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Applying of arbuscular mycorrhizal fungi (AMF) and rock phosphate to wheat (*Triticum aestivum*L.) grown on calcareous soil and irrigated at different irrigation intervals and effect of plant growth and soil physical properties

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Abstract

A field experiment was conducted along two the successive seasons of winter (2014/2015) and (2015/2016) at El-Nubaria Agricultural Experimental Station of the Agricultural Research Center (ARC), west of Alexandria, Egypt. Aim was to evaluate the effect of arbuscular mycorrhiza fungi (AMF) and rock phosphate (RP) application as well as the effect of irrigation intervals on soil properties and growth of wheat (*Triticum aestivum L.*) grown on sandy clay loam calcareous soil. The experiment was factorial (3 factors) with 12 treatments and three replicates. Three irrigation intervals 15, 21and 35 days, two RP treatments non and 16 kg P ha^{-1} and two AMF (non and AMF) treatments. AMF under moderate 21 day irrigation interval combined with RP was mostly effective in increasing total porosityand saturated hydraulic conductivity as well as decreasing bulk density. AMF + RP and irrigation every 21 days gave highest values of most growth and yield characters along with NPK content.

Keywords: mycorrhizal fungi, rockphosphate, irrigation intervals, calcareous soil and wheat plant.

Introduction

Wheat (*Triticum aestivum*L.) is the most important cereal crop as the main food stable for the Egyptian public. Increasing wheat productivity is a national target in Egypt to fill the gap between wheat consumption and production.Growing wheat on the newly reclaimed area of Egypt especially calcareous soil faces various problems.This soil has poor physical properties and lacks organic materials, micro-organisms, macro and micronutrients.

One of the major limiting factors for plant growth is water availability in arid and semiarid regions. **El-Sersawy *et al* . (1993)** reported that total porosity of calcareous soil is affected by irrigation. **El-Sherbiny (2002)** showed that the irrigation at 50% depletion of available water decreased bulk density. **Ghaly and El-Sodany (2009)** found that three weeks irrigation intervals for *Nigella sativa L.* increasesd total porosity, hydraulic conductivity and water consumption as compared to 4 and 5 weeks intervals. Drought affects plant physiology and tends to reduce photosynthesis **Munns (2002)**. **Kumar *et al.* (2016)** showed that AM fungi increased water holding capacity by 5 to 6 % and the mean weight diameter of soil aggregate by 4 to 9 %. **Soha and Yousef (2014)** reported that yield components, oil and carotenoids contents of cress increased by irrigation upon consuming 25 % of available water. **El-Far and Teama (1999)** studied the effect of irrigation intervals of 21, 31 and 41 days on the productivity of bread and durum wheat cultivars and obtained highest number of spikes/m^2, 1000- grain weight and grain yield by the 31- day interval. **Mohsen *et al.* (2012)** noted that maize 100 grain weight, grain weight/ear and yield decreased due to extreme drought.

Arbuscular mycorrhizal fungi (AMF) are capable of alleviating effects of drought on plant growth **(Auge 2001 and Miransari 2010).** Symbiotic relationship between AMF and plants produces colonies on the exterior part of the roots resulting in the enhanced uptake of water and nutrients **(Alizadeh *et al.* 2011; Al-Karaki and Al-Raddad 1997; Al-Karaki and Clark 1998; Sylvia *et al.*, 1993).** AMFenhance plant-water relationship through increasing stomatal resistance by adjusting plant hormonal balance and improve nutrient uptake **(Elwan 2001, Harrier 2001 and Rillig and Mummey 2006).** AMF causes the host plant to grow efficiently under the biotic and abiotic stress conditions **(Subramanian and Charest 1997; Porcel *et al.*, 2003 and Artursson *et al.*, (2006).**

The use of rock phosphate (RP) as a P- fertilizer has merit for areas without easy access to P fertilizer. Direct use of RP is more effective in acidic soils than neutral on calcareous soils **(Kucey and Bole 1984**). Combined application of RP with AMF can be effective **(Schussler *et al.* 2001)** and can be adopted by plants to cope with conditions of low available phosphorus **(Shenoy and Kalagudi 2005; Richardson *et al.* 2009).** Exploitation of the soil by the AMF hyphae results in high efficiency in P acquisition **(Bucher 2007 and Smith and Read 2008).** Uptake of P from RP increases by AMF application **(Cabala and Wild. 1982.; Powell 1979; and Waidyanatha *et al.* 1979). Boland (1994)** observed increased uptake of NPK in many crops when AMF was applied. AMF improve soil structure and aggregate stability **(Marshner and dell 1994).**

Hashem (1996) reported that AMF increased seed, straw yield and NPK soya beans.

Materials and Methods

A field experiment was conducted along two successive seasons of winter (2014/2015) and (2015/2016) at El-Nubaria Agricultural Experimental Station of the Agricultural Research Center (ARC), west of Alexandria in the north western coastal zone of Egypt, lying between 30 ° 54- latitude and 29° 30- longitude and a attitude of 22 meter above sea level. The aim was evaluate the effect of arbuscular mycorrhiza fungi (AMF) and rock phosphate (RP) at different irrigation intervals on wheat (*(Triticum aestivum L cv. Sakha 93)* grown on a sandy clay loam calcareous soil. Main properties of soil are shown in Table 1 according to the methods described by **Page *et al*. (1982)** and **Klute (1986)**.

The experimental design was a randomized complete block. There were 12 treatments carried out in split - plot design with three replicates. The experiment included 3 factors as follows: (1) irrigation intervals: three of evry 15 days (I_1), 21 days (I_2) and 35 days (I_3) days (main plot); (2) rock-P: two treatments *i.e* no- P (P_0) and16 kg P ha^{-1} (P_1) and (3) two mycorrhizal treatments: non (M_0) and inoculation (M_1). Treatments of P and M were randomized as sub-plots.

Rock phosphate was added during soil preparation before planting. N and K rats of 250 kg N+120 kg K ha^{-1} were added to all plots. N was as urea (460 g N kg^{-1}) added in 2 equal doses, before the first and second irrigation, and K was as potassium sulphate (400g K kg^{-1}) was given before the first irrigation. Ten plants from each plot were taken randomly dried and kept for analyses. Grain and straw samples were taken. Analyses of soil and plant samples were done using methods cited by **(Chapman and Pratt 1961**; **Jackson 1973; Page *et al*. 1982 and Klute (1986)**.

Table 1. Main characteristics of soil of the experiment.

Soil depth (cm)		0 - 10	10-20	20 -30
Physical properties				
Particle size distribution %	Coarse sand	2.46	2.35	2.07
	Fine sand	49.82	38.12	50.41
	Silt	20.53	26.03	22.22
	Clay	27.19	33.50	25.30
Texture class		sandy clay loam	sandy clay loam	sandy clay loam
Bulk density (Mgm^{-3})		1.44	1.48	1.57
Total porosity (%)		42.17	41.96	39.85
Saturated hydraulic conductivity (cm h^{-1})		2.41	2.36	2.12
Chemical properties				
$CaCO_3$ (g kg^{-1})		286.6	313.2	310.7
Organic matter (g kg^{-1})		6.1	9.6	5.3
pH**		7.79	7.81	7.80
EC (dSm^{-1})**		2.03	1.05	1.30
Soluble anions mmol$_c$ L^{-1}	HCO_3^-	1.47	0.32	1.48
	Cl^-	5.86	3.09	3.29
	SO_4^{2-}	5.63	3.29	3.53
	CO_3^{2-}	0.00	0.00	0.00
Soluble cations mmol$_c$ L^{-1}	Ca^{2+}	2.05	2.82	1.03
	Mg^{2+}	2.11	2.89	1.67
	Na^+	7.80	0.73	5.00
	K^+	1.00	0.30	0.80

*****According to the USDA soil Texture triangle
** pH of 1 : 2.5 soil : water, EC: of past extract

Results and Discussion

1. Soil physical properties

Results of Table 2 show that the soil physical properties were affected mainly by inoculation with arbuscular mycorrhizal fungi

1.1. Soil bulk density

Data in Table 2 show that the soil bulk density (BD) were significantly decreased under AMF treated plots (M_1) compared with untreated plots (M_0). The effect was more pronounced in the top soil layer (0-10 cm). Average decreases were 4.87, 2.55 and 2.21 % for the soil depths of 0-10, 10-20 and 20-30 cm, respectively. This shows that mycorrhizal network around the plant roots causes maiked positive effect on BD **(Karandashov and Bucher 2005**; **Zaki and Radwan 2006**; **Smith and Read 2008**; **El-Sherbiny 2002 and Harvey *et al*. 2015**).

Concerning the main effect of rock phosphate (RP) treatments on soil bulk density, data reveal that RP results had no significant effect in bulk density. **(Sultani *et al.* 2007 and El-Maddah *et al*. 2012)** found that phosphorus application did not affect bulk density.

BD significantly increased by increasing irrigation intervals. Average values for the 0-10 cm layer were 1.31, 1.27 and 1.33 Mg m^{-3} for irrigation interval 15, 21 and 35 days, respectively, corresponding values for the 10-20 cm layer were 1.36, 1.33 and 1.37 respectively, and those for the 20-30 cm layer were 1.43, 1.38 and 1.44 Mg m^{-3}, respectively. These findings agree with those obtained by **(Ghaly and El-Sodany 2009; El-Maddah *et al*., 2012 and Harvey 2012).** The lowest BD (1.21 Mg m^{-3}) with that of the 0-10 cm depth under 21 day irrigation interval treated with RP +AMF.

1.2. Soil total porosity

Table 2 shows that AMF increased the percentage of total porosity (TP). Average values were 46.38 and 49.00 % for M_0 and M_1, respectively at the depth of 0-10 cm with an average increase of 5.6%. Regarding the 10-20 cm depth the increase was 3.0 % while the 20 – 30 cm the increase was 2.8 %. These illustrate the positive effect of the AMF hyphae increasing aggregation of soil particles (**Wilson *et al*., 2009 and Singh *et al*., 2009). Harvey *et al*. (2015)** stated that AMF decreased BDand increased total porosity**.**

Increasing the irrigation intervals from 15 to 35 days increased TP.While the increase to 21 days caused no significant change. Average TP values in the 0-10 cm layer for the 15, 21 and 35 – day The main effect of irrigation intervals were 47.59, 49.00 and 46.49, respectively .corresponding values of the 10-20 cm were 46.67, 47.65 and 46.08 % respectively. Corresponding values for the 20 – 30 cm were 44.36, 46.50 and 43.97 %, respectively. Soil aggregation was reported to increase by short irrigation intervals (**Sersawy *et al.* 1993; El-Maghraby 1997; El-Sherbiny 2002 and Harvey 2012).**

1-3-Saturated hydraulic conductivity

As soil bulk density decreases the total pore space increases and consequently influence soil hydraulic properties, e.g. saturated hydraulic conductivity, infiltration rate and the related transport processes. Data in Table 2 revealed that at all layers the inoculation with AMF (M_1) increased significantly the values of saturated hydraulic conductivity (K_{sat}) compared with un-inoculated (M_0) plots. The main effect of AMF at the depth of 0-10 cm the values of K_{sat} were 5.09 and 5.47 cm h^{-1} for treatments M_0 and M_1, respectively with increasing percentage of 7.5 % whereas, at the second depth recorded 4.39 and 4.86 cm $h^{-1}$for M_0 and M_1, respectively with increment percentage of 10.7 % and at the third layer recorded 3.35 and 3.65 cm h^{-1} for M_0 and M_1, respectively with percentage of 9 %. These results may be due to the effect of AMF hyphae on soil structure (**Smith and Read 2008; Singh *et al.*, 2009 and Harvey *et al.*, 2015)**.

Concerning the effect of irrigation intervals on K_{sat} data in Table 2 indicated that irrigation interval every 21 days (I_2) was of greater effect on K_{sat} than the (I_1) and (I_3). The main effect of irrigation intervals at the top soil layer were 5.29, 5.33 and 5.21 cm h^{-1} for (I_1), (I_2) and (I_3) respectively. While it decreased 4.62, 4.68 and 4.57 cm h^{-1} at the second soil layer (10-20 cm) the decreased at the third soil layer (20-30 cm) to 3.5, 3.53 and 3.47cm h^{-1} under I_1, I_2 and I_3, respectively . The obtained results can be attributed to the short irrigation intervals induced the formation of water stable aggregates, while long one destroyed it and hence increased micropores which led to increase hydraulic conductivity as compared to the short one. These conclusions stand in well agreement with those reported by **(Aziz *et al.*, 1999; El-Sherbiny 2002 and Harvey 2012).**

From the previous discussion, it can deduced, in general, the inoculated plants (M_1) under moderate soil moisture level (I_2) combined with the rock phosphate treatment (RP_1) was the mostly effective in increases the values of total porosity and saturated hydraulic conductivity as well as decreases the values of bulk density significantly compare with untreated plots and with other treatments.

Table 2. Soil physical properties as affectecdby mycorrhizal fungi and rock phosphate under irrigation intervals

irrigation intervals (I)	Rock phosphate (RP)	Mycorrhizal (M)								
		M_0	M_1	mean	M_2	M_3	mean	M_2	M_3	mean
		Bulk density (Mgm-3)			Total porosity (%)			Saturated hydraulic conductivity cm h^{-1}		
0-10 cm										
I_1	RP_0	1.34	1.27	1.31	46.18	49.00	47.59	5.13	5.45	5.29
	RP_1	1.35	1.26	1.31	45.78	49.40	47.59	5.12	5.47	5.30
Mean		1.35	1.27	1.31	45.98	49.20	47.59	5.13	5.46	5.29
I_2	RP_0	1.32	1.24	1.28	46.99	50.20	48.59	5.14	5.49	5.32
	RP_1	1.31	1.21	1.26	47.39	51.41	49.40	5.21	5.47	5.34
Mean		1.32	1.23	1.27	47.19	50.80	49.00	5.18	5.48	5.33
I_3	RP_0	1.35	1.31	1.33	45.78	47.39	46.59	4.95	5.44	5.20
	RP_1	1.34	1.33	1.34	46.18	46.59	46.39	4.96	5.47	5.22
Mean		1.35	1.32	1.33	45.98	46.99	46.49	4.96	5.46	5.21
Grand mean		1.34	1.27	1.30	46.39	49.00	47.69	5.09	5.47	5.28
Means of RP Treatments										
RP_0		1.34	1.27	1.31	46.32	48.86	47.59	5.07	5.46	5.27
RP_1		1.33	1.27	1.30	46.45	49.13	47.79	5.10	5.47	5.28
$L.S.D_{0.05}$		I: 0.01 RP: n.s M: 0.01 I*PR: n.s I*M: 0.02 RP*M: 0.02 I*RP*M: 0.04			I: 1.51 RP: n.s M: 1.94 I I* PR: n.s I*M: 1.07 RP*M: 1.15 I*RP*M: 2.77			I: 0.09 RP: n.s M: 0.11 I*PR: n.s I*M: 0.26 RP*M: 0.16 I*RP*M: 0.34		
10-20 cm										
I_1	RP_0	1.38	1.35	1.37	45.49	47.06	46.27	4.37	4.87	4.62
	RP_1	1.39	1.32	1.36	45.88	48.24	47.06	4.44	4.81	4.63
Mean		1.39	1.34	1.36	45.69	47.65	46.67	4.41	4.84	4.62
I_2	RP_0	1.36	1.32	1.34	47.06	48.63	47.84	4.41	4.89	4.65
	RP_1	1.35	1.33	1.34	47.67	48.24	47.95	4.47	4.94	4.71
Mean		1.36	1.33	1.34	47.36	48.43	47.90	4.44	4.92	4.68
I_3	RP_0	1.38	1.35	1.37	45.49	47.06	46.27	4.33	4.76	4.55
	RP_1	1.39	1.37	1.38	45.49	46.27	45.88	4.34	4.86	4.60
Mean		1.39	1.36	1.37	45.49	46.67	46.08	4.34	4.81	4.57
Grand mean		1.38	1.34	1.36	46.18	47.58	46.88	4.39	4.86	4.62
Means of RP Treatments										
RP_0		1.37	1.34	1.36	46.01	47.58	46.80	4.37	4.84	4.61
RP_1		1.38	1.34	1.36	46.35	47.58	46.96	4.42	4.87	4.64
$L.S.D_{0.05}$		I: 0.01 RP: n.s M: 0.01 I*PR: n.s I*M: 0.03 RP*M: 0.03 I*RP*M: 0.04			I: 1.11 RP: n.s M: 1.25 I*PR: n.s I*M: 1.67 RP*M:1.43 I*RP*M:1.38			I: 0.01 RP: n.s M: 0.25 I*PR: n.s I*M: 0.4 RP*M: n.s I*RP*M: 0.49		
20-30 cm										
I_1	RP_0	1.44	1.41	1.43	43.58	45.14	44.36	3.34	3.63	3.49
	RP_1	1.45	1.42	1.44	43.97	44.75	44.36	3.39	3.65	3.52
Mean		1.45	1.42	1.43	43.78	44.94	44.36	3.37	3.64	3.50
I_2	RP_0	1.40	1.37	1.39	45.81	47.08	46.45	3.35	3.70	3.53
	RP_1	1.39	1.35	1.37	45.91	47.08	46.50	3.37	3.71	3.54
Mean		1.40	1.36	1.38	45.86	47.08	46.47	3.36	3.71	3.53
I_3	RP_0	1.46	1.42	1.44	43.19	44.75	43.97	3.33	3.59	3.46
	RP_1	1.45	1.43	1.44	43.58	44.80	44.19	3.34	3.61	3.48
Mean		1.46	1.43	1.44	43.39	44.77	44.08	3.34	3.60	3.47
Grand mean		1.43	1.40	1.42	44.34	45.60	44.97	3.35	3.65	3.50
Means of RP Treatments										
RP_0		1.43	1.40	1.42	44.19	45.65	44.92	3.34	3.64	3.49
RP_1		1.43	1.40	1.42	44.49	45.54	45.02	3.37	3.66	3.51
$L.S.D_{0.05}$		I: 0.06 RP: n.s M: 0.02 I*PR: n.s I*M: 0.03 RP*M: n.s I*RP*M: n.s			I: 2.18 RP: n.s M: 0.95 I*PR: n.s I*M: 2.06 RP*M: n.s I*RP*M: n.s			I: 0.04 RP: n.s M: 0.17 I*PR: n.s I*M: 2,66 RP*M: n.s I*RP*M: n.s		

Notes: I_1, I_2 and I_3: irrigation every 15, 21 and 35 days respectively; RP_0 and RP_1: non and 16 kg P ha^{-1}; M0 and M1: non and AMF n.s: non-significant at the 5% levels of probability at L.S.D test.

2. Plant growth and yield characters as affectecd by mycorrhizal fungi and rock phosphate under irrigation intervals:

Results in Tables 3 indicate that application of RP combined with AMF with irrigation at 21-day interval gave highest positive effects. Lowest values of plant growth attributes 89.10, 14.90, 5.90, 4.90 and 5.01 for plant height, shoot dry weight plant^{-1}, No. of spike plant^{-1}, dry weight of spike plant^{-1}, weight of 100 grain, respectively. While highest values 96.80, 16.20, 7.60, 7.30 and 6.02, respectively were obtained by AMF-RP treated plant with irrigation at 21-day interval.

As regard to RP effect, the data shows that all yield characters were increased as affected by RP_1 treatment compare with RP_0. The percentage of increaments were 8.29, 12.17, 24.18, 29.67 and 16.11 % for plant height, shoot dry weight plant^{-1}, No. of spike plant^{-1}, dry weight of spike plant^{-1} and weight of 100 grain, respectively.

Regarding AMF and RP, Plant growth and yield characters were affected significantly by irrigation intervals. Data in Table 3 shows that the irrigation every 21 days is recorded the highest values of all charactersas compare with the other two irrigation intervals (15 and 35 days).

The using of rock phosphate application and inoculation with mycorrhizal fungi gave values higher than untrated plots of all yield characters under all irrigation intervals. These increase might be due to the high efficiency of mycorrhizal fungi in mobilizing the fixed form in rock phosphate, moreover, it may be due to its production of growth promoting substances and organic acids which resulted in the availability of P and thus supplying the growing plants with their phosphorous requirements which reflecting the increases nutrient uptake and consequently enhance growth and yield for wheat plant in calcareous soils. These results are in harmony with those obtained by **(Alizadeh *et al*., 2011; Ghorbanian *et al*., 2011; Arab *et al*., 2013; Gomaa *et al*., 2015 and Aissa*et al*., 2016)** who reported that the uptake of phosphorous was influenced by inoculation with mycorrhizal fungi under water stress in calcareous soil.

The inoculation with AMF (M_1) combined with application of rock phosphate (RP_1) under the irrigation every 21 days (I_2) give positive and significant increase in plant growth and yield characters of wheat plant.The mean values were 102.1, 16.8, 9.7, 7.8 and 6.2 for plant height, shoot dry weight plant^{-1}, No. of spike plant^{-1}, dry weight of spike plant^{-1}, weight of 100 grain, respectively.

3-Wheat yield as affected by mycorrhizal fungi and rock phosphate under irrigation intervals

Data in Table 4 show that grain, straw, grain + straw and harvest index (HI) were significantly increased by AMF with irrigation at 21-day interval lowest values were given by the non-AMF, non RP treatment irrigated at 35-day interval. Highest values were given by the AMF + RP treatment irrigated at 21-day interval. AMF gave average increases of 12.4, 11.0,11.5 and 0.9 % for yields of grain, straw, grain + straw and HI respectively. Corresponding average increases due to RP were 17.0, 14.3, 15.2 and 1.1 % respectively. Irrigation every 21 days gave highest values 4010.76, 70.87, and 11097.90 kg ha^{-1} for grain, straw, grain + straw, respectively while irrigation every 35 days gave lowest values (1925.04, 5655.54 and 7580..58, respectively).

4- NPK contents as affected by mycorrhizal fungi and rock phosphate under irrigation intervals:

Data in Table 5 show that NPK contents were significantly increased by AMF with irrigation at 21-day interval lowest values were given by the non-AMF, non RP treatment irrigated at 35-day interval. Highest values were given by the AMF + RP treatment irrigated at 21-day interval. AMF gave average increases of 3.6, 9.8 and 15.0 % for N, P and K respectively for grain while in straw 5.3, 9.3 and 4.0 respectively. Corresponding average increases due to RP were 5.6, 15.8 and 26.0 % respectively. Irrigation every 21 days gave highest values 2.36, 0.32 and 0.61 % for N, P and K, respictively for grain and 1.03, 0.26 and 1,46 respectively for straw while irrigation every 35 days gave lowest values 1.86, 0.17 and 0.20 % respectively for grain while for straw 0.74, 0.19 and 1,08 % respectively. These results were well in agreement with those reported by **(Marchner and dell 1994; Boland 1994; Grant *et al.*, 2004; Arab *et al*., 2013; Gomaa *et al*., 2015 and Aissa *et al*., 2016).** Who reported that inoculated plants with arbusular mycorrhizal fungi (AMF) and rock phosphate application increases total NPK contents in seed and straw for many crops.

conclusions

Generally, irrigation every 21 days and rock phosphate application as well as inoculation with mycorrhizal effective in increases the values of total porosity and saturated hydraulic conductivity as well as decreases the values of bulk density and procured the highest yield of growing crop, yield characters and components and its contents of NPK. In addition inoculated plants with AMF improved resistance of wheat plant to drought stress and compensate some of the effect of the drought stress.

Table 3. Plant growth and yield characters as affected by mycorrhizal fungi and rock phosphate under irrigation intervals.

Irrigation intervals (I)	Rock phosphate (RP)	Mycorrhizal (M)														
		M_0	M_1	mean	M_2	M_3	mean	M_2	M_3	mean	M_2	M_3	mean	M_2	M_3	mean
		Plant height (cm)			Dry weigh of shoot plant^{-1} (g)			No. of spike plant^{-1}			Dry weight of spike Plant^{-1} (g)			Weight of 100 grain (g)		
I_1	RP_0	89.10	91.80	90.45	14.90	15.10	15.00	5.90	6.40	6.15	4.90	5.50	5.20	5.01	5.39	5.20
	RP_1	93.60	96.80	95.20	15.80	16.20	16.00	7.10	7.60	7.35	6.60	7.30	6.95	5.61	6.02	5.82
Mean		91.35	94.30	92.83	15.35	15.65	15.50	6.50	7.00	6.75	5.75	6.40	6.08	5.31	5.71	5.51
I_2	RP_0	97.00	97.90	97.45	15.30	15.90	15.60	7.20	7.80	7.50	5.84	6.51	6.18	5.12	5.51	5.32
	RP_1	99.30	102.10	100.70	16.10	16.80	16.45	8.20	9.70	8.95	6.97	7.80	7.39	6.13	6.20	6.17
Mean		98.15	100.00	99.08	15.70	16.35	16.03	7.70	8.75	8.23	6.41	7.16	6.78	5.63	5.86	5.74
I_3	RP_0	70.20	76.50	73.35	9.10	9.80	9.45	4.30	5.00	4.65	3.30	3.80	3.55	4.17	4.39	4.28
	RP_1	79.30	84.70	82.00	10.90	11.80	11.35	5.60	6.00	5.80	4.30	4.70	4.50	4.78	4.81	4.80
Mean		74.75	80.60	77.68	10.00	10.80	10.40	4.95	5.50	5.23	3.80	4.25	4.03	4.48	4.60	4.54
Grand mean		88.08	91.63	89.86	13.68	14.27	13.98	6.38	7.08	6.73	5.32	5.94	5.63	5.14	5.39	5.26
Means of RP Treatments																
RP_0		85.43	88.73	87.08	13.10	13.60	13.35	5.80	6.40	6.10	4.68	5.27	4.98	4.77	5.10	4.93
RP_1		90.73	94.53	92.63	14.27	14.93	14.60	6.97	7.77	7.37	5.96	6.60	6.28	5.51	5.68	5.59
L.S.D$_{0.05}$		I: 13.5 RP: 3.90 M: 2.95 I*PR: n.s I*M: 15.80 RP*M: 6.20 I*RP*M: 10.30			I: 4.90 RP: .90 M: 0.40 I* PR: 4.40 I*M: 4.80 RP*M: 1.10 I*RP*M: n.s			I: 2.20 RP: 0.90 M: 0.50 I*PR: 1.90 I*M: 2.30 RP*M:3.30 I*RP*M: 2.40			I: 1.9 RP:0.96 M: 0.52 I*PR: n.s I*M:2.26 RP*M: 0.48 I*RP*M: 4.15			I: 0.21 RP: 0.43 M: 0.19 I*PR: 0.57 I*M: 0.39 RP*M: 0.31 I*RP*M: 0.30		

Note: I_1, $I_2$and I_3: irrigation every 15, 21 and 35 days respectively; RP_0 and RP_1: non and 16 kg P ha^{-1};
M_0 and M_1: non and AMF n.s: non – significant at the 5% level of probability at L.S.D test.

Table 4. Wheat yieldas affected by mycorrhizal fungi and rock phosphate under irrigation intervals.

Irrigation intervals (I)	Rock phosphate (RP)	Mycorrhiza (M)											
		M_0	M_1	mean	M_2	M_3	mean	M_2	M_3	mean	M_2	M_3	mean
		Grain yield (kgha^{-1})			Straw yeild (kgha^{-1})			Biological yield (kgha^{-1})			Harvest index (%)		
I_1	RP_0	3360.72	3785.04	3572.88	5292.72	5767.44	5530.08	8653.44	9552.48	9102.96	93.21	95.10	94.15
	RP_1	3906.72	4328.40	4117.56	6243.12	7094.64	6668.88	10149.84	11423.04	10786.44	92.38	90.94	91.66
Mean		3633.72	4056.72	3845.22	5767.92	6431.04	6099.48	9401.64	10487.76	9944.70	92.79	93.02	92.91
I_2	RP_0	3409.92	3872.40	3641.16	6720.96	6986.16	6853.56	10130.88	10858.56	10494.72	80.78	85.59	83.19
	RP_1	4127.28	4633.44	4380.36	6961.20	7680.24	7320.72	11088.48	12313.68	11701.08	89.33	90.31	89.82
Mean		3768.60	4252.92	4010.76	6841.08	7333.20	7087.14	10609.68	11586.12	11097.90	85.06	87.95	86.50
I_3	RP_0	1681.44	1920.24	1800.84	4769.04	5640.72	5204.88	6450.48	7560.96	7005.72	62.56	60.95	61.76
	RP_1	1933.92	2164.56	2049.24	5736.00	6476.40	6106.20	7669.92	8640.96	8155.44	60.51	60.12	60.32
Mean		1807.68	2042.40	1925.04	5252.52	6058.56	5655.54	7060.20	8100.96	7580.58	61.54	60.54	61.04
Grand mean		3070.00	3450.68	3260.34	5953.84	6607.60	6280.72	9023.84	10058.28	9541.06	79.80	80.50	80.15
Means of RP Treatments													
RP_0		2817.36	3192.56	3004.96	5594.24	6131.44	5862.84	8411.60	9324.00	8867.80	78.85	80.55	79.70
RP_1		3322.64	3708.80	3515.72	6313.44	7083.76	6698.60	9636.08	10792.56	10214.32	80.74	80.46	80.60
L.S.D$_{0.05}$		I: 54.68 RP: 115.45 M: 0.62 I*PR: 193.50 I*M: 119.90 RP*M: 51.90 I*RP*M:193.70			I: 189.90 RP: 249.10 M: 189.90 I* PR: 478.90 I*M: 456.80 RP*M: 225.70 I*RP*M: 399.90			I: 375.50 RP: 351.10 M: 369.8 I* PR: 580.90 I*M: 460.20 RP*M: 137.70 I*RP*M: 659.80			I: 10.40 RP: 0.17 M: 0.19 I*PR: 9.7 I*M: 12.79 RP*M: 0.13 I*RP*M: 4.80		

Note: I_1, $I_2$and I_3: irrigation every 15, 21 and 35 days respectively; RP_0 and RP_1: non and 16 kg P ha^{-1};
M_0 and M_1: non and AMF n.s: non – significant at the 5% level of probability at L.S.D test.

Table 5. NPK contents asaffectecd by mycorrhizal fungi and rock phosphate under irrigation intervals.

Irrigation interval (I)	Rock phosphate (RP)	Mycorrhiza (M)								
		M_0	M_1	mean	M_2	M_3	mean	M_2	M_3	mean
		N %			P %			K %		
Grain										
I_1	RP_0	89.10	91.80	90.45	14.90	15.10	15.00	5.90	6.40	6.15
	RP_1	93.60	96.80	95.20	15.80	16.20	16.00	7.10	7.60	7.35
Mean		91.35	94.30	92.83	15.35	15.65	15.50	6.50	7.00	6.75
I_2	RP_0	97.00	97.90	97.45	15.30	15.90	15.60	7.20	7.80	7.50
	RP_1	99.30	102.10	100.70	16.10	16.80	16.45	8.20	9.70	8.95
Mean		98.15	100.00	99.08	15.70	16.35	16.03	7.70	8.75	8.23
I_3	RP_0	70.20	76.50	73.35	9.10	9.80	9.45	4.30	5.00	4.65
	RP_1	79.30	84.70	82.00	10.90	11.80	11.35	5.60	6.00	5.80
Mean		74.75	80.60	77.68	10.00	10.80	10.40	4.95	5.50	5.23
Grand mean		88.08	91.63	89.86	13.68	14.27	13.98	6.38	7.08	6.73
Means of RP Treatments										
RP_0		85.43	88.73	87.08	13.10	13.60	13.35	5.80	6.40	6.10
RP_1		90.73	94.53	92.63	14.27	14.93	14.60	6.97	7.77	7.37
$L.S.D_{0.05}$		I: 0.01 RP: n.s M: 0.01		I*PR:	I: 1.51 RP: n.s M: 1.94 I			I: 0.09 RP: n.s M: 0.11		
Srtraw										
I_1	RP_0	4.90	5.50	5.20	5.01	5.39	5.20	5.01	5.39	5.20
	RP_1	6.60	7.30	6.95	5.61	6.02	5.82	5.61	6.02	5.82
Mean		5.75	6.40	6.08	5.31	5.71	5.51	5.31	5.71	5.51
I_2	RP_0	5.84	6.51	6.18	5.12	5.51	5.32	5.12	5.51	5.32
	RP_1	6.97	7.80	7.39	6.13	6.20	6.17	6.13	6.20	6.17
Mean		6.41	7.16	6.78	5.63	5.86	5.74	5.63	5.86	5.74
I_3	RP_0	3.30	3.80	3.55	4.17	4.39	4.28	4.17	4.39	4.28
	RP_1	4.30	4.70	4.50	4.78	4.81	4.80	4.78	4.81	4.80
Mean		3.80	4.25	4.03	4.48	4.60	4.54	4.48	4.60	4.54
Grand mean		5.32	5.94	5.63	5.14	5.39	5.26	5.14	5.39	5.26
Means of RP Treatments										
RP_0		4.68	5.27	4.98	4.77	5.10	4.93	4.77	5.10	4.93
RP_1		5.96	6.60	6.28	5.51	5.68	5.59	5.51	5.68	5.59
$L.S.D_{0.05}$		I: 0.09 RP: n.s M: 0.11 I*PR: n.s I*M: 0.26 RP*M: 0.16 I*RP*M: 0.34			I: 0.09 RP: n.s M: 0.11 I*PR: n.s I*M: 0.26 RP*M: 0.16 I*RP*M: 0.34			I: 0.09 RP: n.s M: 0.11 I*PR: n.s I*M: 0.26 RP*M: 0.16 I*RP*M: 0.34		

Note: I_1, $I_2$and I_3: irrigation every 15, 21 and 35 days respectively; RP_0 and RP_1: non and 16 kg P ha^{-1};
M_0 and M_1: non and AMF n.s: non – significant at the 5% level of probability at L.S.D test.

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إضافة فطر الميكروهيزا وصخر الفوسفات على القمح النامى فى أرض جيرية تحت فترات رى مختلفة و تأثيرها على نمو النبات و خواص الأرض الطبيعية

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أقيمت تجربة حقلية لموسمين متعاقبين فى الموسم الشتوى (٢٠١٤ / ٢٠١٠٥) و (٢٠١٥/٢٠١٦) فى محطة بحوث النوبارية التابعة لمركز البحوث الزراعية بهدف دراسة تأثير فطر الميكروهيزا وصخر الفوسفات تحت فترات رى مختلفة على خواص الأرض ونمو نبات القمح فى الأرض الجيرية. تمت التجربة بتصميم القطع المنشقة واشتملت على ١٢ معاملة بثلاثة مكررات وهى ثلاثة معاملات رى:الرى كل ١٥، ٢١ و ٣٥ يوم ومعاملتين صخر فوسفات: بدون إضافة و معدل ١٦ كجم فوسفور للهكتار و معاملتين من التلقيح بفطر الميكروهيزا: بدون تلقيح وبتلقيح البذور .

كانت معاملة التلقيح بفطر الميكروهيزا تحت مستوى الرى المعتدل (الرى كل ٢١ يوم) مع إضافة صخر الفوسفات لها الأثر الأكبر فى زيادة قيم المسامية الكلية و معامل التوصيل الهيدروليكى وفى نفس الوقت خفض قيمة الكثافة الظاهرية مقارنة بالمعاملات الأخرى. بينت النتائج أيضا ان نفس المعاملة كانت هى الأعلى لمعظم قيم نمو وصفات المحصول ومحتوى النبات من NPK لنبات القمح.