Journal of Agricultural and Crop Research
Vol. 5(2), pp. 17-24, July 2017
ISSN: 2384-731X
Research Paper

The response of two naked barley varieties (*Hordeum vulgare* L.) to four phosphorus fertilizer levels

Amani Ben Naceur[1] • Hatem Cheikh-M'hamed[2] • Jaime A. Teixeira da Silva[3] • Chedly Abdelly[4] • M'barek Ben Naceur[5]*

[1]Faculty of Sciences, El-Manar University, Tunis, Tunisia.
[2]Department of Agronomy, National Agronomic Research Institute of Tunisia, Ariana-Tunisia.
[3]P. O. Box 7, Miki-cho post office, Ikenobe 3011-2, Kagawa-ken, 761-0799, Japan.
[4]Borj Cedria Center of Biotechnology, Tunisia.
[5]National Gene Bank of Tunisia, Boulevard Leader Yasser Arafat 1080, Cherguia 1, Tunis, Tunisia.

*Corresponding author. E-mail: nour3alanour@yahoo.com. Tel:+216 98 901 641. Fax: +216 71 771 827.

Accepted 9th June, 2017

Abstract. The objective of this study was to determine the effect of phosphate fertilization on the biological and grain yield and to identify the optimum dose generating the best performance of these two varieties, which had extraordinary β-glucan content in previous study. Four rates of P (0, 50, 100, 150 and 200 kg of P_2O_5/ha) were applied at sowing date and two trials were carried out: the first was done in pots to exhibit the effect of (P) on plantlet root growth while the second was conducted in the field in a completely random design with three replications. In the last case, all elementary plots were fertilized with 25 kg/ha of ammonium nitrate at the elongation stage. The gradual increase in P-fertilization positively affects root growth of the first trial. It affects also biological and grain product of both varieties in the second trial in the field, up to 100 kg/ha. However, both varieties exhibited contrasting behaviour. The first variety «Tombari» showed a significant increase in the number of grains/spike and spike weight; while the second one «Giza 130» produced significantly more fertile tillers/m^2 and more grain/spike according to P-fertilizer increase. Therefore, phosphate fertilization contributes to barley growth and yield up until 100kg/ha in a genotype-independent manner, which responded in different way. Beyond this dose, «Tombari» reacted negatively to the phosphate increase, while «Giza 130» exhibited an unaffected behaviour.

Keywords: Barley, fertilizer, naked, phosphorus, yield components.

INTRODUCTION

Nitrogen (N), phosphorous (P) and potassium (K) are considered as the most important macronutrients for plant growth (Obidiebube *et al.*, 2012). P influences root growth, allows plants to enhance nutrients utilization, and consequently improves flower production, fertilization and yield (Rahimi *et al.*, 2012). It plays also an important role in photosynthesis, in macromolecules structure such as nucleic acids and energy transfer (Sharma *et al.*, 2013). Plants that receive an adequate amount of P at an early stage will grow more vigorously due to the promotion of root growth, and they will reach maturity more rapidly than plants with an inadequate P supply (Teng *et al.*, 2013). According to Warraich *et al.* (2002), wheat plants will produce more fertile tillers/m^2 and more biological yield in response to P fertilization.

Many experiments have been conducted on the effect of N and/or P on yield and yield components of wheat (Baraich *et al.*, 2012; Sarker *et al.*, 2015), rice (Sharma *et al.*, 2011; Usman, 2013), maize (Rashid and Iqbal, 2012; Minapour *et al.*, 2013) and lavindin (Erbas *et al.*, 2017).

However, few papers have assessed the effect of P supply on barley production (Jones *et al.*, 2003; Eftekhari *et al*., 2012).

In Tunisia, barley is commonly used for human and animal consumption, it is still cultivated on marginal lands and often without fertilization. In these regions, low soil fertility and drought are the most limiting barley production constraints (Bergaoui, 2010). Despite being one of the major national food crops, its output average, during the last ten years (2006 to 2015), is about 0.926 T/ha (Tunisian Ministry of Agriculture, 2016), which is much lower than the world's average. Therefore, in order to ensure good production of barley, adequate fertilization should be applied and variety that is capable of being valued should be selected.

Many trials conducted on various crops and in different climatic conditions have responded positively to the application of N and/or P fertilizer. Therefore, Gurmani *et al.* (2006) showed the positive effect of P fertilizer on fodder and grain yield of vetch under rain fed conditions. They obtained the highest green fodder, dry matter and grain yields after applying 15 and 40 kg/ha of N and P fertilizer, respectively. Niri *et al.* (2010) studied the effect of N and P application on yield and protein content of lentil in dry land conditions. Optimal grain and protein yield were obtained with 25 and 40 kg/ha N and P, respectively. Baraich *et al.* (2012) found another combination of P and K for wheat and proposed 90 kg/ha of P (as P_2O_5) combined with 30 kg/ha of K to get the most effective wheat yield. Carpici and Tunali (2012) found that 30 kg/ha of P_2O_5 and 30 kg N/ha were necessary for optimum dry matter and protein content for a mixture vetch/barley.

Farooq *et al.* (2016) have studied the effect of various levels of phosphorus (40, 60 and 80 kg/ha) combined with placement methods (broadcast and band placement) for better quantity and quality of fodder produced by forage maize. They find that P_2O_5 level of 80 kg per hectare applied with band method is better technique for significant improvement in yield and quality traits of forage maize.

Karamanos *et al.* (2014) studied the response of wheat, barley and canola to range of soils P fertilizer applied at different rate in a side-band or seed-placed. They showed that P allows crops to respond positively to greater rates of P fertilizer regardless of their placement. However, 50 kg P/ha applied in side banding resulted an increase of barley yield of about 0.6 Mg/ha greater than when no P fertilizer was applied. On the contrary, Turk *et al.* (2003), showed that the use of 80 kg/ha of P_2O_5 improved the yield compound and the biological product of barley growing in rain fed area of Jordan. As a result, recommendations might depend on the crop and the climate of the region.

Therefore, investigating the response of barley to P_2O_5 fertilization in different climatic area is essential to understand the appropriate P level required for arid and semi-arid regions such as Tunisia.

To achieve this objective, two naked barley varieties «Tombari» from Tunisia and «Giza 130» from Egypt, were selected. The predominant barley type is hulled, having a hard fibrous hull, and is mainly used for feed in Tunisia. The other type is the hulless or naked barley in which the hull is easily removed, being similar to wheat. This barley is rare both in Tunisia and around the world but it is the richest of β-glucan content, at least in North Africa (Ben Naceur, 2013). That is why it regains interest in their use as human nutrition.

β-Glucan, a major component of soluble fiber with many health benefits, could play an important role, not just in preventive medicine, but also in the therapeutics of major illnesses (Vetvicka and Novak, 2011). Because of their high content of β-glucan, the two naked barleys have drawn our attention and thus optimized their yield and productivity is keys to effective crop management.

This paper studied the optimum P level that could result in higher biomass production, grain yield, yield components and other relevant characteristics that are directly linked to the nutritional quality of naked barley. This is the first study conducted in Tunisia, which examines the behavior of naked barley in response to P fertilizer.

MATERIALS AND METHODS

The experiment was conducted at the National Agronomic Research Institute of Tunisia during two growth seasons (2013 and 2014). The amount of precipitation in the growing period was 450 mm and 438 mm, respectively, indicating a normal growth season for the two years. The soil type of the test site was clay loam with 70 mg/kg of P, 284 mg/kg of K and a pH of 8.3. According to Ryan *et al.* (2012), soil is poor in P when the level is between 51 and 100 mg/kg and rich in K when the level is between 201 and 300 mg/kg. Consequently, K fertilizer was not applied in this study. Two naked barley varieties were used: «Tombari», originating from Tunisia (hereafter V1), and «Giza 130», from Egypt (hereafter V2). V2 was supplied by Prof. M. Saker from the National Research Centre (NRC) of Egypt in the frame of the New Partnership for African's Development (NEPAD) project. The key characteristics of these two varieties were previously described (Ben Naceur *et al.*, 2012).

Four levels of P (0; 50; 100; 150; and 200 kg of P_2O_5/ha) were applied at sowing date for the two experiments conducted. The first one was carried out in a small pot (ϕ = 12 cm) to study the effect of P on root growth, 30 days after sowing date (DAS). The second one was carried out in the field. For the last experiment and at the elongation stage (70 DAS) all plots were fertilized with 25 kg/ha of ammonium nitrate. No K was applied since the soil is rich in K (284 mg/kg). Each plot was 3 × 4.0 = 12 m^2 in size and consisted of 15 lines

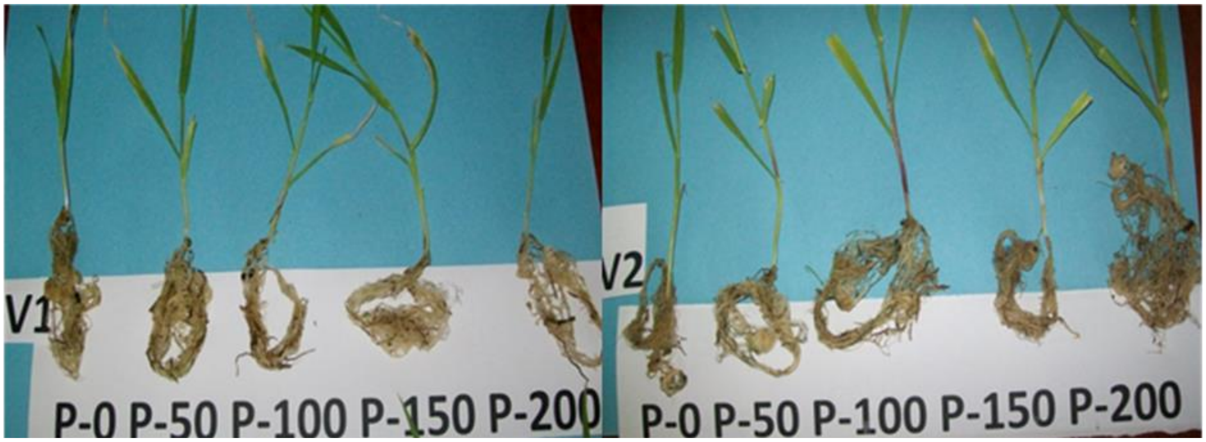

Figure 1. Root growth of two naked barley varieties (V1 = «Tombari» and V2 = var. «Giza 130») in response to different rates of P (P-0, P-50, P-100, P-150 and P-200 kg/ha).

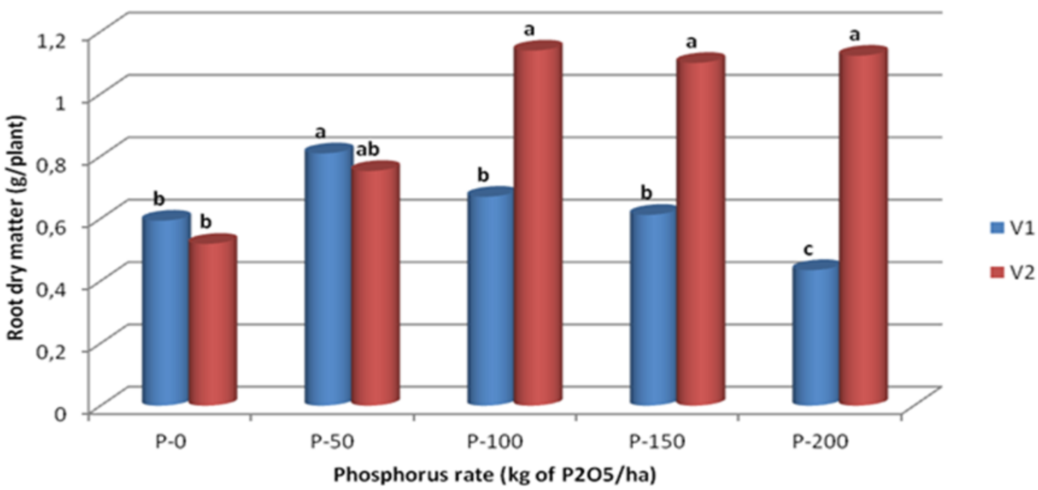

Figure 2. Root dry weight variation of two naked barley varieties (V1 = «Tombari» and V2 = var. «Giza 130») in response to different rates of P (P-0, P-50, P-100, P-150 and P-200 kg/ha).

(20 cm between each line) of 4 m long for each line. Seeds were sown 20 cm apart in rows with a density of 300 grains/m^2. Seeds were sown by hand. The research was conducted in a completely random design with three replications.

For the first trial, only root weight was quantified, by means of a precision balance. For the second trial, the vegetative traits assessed were number of tillers/m^2 and the biological product/ha. The reproductive traits (number of grains/spike, spike weight and grain yield/ha) were measured at the maturity stage.

The data collected for vegetative and reproductive traits were analyzed using Statisca software (Statsoft.com, France), following an analysis of variance (ANOVA). Significant differences between treatments were determined using the Newman-Keul's test at $P \leq 0.05$ or 0.01 to compare differences among treatment.

RESULTS AND DISCUSSION

Vegetative growth

Root growth

The root growth showed two contrasted behavior according to the variety and the phosphorus rate used. For V1 variety, the root growth was improved when P-50 was applied and then decreased for the other rates. However, for V2 variety, the root growth increased when the phosphorus rate was increased (Figure 1). The roots, dried in oven at 80°C for 5 days, were weighed. These results are shown in Figure 2.

The result of this experiment revealed that the root dry matter was dependent on varieties, which were different in their response to phosphorus supply. The root dry matter

Table 1. Analysis of variance of V1 and V2 root dry matter subjected to different phosphorus levels.

V1			V2		
Treatment	**Means and grouping**	**Number**	**Treatment**	**Means and grouping**	**Number**
P-50	0.80933[a]	3	P-50	0.7530[ab]	3
P-100	0.67033[b]	3	P-100	1.1390[a]	3
P-150	0.61223[b]	3	P-150	1.0995[a]	3
P-0	0.59333[b]	3	P-0	0.5191[b]	3
P-200	0.43487[c]	3	P-200	1.1227[a]	3

Table 2. Effect of phosphorus fertilizer level on number of tillers/m^2 in two naked barley varieties.

Phosphorus rates (kg/ha)	**Number of tillers/m^2**	
	V1	**V2**
P-0	227.38[c]	197.72[c]
P-50	279.84[ab]	235.98[c]
P-100	327.37[a]	407.64[a]
P-150	333.75[a]	339.37[b]
P-200	260.32[b]	319.67[b]

Legend: Different letters within a column indicate significant differences (*P* = 0.05) as assessed by the Neuman-Keul's test (*n* = 90 (30 plants/repetition × 3 repetitions). V1 = var. «Tombari»; V2 = var. «Giza 130». P_2O_5 fertilizer levels: P-0, P-50, P-100, P-150, and P-2000 corresponding to 50, 100, 150 and 200 kg P/ha, respectively.

increased in V2 with increasing phosphorus rate until P-100 and stabilized afterward. The statistical analysis (ANOVA) done separately for each variety is shown in Table 1. The Newman-Keuls classification showed three different classes for V1 and two homogenous classes for V2

Various experiments carried out on different species and varieties to assess the effect of P fertilizer on dry root product showed different responses depending on the variety and the environment. In this context, Baraich *et al*. (2012) showed similar behavior of two wheat varieties subjected to various P fertilizers. To explain this contrasting behavior of our two barley varieties, V2 may be more able to have an intense branching of the root system as it was suggested by Peret *et al*. (2014) and as it is illustrated in Figure 2. In addition, V2 may stimulate more efficiently the dissolution of phosphates through acidification of the rhizosphere than V1. Another possible way is that V2 has specialized transporters at the root/soil interface that are more efficient for extracting P from soil and transporting it across membranes than V1. In fact, the availability of P in the soil varies considerably from one-plant varieties to another according to the plant ability to dissolve inorganic phosphate via root exudates or organisms naturally present in the rhizosphere.

The decrease of V1 root growth beyond 50 kg/ha may be related to harmful effect of excessive phosphorus in its absorbing hairs which help the plant to absorb water and nutrients. Alternatively, it may be due to the decrease of the plant's ability to uptake other important nutrients like zinc and iron in the experimental soil which is alkaline (pH = 8.3).

Similar results have shown the reduction of root growth when the soil is excessively rich in phosphate. Recently, Zhang *et al.* (2013), have shown excessive applications of P fertilizers leading to an accumulation of P in soil, which lowers P-fertilizer-use efficiency and leads to P losses via runoff or its insolubilization in the rhizosphere.

Furthermore, Gruber *et al.* (2013) and Erbas *et al.* (2017) suggested the occurrence of some changes in the root system architecture (RSA) upon a wide range of stress (excess or deficit in water, salt or nutrient such as phosphorus) which explains the reduction in root growth observed at V1 when the phosphorus exceeds the optimal dose required for this variety.

Number of tillers/m^2

The number of tillers/m^2 as affected by P fertilizer is shown in Table 2. This parameter increased as P level increased, peaked at 100 kg/ha for V1 and V2 and then declined as the dose exceeded P-100 (No significant difference was observed between P-100 and P-150 for V1).

V2 showed no significantly different response when P was between 0 and 50 and also between P-150 and P-200 kg/ha.

Table 3. Interaction between phosphorous (P) level × naked barley genotypes and its impact on biological yield.

Phosphorus rates (kg/ha)	Biological yield (T/ha)	
	V1	V2
P-0	9.53^{cd}	7.48^{d}
P-50	11.53^{abc}	9.06^{cd}
P-100	14.15^{a}	15.19^{a}
P-150	13.33^{ab}	14.32^{ab}
P-200	10.90^{bcd}	14.05^{ab}

Legend: Different letters within a column indicate significant differences (*P* = 0.05) as assessed by the Neuman-Keul's test (*n* = 90 (30 plants/repetition × 3 repetitions). V1 = var. «Tombari»; V2 = var. «Giza 130». P_2O_5 fertilizer levels: P-0, P-50, P-100, P-150, and P-2000 corresponding to 50, 100, 150 and 200 kg P/ha, respectively.

These results correspond to Sisie and Mirshekari (2011) who showed the increase of wheat tillers with the increase of P fertilizer while excessive application of P decreased tiller number compared to the control. In addition, they are in compliance with Ottman (2011), also working in wheat, who found the greatest number of tillers/m^2 at 90 kg of P_2O_5/ha, which is almost similar to what we found.

Although the number of tillers/m^2 remains higher in V2 than in V1, the reduction of this number in both varieties as a function of the increase in phosphate dose could be attributed to the immobilization of fertilizer phosphorus with time due to dehydration of the fertilizer zone through root action or normal soil drying.

Biological yield

As suggested by several authors (Balemi and Negisho, 2012; Dhankhar *et al.*, 2013; Wakene *et al.*, 2014), differences in response to P fertilizer are under both environmental factors and plant characteristics. Table 3 reinforces this hypothesis and showed an increase of the biological product with P-fertilizer dose increase for both varieties. However, this product declines slightly when the dose exceeds P-100. Besides there are no significant differences between the biological products generated by P-100, P-150 and P-200 for V2 variety. Similar results were obtained by Noori *et al.* (2014) and by Wakene *et al.* (2014), who obtained the highest total biomass at the highest P level, used and the lowest biological yield in the control. However, the biomass produced varied with soil moisture, confirming the dependence of the biomass produced on environmental factors.

In our case, the progressive P-fertilizer dose used may have enhanced more tillers and a greater leaf area, resulting in higher biological yield (Table 3). P-dose significantly affected the biological yield of both naked barley varieties, including the dose × variety interaction. P-100 resulted in greatest biological yield in V1 and V2 (14.15 and 15.19 T/ha, respectively). The lack of P-fertilizer resulted in the least biological yield in the control (7.5 and 9.5 T/ha, respectively for V2 and V1). Similar result was found by Bukvić *et al.* (2003) who showed an increase in biomass of three maize inbred lines (Os87-24, Os86-39 and Os89-35) in response to P fertilizer. Significant differences were found between the lines in all parameters investigated. The behavior of the two varieties examined in this study, that is, V1 and V2, may be a consequence of the different ability to uptake and translocate P throughout their different organs. Lynch and Brown (2001), who attributes this ability to plant root geometry and morphology, which are important for maximizing P uptake, also support this hypothesis. It is probable that V2 was able to exude high amounts of organic acids, which acidify the soil and chelate metal ions around the roots, resulting in the mobilization of P and some micronutrients, as indicated by Marschner (1995) and Erbas *et al.* (2017).

Furthermore, according to our result, we can consider a P dose of about 100 kg/ha in barley is a critical upper limit and exceeding this dose may reduce the biological yield because of insolubility or toxicity effect.

Reproductive growth

Number of grains/spike

P-fertilizer dose had no significant impact on the number of grains/spike of both naked barley varieties relative to control, although P-200 significantly reduced this parameter in V1 (Table 4), suggesting a toxic effect of phosphorus at the highest dose or its insolubilization due to high soil pH. Our result is similar to that obtained by Black (1970), who found that P had no effect on this yield component. In addition, it is similar to that obtained by Mihoub, (2012), working in the effect of different kinds and different rates of phosphate fertilizer on the grains number/spike of durum wheat. He showed that the number of grains/spike varied significantly with the type of phosphate fertilizer provided, whereas the doses of

Table 4. Effect of phosphorus fertilizer level on spike weight and number of grains/spike in two naked barley varieties.

Phosphorus rates (kg/ha)	Spike weight (g)		Number of grains/spike	
	V1	V2	V1	V2
P-0	0.932[c]	1.198[b]	28.43[ab]	31.10[a]
P-50	1.027[b]	1.529[a]	32.20[ab]	33.40[a]
P-100	1.182[a]	1.709[a]	34.37[a]	36.37[a]
P-150	1.010[b]	1.725[a]	29.57[ab]	39.90[a]
P-200	0.795[d]	1.690[a]	27.00[b]	39.23[a]

Legend: Different letters within a column indicate significant differences (*P* = 0.05) as assessed by the Neuman-Keul's test (*n* = 90 (30 plants/repetition × 3 repetitions). V1 = var. «Tombari»; V2 = var. «Giza 130». P_2O_5 fertilizer levels: P-0, P-50, P-100, P-150, and P-2000 corresponding to 50, 100, 150 and 200 kg P/ha, respectively.

Table 5. Effect of phosphorus fertilizer level on yield in two naked barley varieties.

Phosphorus rates (kg/ha)	Grain yield (Q/ha)	
	V1	V2
P-0	21.16[b]	23.70[d]
P-50	28.82[ab]	36.10[c]
P-100	38.70[a]	54.00[a]
P-150	33.70[a]	45.00[b]
P-200	20.80[b]	38.00[c]

Legend: Different letters within a column indicate significant differences (*P* = 0.05) as assessed by the Neuman-Keul's test (*n* = 90 (30 plants/repetition × 3 repetitions). V1 = var. «Tombari»; V2 = var. «Giza 130». P_2O_5 fertilizer levels: P-0, P-50, P-100, P-150, and P-2000 corresponding to 50, 100, 150 and 200 kg P/ha, respectively.

fertilizer had no effect on the number of grains per spike.

The decline of grain number/spike beyond 100 kg/ha may be also attributed to the difficulty in taking up iron and manganese from the soil at a high dose of P as it was demonstrated by Grant *et al.* (2004) and Erbas *et al.* (2017). Phosphate is best utilized and taken up by plants when the soil has a pH between 6.0 and 7.0 or the soil in which we have carried out this trials has a greater pH (pH = 8.3).

Spike weight

The effect of P fertilizer on V1 spike weight was significant (Table 4). Maximum spike weight (1.182 g) was obtained with P-100 while minimum spike weight was observed in P-200 plots. In contrast, no significant difference was observed in V2. Thus, both varieties responded differently when spike weight and number of grains/spike were considered. P-fertilizer positively affected both grain number and spike weight in V1 but when P exceeded 100 kg/ha, it adversely affected almost all of V1's reproductive characters. For V2, an increase in P-fertilizer had no effect on spike weight and number of grains/spike (Table 4). Rather, it affected vegetative growth (number of fertile tillers/m^2 and biological yield). However, increasing the number of fertile tillers/m^2 may eventually also increase total grain yield.

Grain yield

Grain yield of naked barley was significantly improved by P fertilizer, at P-100 and P-150 for V1 and at P-100 for V2. Increasing the P-supply beyond P-100 level caused the decrease of yield for the two varieties (Table 5).

This result was similar to that found previously by Turk *et al.* (2003) and recently by Suranyi and Izsaki (2016) for barley. The best yield found in this study were 38.7 and 54 Q/ha for V1 and V2 respectively when P-100 kg/ha was applied. This yield may possibly be due to the efficiency of (P) solubilization in the rhizosphere and its transfer across the different organs combined to the fertile tillers produced which positively influenced grain yield. Similar work conducted by Eftekhari *et al.* (2012), on barley at different application rates and co-inoculation with mycorrhizae found that the highest grain yield (60 Q/ha) was observed in P-100/ha which increased grain yield by 19.43% compared to the control. They attributed this increase in yield to an enhanced plant root system, which improved the plant's ability to absorb nutrients, especially P.

All yield characteristics increased up to the level of 100 kg/ha of P. Thus, 100 kg/ha of P fertilization in barley will be useful to obtain the ideal biological and grain yield.

CONCLUSION

The present investigation suggests that vegetative and reproductive parameters of two naked barley varieties could be increased by increasing P fertilizer. This result is similar to that found by several authors where the best range of phosphate fertilization is between 60 and 100 kg/ha. Thus, P is an important component of profitable naked barley production. However, increasing the rate of P beyond 100 kg/ha did not improve or adversely affected these components. Therefore, P-100 is the optimum level for vegetative growth and grain yield for naked barley grown under field conditions similar to the present study. However, to find the best P-dose, it is desirable to study the effect of the doses between 50 and 100 kg/ha. On the other hand, the behavior of both naked barley varieties differed in response to P-fertilizer. V1 responded better to low doses of (P) while V2 responded better to high doses. Then it is necessary to evaluate the response of each variety separately before generalizing the P-dose to all varieties of barley. This will generate positive production with direct impact on mass production for fodder purposes, or possibly even for increasing nutritional aspects such as β-glucan level, although this has yet to be tested, and proved.

REFERENCES

Balemi T, Negisho K (2012). Management of soil phosphorus and plant adaptation mechanisms to phosphorus stress for sustainable crop production: *a review.* J. Soil Sci. Plant Nutr. 12(3):547-562.

Baraich AAK, Baraich, AHK, Chattha SH, Salarzi AU (2012). Impact of phosphorus and potassium on the growth and yield of wheat cv. Mehran-89. Pak. J. Agric. Agril. Eng. Vet. Sci. 28(1):8-14.

Bergaoui M (2010). The drought impact on agricultural crop production in Tunisia. In: López-Francos A. (comp.), López-Francos A. (collab.). Economics of drought and drought preparedness in a climate change context. Zaragoza: CIHEAM / FAO / ICARDA / GDAR / CEIGRAM / MARM, 2010. (Options Méditerranéennes: Série A. Séminaires Méditerranéens; 95 :71-74.

Ben Naceur A, Chaabane R, El-Faleh M, Abdelly Ch, Ramla D, Nada A, Sakr M, Ben Naceur M (2012). Genetic diversity analysis of North Africa's barley using SSR markers. J. Genet. Eng. Biotechnol. 10:13-21.

Ben Naceur A (2013). Caractérisation morphologique, moléculaire et nutritionnelle de quelques génotypes d'orge Nord Africaine (*Hordeum vulgare)*. Mémoire de Mastère de la Faculté des sciences de Tunis, p. 82.

Black AL (1970). Adventitious roots, tillers and grain yields of spring wheat as influenced by N–P fertilization. Agron. J. 62:32-36.

Bukvić G, Antunović M, Popović S, Rastija M (2003). Effect of P and Zn fertilisation on biomass yield and its uptake by maize lines (*Zea mays* L.). Plant Soil Environ. 49(11):505-510.

Carpici EB, Tunali MM (2012). Effects of the nitrogen and phosphorus fertilization on the yield and quality of the hairy vetch (*Vicia villosa* Roth.) and barley (*Hordeum vulgare* L.) mixture. Afr. J. Biotechnol. 11 (28):7208-7211.

Dhankhar R, Sheoran S, Dhaka A, Soni R (2013). The role of phosphorus solubilizing bacteria (PSB) in soil management overview. Int. J. Dev. Res. **3**(9):31-36.

Eftekhari SA, Ardakani MR, Rejali F, Paknejad F, Hasanabadi T (2012). Phosphorus absorption in barley (*Hordeum vulgare* L.) under different phosphorus application rates and co-inoculation of *Pseudomonas fluorescenc*e and *Azospirillum lipoferum.* Ann. Biol. Res. 3(6):2694-2702.

Erbas S, Kucukyumuk Z, Hasan Baydari H, Erdal I, Sanli A (2017). Effects of different phosphorus doses on nutrient concentrations as well as yield and quality characteristics of lavandin (Lavandula × intermedia Emeric ex Loisel. var. Super). Turk. J. Field Crops 22(1):32-38.

Farooq MU, Iqbal A, Akhter MJ, Waqas MA, Maqsood M, Anees MU (2016). Impact of phosphorus levels and application methods on growth, quality and quantity of biomass produced by forage maize. Int. J. Biotech. 13(2):241-246.

Grant C, Bittman S, Montreal M, Plenchette C, Morel C (2004). Soil and fertilizer phosphorus: Effects on plant P supply and mycorrhizal development. Can. J. Plant Sci. 84:3-14.

Gurmani ZA, Qamar M, Shafeeq S, Zahid MS (2006). Effect of phosphorus fertilizer application on fodder and grain yield of vetch under rainfed conditions of Pothowar region. Pak. J. Agric. Sci. 43:1-2.

Karamanos RE, Flore NA, Harapiak JT, Stevenson FC (2014). The impact of phosphorus fertilizer placement on crop production. Soils and Crops, proceeding of the University of Saskatchewan, p. 12.

Jones C, Jacobsen J, Mugaas A, Wraith J (2003). Barley response to phosphorus fertilization under dry conditions. Fertilizer Facts, 31:2.

Lynch JP, Brown KM (2001). Topsoil foraging – an architectural adaptation of plants to low phosphorus availability. Plant and Soil, 237(2):225-237.

Marschner H (1995). Mineral Nutrition of Higher Plants. Academic Press, San Diego, CA.

Minapour A, Khourgami A, Rafiee M, Pezeshkpour P, Nasrollahi H (2013). Study the effect of phosphate fertilizer (fertile2), phosphorus and foliar nitrogen on yield and yield components of maize cultivar SC 704 in weather conditions of Kouhdasht. Ann. Biol. Res. 4(5):212-215.

Niri HH, Tobeh A, Gholipouri A, Eakaria RA, Mostafaei H, Jamaati-e-Somarin S (2010). Effect of nitrogen and phosphorus on yield and protein content of lentil in dryland condition. Amer-Eurasian J. Agric. Environ. Sci. 8(2):185-188.

Noori M, Adibian M, Sobhkhizi A, Eyidozehi K (2014). Effect of phosphorus fertilizer and mycorrhiza on protein percent, dry weight, weight of 1000 grain in wheat. Int. J. Plant, Anim. Environ. Sci. 4(2):561-564.

Obidiebube EA, Achebe UA, Akparobi SO, Kator PE (2012). Effect of different levels of NPK (15:15:15) on the growth and yield of maize in rainforest agro-ecological zone. Int. J. Agric. Sci. 2(12):1103-1106.

Ottman MJ (2011). Response of wheat and barley varieties to phosphorus fertilizer. Forage & Grain Report, College of Agriculture and Life Sciences, University of Arizona. pp. 23-29.

Peret B, Desnos T, Jost R, Kanno S, Berkowitz O, Nussaume L (2014). Root Architecture Responses: In Search of Phosphate*.* Plant Physiol. 166:1713-1723.

Rahimi A, Panahi Kordlaghari KH, Kelidari AB (2012). Effects of different rates of nitrogen and phosphorus on morphological traits of bean (*Phaseolus vulgaris* L.) in Yasouj region. Int. J. Agric. Sci. 2(2):161-166.

Rashid M, Iqbal M (2012). Effect of phosphorus fertilizer on the yield, and quality of maize (*Zea mays* L) fodder on clay loam soil. J. Anim. Plant Sci*.* 22(1):199-203.

Ryan J, Ibrikci H, Delgado A, Torrent J, Sommer R, Rashid A (2012). Significance of phosphorus for agriculture and the environment in the West Asia and North Africa Region. In: Sparks D (Ed): Burlington: Academic Press, 2012, Adv. Agron. 114:91-153.

Sisie SA, Mirshekari B (2011). Effect of phosphorus fertilization and seed biofertilization on harvest index and phosphorus use efficiency of wheat cultivars. J. Food Agric. Environ. 9(2):388-391.

Sharma SN, Prasad R, Davari M, Ram M, Dwivedi MK (2011). Effect of phosphorus management on production and phosphorus balance in a rice (*Oryza sativa* L.) - wheat (*Triticum aestivum*) cropping system. Arch. Agron. Soil Sci. 57(6): 655-667.

Sharma SB, Sayyed RZ, Trivedi MH, Gobi TA (2013). Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. Springer Plus. 2:587.

Mihoub A (2012). Dynamique du phosphore dans le système sol-plante en conditions pédoclimatiques sahariennes. Université Kasdi Merbah Ouargla, Algerie. p. 101.

Sarker MAZ, Hossain A, Teixeira da Silva JA (2015). Timing of first irrigation and split application of nitrogen for improved grain yield of wheat in Old Himalayan Piedmont Plain of Bangladesh. Brit. J. Appl. Sci. Technol. 6(5):497-507.

Suranyi S, Izsaki Z (2016). The impact of N and P supply on the performance of yield components of winter barley (*Hordeum vulgare* L.). Columella – J. Agric. Environ. Sci. 3(1):37-43.

Teng W, Deng Y, Chen XP, Xu XF, Chen RY, Tong YP,Yang Lv, Zhao YY, Zhao XQ, He X, Li B, Tong YP, Zhang FS, Li ZS (2013). Characterization of root response to phosphorus supply from morphology to gene analysis in field-grown wheat. J. Exp. Bot*.* 64(5):1403-1411.

Tunisian Ministry of Agriculture, (2016). Conditionnement des semences de céréales et de légumineuses à grains Janvier 2016. p. 45.

Turk MA, Tawaha AM, Taifour H, Al-Ghzawi A, Musallam IW, Maghaireh GA and Al-Omari Y (2003). Two row barley response to plant density, date of seeding, rate and application of phosphorus in absence of moisture stress. Asian J. Plant Sci. 2(2):180-183.

Usman K (2013). Effect of phosphorus and irrigation levels on yield, water productivity, phosphorus use efficiency and income of lowland rice in Northwest Pakistan. Pak. J. Rice Sci. 20(1):61-72-72.

Zhang F, Chen X, Vitousek P (2013). Chinese agriculture: an experiment for the world. Nature*,* 497:33-35.

Vetvicka V, Novak M (2011). Biological actions of β-glucan. In: Biology and Chemistry of Beta Glucan. Beta Glucans - Mechanisms of Action, Vetvicka, V., M. Novak (Eds.). Bentham Science Publishers, city 1:10-18.

Wakene T, Walelign W, Wassie H (2014). Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at Bore District, Southern Oromia, Ethiopia. Am. J. Life Sci. 2(5):260-266.

Warraich EA, Ahmad N, Basra SMA, Afzal I (2002). Effect of nitrogen on source–sink relationship in wheat. Int. J. Agric. Biol. 4:300-302.

http://www.sciencewebpublishing.net/jacr