Annals of Agric. Sci., Moshtohor **ISSN 1110-0419**
Vol. 56(4) (2018), 1139 –1148 **http://aasj.bu.edu.eg/index.php**

Improving Water Use Efficiency and Wheat Productivity By Bed Technique and Nitrogen Application Methods

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Abstract

Raised bed cultivation system for wheat production is a new technique nowadays; changing agricultural practices of wheat from flat to bed planting system required changing application methods of nitrogen fertilizer. A field experiment was conducted during 2015/16 and 2016/17 winter seasons at Giza Agricultural Research Station, ARC, Egypt. These trials aiming at evaluating three cultivation methods: wheat (Masr2) on raised bed (RB) techniques (120, 100 cm and normal surface irrigation practice, NSIP) and three nitrogen application methods, (between RB, on RB and broadcasted). Generally, in most cases, wheat sown on raised bed (RB) 120 or 100 cm with N fertilizer application between RB gave the highest significant values of 1000 grain weight, number and weight of grain spike^{-1} as well as grain, straw and biological yields, also grains N, P and K uptake and protein percentage compared with another nitrogen application methods and normal surface irrigation practice (NSIP) with broadcast in both seasons.

Less seasonal values applied irrigation water for raised bed (RB) techniques were (1835 and 1902) and (1849 and 1925) for the 120 cm and 100 cm treatments comparing with (NSIP) in both seasons in 2015/16 and 2016/17 seasons, respectively. The highest water consumptive use values resulted from (NSIP) were 1645 and 1651 more than those recorded under 120 cm and 100 cm treatments in 2015/16 and 2016/17 seasons, respectively. The highest water use efficiency and water productivity values were higher under raised bed method (120 cm) with N fertilizer application between RB treatments in 2015/16 and 2016/17, seasons, respectively.

Key words: Water saving, surface irrigation, raised bed, wheat productivity

Introduction

Water availability is the most limiting factor for rising production of agricultural and an important factor for crop production is especially for wheat in Egypt as well as arid and semi-arid regions as they face shortage in water demands of agriculture and other activities. Wheat is one of the most important crops in Egypt. However, national production remains low and does not meet the needs of the growing population. Egypt relies heavily on wheat imports to meet the needs of the rapidly-growing population. At the farm level, farmers try to increase production by applying irrigation; unfortunately, they use a traditional technique that requires large amounts of water. Surface irrigation is characterized by lower water application efficiency (45 to 50%) compared to the other methods, mainly because of water loss which is due to deep percolation and evapotranspiration. Farmers are usually seen to over-irrigate their fields, which leads to greater losses leading to profile drainage, which in turn increases water storage that cannot be taken up by crops. Consequently, optimal irrigation application during the growing season is important for increasing wheat productivity per unit of applied water without additional costs **(Swelam and Atta, 2011).**

Raised bed planting method of wheat is advantageous in areas where ground water level is receding and herbicide-resistant weeds are creating a problem. When using the raised bed planting method technology, higher yield, lower water application and higher gross production water use indices for maize crop can be achieved **(Zhang *et al,* 2012 and Bhuyan *et al,* 2016). Karrou *et al,* (2012)** reported that the applied irrigation water for raised bed (RB) techniques and treatments included the farmers' normal surface irrigation practice (FT), were 3841 and 5369 m3/ha. The use of the RB technique increased water productivity from around 1.5 kg/m3 for the farmers' usual water management practice to 2.0 kg/m3. Raised bed planting method has been shown to improve water distribution and efficiency, fertilizer use efficiency, reduces weed infestation and lodging and it also reduces seed rate without sacrificing yield (**Hobbs *et al,* 1998). Sayre and Hobbs (2004**) found that using wheat data from different countries showed increases in grain yield and water productivity as compared to conventional planting and estimated water savings ranging from 20 to 46%. The reduced irrigation applications are probably largely due to reduced deep percolation losses **(Humphreys *et al,* 2004**), but also to evaporation. According to **Farré and Faci (2006**), the relationship between grain yield and irrigation water applied is economically more important than the relationship between grain yield and evapotranspiration. **Ram *et al,* (2013)** concluded that the spike length and number of grains per spike were greater in raised beds than with flat layout. **Osman *et al,* (2015**) reported that the higher for wheat grain, straw, biological yields and harvest index as well as

N, P and K uptake were attained due to raised bed planting, comparable with traditional planting.

Nitrogen (N) and water are the most common limiting factors in agricultural systems throughout the world. Wheat crops needs sufficient available water and N to achieve optimum yield and adequate grain – protein content. The quantity and forms of N in the soil are constantly changing due to chemical, physical and biological soil processes. Nitrogen dynamics in agricultural systems are highly influenced by the large quantities added as N fertilizers. N supply to soils increases productivity and biomass accumulation in the short-term, **(IAEA, 2000).** Changing agricultural practices of wheat from flat to bed planting system required changing application methods of nitrogen fertilizer. In this connection, **Fahong et al, (2004)** stated that nitrogen use efficiency could be enhanced by 10% or more in furrow irrigated bed planting systems because of improved N placement possibilities. In addition, the microclimate inside the field was changed to the orientation of the beds wheat plants, which reduced crop lodging and reduced the incidence of some wheat diseases. This was explained by the reduction in canopy humidity that is conducive to reduce disease pressure and enhances of wheat healthy growth. Nitrogen is a key factor to high wheat yields and optimum economic returns by playing an important role in crop productivity **(Dilshad et al,2011).** Nitrogen deficiency constitutes one of the major yield limiting factors for cereal production **(Sarwar et al, 2012).** Appropriate application methods of nitrogen fertilizer enhance the nutrient use efficiency by reducing their losses. **Ghazanfar et al, 2013** investigate the effect of nitrogen application methods (broadcast and side dressing) were placed in the main plots and various levels of nitrogen(60, 90, 120, 150, 180 and 210 kg/ha) were applied in sub plots, on phonology, growth indices and quality of wheat. They found that the N fertilizer can be applied with a more convenient and economical broadcast method without any risk of reduction in crop growth and grain quality. So, the aim of this study is the effect of raised bed technique and Nitrogen application methods on wheat (var. Mesr 2) productivity, yield and yield components of wheat as well as some crop-water relationships.

Materials And Methods

The present research trials were conducted during 2015/16 and 2016/17 winter seasons at Giza Agricultural Research Station, ARC, Egypt, to study the effect of raised bed technique and Nitrogen application methods on wheat (var. Mesr 2) productivity, yield and yield components of wheat as well as some crop-water relationships. Monthly average agro-meteorological data at the experimental site values for the two growing seasons are presented in Table 1. Soil moisture constants and some physical and chemical properties of the soil at the experimental site were determined according to **Klute (1986)** and listed in Tables 2 and 3.

The experimental treatments were arranged in three replicates in a randomized complete plock design. The Treatments as followed:

1. Raised bed (RB) 120 cm + N fertilizer bet ween RB
2. Raised bed (RB) 120 cm + on RB
3. Raised bed (RB) 120 cm + broadcast
4. Raised bed (RB) 100 cm + N fertilizer between RB
5. Raised bed (RB) 100 cm + on RB
6. Raised bed (RB) 100 cm + broadcast
7. Normal surface irrigation practice (NSIP)+ broadcast N fertilizer

Table 1. Mean agro-meteorological values at the experimental site during the 2015/16 and 2016/17 seasons**.**

Month	Season	Temperature (ºC)			Relative humidity (%)	Wind speed (m/sec)	Sunshine (hr)	E_0 (mm/day)
		Max.	Min.	Mean				
November	2015	24.0	15.40	19.70	57.70	1.6	10.60	2.5
	2016	20.40	16.20	18.30	65.00	2.1	10.50	2.4
December	2015	22.00	12.90	17.45	50.00	1.8	10.10	2.6
	2016	16.10	11.30	13.70	64.70	2.6	10.60	2.4
January	2016	13.80	10.10	11.95	58.00	3.1	11.00	3.0
	2017	14.70	10.90	12.80	34.60	2.7	11.18	4.2
February	2016	18.40	13.40	15.90	53.70	3.1	11.60	4.7
	2017	16.83	12.30	14.57	53.90	3.3	12.52	4.9
March	2016	20.30	15.40	17.85	49.30	3.5	12.8	5.8
	2017	19.24	13.96	11.60	44.89	2.2	12.02	5.1
April	2016	25.70	19.30	22.50	44.00	3.5	12.90	6.8
	2017	26.60	18.90	22.75	45.70	1.9	12.77	5.2
May	2016	41.49	25.17	33.33	29.07	4.59	11.74	11.3
	2017	37.91	22.15	30.03	25.35	4.05	10.74	10.8

Table 2. Some soil water constants and bulk density values of the soil at the experimental site.

Depth (cm)	Field capacity (%, w/w)	Wilting point (%, w/w)	Available water (%, w/w)	Bulk density (gcm-3)
0 0– 15	41.8	18.6	23.2	1.15
15 – 30	38.7	17.5	21.2	1.24
30 - 45	31.4	16.9	14.5	1.20
45 – 60	28.1	16.6	11.5	1.28
Mean	35.0	17.4	17.6	1.28

Table 3. Some soil physical and chemical properties at the experimental site

seasons	Particle size distribution			Textural class	Chemical properties					
	Clay	Silt	Sand		O.M.(%)	EC dS/m	pH	Available (ppm)		
		%						N	P	K
2015/16	35.9	36.5	27.9	Clay loam	1.05	0.65	7.9	31.8	16.1	315.5
2016/17	35.1	35.9	28.0		0.96	0.69	7.8	30.5	15.7	313.0

Submerged flow orifice with fixed dimension was used to measure the amount of water applied according to the following equation (Michael, 1978).

$$Q = CA\sqrt{2gh}$$

Where:

Q = discharge through orifice, (L/sec.).

C = coefficient of discharge, (0.61).

A = cross-sectional area of the orifice, (cm^2).

g = acceleration of gravity, (981 cm/sec^2).

h = pressure head, causing discharge through the orifice (cm).

Cultivar (Masr2) was sown on November 15^{th}, 2015 and November 18^{th}, 2016, in 1^{st} and 2^{nd} seasons, respectively. The area of each plot was 42 m^2. Fertilizers used were based on the recommendations of the regional extension service. Nitrogen fertilizer as ammonium nitrate (33.5 % N) was applied at two times, 2/3 of the assessed N dose before life (Mohayah) irrigation and the remainder at the next irrigation. Phosphorous fertilizer as calcium superphosphate (15.0 % P_2O_5), and potash fertilizer as potassium sulphate (48% K_2O) were supplied during seed- bed preparation at 36 kg P_2O_5 ha^{-1} and 58 kg K_2O ha-1 rates, respectively. The assessed Nitrogen fertilizer application methods were added between RB, on RB and broadcasted. The plants were harvested on first week from May, 2016 and 2017 seasons. All cultural practices were carried out according to the recommendation of the wheat research department.

Plants of each plot were harvested, weighed to determine grain, straw and biological yields as well as harvest index, 1000 grain weight, spike no m^{-1}, grain weight/spike, N, P, K uptake and protein %. Plant samples of grain and straw were digested to determine N, P and K. Nitrogen was determined using micro Kjeldahl ,while phosphorous was determined colourimetrically using ammonium molybdate and ammonium metavanadate according to the procedure outlined by **Ryan *et al,* (1996).** Potassium was determined using the flame spectrophotometer method **(Black, 1982).** N, P and K uptake of grain, straw and biological yield were calculated.

Data collected for the above variables were subjected to statistical analysis using analysis of variance (ANOVA) technique **(Snedecor and Cochran, 1980).** The means were compared using Least Significant Difference (LSD) at 5% probability level according to **Waller and Duncan (1969).**

Crop - Water relations:

1- Water consumptive use (CU):

On determining water consumptive use, soil samples were collected using a regular auger just before and 48 hours after each irrigation and at harvest time in 15cm increment from soil surface down to 60cm of soil profile. Water consumptive use was calculated according to **Israelsen and Hansen (1962)** as follows:

$$CU\ (m) = \frac{\theta 2 - \theta 1}{100}\ X\ Bd\ X\ ERZ$$

Where:

CU = water consumptive use (m).

Ө2 =Soil moisture percentage by weight, determined 48 hours after irrigation.

Ө1 = Soil moisture percentage by weight, determined before the following irrigation.

Bd = Bulk density (kg m^{-3})

ERZ= Effective root zone (0.6 m).

Water consumptive use as ($m^3 fed^{-1}$) was obtained by multiplying the value of CU (m) by 42.

2. Water Productivity (WP):

Water productivity is an efficiency term calculated as a ratio of product output over water input. The output could be biological goods such as crop grain, fodder….etc. So, water productivity, in the present study, is expressed as kilogram of wheat seed obtained per the unit of applied irrigation water. The water productivity values (kilograms of wheat grains m^{-3} of applied water) were calculated as follows:

WP (kg m^{-3}) = seeds yield (kg ha^{-1}) / applied water (m^3 ha^{-1}), FAO (2003).

3. Water use efficiency (WUE)

Water use efficiency was calculated according to **Jensen (1983)** as follows:

$$WUE = \frac{Y}{CU}$$

Where : WUE = kg seeds m-3 water consumed.
Y = Seed yield (kg fed-1).
CU = Seasonal water consumptive use (m^3 fed^{-1}).

RESULTS AND DISCUSSION

Some yield components of wheat crop

Results in Table 4 show that 1000 grain weight, spike no. and grain weight spike-1 of wheat were significantly affected due to the adopted treatments, such findings were true in 2015/16 and 2016/17. Generally, wheat grown on raised bed (RB) 120 or 100 cm with N fertilizer application between RB gave the highest significant values compared with another nitrogen application methods and normal surface irrigation practice (NSIP) with broadcast in both seasons, except for spike No m-2. The highest significant value of 1000 grain weight value (54.37 and 48.94) were recorded with (RB) 120 cm with N-fertilizer application between RB in 2015/16 and 2016/17, respectively. Also, the highest significant value of spike No m-2 (316.0 and 284.3) were recorded in both seasons, respectively. The highest significant value of grain weight spike-1 (1.55 and 1.40) were obtained with (RB) 120 cm with N-fertilizer application between RB in 2015/16 and 2016/17, respectively. In the bed-planting systems, there is the possibility of either broadcasting or banding an N top dress in the furrows. Also, in the wheat bed-planting systems, it was possible to apply up to 180 kg N/ha to the soil in the furrows at the mid-tillering period without any toxic effect on the wheat crop **(Ortiz *et al*, 1996a).**

Table 4. Effect of Raised bed and nitrogen application on some yield components of wheat grown in 2015/16 and 2016/17 seasons

	N-Fertilizer methods	1000 grain weight		spike no/m^1		grain weight /spike	
		1 st	2 nd	1 st	2 nd	1 st	2 nd
120 cm	between RB	54.37	48.94	249.3	224.3	1.550	1.397
	on RB	47.04	42.34	249.3	224.3	1.440	1.297
	broadcast	45.35	40.82	274.7	247.0	1.180	1.060
100 cm	between RB	52.50	47.25	316.0	284.3	1.283	1.153
	on RB	45.17	40.65	259.3	233.3	1.310	1.203
	broadcast	44.60	40.14	269.3	242.3	1.137	1.043
NSIP	broadcast	42.85	38.57	224C	201.3	1.023	0.920
LSD		5.029	4.525	49.61	44.51	0.1688	0.1378

The wheat yield components in raised bed were probably due to wider spacing, which provided better light conditions in the canopy for photosynthesis than with wheat on flat layout. The present results are in harmony with those obtained by the results of **Ram et al. (2013).**

Grain, straw, biological yields and harvest index

The results in Table 5 reveal that the grain, straw, biological yields and harvest index were significantly influenced due to the assessed treatments. Higher values of grain, straw and biological yields were recorded with (RB 120 cm) with N fertilizer application between RB, than those obtained with (NSIP) and broadcast in both seasons. The highest significant value of grain yield (4267 and 3841 kg fed^{-1}) was recorded with (RB 120cm) with N- fertilizer application between RB in 2015/16 and 2016/17, respectively, as compared with other treatments. The increased yield might be due to the fact that the beds were permanent and more efficient in reducing drainage in the furrow and enhancing the lateral movement of water to the roots. Regarding straw yield, the highest values of straw yield (4827 and 4491 kg fed^{-1}) were recorded with (RB) 120 and100 cm with N- fertilizer application between RB in the first season, while, that of 4251 kg fed^{-1} was achieved with (RB) 120 cm with the same N-fertilizer method in the second season. The highest values of biological yield (9095 and 8185 kg fed^{-1}) were obtained with (RB) 120 cm with N- fertilizer between RB in 2015/16 and 2016/17 season, respectively.

Data in Table 5 prove that raised bed technique is still improving biological yield, which is higher than that obtained with normal surface irrigation practice (NSIP) with N- fertilizer application between RB in 2015/16 and 2016/17, respectively. In general, data reveal that raised bed planting with (RB) 120 cm surpassed normal surface irrigation practice (NSIP), where wheat grain, straw and biological yields were higher by (62.80 and 62.68%), (38.90 and 35.94%) and (49.20 and 49.20%) in 2015/16 and 2016/17, respectively, than those under surpassed normal surface irrigation practice (NSIP) with nitrogen fertilizer application broadcast. There are indications that yields of wheat on raised bed can be further increased through nitrogen applications because of the reduced loss of lodging on raised bed. Such findings are in parallel with those of **Fahong *et al,* (2004)** who reported that the humidity within the wheat canopy for raised-bed planting was consistently lower (for both the top of the bed & in the furrow) than the humidity within the crop canopy for flat planting. (**Alam, 2012; Zhang *et al,* 2012; Osman *et al,* 2015 and Bhuyan *et al,* 2016**) stated that wheat grain yield was higher with raised bed planting method than normal surface irrigation practice one due to improving yield components.

Table 5. Effect of Raised bed and nitrogen application on grain, straw and biological yields of wheat grown in 2015/16 and 2016/17 seasons

	N-Fertilizer methods	Grain yield (kg fed^{-1})		Straw yield (kg fed^{-1})		Biological yield (kg fed^{-1})		Harvest index	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
	between RB	4267	3841	4827	4251	9095	8185	45.41	46.93
120 cm	on RB	3762	3386	4520	3696	8283	7455	45.94	45.41
	broadcast	3540	3187	4173	4093	7713	6942	47.44	45.94
	between RB	4052	3647	4491	3713	8543	7689	45.41	47.44
100 cm	on RB	3529	3177	4054	3831	7783	7005	44.48	45.41
	broadcast	3194	2874	3987	3458	7180	6462	43.03	44.48
NSIP	broadcast	2621	2359	3475	3127	6096	5486	43.03	43.03
	LSD	272.9	245.7	439.0	341.8	739.3	665.4	2.337	2.383

N, P, K uptake and protein % of grain wheat

Data in Table 6 demonstrate that values of NPK uptake and protein in wheat grains were significantly influenced due to the assessed treatments. The highest grains NPK uptake and were recorded as wheat was grown using raised bed planting method (120 cm) with N fertilizer application between RB, and broadcast compared with on RB. On the other hand, the highest grain protein percentage was gained with using raised bed planting method (120 cm) with N application on RB in the first season while, in the second season, such character was higher when raised bed planting method (100 cm) was used with N fertilizer application between RB. Such findings may be due to improving water distribution and efficiency, fertilizer use efficiency and improved plant photosynthetic capability. In this connection, **Pandiaraj *et al,* (2015)** pointed out that the N application increased the N uptake by wheat crop. Data also indicate that higher NPK uptake and protein % in wheat grain were obtained and reached to (72.32 and 106.92), (70.50 and 82.80), (83.70 and 118.70) and (20.0 and 27.11) respectively, compared with under normal surface irrigation practice (NSIP). Such findings may be due to used raised bed technique induced higher NPK uptake values and protein % for wheat straw yield even with the best nitrogen fertilizer application methods, regardless different plantation methods. The present results are in harmony with those obtained by the results of **(Sarwar *et al*., 2012 ; Ghazanfar *et al*., 2013 and Osman *et al,* 2015**).

Table 6. Effect of Raised bed and nitrogen application on N, P, K uptake and protein % of grain wheat grown in 2015/16 and 2016/17 seasons

	N-Fertilizer methods	N uptake		P uptake		K uptake		protein	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
	between RB	89.73	85.46	19.88	17.11	36.50	35.19	13.70	12.80
120 cm	on RB	87.60	72.68	17.47	16.11	36.03	29.57	14.22	12.33
	broadcast	92.83	65.70	20.99	14.82	39.85	28.21	13.17	11.85
	between RB	80.47	87.23	17.17	16.72	30.09	31.54	13.13	13.71
100 cm	on RB	73.93	65.18	16.26	13.91	30.68B	24.37	13.32	11.82
	broadcast	57.63	56.53	12.81	12.66	23.06C	22.77	12.57	11.32
NSIP	broadcast	52.07	41.30	11.66	9.367	19.87C	16.09	11.42	10.07
	LSD	6.60	13.88	2.42	2.23	5.23	4.35	0.66	2.07

Crop-water relationships:

Applied irrigation water

Amount of applied irrigation water throughout the growing season for different treatments were presented in Table 7. The highest seasonal values were recorded under normal surface irrigation practice a part comparing with raised bed (RB) techniques treatments in the two growing seasons. The total amount of irrigation water applied for wheat 2015/16 was 1835, 1902 and 2350 m^{3}fed^{-1} for the raised bed (RB) techniques (120 and 100 cm) and normal surface irrigation practice (NSIP). In 2016/17, these quantities were 1849, 1925 and 2359 m^{3}fed^{-1} respectively. The overall mean values are 1842, 1913 and 2354 m^{3}fed^{-1} for the raised bed (RB) techniques (120 and 100 cm) and normal surface irrigation practice in 2015/16 and 2016/17, respectively. The results showed that the water requirements in the second season are higher than for first season, maybe due to increasing the weather temperature in second season. The means that the amount of water saving is 512 and 429 m^{3}fed^{-1} for the raised bed (RB) techniques (120 and 100 cm) in two seasons. The applied water were higher under (NSIP) in comparison with raised bed techniques. These results are in a great harmony with those obtained by (**Karrou, *et al,* 2012 and Sayre and Hobbs, 2004**). (**Moursi and Yehia 2016 and Mollah, *et al,* 2015)** showed that (RB) irrigation is technique that can be easily implemented by the farmers. It can lead to saving applied water as compared with normal surface irrigation practice

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Table 7. Amounts of irrigation water (m^3/fed.) applied under the adopted treatments in 2015/16 and 2016/17 seasons.

Treatments	2015/16		NSIP	2016/17		NSIP
	120 (cm)	100 (cm)		120 (cm)	100 (cm)	
Sowing Irrigation (SI)	327	338	438	330	340	400
Life Irrigation (LI)	311	328	420	315	331	429
2nd Irrigation	284	290	362	284	295	380
3th Irrigation	249	265	349	251	269	361
^{4nd} Irrigation	277	286	389	280	291	399
^{5nd} Irrigation	387	395	392	389	399	390
Total	1835	1902	2350	1849	1925	2359

Water consumptive use (Cu)

Data in Table 8 reveal that the highest water consumptive use values resulted from (NSIP) in 2015/16 and 2016/17, respectively. In 2015/16 season, the increase in water consumptive use for crop due to normal surface irrigation practice (NSIP) with broadcast reached by 28.01 and 24.00%, more than those recorded under raised bed technique (120 and 100 cm) treatments, respectively. Similar trends were observed in 2016/17 seasons. These results may be due to increasing available soil moisture and evapotranspiration under normal surface irrigation practice which led to increasing water consumption use (**Farré and Faci 2006**).

Table 8. Water consumptive use, water use efficiency and water productivity as affected by planting methods and nitrogen application in 2015/16 and 2016/17 seasons

Raised bed	N-Fertilizer methods	Grain yield (t/Fed.)		WCU (cm)		WUE (kg m^{-3})		WP (kg m^{-3})	
		2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
120 cm	between RB	4267	3841	1285	1294	3.32	2.97	2.33	2.08
	on RB	3762	3386			2.94	2.62	2.05	1.83
	broadcast	3540	3187			2.76	2.46	1.93	1.72
100 cm	between RB	4052	3647	1331	1348	3.04	2.71	2.13	1.89
	on RB	3529	3177			2.65	2.00	1.86	2.00
	broadcast	3194	2874			2.40	2.87	1.68	2.01
NSIP	broadcast	2621	2359	1645	1651	1.59	1.43	1.12	1.00

Water use efficiency (WUE)

The water use efficiency (WUE) is one of the most important indices for determining optimal water management practices. Maximizing water use efficiency is an important issue for 120cm with application methods of nitrogen fertilizer between RB. Data presented in Table 8 show differential response of various irrigation methods practices for water use efficiency at both seasons. The highest water use efficiency of 3.32 and 2.97 kg m^{-3} were recorded in raised bed method (120 cm) with N fertilizer application between RB treatments in 2015/16 and 2016/17, respectively. The lowest water use efficiency of 1.59 and 1.43 kg m^{-3} were recorded in NSIP with N fertilizer application broadcast in 2015/16 and 2016/17, respectively. However, it is noticeable that higher WUE of 3.32 and 2.97 kg m^{-3} using raised bed method (120 cm) with N fertilizer application between RB treatments was not only due to higher wheat grain yield but also, lower water use compared to other treatments. These results are in a great harmony with those obtained by **(Zahoor, *et al*, 2015).**

Water productivity (WP)

Data in Table 8 illustrate that, in general, under irrigation with 120 and 100 cm RB with application method of nitrogen fertilizer between RB, the values of water productivity increased. The highest WP values e.g. 2.33 and 2.08 kg m^{-3} were recorded as irrigation was 120 cm with fertilizer between RB in 2015/16 and 2016/17, respectively, also, the high WP value (2.13) was gained using RB 100 cm with the same method of N application in the first season only. Such higher WP values are mainly attributable to higher grain yield under 120 cm with fertilizer between RB, comparable with 100 cm with fertilizer between RB and NSIP with broadcast. **Morsy and Abd El- Latif (2012)** found that increasing water applied for onion yield gave the lower water productivity for all varieties. Under the conditions of the present experiment and to conserve the limited irrigation water resources, as an important national issue, it is advisable to 120 cm with fertilizer between RB in order to obtain reasonable water productivity and water saving **(Swelam and Atta, 2011).**

Conclusion

Changing agricultural practices of wheat from flat to bed planting system required changing application methods of nitrogen fertilizer. This indicates the role that agronomy per se can play in developing and transferring technologies that can enhance yields alone or, of equal importance, that can reduce production costs while maintaining yield levels (increased production efficiency), or both. Improved crop management strategies combined with new varieties possessing higher yield potential can enhance both farm productivity as well as profitability. From this study, we can conclude that the wheat bed planting system of 120 cm with nitrogen fertilizer between raised bed gave the highest values of wheat yield and its components as well as water productivity and water saving under the same condition.

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رفع كفاءة استخدام المياه وتحسين انتاجية القمح بتقنية الزراعة على المصاطب وطريقة اضافة السماد الازوتى

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اصبح نظام زراعة القمح على مصاطب من الطرق المتبعه فى الزراعة، وانه بتغيير زراعه القمح من الطريقة التقليدية (احواض) الى نظام زراعة القمح على مصاطب يستلزم لذلك تغيير طريقة اضافة التسميد النيتروجينى ، ولذلك اقيمت تجربة حقلية خلال الموسمين الشتويين 16/2015 و17/2016 فى محطة البحوث الزراعية بالجيزة محافظة الجيزة– مصر. لدراسة طريقة زراعة القمح صنف مصر 2 على مصاطب بعرض 100 و 120 سم والطريقة التقليدية (احواض) وثلاثة طرق لاضافة السماد النيتروجينى (بين المصاطب و على المصاطب والبدار). عموما، وفى معظم الاحوال، فان القمح النامى على مصاطب بعرض 100 و 120 سم مع اضافة السماد الازوتى بين المصاطب (البحرية) اعطى اعلى قيم معنوية لوزن الالف حبة وعدد الحبوب/سنبلة وكذلك محصول الحبوب والقش والبيولوجى بالاضافة الى الممتص من النيتروجين والفوسفور والبوتاسيوم وكذلك النسبة المئوية للبروتين فى الحبوب مقارنة بطريقة اضافة السماد الازوتى بدار مع طريقة الزراعة التقليدية (احواض) فى كلا الموسمين.

بلغت اقل كميات مياه مضافة سنويا مع طريقة الزراعة على مصاطب (1835 و 1902) و (1849 و 1925) لمعاملة 120 و 100 سم مقارنة بالطريقة التقليدية فى كلا الموسمين 16/2015 و 17/2016.كانت اعلى قيم للاستهلاك المائى تحت طريقة الزراعة التقليدية 1645 و 1651 مقارنة بالزراعة على مصاطب 120 او 100 سم فى كلا الموسمين على التوالى. افضل كفاءة لاستخدام المياه وانتاجية وحدة المياه لمحصول القمح سجلت تحت طريقة الزراعة على مصاطب بعرض 120 سم مع اضافة السماد الازوتى بين المصاطب (البحرية) التقليدية فى كلا الموسمين 16/2015 و 17/2016 .