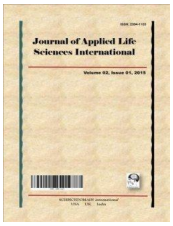

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Impact of Intercropping Egyptian Clover (*Trifolium alexandrinum var Fahel*) with Wheat on Water Use Efficiency of Irrigation

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EMS and EAA managed the analyses of the study. Author STI managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Three field experiments were conducted at the Experimental Farm of Shandaweel Agricultural Research Station, Agric. Res. Center, Sohag Governorate during in the two growing seasons of 2014/15 and 2015/16 to study the water use efficiency for Egyptian clover (fahl barssem) intercropped with wheat under some agricultural treatments. Each experiment was further divided into one of three planting methods (drill on beds, drill and broadcasting) including three weed control method, i.e. spraying with bazagran, hand weeding and without weed control in the main plots. While the three seeding rates of fahl berseem were 15, 25 and 35% of its recommended rate (20 kg/fed) were placed on subplots. Each rate was mixed with the recommended rate of wheat seed (50 kg/fed) using randomized complete block design in split plot arrangement with three replications. The results revealed that the maximum grain yield was obtained through drill on beds planting, spraying with bazagran and seeding rate of fahl berseem 15% intercropped with wheat in

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both seasons. Cultivation on drill on beds, chemical weeds control and fahl barseem intercropped with wheat systems can be the suitable production package under the conditions of water deficiency that Egypt experience. Up to 29% of the applied water to fahl barseem can be saved, as a result of cultivation on drill on beds. Up to 5% of the applied water to fahl barseem can be saved as a result of chemical weeds control. Furthermore, 538, 897 or 1255 m^3/fed from the applied water to fahl barseem can be saved if 15, 25 or 35% of it intercropped with wheat. In addition to, it obtained the highest water use efficiency.

Keywords: Applied irrigation water; water use; intercropping; planting methods and Triticum aestivum.

1. INTRODUCTION

In Egypt, 85% of total available water is consumed in agriculture and most of the on-farm irrigation systems are low efficient coupled with poor irrigation management. Furthermore, there is a gap between the needs and availability of water is about 20 BCM/year. This gap is overcome by recycling agricultural drainage water [1]. Thus, water scarcity will negatively affect food security. Therefore, implementations of agricultural management practices that can save on the applied irrigation water to crops are important under these circumstances. Examples of these practices are cultivation on drill on beds, chemical weed control and implementing intercropping systems.

Cultivation on drill on beds was previously implemented for wheat in Egypt. Karrou [2] stated that drill on beds cultivation for wheat resulted in the application of 3841 m^3/ha and saving of 1528 m^3/ha, with 28%, compared to farmer irrigation and resulted in saving of 1500 m3/ha, with 26%, compared to full irrigation. Whereas, El-Hadidi [3] indicated that cultivation on drill on beds for wheat saved 17% of irrigation water, compared to flat cultivation. Weed infestation is one of the main causes of wheat yield reduction, as it reduces wheat yield by 37-50% [4]. Furthermore, weeds can reduce crop yields more than 50% through moisture competition alone [5].

Intercropping of legume with cereal is widespread among smallholder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility [6]. Under water scarcity condition, intercropping systems can be a way to save on the applied irrigation water [7] and increase water use efficiency [8]. Abdel-Zaher [9] intercropped fahl barseem with wheat and they concluded that the yield and its attributed traits of wheat significantly decreased with increasing the percentage of fahl berseem seeding rates.

Thus, the objective of this research was to calculate water saving and water use efficiency for fahl barseem and wheat intercropping systems under different planting methods and weeds control.

2. MATERIALS AND METHODS

The present investigation was conducted during the two growing seasons of 2014/15 and 2015/16 at the Experimental Farm of Shandaweel Agricultural Research Station, Agric. Res. Center, Sohag Governorate.

The whole field was divided into three separates experiments. Each experiment was further divided into one of three planting methods (drill on beds, drill and broadcasting). Each experiment was using randomized complete block design in split plot arrangement with three replications. Three weed control method, i.e. spraying with bazagran[3-(1-methylethyl)-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide], hand weeding and without weed control were arranged in the main plots. Each main plot was divided into three subplots to allocate seeding rates of fahl berseem 15, 25 and 35% of its recommended rate (20 kg/fed). Each rate was mixed with the recommended rate of wheat seed (50 kg/fed). In addition, sole wheat and sole fahl berseem were included for comparison. The soil of such experiment was Silty clay loam as presented in Table 1.

Weather data values were collected for the studied two growing season and presented in Table 2.

Sowing date for both sole wheat and fahl barseem intercropped with wheat were on November 20th and 18th in 2014/15 and 2015/16 seasons, respectively. The plot size was 12 m^2. Wheat seeds variety cv. Sids 1 (*Triticum aestivum*).

The fertilization requirements ware calculated based on area of feddan (4200 m^2). The

application of recommended dose of nitrogen, phosphorus and potassium were given through ammonium nitrate, calcium super phosphate and potassium sulfate which contain 33.5% N, 15.5% P_2O_5 and 48% K_2O, respectively. Recommended dose of fertilizer was applied to wheat and intercropping systems on area basis 75, 15 and 24 for N, P_2O_5 and K_2O, respectively. Nitrogen fertilizer rate was applied in three equal rates. The first dose was added at planting date, the second dose added prior the first irrigation and the third dose added at the third irrigation.

Calcium super phosphate and potassium sulfate were applied during land preparation.

Surface irrigation was used for the studied crops, where 5 irrigations were applied to either sole wheat, sole fahl barseem, or fahl barseem intercropped with wheat systems. Irrigation was done every 21 days. Soil moisture constants are presented in Table 3.

Cultural management and disease and pest control programs for wheat and fahl berseem crops were followed as recommended by the Egyptian Ministry of Agriculture.

Harvest took place on May 15th and May 11th in the first and second seasons, respectively. At harvest, the grain of the crops was separated and each of wheat and fahl berseem seeds were weighted and converted into kg/fed. Straw yield in sole wheat and in intercropping systems (fahl berseem + wheat) was weighted and converted into kg/fed.

2.1 Water Relations

2.1.1 Crop water consumptive use (WCU)

Water consumptive use was determined using soil samples. The samples were taken from the soil surface for four layers, each 15 cm depth (0-15, 15- 30, 30-45 and 45-60 cm) by a regular augur. The samples were weighed immediately and oven dried to a constant weight at 105°C. Percentage of soil moisture at the four soil depths was calculated on oven dry weight basis. The amount of water consumed in each irrigation event was obtained from the difference between soil moisture content after and before the following irrigation.

Crop water consumptive use (crop evapotranspiration, ETc) was estimated using soil sampling method and calculated according to Majumdar [10].

$WCU\ (ETc) = D*BD*[(Q_2-Q_1)/100]$

Where:

WCU = Water consumptive use (mm).
D = Irrigation soil depth.
Bd = bulk density of soil (g/cm^3).
Q_2 = 'the percentage of soil moisture two days after irrigation.
Q_1 = the percentage of soil moisture before next irrigation.

2.1.2 Applied irrigation water

The applied amounts of irrigation water to sole wheat and sole fahl berseem, as well as fahl berseem intercropped with wheat system was calculated using 4 inch diameter tube according to Michael [11].

$$Q = \frac{0.61 \times \mathrm{A} \times \sqrt{2 \times 981 \times h}}{1000 \times 1000} \times 60\ (\mathrm{m}^3/\mathrm{t})$$

Q = water discharged (m^3/t)
A = tube sectional area (cm^3)
h = water head over the center of the tube (cm)
Gravity ground of speed = 981 CM/S^2

Table 1. Mechanical and chemical of soil analyses of the experimental field before cultivation

Properties	2014/15	2015/16
Mechanical analysis		
Sand%	19%	21%
Silty%	48%	51%
Clay%	33%	28%
Soil texture	Silty clay loam	Silty clay loam
Chemical analysis		
pH	7.66	7.60
Organic matter %	1.68	1.70
$CaCo_3$ %	3.88	3.90
Ec ds/m	1.6	1.65
Total N %	1.8	1.6

Table 2. Weather data and ETo values for the experimental site in 2014/15 and 2015/16 growing seasons

	SRAD	TMAX	TMIN	TDEW	ETo
2014/15					
Nov	16.5	27.8	13.5	4.6	4.6
Dec	14.8	19.4	6.3	2.1	3.1
Jan	16.0	19.5	5.5	-1.6	3.3
Feb	18.9	22.8	8.1	-2.6	4.3
Mar	18.5	27.7	12.3	-0.1	5.7
Apr	26.0	30.1	13.0	-3.0	7.4
2015/16					
Nov	17.0	26.5	12.7	7.0	4.4
Dec	14.8	20.3	6.7	3.1	3.2
Jan	15.5	18.7	4.6	-0.3	3.1
Feb	19.6	24.4	8.2	-0.8	4.5
Mar	21.0	28.0	12.9	-0.6	5.8
Apr	25.6	34.8	17.0	-2.1	7.6

SRAD =solar radiation (MJ/m2/day), TXAX, TMIN and TDEW=maximum, minimum and dew temperature, respectively (°C), ETo = Reference evapotranspiration (mm/day)

Table 3. Soil moisture contents in the experimental site for the two growing seasons

Soil depth (cm)	Field capacity (%)	Welting point (%)	Available soil moisture (%)	Bulk density (g/cm^3)
0 – 15	35	18.50	16.50	1.18
15 – 30	34	17.20	16.80	1.23
30 – 45	32	16.50	15.50	1.28
45 – 60	30	15.45	14.55	1.33

2.1.3 Saving in the applied irrigation water

The amount of irrigation water to the sole wheat or intercropped wheat under seeds broadcasting and drill planting methods was compared to drill on beds cultivation method to determine the used/ saved amount of water. The saved amount of irrigation water as a result of using wheat intercropping systems was, compared to sole wheat planting was. Similarly, the used/saved amount of irrigation water, as a result of using weeds control methods was calculated and compared to without weed control treatment.

2.1.4 Water use efficiency (WUE)

WUE is a quantitative term used to define the relationship between crop produced and the amount of water involved in crop production. It is a useful indicator for quantifying the impact of irrigation scheduling decisions, with regard to water management [12].

Water use efficiency (kg/m^3) was calculated for the different treatments according to the following formula of Vites [13].

WUE= Seed yield (kg/fed)/Water consumptive use (m^3/fed).

2.2 Statistical Analysis

Data were analyzed by MSTAT-C [14] software package. Separate analysis of variance using randomized complete block design (RCBD) was carried out for each planting method. Bartlett's test for variance homogeneity was done following [15], and then combined analysis for data from all planting methods were carried out for each year according to Gomez [16]. Means were compared by revised Least Significant Difference (LSD′) at 5% level of significant [17] Mean values were compared by using Duncan's multiple range test [18].

3. RESULTS AND DISCUSSION

3.1 Grain Yield of Wheat

Data in Table 4 illustrates that planting methods, weed control methods and seeding rates of fahl berseem has significantly affected grain yield in

favor of drill on beds planting, spraying with bazagran and 15% of fahl berseem seeding rate intercroppe with wheat in both growing seasons. The highest wheat yields was observed under sowing method of drill on beds planting, with 2758 and 2504 kg/fed in the first and second growing seasons respectively. Whereas, the lowest wheat yield was obtained from seed broadcasting, with 2335 and 2063 kg/fed in the two growing seasons of 2014/15 and 2015/16, respectively. These results are in good agreements with yields obtained by Chauhdary [19] who reported that the same trend was observed for weed control method using bazagran spray w, where it produced the highest wheat yield, 2887 and 2585 kg/fed, compared to no weed control, which produced the lowest yield of 1960 and 1773 kg/fed, in the two growing seasons of 2014/15 and 2015/16, respectively. Results in Table 4 also revealed that 15% seeding rate of fahl berseem gave the highest grain yield compared to seeding rate of 35% fahl berseem intercropped with wheat in the two growing seasons. Whereas, sole wheat gave the highest f grain yield, compared tp all intercropping treatments with wheat in the two growing seasons. Similar results were obtained by Abdel- Zaher [9]. Thorsted [20] that showed intercropping winter wheat and white clover decreased wheat grain yield by 10-25%, as compared with wheat sole cropping. The yield reductions in mixtures were likely caused by intera-specific and intra-competition for light, nutrients and water during vegetative growth and during grain filling stage.

3.2 Water Use

The results in Table 5 indicates that there was a significant difference in water use between all the treatments, except interaction between weeds control methods and intercropping systems in the first growing season and interaction between planting methods, weeds control methods and intercropping systems in the second growing season. The results also showed that the lowest water use was obtained from cultivation on drill on beds for either wheat or fahl barseem intercropped with wheat, compared to the other planting methods. Sprayed wheat (sole or intercropped) with bazagran reduced water c use, compared to the other weeds control methods. Moreover, sole wheat gave the lowest water use, followed by intercropping fahl barseem with wheat at 15% of its recommended planting density. In general, the lowest water use was obtained for sole wheat when it cultivated on drill on beds and sprayed with bazagran, followed by intercropping fahl barseem with wheat by 15% of its recommended planting density, cultivated on drill on beds and sprayed with bazagran. This result was true for both growing seasons, where the amont of water used was 1375 and 1395 m^3/fed, for the first and second season, respectively. Similar results were obtained by Khalil [21], El- Hadidi [3], and Karrou [2].

3.3 Irrigation Water Use

The results in Table 6 indicates that, in the first growing season, there were significant differences in the amount of irrigation water between all the studied treatments, except interaction between planting methods and intercropping systems. Moreover, there were no significant differences between weeds control methods and intercropping as well as interaction between planting methods, weeds control methods and intercropping systems. Whereas, in the second growing season, there were no significant differences between planting methods, weeds control methods and intercropping systems only. Similar to water use efficiency, the applied irrigation water followed the same trend (Table 6). The results indicated that the lowest applied irrigation water was obtained under cultivation on drill on beds for either wheat or fahl barseem intercropped with wheat, compared to the other planting methods. Sprayed wheat (sole or intercropped) with bazagran reduced the amount of irrigation water, compared to the other weeds control methods Moreover, sole wheat gave the lowest irrigation water, followed by intercropping fahl barseem with wheat by 15% of its recommended planting density. Additionally, the lowest applied irrigation water can be obtained for sole wheat when it cultivated on drill on beds and sprayed with bazagran, followed by intercropping fahl barseem with wheat by 15% of its recommended planting density, cultivated on drill on beds and sprayed with bazagran. This result was true for both growing seasons, where amount of irrigation water was 1924 and 19323/fed, for the first and second season, respectively. Similar results were obtained by Karrou [2] for irrigation amount on drill on beds and using seeds broadcasting where he got yield of. Furthermore, the applied irrigation water amounts to intercropping fahl barseem with wheat systems were alittle bit higher than the applied irrigation water to sole wheat.This result was true under planting methods and weeds control methods in both growing seasons.

Tabl 4. Effect of planting method, weed control method, seeding rate of fahl berseem intercropping with wheat and their interactions on grain yield of wheat (kg/fed) during the 2014/15 and 2015/16

Seasons		2014/15				Mean	2015/16				Mean
Planting methods (M)	Weed control Method (W)	S0	S1	S2	S3		S0	S1	S2	S3	
M1	W1	3283^{a}	3234^{a}	3025^{cd}	2738^{hi}	3070^{a}	3032^{a}	2899^{ab}	2842^{bc}	2361^{hijkl}	2783^{a}
	W2	3096^{bc}	3052^{bcd}	3043^{cd}	2705^{hij}	2974^{ab}	2871^{abc}	2800^{bcd}	2708^{cde}	2365^{hijkl}	2686^{a}
	W3	2385^{n}	2274^{o}	2167^{p}	2093^{q}	2230^{e}	2201^{l}	2044^{m}	1997^{m}	1925^{m}	2042e
Mean		2921^{a}	2853^{b}	2745^{c}	2512^{f}	2758^{A}	2701^{a}	2581^{b}	2516^{b}	2217^{d}	2504^{A}
M2	W1	3114^{b}	3030^{cd}	3013^{d}	2613^{kl}	2942^{b}	2773^{bcde}	2652^{def}	2613^{efg}	2238^{kl}	2569^{b}
	W2	3030^{cd}	2948^{e}	2879^{f}	2498^{m}	2839^{c}	2474^{ghi}	2326^{ijkl}	2292^{jkl}	2015^{m}	2277^{d}
	W3	2035q	1917^{r}	1855^{rs}	1707^{t}	1878^{f}	1956^{m}	1685^{n}	1658^{n}	1562^{n}	1715^{f}
Mean		2726^{c}	2632^{d}	2582^{e}	2272^{i}	2553^{B}	2401^{c}	2221^{d}	2187^{d}	1938^{f}	2187^{B}
M3	W1	2818^{fg}	2757g^{h}	2655^{jkl}	2363^{n}	2648^{d}	2509^{fgh}	2449^{ghij}	2399^{hijk}	2251^{kl}	2402^{c}
	W2	2720^{hij}	2675^{ijk}	2597^{l}	2348^{n}	2585^{d}	2356^{hijkl}	2301^{ijkl}	2258^{kl}	1993^{m}	2227^{d}
	W3	1913^{r}	1829^{s}	1750^{t}	1598^{u}	1772^{g}	1624^{n}	1619^{n}	1607^{n}	1395^{o}	1561^{g}
Mean		2483^{f}	2420^{g}	2334^{h}	2103^{j}	2335^{C}	2163de	2123de	2088^{e}	1880^{f}	2063^{C}
General mean		2710^{a}	2635^{b}	2553^{c}	2296^{d}	2549	2422^{A}	2308^{B}	2264^{B}	2011^{C}	2251
W×S	W1	3071^{a}	3007^{b}	2897^{d}	2571^{f}	2887^{a}	2771^{a}	2666^{b}	2618^{bc}	2283^{e}	2585^{A}
	W2	2949^{c}	2892^{d}	2839^{e}	2517^{g}	2799^{B}	2567^{c}	2475^{d}	2419^{d}	2124^{f}	2396^{B}
	W3	2111^{h}	2006^{i}	1924^{j}	1799^{k}	1960^{C}	1927^{g}	1783^{h}	1754^{h}	1627^{i}	1773^{C}
					LSD′						
M			48.81				53.62				
W			48.81				53.62				
S			18.84				45.33				
M×W			97.40				N.S.				
M×S			N.S.				N.S.				
W×S			33.60				94.26				
M×W×S			N.S.				N.S.				

Where: M1, M2 and M3 means drill on beds, drill and broadcasting planting method, respectively, W, W2 and W3 means spray with bazagran, hand and without weed control method, respectively, S0 means sole wheat. S1, S2 and S3 means seeding rate of fahl berseem 15, 25 and 35% of the recommended rate of fahl berseem (20 kg/fed) intercropping with wheat, respectively, NS means Non-significant at 5% level of probability

Table 5. Water use (m3/fed) for sole wheat and fahl barseem intercropped with wheat in in 2014/2015 and 2015/2016 cropping seasons

Seasons		2014/15				Mean	2015/16				Mean
Planting methods (M)	Weed control Method (W)	S0	S1	S2	S3		S0	S1	S2	S3	
M1	W1	1375	1386	1393	1401	1389	1395	1407	1413	1421	1409
	W2	1379	1392	1396	1411	1395	1397	1412	1416	1429	1414
	W3	1465	1477	1486	1513	1485	1476	1487	1498	1511	1493
Mean		1406	1418	1425	1442	1423	1423	1435	1442	1454	1439
M2	W1	1445	1457	1460	1468	1458	1463	1472	1480	1493	1477
	W2	1443	1454	1456	1464	1454	1465	1474	1486	1503	1482
	W3	1454	1465	1471	1483	1468	1476	1487	1498	1515	1494
Mean		1447	1464	1462	1472	1460	1468	1478	1488	1504	1484
M3	W1	1568	1585	1595	1600	1587	1594	1602	1614	1620	1599
	W2	1575	1588	1596	1605	1591	1601	1608	1616	1633	1604
	W3	1597	1610	1613	1618	1610	1616	1630	1641	1646	1624
Mean		1580	1594	1601	1608	1596	1596	1604	1613	1624	1609
General mean		1478	1490	1496	1507	1491	1498	1509	1518	1530	1514
W×S	W1	1463	1476	1483	1490	1478	1484	1494	1502	1511	1498
	W2	1466	1478	1483	1493	1480	1488	1498	1506	1522	1503
	W3	1505	1517	1523	1538	1521	1523	1535	1546	1557	1540
					LSD'						
M		2.12					1.68				
W		2.12					1.68				
S		1.62					1.47				
M×W		3.67					2.91				
M×S		3.05					3.01				
W×S		N.S.					2.98				
M×W×S		5.61					N.S.				

Table 6. Amount of irrigation water (m^3/fed) for sole wheat and fahl barseem intercropped with wheat in 2014/2015 and 2015/2016 cropping seasons

Seasons		2014/15				Mean	2015/16				Mean
Planting methods (M)	Weed control	S0	S1	S2	S3		S0	S1	S2	S3	
	Method (W)										
M1	W1	1924	1928	1934	1946	1933	1932	1939	1943	1951	1941
	W2	1988	2001	2008	2021	2004.5	2032	2038	2044	2052	2042
	W3	1992	2003	2009	2021	2006.3	2030	2037	2046	2055	2042
Mean		1968	1977	1984	1996	1981	1998	2005	2011	2019	2008
M2	W1	2447	2455	2465	2473	2460	2471	2484	2499	2487	2485
	W2	2548	2553	2558	2571	2557.5	2557	2565	2574	2586	2571
	W3	2549	2560	2566	2578	2563.3	2561	2570	2586	2595	2578
Mean		2515	2523	2530	2541	2527	2530	2540	2553	2556	2545
M3	W1	2708	2719	2726	2735	2722	2738	2753	2764	2774	2757
	W2	2805	2812	2820	2813	2813	2826	2838	2851	2864	2845
	W3	2806	2813	2824	2832	2819	2825	2843	2859	2871	2850
Mean		2773	2781	2790	2793	2784	2796	2811	2825	2836	2817
General mean		2419	2427	2434	2443	2431	2441	2452	2463	2471	2457
W×S	W1	2360	2367	2375	2385	2372	2380	2392	2402	2404	2395
	W2	2447	2455	2462	2468.3	2458	2472	2480	2490	2501	2486
	W3	2449	2459	2466.3	2477	2463	2472	2483	2497	2507	2490
					LSD′						
M		1.43					1.30				
W		1.43					1.30				
S		1.92					1.60				
M×W		2.47					2.31				
M×S		N.S.					2.88				
W×S		N.S.					3.01				
M×W×S		N.S.					N.S.				

3.4 Water Holding Capacity in the Different Planting Methods

The results in Table 7 shows that irrigation water holding were 29 and 28% for sole wheat in the first and second growing seasons, respectively when cultivation was on drill on beds, and seeds broadcasting method. A range between 28-29% water holding capacity in the irrigation water can be attain for fahl barseem intercropped with wheat for the same/in the same cultivation method in both growing seasons.

Regarding to seeds drill planting method, the water holding capacity in the irrigation water was lower, ranging between 9-10% under both sole and intercropping wheat systems. El- Hadidi [3] indicated that drill on beds cultivation saved 17% of the applied water to wheat, compared to traditional cultivation methods. Whereas, Karrou [2] reported that drill on beds cultivation for wheat resulted in 28% saving in the applied water, compared to traditional cultivation methods.

3.5 Water Holding Capacity of Irrigation Water in Chemical Weed Control and without Weed Control

The results in Table 8 reveals that using chemical weed control could save applied irrigation water in sole or intercropped wheat by 3-5%, in both growing seasons under drill on beds cultivation, compared to without weed control. However, the water holding capacity in the hand weeding treatment was very low, between 0 and 0.2%, compared to without weed control. Similarly, the water holding due to irrigation in drill planting method and chemical weed control was 3-4% and the water holding was very low for hand weeding treatment, that range between 0 and 0.5%, compared to without weed control. Whereas, for seed broadcasting method, the water saving was 3% in both growing seasons under chemical weeds control and was between 0-0.7% under hand weeding treatment, compared to without weed control.

3.6 Water Holding Capacity of Irrigation in Sole Crops and Intercropping Systems

Data in Table 9 shows that all intercropping fahl barseem with wheat systems using supplement/extra irrigation water amounted to 1% or less, compared to sole wheat planting. Increasing percentage of fahl barseem in the intercropping systems increase the applied irrigation water by 1% in S3 (fahl barseem intercropped by 35% of its planting density). However, the saving in the applied irrigation water in the tested intercropping systems come from saving a percentage of the required irrigation amount to fahl barseem, when it intercropped with wheat. Thus, the saved amount will be 538, 897 or 1255 m^3/fed, if the planted percentage of fahl barseem was solely planted at 15, 25 or 35% seed rate.

3.7 Water Use Efficiency

The results in Table 10 indicate that water use efficiency was highest when sole wheat and fahl barseem cultivated on drill on beds, compared to the other planting methods. In addition, sprayed, either sole or intercropped wheat with bazagran herbicid increase water use efficiency, compared to the other weeds control methods. With respect to intercropping systems, sole wheat gave the highest water use efficiency, followed by intercropping fahl barseem with wheat at seed

Table 7. Percentage of water holding capacity in different planting method

Planting methods (M)	Weeds control (W)	2014/15				2015/16			
		S0	S1	S2	S3	S0	S1	S2	S3
Broadcast	W1	29	29	29	29	29	30	30	30
	W2	29	29	29	28	28	28	28	28
	W3	29	29	29	29	28	28	28	28
Average		29	29	29	28	28	28	28	28
Drill	W1	10	10	10	10	10	10	10	10
	W2	9	9	9	9	10	10	10	10
	W3	9	9	9	9	9	10	10	10
Average		9	9	9	9	9	10	10	10

Table 8. Percentage of water holding capacity in different weed control methods/practices

Planting methods (M)	Weeds control (W)	2014/15				2015/16			
		S0	S1	S2	S3	S0	S1	S2	S3
M1	W1	3	4	4	4	5	5	5	5
	W2	0.2	0.1	0	0	0.1	0	0.1	0.1
M2	W1	4	4	4	4	4	3	3	4
	W2	0	0.3	0.3	0.3	0.2	0.2	0.5	0.3
M3	W1	3	3	3	3	3	3	3	3
	W2	0	0	0.1	0.7	0	0.2	0.3	0.2

Table 9. Percentage of saving in the applied irrigation water (%) as a result of intercropping systems, compared wheat sole planting average over the two growing seasons

Planting methods (M)	Weed control method (W)	Sole wheat (S0)	Sole fahl Barseem	Applied water (m^3/ha)			% of increase under intercropping		
				S1	S2	S3	S1	S2	S3
M1	**W1**	1928	--	1934	1939	1949	0.3	0.5	1
	W2	2010	--	2020	2026	2037	0.5	0.8	1
	W3	2011	--	2020	2028	2038	0.4	0.8	1
M2	**W1**	2459	--	2470	2482	2480	0.4	0.9	1
	W2	2553	--	2559	2566	2579	0.3	0.5	1
	W3	2555	--	2565	2576	2587	0.4	0.8	1
M3	**W1**	2723	--	2736	2745	2755	0.5	0.8	1
	W2	2816	--	2825	2836	2839	0.3	0.7	1
	W3	2816	3586	2828	2842	2852	0.4	0.9	1

Table 10. Water use efficiency for sole wheat and fahl barseem intercropped with wheat in 2014/2015 and 2015/2016 cropping seasons

Planting methods (M)	Weeds control (W)	2014/15				2015/16			
		S0	S1	S2	S3	S0	S1	S2	S3
M1	**W1**	2.39	2.34	2.18	1.96	2.17	2.06	2.01	1.66
	W2	2.24	2.22	2.18	1.91	2.06	1.98	1.91	1.64
	W3	1.63	1.54	1.45	1.39	1.49	1.37	1.33	1.27
M2	**W1**	2.16	2.08	2.07	1.78	1.89	1.80	1.77	1.50
	W2	2.10	2.03	1.98	1.71	1.69	1.58	1.54	1.34
	W3	1.40	1.31	1.26	1.15	1.33	1.13	1.11	1.03
M3	**W1**	1.80	1.74	1.66	1.48	1.57	1.53	1.49	1.39
	W2	1.72	1.68	1.63	1.47	1.47	1.43	1.40	1.22
	W3	1.20	1.14	1.09	0.99	1.01	0.99	0.98	0.85

rate of 15% In general, the highest water use efficiency can be obtained from use or planting of sole wheat cultivated on drill on beds and when sprayed with bazagran, followed by intercropping fahl barseem with wheat at seed rate of 15% plant density, cultivated on drill on beds and sprayed with bazagran. This result was true for both growing seasons, where the amount of water use efficiency were 2.39 and 2.17 kg/m^3. Similar results were reported by El-Hadidi [3] and Khalil [21].

4. CONCLUSION

The results of the study showed that the lowest water use was obtained from cultivation on drill on beds both for wheat or fahl barseem intercropped with wheat, compared to the other planting methods. Similarly herbicide sprayed wheat (sole or intercropped) with bazagran also reduced water use, compared to the other weeds control methods. Water use efficiency and water productivity was highest when sole wheat

cultivated on drill on beds and sprayed with bazagran, followed by intercropping fahl barseem with wheat at seed rate of 15% plant density, cultivated on drill on beds and sprayed with bazagran. The results of the study showed that the tested production package, namely cultivation on drill on beds, chemical weeds control and fahl barseem intercropped with wheat systems can be the suitable production package under the conditions of water deficiency. Up to 29% of the applied water to fahl barseem can be saved, as a result of cultivation on drill on beds. Up to 5% of the applied water to fahl barseem can be saved due to use of chemical weeds control. Furthermore, 538, 897 or 1255 m^3/fed from the applied water to fahl barseem can be saved when the seed rate is 15, 25 or 35% and when intercropped with wheat. In addition, it provides the highest water use efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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