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Effect of planting method on barley productivity, water saving and nutrient use efficiency under El-Minia conditions

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ABSTRACT

The objective of this work is to study the effect of planting method on barley yield; water productivity and water saving as well as nutrient use efficiency in middle Egypt region. Two field experiments were conducted at Mallawi Agric. Res., Station El-Menia Governorate during the two successive seasons of 2015/2016 and 2016/2017. A randomized complete block design with four replications was used. Three planting methods were drilling (traditional method), ridges and raised bed. Planting barley on raised bed gave the highest significant values grain, straw and biological yields as well as grain protein content followed by ridges compared with drilling method.

Results reveal that the highest N use efficiency (87.16 kg grain kg^{-1} N) was observed in raised bed planting system followed by ridges planting system (74.10 kg grain kg^{-1} N fertilizer).

The highest values of physical and economic water productivity for biological yield (8.27-10.29 kg m^{-3} and 18.27 L.E m^{-3}), grain yield (2.63-2.91kg m^{-3} and 11.76 L.E m^{-3}) and straw yield (5.64-7.38 kg m^{-3} and 6.51 L.E m^{-3}) were obtained by planting barley plants on raised bed, respectively.

It could be concluded that using raised bed technique increase barley yield and reduce irrigation water application, consequently improve water productivity and nitrogen use efficiency.

***Keywords*:** Bed and drilling planting, water productivity, nitrogen use efficiency, barley

Introduction

Barley is one of the most important winter cereal crops. It's grown over a wide range of soil variability (saline and poor) and under many diverse climate conditions as well as water shortage compared with other grains crops.

Raised bed, an improved surface irrigation technique, represents a practical and more sustainable alternative to conventional flat irrigation system, which tends to be highly inefficient and wastes already scarce water resource. Instead of spreading water over the entire surface area, the practice most commonly applied by farmers, raised bed planting collects water more efficiently, applying this precious resource where it is most needed. Replacing the traditional flat bed by the raised bed has been reported to offer many advantages; it allows effective control of irrigation and drainage, facilitates fertilizers application and enhances its use efficiency, ensures good stand establishment and tillering, reduces weed infestation and lodging which results all in raising yield and saving irrigation water as well (Abdul Majeed *et al*., 2015 and ICARDA, 2016)

So, this work focuses on evaluate the effect of raised bed on yield; water productivity of barley and water saving as well as nutrient use efficiency in middle Egypt region.

Materials and Methods

Two field experiments were conducted during the two successive seasons 2015/2016 and 2016/2017 at Mallawi Agric. Res., Station El-Menia Governorate (Middle Egypt) on a clay soil to study the effect of planting method on yield, yield attributes, water productivity as well as nutrients use efficiency barley cultivar Giza 123.

Data in Table (1) show the weather data of the experimental site according to Menia agro-meteorological station.

Soil samples were collected to determine some soil physical and chemical properties of the experimental site (Table, 2) before planting according to Estefan *et al*. (2013).

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Table 1: Meteorological data at Menia during the two growing seasons.

Month	Temperature (°C)			RH%	Wind speed (km day^{-1})	Sun shine (hr)
	Max.	Min.	Mean			
			2015/16			
Dec.	20.7	8.7	14.4	68	211	8.9
Jan.	18.7	6.1	12.2	65	192	8.8
Feb.	23.8	8.4	15.9	58	185	9.6
Mar.	26.6	12.0	19.4	48	233	9.8
Apr.	33.6	16.6	25	36	245	10.2
			2016/17			
Dec.	19.4	7.8	13.1	67	185	8.9
Jan.	18.8	6.1	12.1	61	158	8.8
Feb.	20.5	6.7	13.6	58	182	9.6
Mar.	25.0	11.5	18.2	49	202	9.8
Apr.	30.1	14.6	22.4	41	228	10.2

Table 2: Some physical and chemical properties of the experimental soil sites in 2015/16 and 2016/17 seasons.

Character	Season	2015/16	2016/17
Clay %		53.01	55.81
Silt %		24.55	23.5
Sand %		22.44	20.69
Texture		Clay	Clay
Bulk density (g cm^{-3})		1.28	1.32
Field capacity% (v v^{-1})		42.01	46.62
Wilting point% (v v^{-1})		30.44	32.27
$pH_{1:2.5}$		7.95	7.90
EC_e (dsm^{-1})		1.46	1.52
OM%		1.02	1.11
$CaCO_3$%		2.26	2.13
Available nutrients (mg kg^{-1} soil)	N	58	62
	P	15	19
	K	492	512

A randomized complete block design with four replicates was applied. Three treatments of planting method were studied; drilling (traditional method), ridges 60 cm wide and raised bed 120 cm wide. Area of the experimental unit was 16.8 m^2; 3.5 m in length and 4.8 m in width. Each plot included 8 ridges of 60 cm and 4 raised bed of 120 cm. Barley grains were hand drilled in rows 20 cm apart, number of rows was 24 rows plot^{-1}, 3 row/60 cm ridges and 6 rows/ 120 cm raised bed. Planting date was 6th of December in 2015/16 and 2016/17 seasons, respectively.

Nitrogen fertilizer was applied at a rate of 30 kg fed^{-1} as ammonium nitrate (33.5% N). All other cultural practices were done as recommended for barley crop during both growing seasons.

Surface irrigation was used with calibrated contracted rectangular weir to measure water amounts for all plots. A standard contracted rectangular weir was installed at the inlet of the irrigation plots under free flow conditions. The head of the water (h) was monitored and the discharge (Q) was determined using Francis (1883) equation.

$$Q = 3.33h^{3/2}(L - 0.2h)$$

Where:
Q =Discharge Q, in cubic foot per second (cfs)

h = Head on the weir, in foot
L = Length of the weir, in foot

At heading and maturity the dates of these phases were recoded. At harvest ten plants were randomly taken from each plot to study the following characters: plant height (cm), spike length, weight of grains spike^{-1}, number of grains spike^{-1} and weight of 1000-grains. As well as one square meter was taken randomly from each plot to determine biological, grain and straw yields. Harvest index (%) was calculated as follows:

$$Harvest\ index = \frac{Grain\ yield\ (Kg\ fed^{-1})}{Biological\ yield\ (Kg\ fed^{-1})}\ X\ 100$$

Grain samples were milled; then accurately weighted at 0.5 g for digestion. The collected grain samples were subjected to analysis using the wet digestion in H_2SO_4-H_2O_2 mixture as described by Parkinson and Allen (1975). Nitrogen content of grains was determined by using the micro Kjeldahl method (Black, 1965). Grain protein content was estimated by multiplying the grain nitrogen percentage by 5.83 according FAO (2003).

- Grain protein yield was estimated as the following equation:

$$Protein\ yield\ (Kg\ fed^{-1}) = \frac{Grain\ yield\ (Kg\ fed^{-1})\ x\ Protein\ \%}{100}$$

Nitrogen use efficiency was calculated according to Moll *et al*. (1982) as follows:

$$NUE = \frac{Grain\ yield\ (Kg\ fed^{-1}) x\ Protein\ \%}{Nitrogen\ applied\ (Kg\ fed^{-1})}$$

Irrigation Water productivity (IWP) can be expressed as physical productivity (PWP) and economical productivity (EWP) according to Molden (1997). It was calculated as follows:

$$PWP\ (Kg\ m^{-3}) = \frac{Grain\ yield\ \ or\ straw\ yield(Kg\ fed^{-1})}{Total\ amount\ of\ irrigation\ water\ applied\ (m^3\ fed^{-1})}$$

$$EWP\ (L.E\ m^{-3}) = \frac{Grain\ value\ of\ product\ (L.E\ fed^{-1})}{Total\ amount\ of\ irrigation\ water\ applied\ (m^3\ fed^{-1})}$$

$$Water\ saving = 100 - [\ \frac{Total\ irrigation\ of\ raised\ bed\ or\ ridges\ (m^3\ fed^{-1})}{Total\ irrigation\ water\ of\ drilling\ (traditional\ method)\ m^3\ fed^{-1}}\ x\ 100]$$

Statistical analysis

A homogeneity test of experimental error was calculated before analysis according to Bartlett test (Bartlett, 1937). The obtained data were subjected to standard analysis of variance and the means of treatments were tested for significant differences using the least significant difference method (LSD) at P = 0.05. The MSTATC (version 2.10) computer program written by Freed *et al*. (1987) was used to perform all the analysis of variance. A combined analysis was performed for each trait over the two seasons.

Results and Discussion

1. Phenological Traits

Phonological data reveal that planting method insignificantly influenced the barley heading duration in both growing seasons (Table, 3). Similarly combined analysis of the two seasons' data caused no significant effect due to planting method. On the other hand, planting method had significant effect on maturity duration.

Number of days to heading under raised bed and ridges were 3-5, and 1-4 days delayed over drilling, respectively. Longer periods (133 and 131 days) were required for physiological maturity at raised bed and ridges planting compared to drilling planting (127 to 129 days). This delayed maturity of the raised bed treatments compared with the drilling treatment resulted in 3-5 days longer growth season. This delaying in barley growth duration might be due to there aren't water, nutrient and light stresses. Kakar *et al*. (2015 a & b) reported similar results on wheat.

Table 3: Effect of planting method on number of days to heading and maturity of barley in 2015/16 and 2016/17 seasons.

Planting method	Number of days to heading			Number of days to maturity		
	2015/16	2016/17	Combine	2015/16	2016/17	Combine
Drilling	84	85	85	127	129	128
Ridges	85	89	87	131	131	131
Raised bed	87	90	88	133	133	133
F test	ns	ns	ns	*	*	**
LSD 0.05	-	-	-	4.55	2.98	2.42

2. Growth traits and Yield Components

As shown in Table (4), planting method has significant effect on most growth traits and yield components of barley in both seasons and combined analysis. Sowing barley on ridges or raised bed enhanced plant height, spike length, weight of grains spike^{-1} and weight of 1000 grains compared with drilling. Combined analysis reveals that ridges or raised bed methods increased spike length by 27.67 and 19.41%, weight of grains spike^{-1} by 17.87 and 6.78%, weight of 1000 grains by 15.02 and 11.41%, respectively. Raised bed is superior to conventional drilling as it allows good physical conditions of the soil, leading to more water availability and higher root growth, which may be reflected on plant growth. These results are in agreement with the findings of Khaleque *et al*. (2008), Kiliç (2010) and Swelem *et al*. (2015) who mentioned that raised bed planting formed longer spike length and maximum grain weight drilling.

Table 4: Effect of planting method on growth and yield components of barley in 2015/16 and 2016/17 seasons.

Trait	Season	Drilling	Ridges	Raised bed	F test	LSD 0.05
Plant height (cm)	2015/16	91.8	97.0	104.5	**	3.33
	2016/17	99.5	117.3	119.5	**	6.67
	Combine	95.6	107.1	112.0	*	3.32
Spike length (cm)	2015/16	4.51	4.81	5.34	**	0.22
	2016/17	4.97	6.51	6.77	**	0.68
	Combine	4.74	5.66	6.05	**	0.32
No. spike m^{-2}	2015/16	384.08	394.11	394.56	ns	-
	2016/17	376.94	379.88	380.45	ns	-
	Combine	380.51	386.99	387.51	ns	-
No. grains spike^{-1}	2015/16	35.50	33.71	35.52	ns	-
	2016/17	37.30	35.92	37.92	ns	-
	Combine	36.40	34.82	36.72	ns	-
Spike weight (g)	2015/16	1.26	1.32	1.47	**	0.07
	2016/17	1.34	1.45	1.60	**	0.13
	Combine	1.30	1.39	1.53	**	0.07
1000-grains weight (g)	2015/16	39.00	43.50	44.93	*	3.89
	2016/17	39.90	44.40	45.83	*	3.89
	Combine	39.45	43.95	45.38	**	2.45

The obtained data also show significant differences between ridges and raised bed methods in weight of 1000 grains in both seasons as well as combined analysis.

On the other hand, planting method has insignificant effect on number of spikes m^{-2} and number of grains $spike^{-1}$. However, these traits followed the same trend, where planting barley on raised bed gave the highest values followed by ridges.

3. Biological, Grain and Straw Yields as well as Harvest Index

Sowing barley on ridges or raised bed gave significant effect on biological, grain and straw yields compared with drilling in both season and combined analysis (Table, 5). Based on combined analysis, raised bed were increased biological, grain and straw yields of barley by 34.08, 42.24 and 30.88%, respectively. These increments were decreased with ridges to 24.03, 20.92 and 25.25%, respectively, in comparison with drilling method. Increasing yield under raised bed may be due to improve root proliferation along with better stand establishment and tillering, reduce weed infestation and lodging which all could enhancing plant growth and productivity of barley. These findings are in agreement with those obtained by Hossain *et al*. (2006) and Waraich *et al*. (2010) who reported that the raised bed planting recorded more grain and straw yield due to higher yield attributes.

The superiority of raised bed over ridges in this respect may be due to more availability of water and nutrients in the raised bed. Similar results were reported by Ahmed *et al*. (2011), Zayed *et al*. (2011), Zhang *et al*. (2012), Osman *et al*. (2015).

Table 5: Effect of planting method on biological, grain and straw yields as well as harvest index of barley in 2015/16 and 2016/17 seasons.

Trait	Season	Drilling	Ridges	Raised bed	F test	LSD 0.05
Biological yield (kg fed^{-1})	2015/16	5764	7498	7934	**	699.41
	2016/17	7308	8715	9592	**	703.66
	Combine	6536	8107	8763	**	441.73
Grain yield (kg fed^{-1})	2015/16	1768	2138	2522	**	265.19
	2016/17	1909	2308	2708	**	311.54
	Combine	1838	2223	2615	**	182.16
Straw yield (kg fed^{-1})	2015/16	3996	5360	5412	**	527.66
	2016/17	5399	6407	6884	**	702.79
	Combine	4697	5884	6148	**	391.29
Harvest index (%)	2015/16	30.63	28.52	31.83	*	2.50
	2016/17	26.12	26.54	28.30	ns	-
	Combine	28.37	27.53	30.07	ns	-

Data also show that harvest index was significantly influenced by planting method in the first season only. Meanwhile, this effect was insignificant in the second season and combined analysis. Planted barley plants on raised bed gave the highest values of harvest index (31.83 and 28.30 % over drilling method) in 1st and 2nd seasons.

4. Grains Quality

Data in Table (6) pointed out that applying raised bed was insignificantly affected the protein content (%). Meanwhile, this effect was significant on protein yield (kg fed^{-1}). Higher increases in protein content and protein yield were obtained by the application of raised bed compared with the other treatments. The protein content of barley grain reached the maximum of 10.83, 11.10 and 10.97% with raised bed in both season and combined analysis, respectively. As well as, the same treatment gave the highest protein yield (274.06, 300.79 and 287.42 kg fed^{-1}) followed by ridges (222.90, 249.52 and 236.21 kg fed^{-1}). This positive effect of raised bed technique on grain protein may be due to more uptakes of nitrogen and accumulation of carbon dioxide and solar radiation in bed planting system (Khaleque *et al*., 2008; Singh *et al*. 2012).

5. Nitrogen Use Efficiency

Nitrogen use efficiency showed a great diversity as the planting method changed from drilling to ridges and raised bed. Planting barley grains on ridges or raised bed had highly significantly increased the amounts of N use efficiency of barley plants compared with drilling system (Table, 7). Combined analysis reveal that the highest N use efficiency (87.16 kg grain kg^{-1} N) was observed in

raised bed followed by ridges planting system (74.10 kg grain kg^{-1} N). On contrary, the drilling system gave the lowest values of N use efficiency (61.28 kg grain kg^{-1} N). These results could be explained in conjunction with the effects of raised bed planting system on nutrients availability in the root zone soil that reflected on grain yield. These results are in agreement with those obtained by Abou El enein *et al*. (2009a), Abdul Majeed *et al*. (2015) and Swelem *et al*. (2015).

Table 6: Effect of planting method on protein content (%) and protein yield of barley grains in 2015/16 and 2016/17 seasons.

Treatments	Protein content (%)			Protein yield (kg fed^{-1})		
	2015/16	2016/17	Combine	2015/16	2016/17	Combine
Drilling	9.91	10.01	9.96	176.35	189.28	182.81
Ridges	10.51	10.75	10.63	222.90	249.52	236.21
Raised bed	10.83	11.10	10.97	274.06	300.79	287.42
F test	ns	Ns	ns	*	*	**
LSD 0.05	-	-	-	53.62	66.95	38.19

Table 7: Effect of planting method on nitrogen efficiency of barley in 2015/16 and 2016/17 seasons.

Treatments	Nitrogen use efficiency (kg kg^{-1})		
	2015/16	2016/17	Combine
Drilling	58.93	63.64	61.28
Ridges	71.27	76.93	74.10
Raised bed	84.05	90.28	87.16
F test	**	**	**
LSD 0.05	8.84	10.38	6.07

6. Water Indices

6.1. Irrigation Water Applied and Water Saving

Total amounts of applied irrigation water were remarkably differed between the traditional method and raised bed planting treatments. The traditional method received the highest amount of water was 1042 and 1038 m^3 fed^{-1} followed by ridges (993 and 968 m^3 fed^{-1}) and raised bed (960 and 933 m^3 fed^{-1}) in 1st and 2nd seasons, respectively (Table, 8). Total water savings by ridges and raised bed over drilling method were 4.73-6.77%, 7.89-10.14%, respectively. The ridges required slightly higher amount of irrigation water than raised bed. In raised bed planting, irrigation water was applied only in furrows. The area of furrows $unit^{-1}$ area in the raised bed is lower than the ridges (Mollah *et al*., 2009). So, it received lower amount of irrigation water. Consequently, the raised bed method maximized irrigation water application uniformity through decreasing water losses by eliminating evaporation, deep percolation, surface run-off, and seepage (Swelem *et al*., 2015). Savings of irrigation water by raised bed planting ranged from 14 to 32% in wheat were reported many researchers (Hossain *et al*., 2004; Abou El enein *et al*., 2009b; Waraich *et al*., 2010; Ram *et al*., 2012; Ram *et al*., 2013).

Table 8: Effect of planting method on applied water and water saving of barley in 2015/16 and 2016/17 seasons.

Treatments	Applied water (m^3 fed^{-1})			Water saving (m^3 fed^{-1})		
	2015/16	2016/17	Combine	2015/16	2016/17	Combine
Drilling	1042	1038	1040	-	-	-
Ridges	993	968	980	49 (4.73%)	70 (6.77%)	60 (5.75%)
Raised bed	960	933	946	82 (7.89%)	105 (10.14%)	94 (9.01%)
F test	**	**	**	-	-	-
LSD 0.05	18.28	14.52	10.39	-	-	-

6.2. Physical Irrigation Water Productivity

Physical Water productivity (PWP) can be increased by increasing yield and/or reducing water use. Data in Table (9) show the effect of planting method on physical irrigation water productivity of biological, grain and straw yields of barley. Physical water productivity was showed the highest values for biological, grain and straw yields of barley under raised bed. These values were 8.27-10.29, 2.63-2.91 and 5.64-7.38 kg m^{-3} under raised bed planting respectively. Ridges planting came in the second rank. Meanwhile, drilling gave the lowest values of irrigation water productivity of barley. Such results are agreed with those reported by Hobbs *et al*. (2000) Abou El enein *et al*. (2010), Abou El enein (2011) and Ouda *et al*. (2012), they demonstrated that raised bed planting contributed significantly to improved water distribution and efficiency, increased fertilizer use are in agreement efficiency and reduced weed infestation, lodging and seed rate without sacrificing yield.

Table 9: Effect of planting method on physical water productivity of barley in 2015/16 and 2016/17 seasons.

Trait	Season	Drilling	Ridges	Raised bed	F test	LSD 0.05
PWP of biological yield (kg m^{-3})	2015/16	5.53	7.55	8.27	**	0.71
	2016/17	7.04	9.01	10.29	**	0.71
	Combine	6.29	8.28	9.28	**	0.45
PWP of grain yield (kg m^{-3})	2015/16	1.70	2.15	2.63	**	0.26
	2016/17	1.84	2.39	2.91	**	0.34
	Combine	1.77	2.27	2.77	**	0.19
PWP of straw yield (kg m^{-3})	2015/16	3.84	5.40	5.64	**	0.55
	2016/17	5.20	6.63	7.38	**	0.70
	Combine	4.52	6.01	6.51	**	0.39

6.3. Economical Irrigation Water Productivity

Economical water productivity (EWP) is a measure to capture the value of economic gains made through consumption of the unit amount of water (LE m^{-3}). Economical water productivity follows the same trend of physical water productivity. Based on combined analysis, the effect of planting method on EWP was significant. Planted barley plants on raised bed were more profit than ridges or drilling per irrigation water unit. Raised bed was gave the highest values of EWP for biological yield (18.27 LE m^{-3}), grain yield (11.76 LE m^{-3}) and straw yield (6.51 LE m^{-3}). The ridges came in the second rank with significant differences. Meanwhile, the drilling method gave lowest values of EWP. These results are in harmony with those of El-Hadidi *et al*. (2015).

Table 10: Effect of planting method on economical water productivity of barley in 2015/16 and 2016/17 seasons.

Trait	Season	Drilling	Ridges	Raised bed	F test	LSD 0.05
EWP of biological yield (LE m^{-3})	2015/16	11.05	14.55	16.80	**	1.47
	2016/17	13.02	16.76	19.71	**	1.44
	Combine	12.04	15.66	18.27	**	0.92
EWP of grain* yield (LE m^{-3})	2015/16	7.22	9.15	11.16	**	1.11
	2016/17	7.81	10.14	12.35	**	1.43
	Combine	7.52	9.64	11.76	**	1.80
EWP of straw** yield (LE m^{-3})	2015/16	3.84	5.40	5.64	**	0.55
	2016/17	5.20	6.63	7.38	**	0.70
	Combine	4.52	6.01	6.51	**	0.39

*Price of 1 kg grains= 4.25 LE **Price of 1 kg straw= 1.0 LE

Conclusion

It could be concluded that using raised bed technique increase barley yield and reduce irrigation water application, consequently improve water productivity and nitrogen use efficiency in comparison with drilling method.

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