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INFLUENCE OF PHOSPHORUS CONTENT OF SEEDS ON THE PLANT GROWTH OF 11 VARIETIES OF DURUM WHEAT (*TRITICUM DURUM* DESF.)

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Abstract: The phosphorus has an important role in the plant growth. Furthermore, the use of alternative methods, such as the cultivation of appropriate cultivars to satisfy the plant nutrient requirements and to reduce the negative effect of chemical fertilisers, is highly recommended. Thus, the aim of the present study was to screen the influence of the seed phosphorus content on the plant growth of 11 durum wheat (*Triticum durum* Desf.) varieties from numerous origins. Different morphological traits and their relation with the phosphorus quantities were investigated. These traits include root and aerial length, number of leaves, number of herbaceous tillers and number of ears. The obtained results revealed significant differences in the studied morphological characters among the examined wheat varieties. In addition, a positive correlation was recorded between the phosphorus levels in seeds and some morphological characters, particularly the aerial length, the number of leaves and tillers and the root length. It is concluded that higher phosphorus content in seeds has helped some varieties to achieve a good start. This suggests the necessity to consider this property when choosing durum wheat varieties for regions where P is scarce at sowing. It also fits into a broader global vision of sustainability by lowering the need for phosphate fertilisers.

Key words: durum wheat, sustainability, morphological parameters, correlation, genotype.

Introduction

Phosphorus (P) is an essential nutrient for plants that affects the productivity of crops (Karandashov and Bucher, 2005; Lin et al., 2020). P is the second most limiting nutrient for crop production after nitrogen (N) (Bernardino et al., 2019).

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Worldwide, 67% of the total farmed land is considered P deficient (Cakmak, 2002). P exhibits poor mobility and availability to plants in soil. Low soil phosphorus availability is a primary constraint for plant growth in many terrestrial ecosystems, as P is involved in several energy transformation and biochemical reactions essential for plant growth and development (Liao et al., 2008). Thus, plants have various adaptive strategies to boost P absorption and mobilisation to cope with reduced P availability in soil (Guo et al., 2022). Besides, the P reserve in the seed can have a positive impact on crop establishment in P-deficient environments.

In durum wheat, the development of the root system is one of the traits associated with P-efficient genotypes (Liu et al., 1998). At harvest, most phosphorus is found in the grain, while the content in the straw is generally low (Johnson, 1993). Growing plants store few simple phosphate ions, generally PO_4^{-3} (orthophosphate), unlike seeds. This storage ensures a good start to growth and the development of germinating seeds before the root system is established (Johnston and Steen, 2000). The embryo in plant seeds needs phosphorus to grow and develop. Before the embryo develops a root system, its only source of phosphorus is the seed, so phosphorus from the seed has the greatest direct effect on plant yield during the very early stages of plant growth (Bolland and Paynter, 1990). The importance of phosphorus during the early stages of development is illustrated by the impossibility of compensating for its temporary absence with later additions (Gervy, 1970). Phosphorus is mainly stored in the form of polyphosphates such as phytates, which represents around 50% of the total phosphorus contained in legume seeds and around 60–70% in cereal seeds. In germinating seeds, phosphorus is released by the phytase enzyme and incorporated into other molecules (Azeke et al., 2011). The effect of the initial P reserve on plant performance is mainly significant under specific conditions such as low P environments (Ros et al., 1997) or drought (Burnett et al., 1997).

Thus, the aim of the present study is to screen the influence of the P content in seeds on the development of wheat varieties in a semi-arid region characterised by low to medium phosphorus levels and drought.

Material and Methods

Plant material

The plant material consisted of 11 durum wheat varieties, cultivated in Algeria (local, introduced and improved): Waha, GTA dur, Semito, Boussellam, Vitron, Cirta, Wahbi, Beliouni, Mohamed Ben Bachir, Djennah Khetifa, and Guemgoum R'khem. The main characteristics of these varieties are shown in Table 1.

Methodology

Seeds of the chosen 11 contrasting varieties of durum wheat (*Triticum durum*) were sown in trays filled with a phosphorus-free peat substrate, to germinate and obtain rooted seedlings. Sowing was carried out on 12 May 2021. The trial was set up in the greenhouse located at the Khenchela Agricultural Vocational Training Institute in Algeria.

Table 1. Properties of the studied durum wheat varieties.

Code	Variety	Origin	Type	Registration year
V1	Waha	Syria	Pure line	1997
V2	GTA dur	Mexico	Pure line	2001
V3	Simeto	Italy	Pure line	2001
V4	Boussellam	ICARDA-CIMMYT	Pure line	2000
V5	Vitron	Spain	Pure line	1997
V6	Cirta	Algeria	Pure line	1999
V7	Wahbi	Algeria	Pure line	1986
V8	Beliouni	Algeria	Local variety	/
V9	Mohamed Ben Bachir	Algeria	Local population	2001
V10	Djenah Khetifa	Algeria/Tunisia	Local population	/
V11	Guemgoum R'khem	Algeria	Local population	2008

Source: Authors' systematisation based on published literature.

Once they had emerged and reached a stage of growth at which they could be transplanted, the seedlings were grown hydroponically. This method was chosen because it allows: better control and homogenisation of the mineral input, and the production of healthy roots free from any disturbance that could interfere with the plants' own responses (Dubos, 2001). Furthermore, it avoids soil stresses, allowing rapid growth and good plant development under totally controlled conditions, as well as making it easier to monitor and measure the root development at each stage.

The plants were transplanted into the hydroponics tank as follows:

1. At the beginning, the cups intended to hold the seedlings were perforated, and then holes were made in the polyester plate to accommodate the number of the tested varieties and their repetitions (Figure 1a) (Mahlangu et al., 2016);
2. Once the seedlings were placed in the cups, they were surrounded by pieces of sponge (Figure 1b). The sponge serves as a support to help the plant to maintain its balance;
3. Next, the seedlings surrounded by the sponge were placed inside the cups so that both the aerial part and the root system were outside the cup (Figure 1c);

4. The seedlings transplanted into the hydroponic system were labelled (V1, V2, V3, etc.) to distinguish them and make it easier to monitor and record their progress (Figure 1d);

5. A nutritive solution was then prepared and poured into the hydroponic tank to feed the seedlings. This preparation was made in two separate compositions: the first (A) consisted of 850g of NPK, 350 g of KNO_3, 400 g of magnesium sulphate and 10 L of water. The second solution (B) consisted of 100 g of calcium nitrate, 35 g of iron chelate and 10 L of water. For the A+B solution to be used, 1 L of the mixed solution was diluted in 100 L of water (Figure 1e);

6. The polyester plate containing the cups with the seedlings was placed on top of the water film in the tank, so that the root system was immersed in the water in the tank (Figure 1f), according to the experimental protocol described by Mahlanagu et al. (2016), with three repetitions.

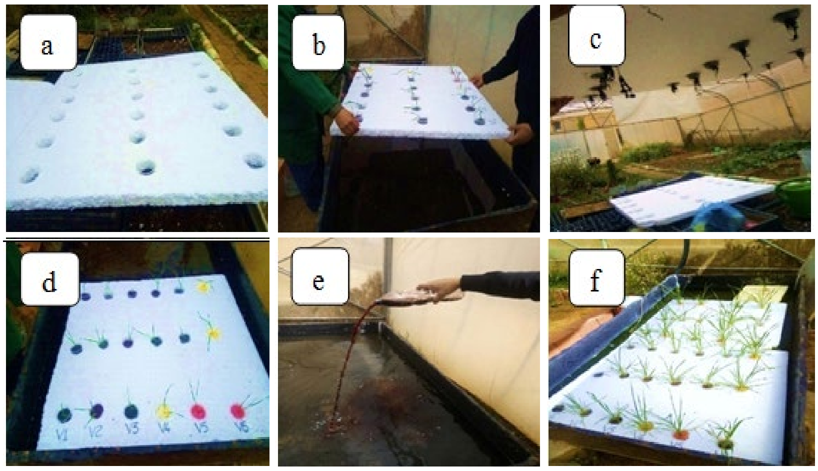

Figure 1. Steps followed when transplanting plants into the hydroponic tank.
Source: Authors' own data.

The phosphorus content of the seeds: the phosphorus dosage is carried out on the extract obtained by mineralisation according to the general procedure. Phosphorus is present in the extract as orthophosphate. In the presence of vanadate and molybdate ions, phosphorus forms a yellow phospho-vanado-molybdate complex that can be measured by a molecular absorption spectrophotometer at 430 nm.

According to the Misson method (ref. NF U42-246), phosphorus was measured using molecular absorption spectrophotometry as a yellow phosphovanadomolybdate complex. A nitro-vanadate-molybdate reagent was used with the mineralised extract. Vanadomolybdophosphoric acid, which is stable and yellow, is created when orthophosphate combines with vanadate and molybdate ions in an acidic medium. A spectrophotometer was used to measure the absorbance at a wavelength of 430 nm following a 15-minute incubation period at room temperature to allow the colour to develop. The phosphorus content of the samples was determined using a monopotassium phosphate (KH_2PO_4) calibration range of 0 to 20 mg/L P (Vogel and Mendham, 1989).

Morphological parameters: The first period occurs during the installation of seedlings in the trays (before transplanting into the hydroponic tank) (12 May 2021). At this stage, we measured the following parameters: the seedling length (before transplanting) and the leaf number before transplanting.

During the second period, which is the transplantation day in the hydroponic tank (15 May 2021), the root length (during transplanting) was measured.

In the final period, after transplanting (19 May, 27 May, 03 June, 09 June, and 24 June 2021), the plant was removed from its polyester cup and the following parameters were measured:

– Number of leaves (Leaf 19, Leaf 27);
– Aerial length (Aerial 19, Aerial 27, Aerial 3, and Aerial 9);
– Number of herbaceous tillers (from the fourth leaf stage to the early swelling stage);
– Number of ears;
– Root length on different dates (Root 19, Root 27, Root 3, Root 9, and Root 24).

All measurements were repeated three times, and the lengths are given in cm.

Using SPSS software, version 10, two analyses were carried out: analysis of variance ANOVA (at a threshold of 5% followed by a Student-Newman-Keuls test) to compare the means of the various measured morphological parameters, in addition to a correlation test between the quantity of phosphorus contained in the seeds and the morphological parameters.

Results and Discussion

ANOVA analysis revealed a highly significant difference in the phosphorus content of seeds among the studied varieties (Table 2). The Waha and GTA dur varieties had the lowest quantities, whereas the Mohamed Ben Bachir, Vitron, Beliouni and Cirta varieties recorded the highest levels of P (Figure 2). Similarly, the examination of the measured morphological parameters shows highly significant differences between the varieties during all the growth phases (Table 2). In general, the Djenah Khetifa variety (V10) recorded the highest values after the transplanting stage, while the Waha variety (V1) had the lowest ones (Figure 3).

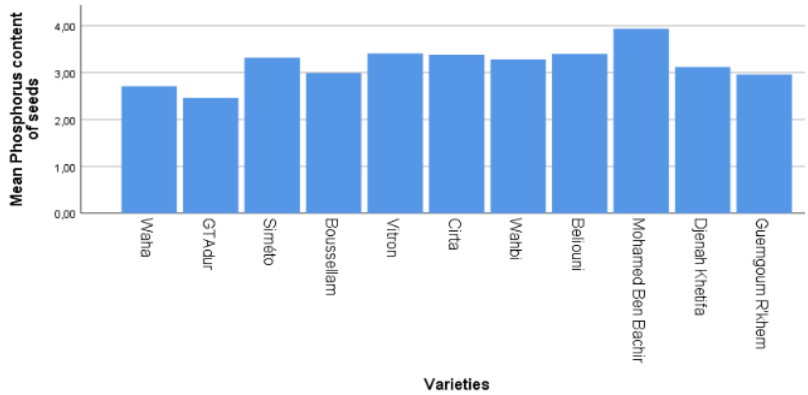

Figure 2. Phosphorus content (mg P/g dry matter) of seeds of varieties.
Source: Authors' own data.

Table 2. ANOVA results for measured parameters.

Measured parameters	Significance
Phosphorus content of the seeds	<0.001*
Plant length before transplanting	<0.001*
Leaf number before transplanting	0.473*
Root length during transplanting	0.022*
Aerial length 19/05/2021	<0.001*
Root length 19/05/2021	<0.001*
Number of leaves 19/05/2021	<0.001*
Aerial length 27/05/2021	<0.001*
Root length 27/05/2021	0.001*
Number of leaves 27/05/2021	<0.001*
Aerial length 03/06/2021	<0.001*
Root length 03/06/2021	0.002*
Number of tillers 03/06/2021	<0.001*
Aerial length 09/06/2021	<0.001*
Root length 09/06/2021	0.001*
Number of tillers 09/06/2021	0.000*
Number of ears 24/06/2021	0.000*
Root length 24/06/2021	0.000*

**Significant at $P < 0.05$.* Source: Authors' calculations.

On the other hand, the analysis of the relation between the phosphorus content of the seeds and some morphological characters revealed a positive correlation with the plant length before transplanting in addition to the aerial length, the number of leaves and tillers, and the root length during three measurements after transplanting (27/05, 03/06, and 09/06/2021) (Table 3).

Massle (1985) has confirmed that the number of tillers produced depends on the variety, the climate, and the plant’s mineral and water supply. Moreover, Palta and Watt (2009) have mentioned that variations in root system depth are linked to genotypes.

The varieties Mohamed Ben Bachir, Cirta, Vitron, Beliouni, Djenah Khetifa and Guemgoum R'khem have a higher seed phosphorus content, which enables them to develop their root systems better and therefore achieve a good ear tillering capacity. The obtained results are similar to those of Hazmoune (1994), who carried out a study on the characterisation of the root system of a number of durum wheat varieties in relation to yield components.

Table 3. Correlations between phosphorus levels in seeds and morphological parameters in the studied wheat varieties.

Morphological parameters	Correlation with P content of seeds
Plant length before transplanting	0.540
Leaf number before transplanting	0.249
Root length during transplanting	-0.170
Aerial length 19/05/2021	0.186
Root length 19/05/2021	-0.025
Number of leaves 19/05/2021	-0.207
Aerial length 27/05/2021	0.407
Root length 27/05/2021	0.471
Number of leaves 27/05/2021	0.449
Aerial length 03/06/2021	0.375
Root length 03/06/2021	0.359
Number of tillers 03/06/2021	0.467
Aerial length 09/06/2021	0.487
Root length 09/06/2021	0.331
Number of tillers 09/06/2021	0.569
Number of ears 24/06/2021	-0.357
Root length 24/06/2021	0.3116

Source: Authors’ calculations.

According to Zhang et al. (1990), root growth rate, root yield, and root height were lowest for seeds with low phosphorus content in barley21 days after planting. Besides, the highest root dry weight and the fastest spike emergence were observed in seedlings grown from seeds with higher phosphorus content (Thomson and Bolger, 1993). These findings are consistent with those of Derrick and Ryan (1998), who argue that seed P concentration and seed mass after three weeks, had a substantial beneficial impact on seedling shoot dry mass; in other words, shoot dry mass and seed P content had a positive correlation. After three weeks, the root dry mass and seed P content likewise showed a positive correlation.

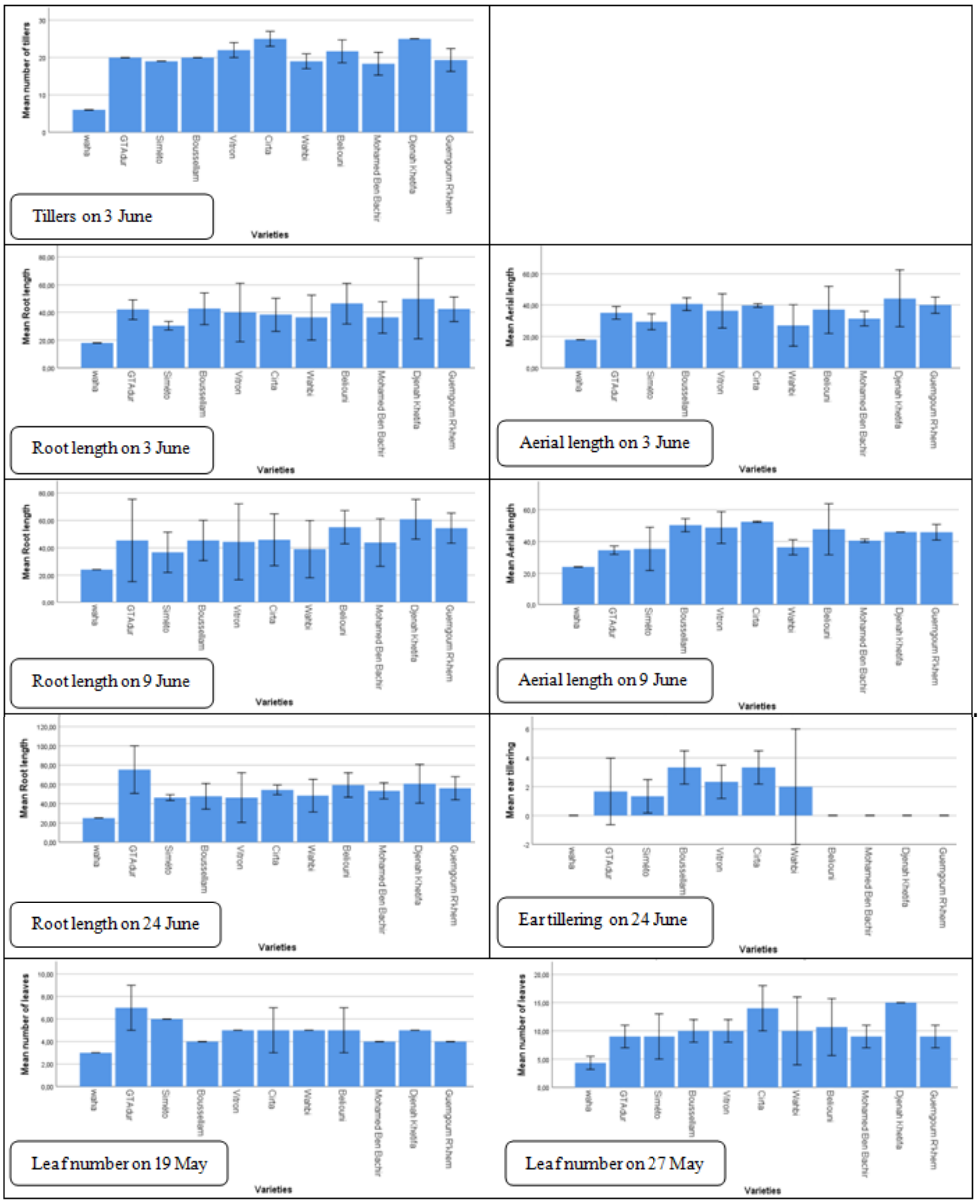

Figure 3. Agro-morphological parameters of the studied varieties. The values represent means ± standard deviation. Lengths are indicated in ‘cm’.
Source: Authors’ own data.

The results of the present study, which are supported by the results of previous studies, showed that seed phosphorus content had a significant effect on different organs, and that this effect was independent of external P supply. For instance, in the study on subterranean clover seed (*Trifolium subterraneum* cv. Dalkeith) with phosphorus concentrations of 0.75% (high P seed) and 0.48% (low P seed) and of uniform size, Thomson and Bolger (1993) found that seedling emergence numbers were 35% greater for the high P seed, and this effect was independent of external P supply. They also found that leaf emergence was faster and shoot dry weight was greater for seedlings grown from high seed P compared with seedlings grown from low seed P, but only when external P supply was deficient for plant growth.

White and Veneeklas (2012) have suggested that this relation between phosphorus seed content and root length is likely due to faster initial root growth, which provides seedlings with earlier access to growth-limiting resources, such as water and mineral elements. Furthermore, a previous study has indicated that the genotype developing a greater root length is the most efficient at using phosphorus, and one aspect of this efficiency is that root development performance was correlated with the initial phosphorus reserve of the grain (Schweiger et al., 1995). The seed P reserves can sustain maximal growth of cereal seedlings for several weeks after germination, until the plant has three or more leaves and an extensive root system (White and Veneeklas, 2012). Seed P is the only phosphorus source available to sustain the initial growth of seedlings and, upon germination, seed P reserves are rapidly mobilised and translocated to emerging root and shoot tissues (Schweiger et al., 1995). This P source is subsequently supplemented by P uptake by the developing root system. Thus, greater seed P reserves allow seedlings to establish faster and ultimately produce plants with higher yields (Zhu and Smith, 2001). Indeed, according to Marco and De (1990), three batches of uniform-weight wheat seeds with phosphate (P) contents of 0.14, 0.17, and 0.19% were seeded in soil treated with various P treatments. The faster the seedlings emerged, the greater the seed P content. All plants cultivated at the maximum applied P concentration were comparable in size by 25 days after planting, however plants from seeds with higher P concentrations had an advantage with lower applied P. Besides, in a study to determine the relative contribution of seed P reserves and exogenous P to maize nutrition during the early stages of growth, Nadeem et al. (2011) stated that, although the two P supply processes overlapped in time, seed P was the main source of P during the early stages of growth. Of the total P in the seed, 60% and 92% were transferred to the growing seedlings by the 7^{th} and 17^{th} days after sowing, respectively, after which seed P ceased to be a significant source of P for growth.

Conclusion

The first result worth mentioning is the variability observed in the different studied morphological characters, including the root system growth, among the 11 durum wheat varieties studied. In general, this variability is characterised by its proportional relationship with grain phosphorus content. This suggests that higher seed phosphorus content has contributed to the better initial growth of certain varieties, which may prompt consideration of this parameter when selecting durum wheat varieties for areas with low phosphorus availability at sowing. Additionally, this approach aligns with a broader vision of sustainability by reducing the use of phosphate fertilisers.

The Cirta, GTA dur, Beliouni, Djennah Khetifa and Guemgoum R'khem varieties have high phosphorus levels and are characterised by a long root system and a large number of spikes. As a result, these varieties produce good yields when improved, as is the case for Cirta and GTA dur, and show better adaptation to difficult conditions when they are local varieties, such as Beliouni, Djennah Khetifa, or Guemgoum R'khem.

As recommendations and future directions, raising awareness among cereal farmers about the use of varieties with high phosphorus content should be part of a broader approach to improve productivity and sustainability, enabling individual fields to yield better and farms to become more resilient.

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UTICAJ SADRŽAJA FOSFORA U SEMENU NA RAST BILJAKA 11 SORTI TVRDE PŠENICE (*TRITICUM DURUM* DESF.)

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R e z i m e

Fosfor ima važnu ulogu u rastu biljaka. U tom kontekstu, preporučuje se primena alternativnih metoda, kao što je gajenje odgovarajućih sorti radi zadovoljenja potreba biljaka za hranljivim materijama i smanjenja negativnih uticaja hemijskih đubriva. Stoga je cilj ovog istraživanja bio da se ispita uticaj sadržaja fosfora u semenu na rast biljaka 11 sorti tvrde pšenice (*Triticum durum* Desf.) različitog porekla. Ispitivane su različite morfološke osobine i njihov odnos sa količinama fosfora. Ove osobine obuhvataju dužinu korena i stabla, broj listova, broj bočnih izdanaka (bokora) i broj klasića. Dobijeni rezultati su pokazali značajne razlike u ispitivanim morfološkim osobinama među proučavanim sortama pšenice. Pored toga, utvrđena je pozitivna korelacija između nivoa fosfora u semenu i pojedinih morfoloških osobina, naročito dužine stabla, broja listova i izdanaka, kao i dužine korena. Zaključuje se da je veći sadržaj fosfora u semenu pomogao pojedinim sortama da ostvare dobar početni rast. Ovo ukazuje na potrebu da se ovo svojstvo uzme u obzir prilikom izbora sorti tvrde pšenice za područja u kojima je oskudan sadržaj fosfora u zemljištu u vreme setve. Takođe, ovo se uklapa u širu globalnu viziju o poboljšanju održivosti poljoprivredne proizvodnje, kroz smanjenu upotrebu fosfatnih đubriva.

Ključne reči: tvrda pšenica, održivost, morfološki parametri, korelacija, genotip.

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