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PHOSPHORUS AND POTASH EFFECTS ON WHEAT CROP UNDER THE INFLUENCE OF VARIOUS IRRIGATION LEVELS IN ARID REGIONS OF ALGERIA

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Abstract:
Three field experiments were carried out at the experimental Station of Adrar, during three successive growing seasons 2013/2014 to 2015/2016. The aim of this study was to investigate the relationship between the water supply levels and phosphorus and potash applications. The experimental design was a split plot design with three replications. The main plots were five irrigation levels (50, 70, 90, 100 and 120% of reference evapotranspiration (ET0)), while the sub- plots contained four fertilization treatments: control (T0), K_2O (T1), P_2O_5 (T2) and K_2O + P_2O_5 (T3). The obtained yields were 5.64, 5.37 and 7.87 t ha^{-1}, during the three consecutive seasons. They were significantly affected by phosphorus apply ($P < 0.01$) during the all trial seasons. No significant effect of potash was observed during the first season. Its effects were significant ($P < 0.05$) and highly significant ($P < 0.01$) during the second and the third season respectively. Water treatment effects were significant on yield and almost all its yield components. The highest water efficiency was recorded when water apply was close to 100 % of MET and elements N P K are available.

Keywords: fertilization, significant effect, split plot, water levels, wheat yield, yield components

1. INTRODUCTION

During the last two decades, wheat production and consumption is considered as among the most significant crops in the world. Owing to existing and upcoming difficulties, such as increased consumption and the demand for grain for both food and fuel, it is necessary to increase the yield potential of wheat (Curtis et al., 2014). Wheat is the epicenter of global food security grain, its production needs to double to feed a world population that is estimated to reach approximately 9 billions by 2050 (Acevedo et al., 2018).

However, growing water scarcity and competing water demands are expected to reduce diversion of water for agriculture in the future. Thus, efforts are needed to utilize the available limited water resources efficiently and effectively. Multiple uses of water are inevitable to produce more with less water (Khan, 2010). In this context, Ertek (2014) has mentioned that any fertilization application program must be able to meet the nutritional requirements of the plants and allow the efficient use of irrigation water, Because, the soils generally having lower quality and nutrient content can be a limiting factor for obtaining high yields (Káš et al., 2019). Currently, the excessive use of chemical

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fertilizers in agriculture field is under debate due to environmental problems. Therefore, it is important to search for sustainable plans to reduce harmful effects of farming practices (Emami et al., 2018). That is why, Yousaf et al. (2017) have noted that balanced fertilizer application is not only essential for producing top quality crops in high yields but also for environmental sustainability. In this context, according to Rütting et al. (2018), deficit of reactive N is limiting food production in many areas, still causing hunger today in the developing world, while excess of reactive N causes inefficient use and environmental problems in mainly the industrialized world. For these reasons, optimization of fertilization enables to obtain a yield of high quality and quantity, brings economic profits, and reduces environmental threats (Tabak et al., 2020). In this context Kubar et al. (2019) have mentioned that the values for all the growth and grain yield components of wheat markedly increased with the application of potassium. Maximum potassium rate of 100 kg K_2O per ha produced higher yields and increased the content of nitrogen, phosphorous and potassium in grain and straw of wheat. It must be noted that soil quality is a complex functional concept, which cannot be measured directly but only be inferred from both soil characteristics and cultivation practices (Triantafyllidis et al., 2018).

In Algeria, despite the fact that during the last decade, cereal production was above the ten-year average of 2.97 million tones, however, it remains well below the 8 million tones required for domestic consumption (Hales, 2019). The deficit is largely filled by imports, characterized by a steadily increasing increase (Bessaoud, 2016).

Saharan regions of Algeria are an arid area that depends on irrigated agriculture and intense fertilization due to its scarce water resources and less fertile soil. The average yields obtained (4.2 t ha^{-1}) remain relatively low compared to the peak yields achieved (7.5 t ha^{-1}) in these regions (Laaboudi et al., 2016). In these areas where the soils are heterogeneous and relatively alkaline, the problem of fertilization management is acute. That is why, deficiency symptoms in occasional or generalized phosphorus in wheat fields are often observed. Potassium is not used at all or not supplied in adequate amounts due the belief that soil is rich in this element.

This study was aimed at investigating the response of wheat to the phosphorus and potash fertilizers and their interactions with water apply in terms of yield and its components.

2. MATERIALS AND METHODS

2.1. Experimental site

Three field experiments were conducted at the experimental Station of National Institute of Agronomic Research. Located at Adrar region in southwestern Algeria (27° 49′ N, 00° 18′ E, 278 m) (figure 1).

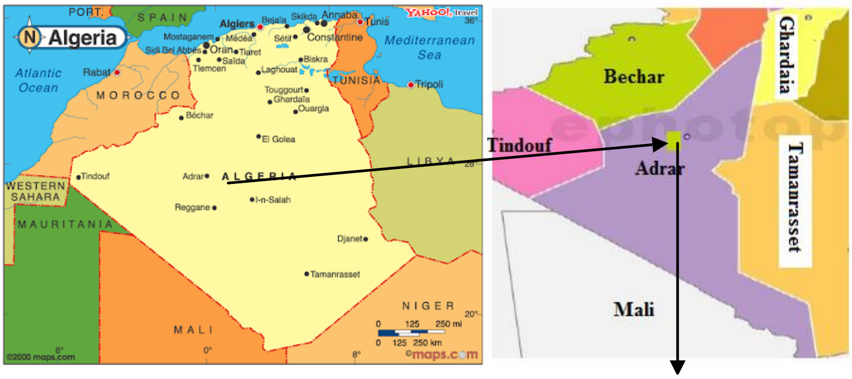

Figure. 1. Location of the experimental site

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The climate is characterized by high temperature, low humidity and low precipitation (<25 mm/year). Consequently, evaporation and water requirements are very important. The wind blows almost continuously, predominantly East-North-East. The average values of meteorological parameters and their statistical description over 11 years (2009 - 2019) are summarized in Table 1.

Table 1. Mean values of meteorological parameters and their statistical values

		M T	m T	R H	E	U	P
Months	January	29.5	0.0	64.9	4.3	134	3.7
	February	39.0	-1.0	56.5	5.7	137	2.6
	March	40.0	0.0	49.7	8.0	147	1.6
	April	44.5	3.2	39.7	10.4	150	3.7
	May	46.0	10.0	42.4	13.1	164	1.3
	June	48.5	14.2	34.4	14.4	143	0.3
	July	49.5	20.0	31.8	16.0	161	0.0
	August	48.0	19.0	39.3	14.6	160	1.9
	September	47.0	14.0	39.8	11.7	142	1.5
	October	43.0	5.2	42.9	8.9	133	2.7
	November	37.5	4.0	57.1	5.7	135	1.5
	December	31.5	0.0	69.3	4.3	131	0.2
Statistical descriptions	Mean	42.1	7.3	47.2	9.7	144.7	1.9
	Median	43.5	4.5	42.5	9.5	142.5	2.0
	Mode	48	0	40	4^a	131^a	2
	Std. Deviation	6.4	7.7	12.0	4.2	11.7	1.4
	Variance	41.3	59.8	144.9	18.0	137.1	2.1
	Range	20	21	37	12	33	4
	Minimum	30	-1	32	4	131	0
	Maximum	50	20	69	16	164	4
	1 st Quartile	38.2	.00	39.2	6.00	134.25	.25
	3 th Quartile	47.7	14.00	56.75	13.75	157.50	3.00

M T: maximum temperature (°C), m T: minimum temperature (°C), RH: relative humidity (%), E: evaporation (mm/day), U: wind speed (Km/day), P: rainfall (mm/month)

2.2. Physic and chemical characteristics of soil

At the start of each season, the soil of the experimental field was analyzed. Chemical property values of the soil are depicted in table 2.

Exchangeable base values (mEq/100 g of soil) were for potash K=0.31, Sodium Na+=0.68 Magnesium Mg++= 1.72, Calcium Ca++ = 3.25 and Cation exchange capacity CEC=7.66.

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The soil has a high percentage of sand: 63.6% and 31.3% of fine sand and coarse sand respectively. The clay value was 6.9%. Fine silt and coarse silt values were 3.9% and 4.7% consecutively. The irrigation water source was the groundwater aquifer. Its electrical conductivity C.E was 2.5 ms/cm. Plant material was wheat (*Triticum durum*), variety named Shèn-S, selected by CIMMYT/ITGC in 1990, 88 cm tall (Benbelkacem and Kellou, 2000).

Table 2. Chemical properties of the soil

Parameters	Season 1	Season 2	Season 3
pH	8.25	8.33	8.40
EC (dS/m)	3.64	4.02	4.01
Total Ca (%)	8.32	7.5	7.4
Active Ca (%)	0.62	0.56	0.54
Available K_2O (meq/100 g)	0.17	0.06	0.05
Available P_2O_5 (mg.Kg^{-1})	10. 00	12.50	20.88
Available N (%)	0.12	0.08	0.08
Carbone C (%)	0.67		

pH=potential of hydrogen, EC=electrical conductivity, Ca=limestone, CEC=exchange capacity, K_2O=available exchangeable potassium, P_2O_5 =available phosphorus, N=total nitrogen, C=carbone

2.3. Experimental design and treatments

Four fertilizer treatments: control (T0), K_2O (T1=100 units/ha), P_2O_5 (T2=184 units/ha), and K_2O + P_2O_5 (T3=100 units + 184 units respectively). Phosphorous was added in the form of triple superphosphate at the rate of 184 units and potassium at the rate of 100 units. For each plot, the recommended dose of chemical fertilizer were added as positive control i.e. nitrogen fertilizer was added in the form of urea (46 % N) at the rate of 280 (units. ha^{-1}).

Five water levels: 50, 70, 90, 100, 120% of irrigation requirements were applied in a randomized split plot design with three replicates. The experimental unit consisted of 12 rows each of 6 meter length and 20 cm between rows, where the size of each plot was 12.5 m². Seed rate of wheat (Shen-S; durum wheat) was 200 kg/ha. Planting dates were on 14th to 16th November in the three experimental seasons, respectively.

Measured variables were: grain yield, straw yield, grain number/spike, 1000 grain weight, plant height, spike length, harvest index.

2.4. Data analysis

Analysis of variance (ANOVA) was performed out using XLSTAT Software 2014. Whenever treatment effects were significant, mean separations were made using the least significant difference (LSD) test at the 5% or 1% levels of probability.

3. RESULTS AND DISCUSSIONS

3.1. Vegetative behavior towards phosphorus and potassium fertilization

The response of wheat to phosphorus fertilization has started from the 3-4 leaf stage. In this context, Gaj and Rębarz (2014) have reported that the absorption of phosphorus by wheat begins from the start of growth until the flowering stage. At the tillering stage, the vegetative development of wheat under P_2O_5 treatments was important versus the control. Similar result was obtained by Holzapfel et

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al. (2016). Indeed, the average lengths of stems at harvest were 58 cm and 73.66 cm respectively in T0 and T2 plots.

The P element has showed a very positive effect on root extensions: 32.2 cm and 37 cm respectively in T0 and T2. According to Hansel and Ruiz Diaz (2017), this was because the managing phosphorus fertilization results in significant changes in root growth and nutrient uptake by wheat. During the first trial season, potassium (K) intake did not improve root extension. Moreover, roots were more developed in well irrigated plots than stressed plots. In this context, Seto et al. (2018) have noted that significant relationship between the total root length and the P uptake implies that the lower uptake of P under the rainfed condition was due partly to the restricted root growth.

3.2. Symptoms of phosphorus deficiency

According to soil analysis results, soil of experimental site was nitrogen (N) and phosphorus (P) deficiencies. In fact, nearly all soils in southern of Algeria are nitrogen and phosphorus deficient in their natural state. N and P deficiencies are major yield limiting factors in many parts of the world (Zhu et al., 2013). Nevertheless, leaf color is one of the common diagnostic indicators used to prevent losses of potential yield. Thus, following-up of crop development during its growing cycle has highlighted three symptom levels according to the degree of deficiency:

- a purplish color at the stems and at the base of the leaves. This is a slight deficit and the crop is developing normally, without serious repercussions on the yield.
- a violated coloration at stems levels, yellowish leaves. They were manifested by slowed growth, reduced vegetative habit and limited number of tillers. This is a large deficit which is seriously affecting the harvest.
- yellow coloring with puny vegetation accompanied by partial drying out of the basal leaves. The number of tillers was very low and the aerial and root development was inhibited. This indicated that the soil phosphorus was very low. This confirmed results of Niu et al. (2013), who had underlined that the phosphorus deficiency favors a weak root and vegetative development. In this situation, the expected harvest will be very low. For the last two cases, an urgent phosphorus correction is necessary.

3.3. Water and fertilizer effects on yields and their components

The response of wheat to different treatments of water and fertilizer resulted in significant differences in yields, but also in tiller occurrence and dry matter production. Figure 2 show the interaction effects between the applied water levels and fertilizer treatments. The high yields were obtained when water supply was close to 100 % of maximum evapotranspiration (MET) without any fertilizer deficiency (figure 2a). This proved that nutrient deficiencies are a major source of yield and income loss in winter wheat. Similar result was obtained by Zhu et al. (2013). The highest yield (3.39 t ha^{-1}) was obtained during the third season (figure 2b). Regarding the best fertilizer treatment, it always was the T3 during the three seasons; the highest yield was recorded in the third season (figure 2c). Overall, there was a positive relationship between the achieved yields and the water supply until the threshold satisfaction of wheat water need, beyond which the adding water became nefarious (figure 2d).

Statistical analysis revealed significant effects ($P< 0.01$) of water treatment on grain yield, straw yield, 1000 grain weight and on spike length. Fertilizer treatments have significant effects ($P< 0.01$) on grain yield, plant height and straw yield. Except straw yield and harvest index, seasons have significant effects ($P< 0.01$) on all yield components. WT* Seasons interaction has significant effect only on grain yield. No significant effect of WT*FT and FT*Seasons interactions on yield and its components (Table 3).

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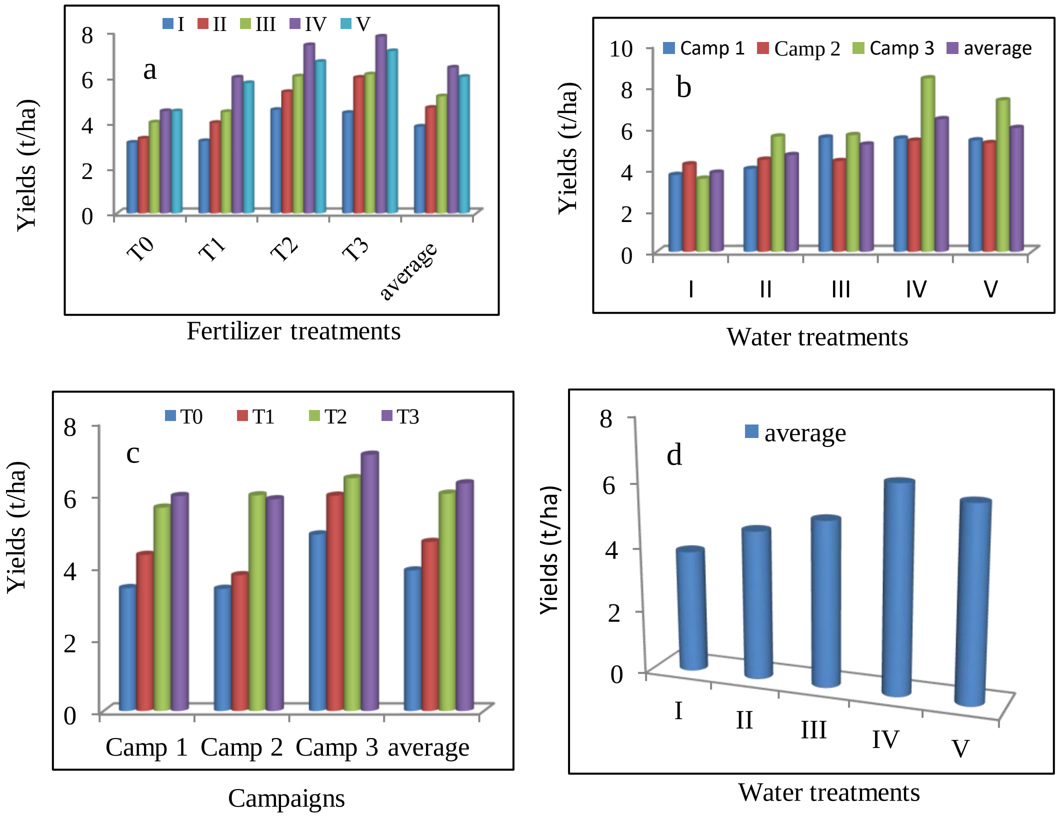

Figure 2-Yields according to water and fertilizer treatments: a-yields and fertilizer treatment for each water treatment, b-yield and water treatment for during each season, c-yield and fertilizer treatment during each season, d-yield average of water treatment during three seasons

Table 3. Treatments and interaction effects on yields and yield components

Variation source	grain yield	straw yield	grain number/spike	1000-grain wt.	plant height	spike length	harvest index
WT	< 0.0001	< 0.0001	0.0056	< 0.0001	0.0115	< 0.0001	0.0727
FT	< 0.0001	< 0.0001	0.0488	0.8535	0.0002	0.1011	0.0135
Seasons	< 0.0001	0.0147	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0011
WT*FT	0.3530	0.2668	0.2253	0.3452	0.3046	0.2310	0.5723
WT*Seasons	< 0.0001	0.0201	0.0027	0.0007	0.0015	0.0002	0.1597
FT*Seasons	0.0606	0.6425	0.3869	0.1403	0.2802	0.3797	0.7679

WT: water treatment, FT: fertilizer treatment, WT*FT interaction, WT*seasons interaction, FT*seasons interaction

According to expectations, wheat yields achieved in the control treatment (without any phosphorus and potassium fertilization) were always the lower. Data presented in Table 3 show that yields ($P < 0.001$) were significantly affected by water and fertilizer treatments, seasons and interaction between water treatment and seasons. Regarding yield components, no treatment has affected harvest index. While straw yield, grain number/spike, 1000- grain wt, plant height and spike length

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were affected by some treatments. Overall, most of them did not expressed significant differences between treatments.

ANOVA results show that straw yield depended significantly on the water treatment and fertilizer treatment. Seasons and interaction between treatments did not have any significant effect on this parameter. However, the grain yield depended significantly on the water treatment, fertilizer treatment and seasons and interaction between water treatment and seasons.

In order to distinguish which treatment that has really a significant effect, least significant difference (LSD) test has been performed (Table 4).

Table 4. Treatments and interaction effects on yields and yield components

Pr. and LSD	T	grain yield (t ha^{-1})	straw yield (t ha^{-1})	grain number /spike	1000-grain wt. (g)	plant height (cm)	spike length (cm)	harvest index
Water treatment	WT1	3.89	10.13	56.28	37.49	61.00	5.19	0.38
	WT2	4.68	11.15	61.44	42.72	59.67	5.59	0.42
	WT3	6.01	12.62	59.39	40.12	61.97	5.30	0.41
	WT4	6.30	15.05	63.03	43.85	63.58	5.84	0.43
	WT5	5.22	14.99	62.86	39.36	64.72	5.81	0.40
Pr.		< 0.0001	< 0.0001	0.0056	< 0.0001	0.0115	< 0.0001	0.0727
LSD		0.73	2.11	3.94	2.40	3.39	0.36	0.03
Fertilizer treatment	T0	3.9	10.63	57.96	40.51	58.34	5.39	0.38
	T1	4.7	11.26	59.89	40.44	62.13	5.57	0.41
	T2	6.0	14.52	62.53	40.70	64.42	5.65	0.42
	T3	6.3	14.74	62.02	41.19	63.86	5.58	0.43
Pr.		< 0.0001	< 0.0001	0.0488	0.8535	0.0002	0.1011	0.0135
LSD		0.66	1.89	NS	NS	4.25	NS	0.02
Seasons	Camp. 1	4.82	12.61	56.97	35.23	63.92	5.18	0.39
	Camp. 2	4.74	12.00	56.05	42.88	72.41	6.25	0.40
	Camp. 3	6.09	13.72	68.78	44.02	50.23	5.21	0.44
Pr.		< 0.0001	0.0147	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0011
LSD		0.95	NS	4.97	3.76	4.31	0.3	0.04

According to LSD (0.29 t ha^{-1}), no significant effect between WT3 and WT4 on grain yield, but they have significant effect on straw yield (LSD= 2.42 t ha^{-1}). Regarding 1000 grain weight, no significant difference was recorded between WT1 and WT5. The LSD test suggested that statistically, the differences in spike length between water treatments of WT2, WT3, WT4, WT5 were significant ($P<0.01$).

Fertilizer treatments have significant effects ($P<0.01$) on grain yield and straw yield. The LSD value (= 0.66 t ha^{-1}) indicated that all fertilizer treatments have significant effects on grain yield improvement, while FT1 did not has any significant effect on straw yield.

Seasons have significant effects on grain yield and almost all yield components. Significant grain yield improvement was recorded during the third season. This was due not only to the studied treatments but also it was due to the climatic conditions. Thus, during the third season the average temperature was the lowest. Especially during the grain filling phase when the average of temperatures recorded were 21.14°C, 21.71°C and 18°C respectively for the first, the second and the third season.

These results are similar to those obtained by Laib (2011), although Bashir et al. (2015) pointed out that the response of wheat yield to phosphate fertilization depends on the applied rate and the method of application.

As for the results relating to potash inputs, they showed fluctuations in relation to their effect on yields. They were insignificant, significant (T2 *) and highly significant (T2 **) during the three consecutive seasons.

During the third season, the effect of fertilization on the yield is highly significant for all treatments. The LSD Values indicate that the differences come simultaneously from the inputs of phosphorus and potash. The yield response to potassium fertilizer inputs is highly significant. In this sense Brhane et al. (2017) claimed that the application of different rates of potassium fertilizer has a significant impact on wheat yield. Thus, under the conditions of the study area (arid to semi-arid), these researchers added 30 kg of K_2O ha^{-1} to a recommended mixed fertilizer (NPKSZn), they obtained a 120% improvement compared to the control.

Finally, we can conclude that in the case of a soil rich in potash, the additional inputs in this element are unnecessary. The application of potassium fertilizers requires a preliminary analysis of soil to confirm their necessity. In this direction, Saifullah et al. (2002) obtained the highest yield (4.57 t ha^{-1}) with an application of 225 kg of K_2O/ha, beyond which all performance components are reduced.

4. CONCLUSIONS

Although the wheat yield averages have slightly increased in recent years, they are yet far to the potential yields that can be achieved in the study area. Thus, the achieved yield by this work (8 t ha^{-1}) and peak yield (7.8 t ha^{-1}) achieved by some farmers testify this reality. Low yields are partly attributed to technical problems, especially fertilization. To avoid this problem, special attention must be given to this subject.

We have noted that the symptoms of phosphorus deficiency appear very early in plots poor from this element and take several aspects according to the deficiency level. This has a negative effect on the vegetative development and on the final yield. To remedy this problem, early correction supplies are necessary.

Regarding potassium, it is certain that the soils in the study area are moderately rich in this element. Nevertheless, we must take into consideration the exports by crops which are also enormous. Results show that the application of potassium fertilizer has significantly affected the yield of wheat in the study area beginning of the second season. So, this falsifies the thought that potassium fertilization is unnecessary for Saharan soil. Therefore, it is essential to take it into account in the fertilization program, especially from the third year of operation

Indeed, improving soil fertility and preserving it remain the essential keys to meeting the challenges facing Saharan agriculture. Knowledge of the soil content of nutriment elements, their dynamics in the zone explored by the roots and the crop needs of these elements are the essential conditions for better managing fertilization.

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