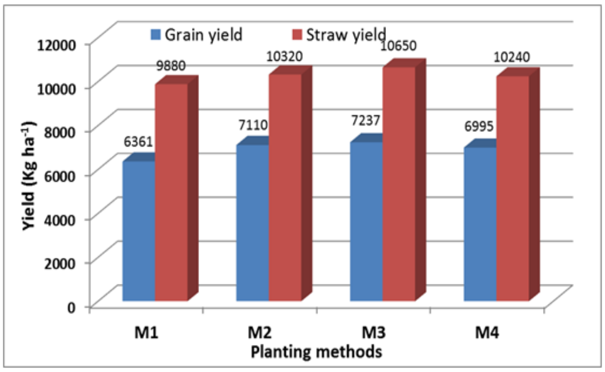


Fig. 6. Effect of planting methods on grains and straw yields of wheat crop (kg ha^{-1}) (as the average of two seasons).

Concerning M_4 treatment was received the lowest value of applied water 4626 m^3 ha^{-1} (Table, 2), and gave the highest value of water saving (23.19%), however, it gave a slight increase in grains yield 9.88% (Table, 4). This can be due to bad water distribution for the area of the beds which leads to middle rows suffering from the water stress accordingly reduced yield components and therefore decrease grains yield. These results are in harmony with those obtained by Mollah *et al*, (2009) and Atta and Nassar (2010). Dhillon *et al*, (2005) reported that bed planting produced higher grains yield as compared to flat planting. They added that under bed planting better crop stand, better radiation interception, more number of tillers, effective tillers, number of grains/spike, 1000-grain weight, and less lodging were recorded than flat planting.

3-Economic evaluation

A simple economic analysis such as total costs, total return, and net return for different planting methods of wheat are shown in Table (5) as average for two seasons. The data listed in Table (5) indicated that the total costs of M_1 (traditional method) were higher than the new technique (raised beds) in three planting treatments (M_2, M_3, and M_4), respectively. This is due to that the seed rate used for the traditional method is higher than that required for raised beds method (167 kg ha^{-1}) against (110 kg ha^{-1}) for treatments of raised beds method. Also, the cost of irrigation for the traditional method was higher compared to the raised method.

The highest value of total return was obtained from M_3 treatment (medium beds) followed by M_2 treatment (narrow beds) then M_4 treatment (wide beds), while M_1 treatment (traditional method) gave the lowest value. The highest net return was obtained from M_3 treatment followed by M_2 and M_4 treatments, while M_1 treatment (traditional method) gave the lowest value.

Many benefits from bed planting have been reported by Kumar *et al.* (2007) and Holland *et al.* (2007). Likewise, there are some benefits of this planting system such as low seed rate, reduction of crop lodging, better control of excess water in heavy soil conditions (Sayre and Ramos 1997).

Table 5. Enterprise cost and return per hectare of wheat crop under different planting methods (as the average of two seasons).

Economical items	Characters	Unit	Planting methods			
			M_1	M_2	M_3	M_4
List of inputs	Land preparation and leveling	$/h	59.52	59.52	59.52	59.52
	Labor for borders and canals construction	$/h	13.53	13.53	13.53	13.53
	Furrowing	$/h	-	10.81	10.81	10.82
	cultivation costs	$/h	18.94	37.88	37.38	37.88
	Seed costs	$/h	47.35	30.44	30.44	30.44
	Mineral fertilizers	$/h	188.04	188.04	188.04-	188.04
	Labor for fertilizing	$/h	16.23	16.23	16.23	16.23
	Weed control	$/h	16.23	16.23	16.23	16.23
	Cost of irrigation (pumping and it labor)	$/h	114.07	94.47	89.51	87.61
	Harvesting and threshing	$/h	284.09	284.09	284.09	284.09
	Land rent cost	$/h	649.35	649.35	649.35	649.35
	Total Costs/ha/season	$/h	1407.35	1400.60	1395.64	1393.74
List of outputs	Grains value	$/h	1445.68	1611.91	1644.77	1589.77
	Straw value	$/h	673.64	703.64	726.14	698.18
	Total return	$/h	2119.34	2319.55	2370.91	2287.95
	Net return	$/h	711.97	918.95	975.27	894.21

Where: 1 $ = 17.60 L.E (average price of two growing seasons).
Market price of grains = 0.2273 $ kg^{-1} and wheat straw = 0.0682. $ kg^{-1}. Fertilizers cost of ammonium nitrate = 0.25 $ kg^{-1}, calcium super phosphate = 0.0625 $ kg^{-1}, potassium sulphate = 0.4545 $ kg^{-1}.
Costs of pumping (7.7 Hp) discharging 60 m^3 hr^{-1} includes labor cost of irrigation = 1.136 $ hr^{-1}. ($/h) = Dollar / hectare

Accordingly, the total return was increased by 9.45, 11.87, and 7.96%, and net return increased by 29.05, 36.98, and 25.60% for treatments M_2, M_3, and M_4 respectively, compared to treatment M_1 (traditional method). This conclusion is attached with each of Hassan *et al*. (2005) and Mollah *et al*. (2009) also, there is the highest net return in the bed planting compared to the traditional method.

CONCLUSION

It could be concluded from this study that, using (medium raised beds) M_3 treatment width 100 cm with four rows of plants 15 cm apart and 10 cm between hills with a rate of seed 110 kg ha^{-1} had the highest values of each of grain yield 7237 kg ha^{-1} an increase of, 13.77% and straw yield about 10650 kg ha^{-1} with an increase of 7.79% compared to traditional method (M_1 treatment) which planted by broadcast with 167 kg ha^{-1} as a seeding rate. Values of water saving were increased from 17.18%, 21.53%, and 23.19% for M_2, M_3, and M_4 treatments, respectively compared to M_1 treatment. The highest value of water productivity was recorded in M_3 treatment followed by (1.51 kg m^{-3}) for M_4 treatment then (1.43 kg m^{-3}) for M_2 treatment compared to M_1 treatment (1.06 kg m^{-3}). M_3 treatment had the highest values of total and net return and the lowest values of total costs, compared to M_1, M_2 and M_4 treatments, respectively.

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توفير المياه وزيادة إنتاجية وحده المياه باستخدام طرق زراعة جديدة لمحصول القمح

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معهد بحوث ادارة المياه – المركز القومي لبحوث المياه

أجريت تجربتين حقليتين خلال الموسمين الزراعيين 2018- 2019 ، 2019-2020 م بمحطة المقننات المائيه البحثية بالزنكلون بمحافظة الشرقيه التابعة لمعهد بحوث ادارة المياه - المركز القومي لبحوث المياه - مصر، وذلك بهدف دراسة مدى امكانية زيادة إنتاجية وحده المياه لمحصول القمح باستخدام طرق زراعه جديده ومختلفه عن الطرق التقليديه وتأثير ذلك على الاحتياجات المائية الفعلية والاستهلاك المائي الفعلي وكفاءات استخدام المياه والكفاءة الكلية للري الحقلي وانتاجية المحصول بالإضافة الى تقييم جميع المعاملات تقييما اقتصاديا من النواحي الانتاجية والمائية تكونت الدراسة من المعاملات التالية ، طرق الزراعة: طريقة الزراعة التقليدية: زراعه القمح فى احواض. طريقة الزراعة في شرائح بعرض 80 سم (3 خطوط – 15 سم بين الخطوط – 10 سم بين الجور). طريقة الزراعة في شرائح بعرض 100 سم (4 خطوط – 15 سم بين الخطوط – 10 سم بين الجور). طريقة الزراعة في شرائح بعرض 120 سم (5 خطوط – 15 سم بين الخطوط – 10 سم بين الجور). وتم تصميم التجربة في قطاعات كاملة العشوائية في ثلاثة مكررات . وقد اظهرت نتائج هذه الدراسة ما يلى: وكانت النتائج كالتالي: أعطت المعاملة الثالثه تأثير معنوي على كل الصفات المدروسة ، حيث تحققت أعلى القيم لكلا من طول النبات، وطول السنبله وعدد السنابل فى المتر مربع ووزن الحبوب تليها المعامله الثانيه ثم الرابعه بينما المعامله الاولى هى الاقل فى الانتاجيه. كانت هناك زيادة معنوية في انتاجيه الحبوب لمحصول القمح مقدارها 11.77 , 13.77 ، 9.88% وذلك كنتيجة لاستخدام المعاملة الثانيه والثالثه والرابعه بالمقارنة بالمعاملة الاولى على التوالي. بالمثل زياده انتاجيه القش (التبن) فكانت مقدارها 4.45 , 7.79 ، 6.68% وذلك كنتيجة لاستخدام المعاملة الثانيه والثالثه والرابعه بالمقارنة بالمعاملة الاولى على التوالي. كمية المياه المتوفره باستخدام طرق الزراعه على شرائح بالمقارنه بالطريقه التقليديه حيث تم توفير (17.18 %) للمعامله الثانيه بينما الثالثه (21.53 %) اما الرابعه (23.19 %) بالمقارنه بالمعامله الاولى (الزراعه فى احواض). أعلى كفاءة للإنتاجية المائية لمحصول القمح تحققت باستخدام المعاملة الثالثه (1.53) تلنها المعاملة الرابعه (1.51) تلنها المعاملة الثانيه (1.43) بينما سجلت المعاملة الاولى أقل فيمه (1.06 كجم/م^3). كان أعلي صافي ربح وصافي العائد من الوحدة المائية كانت المعاملة الثالثة تليها المعامله الثانيه ثم الرابعه مقارنة بالمعامله الاولىومن ثم يمكن التوصية باستخدام المعاملتين الثالثه والثانيه لزراعة محصول القمح في شرائح الخطوط 100، 80 سم للحصول على أعلى محصول حبوب/فدان وتوفير كمية من المياه وتقليل التكلفة تحت ظروف التجربة (منطقة شرق الدلتا).