ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT

SCHOLARLY, PEER REVIEWED

Volume 24 No. 2
February 2024

PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(2): 25603-25627 https://doi.org/10.18697/ajfand.127.23185

Date	Submitted	Accepted	Published
	7th November 2022	20th December 2023	29th February 2024

THE EFFECT OF PHOSPHORUS UTILIZATION EFFICIENCY ON DURUM WHEAT CULTIVARS UNDER SEMI-ARID ENVIRONMENTAL CONDITIONS

Mazouz L[1,2]*, Boussaa A[3] and A Kentour[4]

Lakhdar Mazouz

*Corresponding author email: mazouz.lakhdar@univ-khenchela.dz

[1]Agroveterinary Institute, Batna 1 University, Biskra Road, Batna 05000, Algeria

[2]Department of Agronomy, Faculty of Natural and Life Sciences, AbbèsLaghrourkhenchela University, BP 1252 Road of Batna, Khenchela 40004, Algeria

[3]Faculty of life sciences, University Abbes Laghrour, Khenchela, Algeria, BP 1252 Road of Batna, Khenchela 40004

[4]Technical Institute of Field Crops, Khroub, Constantine, Algeria

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Faced with the high cost of phosphate fertilisers in several African countries, including Algeria, and in order to better select varieties according to their fertiliser use efficiency, this study was proposed. The goal of the study was to determine how “variety” impacts durum wheat's capacity to utilize phosphorus effectively and to try to pinpoint the agro-morphological factors that contribute to this efficiency so that they can be taken into consideration when choosing which varieties to sow in semi-arid environments. The experimental setup consisted of a split plot with two investigated factors and three repetitions, with the main plot receiving the phosphate treatment while the sub plot receives the variety. The trial set up consisted of 11 durum wheat varieties, which were cultivated over two years successively. The PUE of the fertiliser, provided in 46% triple superphosphate (TSP) granules, and agro-morphological parameters like aerial biomass, plant height, grain yield and yield components were determined. The findings demonstrated that triple superphosphate, a type of phosphorus fertilizer, increases grain yield by between 40 and 60% for all varieties examined as compared to the phosphorus-free control at the average dose employed in this field trial, or 20 kg P_2O_5.ha-1. This increase in yield is due to an increase: from 20 to 22% in the number of ears per m², 41.5% in the number of grains per ear, and 9% in the average weight of the grain. The PUE is strongly correlated to the yield components (Number of ears per square meter- NEM, Number of grains per ear- NGE, thousand grain weight- TGW and Yield) but also to the height at heading (r=0.86) and dry matter (r=0.85). Phosphorus use efficiency is also strongly correlated to flag leaf length and width as well as leaf area. Also, that genotypes with higher weight of thousand grains (WTG) showed better use of available phosphorus. The principal component analysis (PCA) confirms that the efficiency of phosphorus use by the varieties tested explains a large portion of the variation noted in these varieties. This genetic variation in PUE was associated with plant height and phosphorus content of the sown grains. These results could be of a significant impact in improving rainfed durum wheat productivity in semi-arid areas and preserving the environment as well.

Key words: Durum wheat, Phosphorus use efficiency, Plant’s height, Genetic variation, Fertilizers’ reduction

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Global food security is threatened by both the rapid increase in human population and the abrupt changes in the climate [1].

Meeting human needs within the ecological limits of the planet calls for continuous reflection on, and redesigning of, agricultural technologies and practices [2]. Currently, agriculture practices have become dependent on the use of fertilizers, without which global food production would be reduced by a half [3].

Unlike nitrogen, which can be biologically and industrially fixed from the atmospheric source - a virtually infinite reservoir-, the dependency on phosphate fertilizers is unsustainable, as it is manufactured from phosphate rocks that has finite stocks [4].

The conventional approach to fertilisation consisted of modifying the growing environment with amendments according to the needs of the plant. The new approach takes into account the efficiency of use of mineral elements taking into consideration the genetic material and its potential to adapt to conditions of limitations in the element in question [5].

Phosphorus is a fundamental nutrient for primary productivity of ecosystems and agricultural production, but its misuse impacts agricultural sustainability and has important environmental consequences [6]. The selection and cultivation of efficient varieties on low-phosphorus soils could lead to improved yields [7]; the identification of varieties that are efficient in the use of phosphate fertiliser will make it possible to reduce the amount of phosphate fertiliser used and thus to preserving the environment and ensuring better economic profitability.

In Algeria, average farmers face the high cost of phosphate fertilisers as well as the ecological concern of eutrophication for surface or ground water, but they also cannot do without this vital element, particularly in cereal farming; A shortfall in phosphorus results in a reduction of crop yield [8]. It is critical to consider attempting to discover varieties that are efficient in the use of this element in order to attain a dual economic and environmental goal; this study has never been conducted in Algeria.

Wheat cultivation is widely practiced in Algeria, by both large and small farmers. However, yields remain very low [9]. They can be improved through tillage, pest control, the use of high-performance varieties, but also through fertilization. The use of fertilizers is limited or even absent in Algeria [10].

In cereals, nitrogen is relatively well studied and potassium is neglected, as Algerian soils are reputed to be rich in this element. The interest given to phosphorus is justified by the lack of work, especially in cereals. The nature of the element P, which is not very mobile in the soil and therefore less accessible to the plant. The contribution of P in the soil in the form of fertilizer under goes retrogradation (adsorption, conversion), therefore less available to the plant. Large amounts of soil P are "locked up" in recalcitrant organic P fractions or nonlabile inorganic P pools in complexes with iron/aluminium in acid soils or with calcium in alkaline soils [11], phosphate fertilization, which is a factor in improving yield [12].

Phosphate fertilization must of course take into account the needs of the crop, but also its ability to extract it from the soil and invest it in grain production. It is the latter aspect that is evaluated by studying the efficiency of phosphorus use (PUE).

In this study, the authors have tried to provide some answers to these two questions:
- Do the varieties of durum wheat grown in Algeria contain a genetic variation in the phosphorus use efficiency (PUE)?
- What are the agro-morphological parameters that favour PUE in one variety over another?

Phosphorus input can help improve wheat yields [13,14]. Phosphorus (P) is an essential macronutrient and P deficiency limits plant productivity [15]. Any deficiency in this element leads to lower yields [15,17]. The intensification and increase in productivity of cereal crops in favourable areas require, among other things, a rational and reasoned use of chemical fertilizers [18]. If, over the past few years, the "technological package" of nitrogen fertilizer use for cereals has been largely mastered, with a great deal of work having been done in this area [19,20], on the contrary, phospho-potassium fertilization of cereals remains insufficiently explored and few studies have been carried out under conditions of intensification. The results of work carried out at the National Agronomic Institute of Tunisia [21] and by the Kef Higher School of Agriculture [22], to mention but a few, have proved the effectiveness of phospho-potassium input in increasing grain and biomass yields and grain quality of durum wheat grown under intensive conditions, as well as better resistance of this crop to heat stress.

The interest given to phosphorus in this study also stems from its nature as an element that is not very mobile in the soil [23, 24] and therefore, not easily accessible to plants, as well as from its retrogradation once applied as a fertilizer. About 80% of the P supplied is immobilized and therefore, becomes unavailable, at least in the short term, to plants due to adsorption, precipitation or conversion to organic form [25]. Therefore, the reasoning behind phosphate fertilization should take into account not only the plant's need for this element, but also the mechanisms of its availability and its use by the plant for the development of economic yield. This orientation is reflected in the phosphorus use efficiency (PUE), which is the quantity of economic biomass obtained per unit of phosphorus supplied. It is on this aspect that the study focused. It remains to be seen whether all cereal varieties react to phosphate input in the same way or whether they show a genetic variation in the use of P?

In other words, does this PUE differ from one variety to another? If so, then directing farmers' choice towards varieties that are efficient in the use of P is an economic way of improving their productivity [26], in other words, varieties that are able to redirect

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

absorbed fertiliser towards grain production. Proving the varietal difference in this efficiency in the varieties tested and identifying the agro-morphological parameters correlated with it is the main objective of this study.

MATERIALS AND METHODS

Conduct of experimentation and plant material

The study was conducted at the Agricultural Research Station in the city of Oum El Bouaghi, Algeria. The station is located in the semi-arid region characterized by a typically Mediterranean continental climate. The trial set up consists of 11 durum wheat genotypes (Table 1). These cultivars, whose seeds were supplied by the ITGC (the technical institute for field crops-Constantine province) Algeria, are of diverse origins and characterized by a contrasted agricultural production and include Algerian commercial varieties and advanced breeding lines from the national durum wheat breeding programs and those of Cimmyt-ICARDA. (Cimmyt is the International Maize and Wheat Improvement Center and ICARDA the International Center for Agricultural Research in the Dry Areas).

Experimental trial

These varieties were cultivated with 3 doses of P_2O_5 brought according to the sowing treatment in the form of TSP 46% (triple super phosphate) for two years in a row. The doses were chosen according to the following reasoning:
Dose 0 (P-). Without any external phosphorus input
Dose 1 (P): estimated as follows: crop need (1.8 kg of phosphorus to produce 1 quintal of grains X expected yield in the region (22 qx/ha) and we get 22*1.80 =39.60 about 40 kg/ha.
Dose 2 (p+): the dose of the need + a supplement and in this case, we opted for a double dose that is 80 kg/ha. Required dose for a yield objective of 440 kg /ha).

The experimental device (design) is a split plot with 3 repetitions and two factors where the phosphate treatment is assigned to the main plot while the variety is assigned to the sub plot.

Each experimental plot is made up of 4 lines 2 m long spaced 0.5 m apart, each block will be 144 m^2. The distance between phosphate treatments is 1 m. the total surface area of the trial is 600 m^2.
Sowing rate 250 g/m^2.
The number of seeds sown per sub plot is 500 seeds.

Conditions of conducting the test

Tillage consisted of deep ploughing to a depth of 30 cm, followed by a cover crop followed by harrowing. Sowing was carried out on November 17th (November23 for the second year) by hand, at a rate of 0.24 t/ha and at an average depth of 4 cm. Nitrogen fertilizer (Urea 46%) is applied in a single application at the 3-leaf stage at the rate of 100 kg per hectare. Harvesting took place on 30 June and 27 June for the second year.

Follow-up and notations

The cultural precedent of the experimental site is a grassy fallow.
Variety characterization was based on plant yield components, biomass (at heading and maturity), morphological characteristics, calculation of phosphorus use efficiency and soil phosphorus analysis before sowing.

Aerial biomass

Above-ground biomass is determined at the maturity stage from the weight of the bundles coming from the harvest of a 1 m long row segment per elementary plot. It is expressed in g/m², without passing through the drying oven.

Number and weight of ears

The number and weight of ears produced per unit area are deduced from counting and weighing the number of ears present in the bundles of vegetation harvested at maturity. They are expressed in number of ears/m² and in g/m².

Phosphorus use efficiency: (PUE)

In order to be able to compare the different treatments for phosphorus use efficiency with no input treatment, the PUE was calculated according to the following formula: [26]: PUE: yield/ P Available where P available = Psoil + P brought in
Psoil: refers to the supply of P from the ground. Taking into account the soil analysis according to the Truog method, these supplies are, respectively, for the two campaigns in the order of 358.53 kg P/ha and 750.18 kg P/ha. These quantities have been estimated according to the equation:
Soil supply in estimated P = d * S * Z * P (soil) with:
D: bulk density of the soil (estimated at 1.2 g/cm^3).
S: area (1 ha).
Z: the root depth for nutrient exploration (30 cm).
And P (soil) the phosphorus content of the soil expressed in mg P/ kg soil.

Grain yield and yield components

Grain yield was determined by the weight of the seeds resulting from the threshing of the ears counted per bunch of harvested vegetation. It is expressed in g/m². 250 seeds were counted from the product of the threshing of the ears and weighed to determine the yield component, which is the weight of 1000 grains. The number of grains per ear (NGE) and the number of seeds produced per m^2 (NGM2) are estimated by direct calculation from the estimates of grain yield (yield, g/m²), 1000 grain weight (TGW, g/1000 grains) and number of ears/m² (NE, nbr/m²): NGE = (1000 yield)/(TGW x NE) (2)
and NGM^2= NGE X NE (3).

Determination of phosphorus of seeds sown

The phosphorus dosage is done on the extract obtained by mineralization according to the general procedure; organic substances are decomposed to simple inorganic compounds. Phosphorus is present in the extract in the form of ortho phosphate.

Together with vanadate and molybdate ions, phosphorus forms a yellow phospho-vanado-molybdate complex that can be measured by molecular absorption spectrophotometry at 430 nm [27].

Determination of soil's phosphorus content

Calcium phosphate and magnesium phosphate in soils easily dissolve under acidic conditions. The Truog method adopts diluted H_2SO_4 (pH=3.0) as an extractant [28].

Statistical analysis

An analysis of variance was done at the 5% probability level in order to identify the main dimensions of variability for the treatments. The program used was Statitcf, version 5, year 1991.Then analyses of variance for the varieties followed by a series of homogeneous groups with doses using xl stat when the analysis of variance proves significant. Finally, a PCA to determine the relationships of phosphorus use efficiency with the other parameters was carried out with statistica, version 7.0 on the year 2008. Split plot model for 2 factors studied is as shown below:

$x_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha_i\beta_j + e_{ik} + e_{ijk}$

xijk: response observed on the unit subject treatment AiBj in block k.

μ: average level.

α i = effect of factor A for modality i (i = 1....a).

β j = effect of factor B for condition j (j = 1....b).

αi is the fixed effect of fertilization scheme, βj is the fixed effect of Durum wheat variety and (αβ)ij is the corresponding interaction term

γ k= effect of block factor for block k (k = 1....r).

α iβ j= effect of 1st order interaction between factors A and B.

eik = residual effect between sub-blocks.

eijk= residual effect between plots. (Table 2).

RESULTS AND DISCUSSION

Examination of the following graph (Figure 1) clearly shows that the Semito variety, in the absence of any phosphate input, has achieved the feat of achieving the highest phosphorus use efficiency followed by Wahbi, MBB and Cirta. When 40 kg/ha of TSP 46% is applied, it can be seen that the Semito variety is still among the most efficient varieties, together with Gta dur MBB and Vitron. When the varieties tested are subjected to an application of 80 Kg/ha of 46% TSP, the most efficient varieties are still among the most efficient, with Semito, Vitron, Cirta and Essalam. This varietal difference in phosphorus use efficiency is confirmed by the results of Ozturk *et al.* [29] who suggested that P efficiency mechanisms can be different from one genotype to other within a given plant species.

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

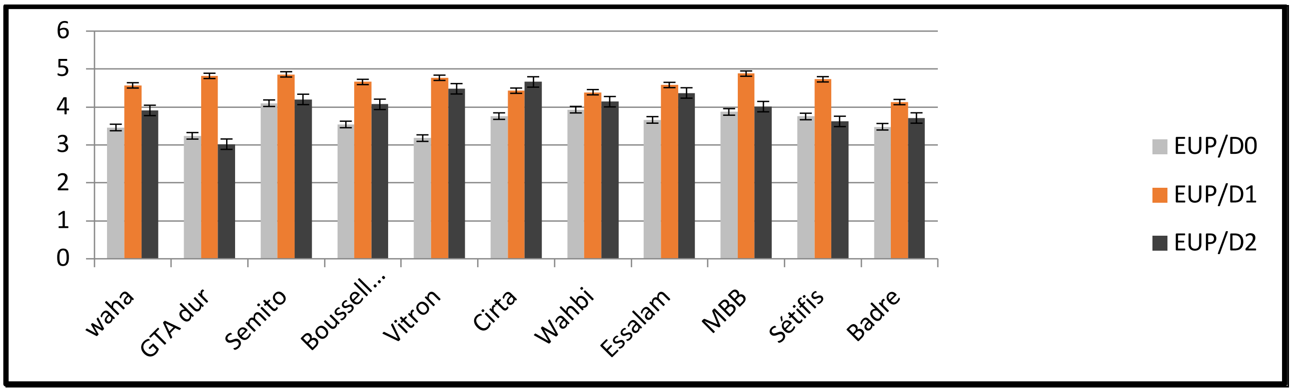

Figure 1: Phosphorus use efficiency (PUE) in the first year

In a drought situation during the second year, (Figure 2) varieties such as Gta dur, Boussellam, waha essalam and vitron are especially efficient in the absence of input, whereas four of these varieties, Gta dur, waha essalam and vitron, can be found among the efficient varieties, but also Cirta, during the D 40. Gta dur and vitron seem to insist on their efficient character when applying D80.at this level of fertilization Semito and badre are also part of the lot.

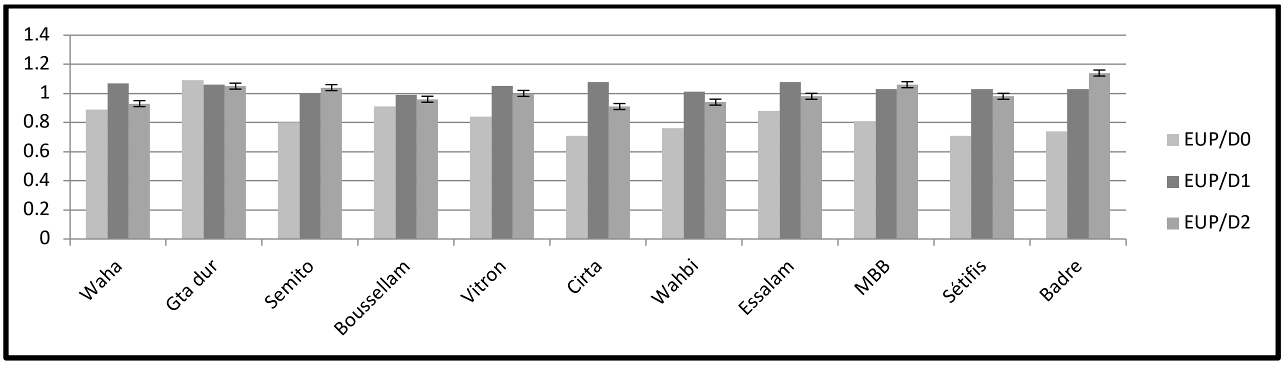

Figure 2: Phosphorus use efficiency (PUE) in the second year

In order to identify the agro-morphological characteristics that make these varieties the most efficient in terms of phosphorus use compared to others: a matrix of PUE correlations with all the other parameters measured was made: (table 2).

It can be noted that the PUE is strongly correlated to the yield components (NEM, NGE, TGW and Yield) but also to the height at heading (r=0.86) and dry matter (r=0.85). Phosphorus use efficiency is also strongly correlated to flag leaf length and width as well as leaf area. So, on the basis of this observation, can it be said that, a priori, the varieties that should now be used, or that cereal growers should be directed towards using, are the varieties that have the highest values of the characteristics mentioned above? It is useful to point out that the varieties that have been able to extract phosphorus despite the low to medium soil input content or (no input) and direct it towards the grain (high PUE varieties) are also those that score the highest in terms of the above-mentioned agro-morphological characteristics: Essalam, MBB and Semito have the best GMPs under zero input with 32.6, 32.2 and 31.8 g, respectively, in the first year.

The national centre for the control and certification of seeds and seedlings published the "Bulletin of cereal varieties" (2009), which details the characteristics of durum wheat varieties cultivated in Algeria (table 2). Upon analysing the results of this study to determine which varieties are the most phosphorus-efficient, the following characteristics are found to be shared by these varieties:

The first year:
-Efficient varieties at the DO dose (without fertilizer): Semito, Wahbi, MBB and Cirta.
-efficient varieties at the D1 fertilizer dose: MBB, Semito, Gta dur and Vitron
-effective varieties at the dose of D2: Cirta, Vitron, Semito and Essalam.
The second year:
-Efficient varieties at D0 dose (without any phosphate fertilizer): Gta dur, Boussellam, Waha and Essalam.
-effective varieties at dose D1: Cirta, Essalam, Waha and Gta dur
-effective varieties at dose D2: Badre, MBB, Semito and hard Gta.
It can be seen from this approach that the most efficient varieties according to the results of the study are also those with the highest thousand grains weight (TGW) and also those with a short to medium plant height.

It can be seen from the P content of the seeds of the varieties tested that those with the best concentrations are practically also those with the best yields, TGW as well as the best phosphorus use efficiency (PUE), in this case MBB, Cirta, Vitron, Semito and Wahbi (Table 3). Better management of fertilisers, combined with the use of more phosphorus-efficient genotypes, is essential to improving quality and developing sustainable agriculture [30].

The analysis in main components:
with the D0 dose in the first year.

ajfand
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

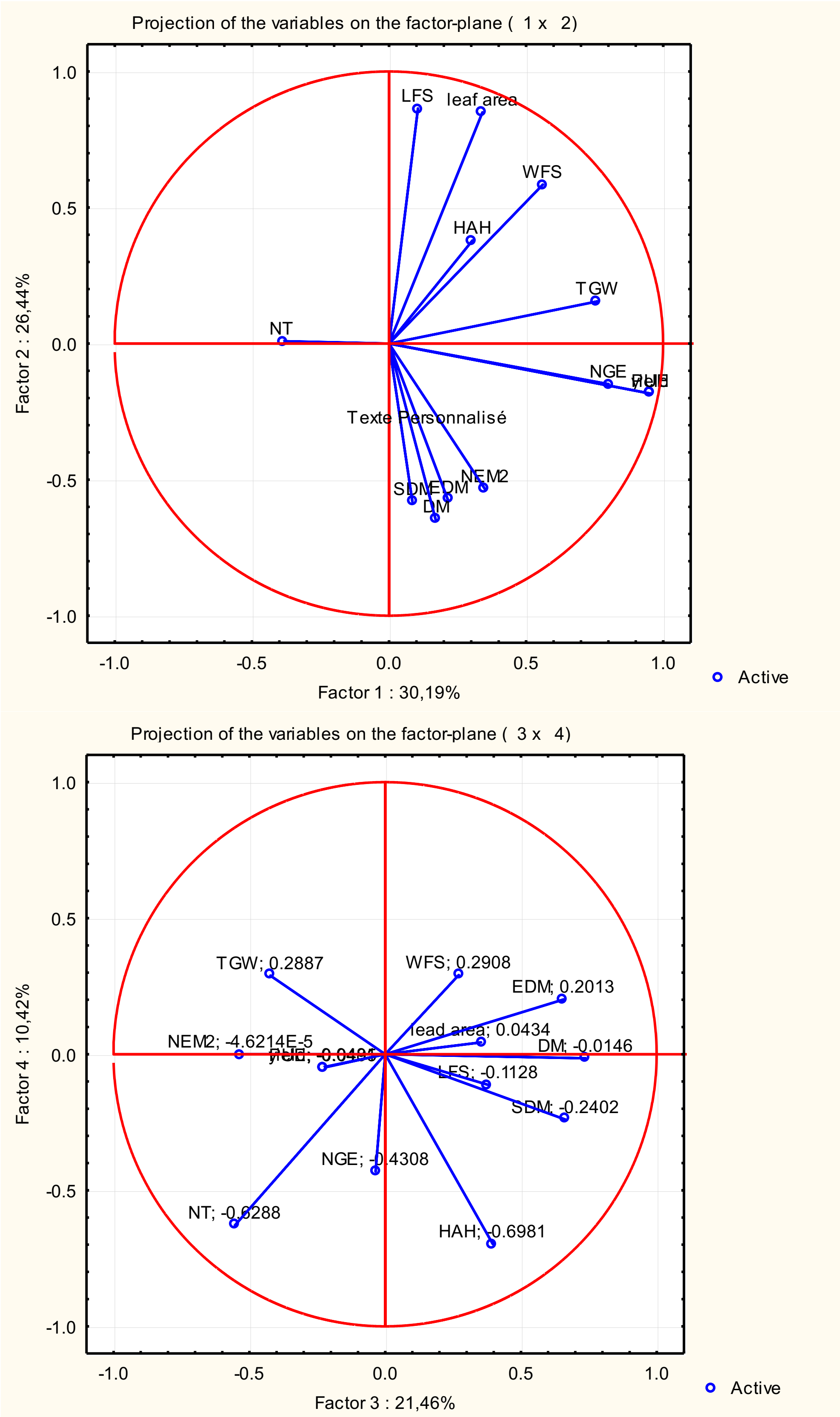

Figure 3: Principal component analysis of the parameters measured with dose 0 in the first year

https://doi.org/10.18697/ajfand.127.23185

With the dose D40 in the first year:

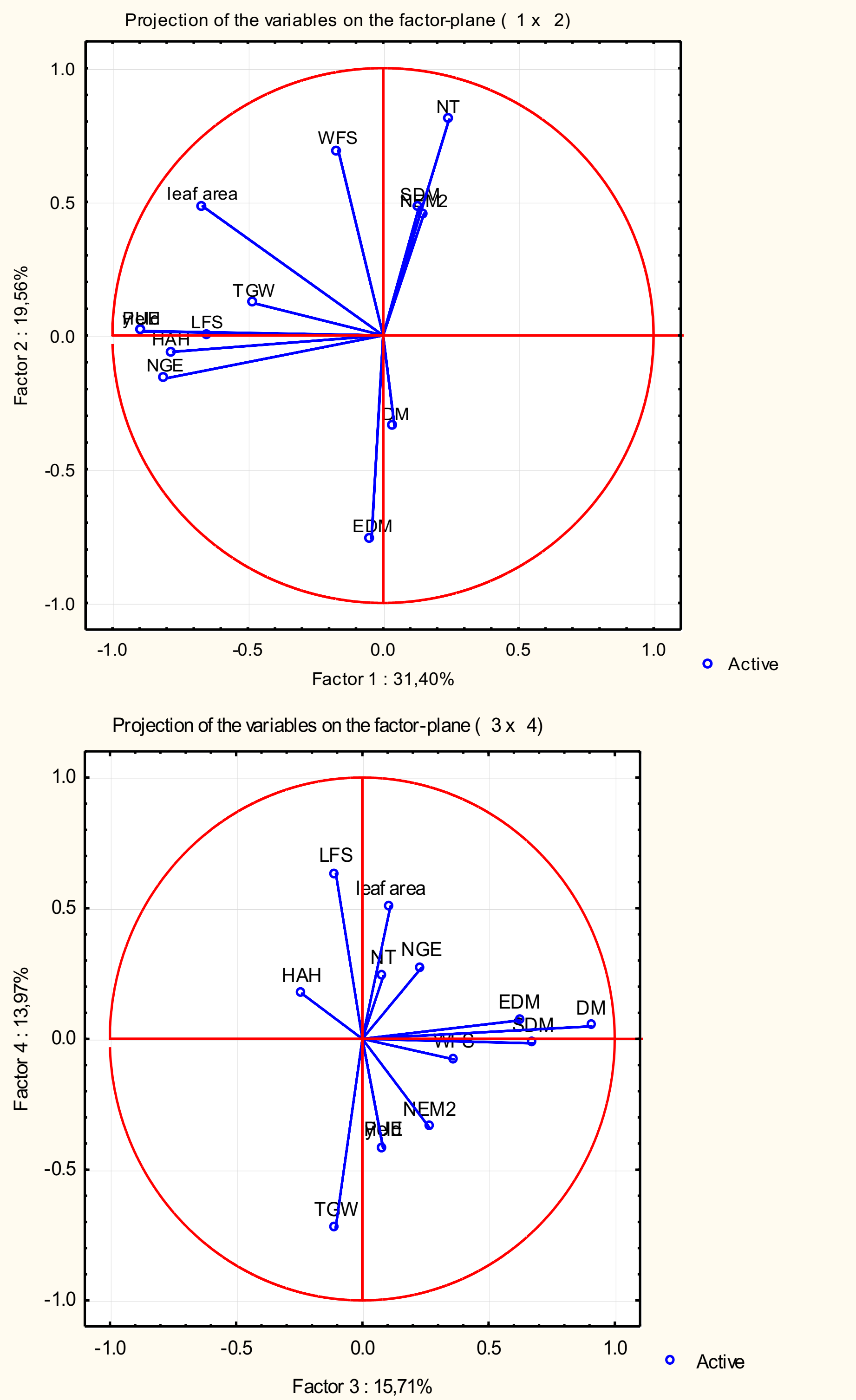

Figure 4: Principal component analysis of the parameters measured with dose 40 in the first year

ajfand
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

with the D80 dose in the first year:

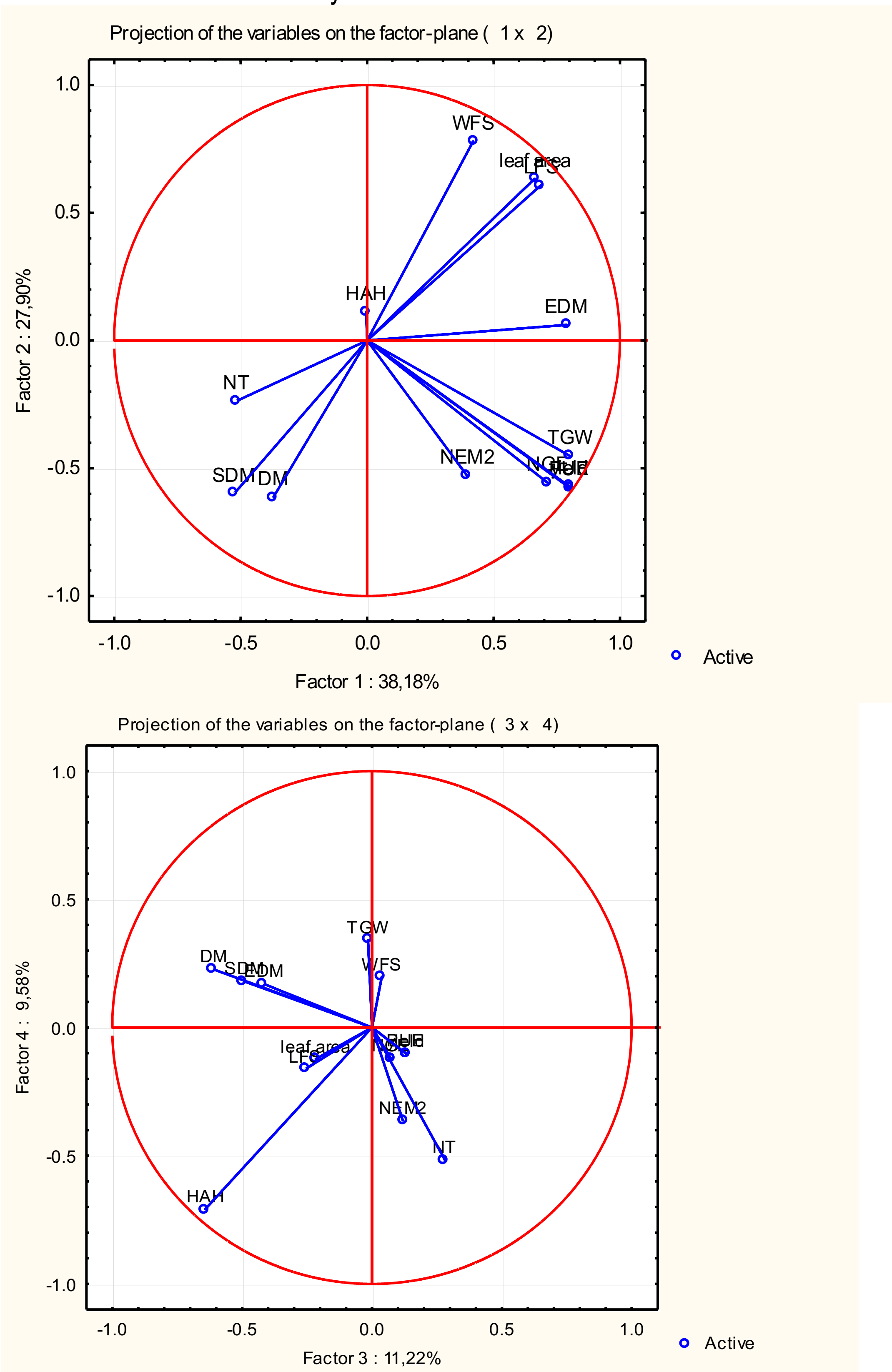

Figure 5: Principal component analysis of the parameters measured with dose 80 in the first year

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

The PCA confirms that the efficiency of phosphorus use by the varieties tested explains a large portion of the variation noted in these varieties. This efficiency is closely correlated with the yield components, especially TGW.

Statistical analysis shows that the number of grains per ear, the number of ears per m² and the weight of 1000 grains were decisive for good yields. Indeed, there are good correlations between these three components and grain yield. However, the degree to which they are related to yield is not of the same importance: the difference is due to the nature of the parameter but also to the phosphorus dose applied. In fact, the weight of a thousand grains seems to have the strongest link with yield ($r = 0.86$) but with phosphorus dose 2 during the first year of the study and ($r = 0.65$) with dose 1 whereas this link is only ($r = 0.32$) for varieties without phosphate input. Phosphate fertilization in dry conditions seems to have a depressing effect on this linkage: during the second year, r which was 0.78 for the control without phosphate supply, rose to 0.47 then 0.30 for D1 and D2, respectively. The same observation applies to the number of grains per ear (0.93, 0.58 and 0.28, respectively, for D2, D1 and D0) in the first year of the study. While for the dry year this parameter seems to be stable and high especially for the maximum dose helped in this maybe by the phenomenon of compensation. (0.84, 0.75 and 0.88 for D0, D1 and D2, respectively). For the number of ears per square metre, it is clear that its very weak binding at the beginning evolves quickly towards a very strong binding with the yield as soon as phosphorus inputs are applied (0.02, 0.17 and 0.62 for D0, D1 and D2, respectively). The results obtained on the positive effect of the phosphate input on yield components by always classifying the control in a separate group are similar to those obtained by Boukhalfa-Deraoui *et al.* [31] on common wheat and Garba [32] and Beebe *et al.* [33] on cowpea in Niger where the climate is arid. The positive effect on TGW and NEM demonstrated in this study is in line with the work of Belaid [34] working on durum wheat who found that the clearest effect of phosphorus is seen in the sterility of spikelets. This went from 3.34 to 2.41 following a contribution of 92 units of superphosphate. As for the weight of 1000 grains, it goes from 39 to 44 grams in the same experimental interval. This beneficial effect of phosphorus on the sterility of the ear and the weight of 1000 grains sees however its effect reduced within creasing nitrogen inputs.

Varietal behaviour was a determining factor in the development of the yield as well as in the differences obtained in phosphorus use efficiency; the results show that there is some genetic variation in phosphorus use efficiency in the varieties tested Beebe *et al*. [33] revealed genetic diversity in P utilisation efficiency, which they linked to the geographical origin of the cultivars employed. They suggest that genotypes with high yields under phosphate-limited conditions would be the most efficient for the use of P, a finding that is in line with results, especially for the Semito variety. Djadjaglo and Richter [7] working on the efficiency of phosphorus uptake by Sorghum bicolor and Phaseolus vulgaris plants found that their results indicate a difference in the phosphorus uptake capacity of the plants and between varieties of the same crop. The most efficient varieties following the results of the study are also those with the highest thousand grain weight (TGW), and also those with short to medium plant height; the work of De tafur *et al*. [35] on cassava (Manihot esculenta) showed that the efficiency of use of mineral elements was higher in medium to small cultivars. The same result was found in semi-dwarf wheat cultivars, these cultivars produced more kg of grain per kg of phosphorus input than the older large genotypes, especially under conditions of high phosphate application [36].

The results also indicate that the productive varieties without phosphate input are not all the same compared to those that produce well with inputs. These results agree with those of Sattelmacher *et al*. [37] who believe that genotypes that can produce well in conditions limiting mineral elements are not necessarily the most efficient in conditions of mineral availability and vice versa, which obviously leads us to propose varieties to farmers according to the mineral state of their soils for better efficiency and productivity; this goes without saying with the approach of improving the phosphorus use efficiency (PUE) of the crops themselves by genetic means, about by plant breeding as proposed by Van De Weil *et al*. [38]

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

The phosphorus contribution, in the form of triple superphosphate, allows, at the average dose used in this field trial, 20 kg P_2O_5.ha-1, an increase in grain yield obtained between 40 and 60% compared to that of the phosphorus-free control, for all the varieties tested. This increase in yield is due to an increase: from 20 to 22% in the number of ears per m², 41.5% in the number of grains per ear, and 9% in the average weight of the grain.

The maximum dose, in this case 40 kg/ha P_2O_5, also achieved a gain in yield compared to the control, but which is lower than that achieved by the average dose, except for Cirta and Essalam in years with relatively good rainfall. This leads us to conclude that in our opinion it is useless to use a greater quantity of phosphate fertilizer if a lesser quantity can give us satisfaction with certain varieties that have shown a better PUE compared to the others by achieving the best yields without phosphate fertilizer; a fact that has been widely observed in this modest study: with the exception of the Cirta and Essalam varieties, which obeyed a certain cross order in terms of phosphate fertiliser to increase their grain production, all the other varieties gave the best of themselves with only the 20 kg dose. Ha-1 of P_2O_5., 40 kg of TSP 46%. But with different yields, Gta dur and vitron in this perspective remain among the best varieties. Semito is the variety that seems to be best suited to the absence of phosphate fertilisation and a low-dose application.

A high TGW is in favour of better use of the available phosphorus. Varieties that have achieved maximum productivity with minimum phosphorus have also proven to be the most efficient in the use of phosphorus.

A more generous climate in terms of rain fall is a favourable factor for better assimilation of phosphate fertiliser, especially for varieties with a high PUE.

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

An equilibrium is necessary in the phosphorus cycle, in other words, P absorption by harvested crops and P fertilization should be in equilibrium to avoid phosphorus depletion [38,39]. Current estimates indicate that plants only use 10-25% of the applied P [40], indicating that there is room for improvement. Strategies to address the need to restrict P use and avoid P depletion in the future at the same time include the approach of improving the phosphorus use efficiency (PUE) of the crops themselves through genetic means, that means., plant breeding [41]. Efficient wheat genotypes adapted to inadequate P and water conditions should be evaluated to generate phenotyping data as a priority need to crop modelling [42].

https://doi.org/10.18697/ajfand.127.23185

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Lists of durum wheat varieties studied, origin and pedigree

Varieties	Origin	Pedigree	Type
Waha	Algeria	PLC/Ruff/Gta S »/3/Rolette Cm.17904 (genealogical selection)	Pure line
GTA dur	Algeria	Gaviota x durum Crane/4/PolonicumPI185309//T.glutinen/2*Tc60/3/GII	Pure line
Semito	Italia	Capeiti x Valvona	Pure line
Boussellam	Algeria	Heider/Martes//Huevos de Oro	Pure line
Vitron	Espagne	Genealogical selection Turkey77/3/Jori/ Anhinga//Flamingo	Pure line
Cirta	Algérie	KB2140KBOKB2KBOKBOKB1KBOKB (T2)	Pure line
Wahbi	Algérie	T4	Pure line
Essalam	Algéria	Ofanto/*2/Waha	Pure line
Mohamed Ben Bachir	Algeria	selection of local population	Local population
Sétifis	Algeria	Ofanto/Waha//MBB	Pure line
Badre	Algeria	Boussalem/Ofanto	Pure line

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Sources of variation in the split plot trial

Source of variation	Degrees of freedom	Degrees of freedom
Factor 1 (Phosphate fertilizer dose)	p-1	2
Blocks	r-1	2
Residual variation 1	(p-1)(r-1)	4
Factor 2 (varieties)	q-1	10
Factor 1 * factor 2 (dose interaction * variety)	(p-1)(q-1)	20
Residual variation 2	P(q-1)(r-1)	60
Totals	Pqr-1	98

ajfand
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Correlation matrix

	Doses	Bloc	height at heading	number of tiles	straw dry matter (g/m2)	(dry matter ears (g/m2)	Dry matter (g/m2)	number of ears per square metre	number of grains per ear	TGW	Yield qx/ha	Yield g/m2	length flag sheet	width flag sheet	leaf area	PUE
Doses	1	0.000	-0.002	0.013	-0.065	-0.129	-0.101	0.321	0.035	0.295	0.234	0.234	-0.004	0.011	0.001	0.080
Bloc	0.000	1	-0.168	0.013	-0.014	0.052	0.016	0.003	0.020	0.002	-0.011	-0.011	-0.113	-0.085	-0.105	-0.010
height at heading	-0.002	-0.168	1	-0.275	0.803	0.479	0.765	0.786	0.759	0.621	0.809	0.809	0.682	0.731	0.731	0.859
number of tiles	0.013	0.013	-0.275	1	-0.302	-0.378	-0.372	-0.352	-0.336	-0.239	-0.359	-0.359	-0.321	-0.324	-0.330	-0.373
straw dry matter (g/m2)	-0.065	-0.014	0.803	-0.302	1	0.553	0.932	0.770	0.773	0.602	0.791	0.791	0.602	0.703	0.658	0.857
(dry matter ears (g/m2)	-0.129	0.052	0.479	-0.378	0.553	1	0.816	0.498	0.562	0.428	0.560	0.560	0.437	0.490	0.466	0.596
Dry matter (g/m2)	-0.101	0.016	0.765	-0.372	0.932	0.816	1	0.749	0.780	0.603	0.791	0.791	0.608	0.700	0.658	0.852
number of ears per square metre	0.321	0.003	0.786	-0.352	0.770	0.498	0.749	1	0.795	0.680	0.945	0.945	0.608	0.713	0.669	0.932
number of grains per ear	0.035	0.020	0.759	-0.336	0.773	0.562	0.780	0.795	1	0.764	0.912	0.912	0.609	0.676	0.659	0.915
TGW	0.295	0.002	0.621	-0.239	0.602	0.428	0.603	0.680	0.764	1	0.830	0.830	0.533	0.584	0.572	0.774
Yield qx/ha	0.234	-0.011	0.809	-0.359	0.791	0.560	0.791	0.945	0.912	0.830	1	1.000	0.638	0.718	0.692	0.979
Yield g/m2	0.234	-0.011	0.809	-0.359	0.791	0.560	0.791	0.945	0.912	0.830	1.000	1	0.638	0.718	0.692	0.979
length flag sheet	-0.004	-0.113	0.682	-0.321	0.602	0.437	0.608	0.608	0.609	0.533	0.638	0.638	1	0.880	0.972	0.678
width flag sheet	0.011	-0.085	0.731	-0.324	0.703	0.490	0.700	0.713	0.676	0.584	0.718	0.718	0.880	1	0.947	0.766
leaf area	0.001	-0.105	0.731	-0.330	0.658	0.466	0.658	0.669	0.659	0.572	0.692	0.692	0.972	0.947	1	0.735
PUE	0.080	-0.010	0.859	-0.373	0.857	0.596	0.852	0.932	0.915	0.774	0.979	0.979	0.678	0.766	0.735	1

In bold, significant values (excluding diagonal) at threshold alpha=0.050 (bilateral test)

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 4: Agro-morphological characteristics of efficient varieties

	TGW	Yield	Height
Semito	high	High	Average
MBB	high	Average	High
Cirta	high	High	Average
Gta dur	high	High	Average
Essalam			
Vitron	high	High	Short

Table 5: P-content of sown seeds of the tested varieties

Varieties	Concentration of the extract (mg P / g MS)
Mohamed Ben Bachir (MBB)	3.94
Essalam	2.92
Wahbi	3.28
Waha	2.71
Gta dur	2.46
Setifis	2.91
Semito	3.32
Vitron	3.41
Badre	2.81
Cirta	3.38
Boussellam	2.99

REFERENCES

1. **Meier S, Moore F, Morales A, Jobet, Olivari C, Aponte R L and N Khan** Interactive role between phosphorus utilization efficiency and water use efficiency. A tool to categorize wheats co-adapted to water and phosphorus limiting conditions. *Agricultural Water Management.* 2021; 248 https://doi.org/10.1016/j.agwat.2021.106765

2. **Bindraban P, Dimkpa C and LA Nagarajan** Revisiting fertilisers and fertilisation strategies for improved nutrient uptake by plants. *Biol Fertil Soils*, 2015; **51:** 897–911. https://doi.org/10.1007/s00374-015-1039-7

3. **Bruinsma J** World agriculture: Towards 2015/2030: An FAO Study. FAO. 2017. https://www.fao.org/3/y4252e/y4252e.pdf *Accessed July 2020.*

4. **Cong WF, Suriyagoda LD and H Lambers** Tightening the phosphorus cycle through phosphorus-efficient crop genotypes. *Trends Plant Sci.* 2020; **25:** 967-975. https://doi.org/10.1016/j.tplants.2020.04.013

5. **Rengel Z** Physiological mechanisms underlying differential nutrient efficiency of crop genotypes. Mineral Nutrition of Crops: Mechanisms and Implications. 1999; 227-265.

6. **Georges TS, Hinsinger P and TL Benjamin** Phosphorus in soils and plants – facing phosphorus scarcity. *Plant soil*. 2016; **401:** 1-6. https://doi.org/10.1007/s11104-016-2846-9

7. **Djadjaglo D and C Richter** Efficacité de prélèvement du phosphore par les plantes *Sorghum bicolor* (L.) Moench et *Phaseolus vulgaris* L. *Agrosolutions*. 2008; **19 (2):** 45-50.

8. **Tirado R and M Allsopp** Phosphorus in agriculture: Problems and solutions. Greenpeace International, 2012.

9. **Benbelkacem A** The history of wheat breeding in Algeria. In: Porceddu E. (ed.), Damania A.B. (ed.), Qualset C.O. (ed.). Proceedings of the International Symposium on Genetics and breeding of durum wheat. Bari : CIHEAM, 2014. p. 363-370 (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 110).

10. **FAO.** Fertilizer use by crop. Fifth edition. Rome. 2002.

11. **Rose T and M Wissuwa** Rethinking internal phosphorus utilisation efficiency (PUE): a new approach is needed to improve PUE in grain crops. *Advances in Agronomy.* 2012; 183-215. http://doi.org/10.1016/B978-0-12-394277-7.00005-1

12. **Jorfi A, Alavifazel M, Gilani A, Ardakani MR and S Lak** Yield and morpho-physiological performance of quinoa (*Chenopodium quinoa*) genotypes as affected by phosphorus and zinc. *J. Plant Nutr.* 2022; **45:** 2432–2446.

13. **Morel C, Plenchette C and J Fardeau la** fertilisation phosphatée raisonnée de la culture du blé. *Agronomie*. 1992; **12**: 565-579.

14. **Aissa A and A Mhiri** Fertilisation phospho-potassique du blé dur en culture intensive en Tunisie. Cahiers Agriculture. 2002; **11(6):** 391-397. https://revues.cirad.fr/index.php/cahiers-agricultures/article/view/30366 *Accessed on 12/11/2021.*

15. **Carstensen A, Herdean A, Schmidt SB, Sharma A, Spetea C, Pribil M and S Husted** The Impacts of Phosphorus Deficiency on the Photosynthetic Electron Transport Chain. *Plant physiology.* 2018; **177(1):** 271-284. http://doi.org/10.1104/pp.17.01624

16. **Le Buanec B** contribution à l'étude de la carence en phosphore des sols sur granite en Cote d'Ivoire. Abidjan: Faculty of Sciences. 1973.

17. **Vance C, Uhde-Stone C and D Allan** Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. New Phytologist. 2003; **157(3):** 424-440. https://doi.org/10.1046/j.1469-8137.2003.00695.x

18. **Mhiri A** Production and use of chem/cal fertilizers. Proceeding of the Seminar « Production and use of chemical fertilizers and environment". 1995. 17-21. Cairo: Edit. El Fouly Abdalla, Egypt.

19. **Gharbi A, Haddad A and K Ettounsi** Nitrogen and phosphorus in rainfed region of Tunisia. Proceeding of the 4th regional workshop. 1991. Agadir, Morroco.

20. **Sboui T, Mhiri A, Sanaa M and O Van Cleemput** Efficacité des engrais azotés sur le blé après deux années sèches. Revue de l'INAT. 1997; **12:**1.

21. **Rguez B** Contribution à l'étude de la fertilisation phospho-potassique du blé dur en irrigué. Mémoire de fin d'étude de spécialisation Inat.1998.

22. **Aissa AD and A Mhiri** Fertilisation phosphopotassique des céréales en Tunisie. Revue de l'INAT. 2000; **15(2):** 7-17.

23. **Munns D and B Mosse** Mineral nutrition of legume crops. Advances in legume Science, 2000. 115-125.

24. **Roberts TL and AE Johnston** Phosphorus use efficiency and management in agriculture. (Elsevier, Éd.) Resources, Conservation and Recycling. 2015; **105:** 275-281. http://doi.org/10.1016/j.resconrec.2015.09.013

25. **Holford I** Soil properties related to phosphate buffering in calcareous soils. communications in soil science and plant analysis, (1977);125-137. http://doi.org/10.1080/00103627709366707

26. **Daoui K** Recherche de stratégies d'amélioration de l'efficience d'utilisation du phosphore chez la fève (*Vicia faba* L.) dans les conditions d'agriculture pluviale au Maroc. Thèse présentée en vue de l'obtention du grade de docteur en sciences agronomiques et ingénierie biologique. 2007.

27. **HACH.** DOC313.53.94184 EZ1031. Phosphate analyzer Method and reagent sheets 09/2021, Edition 1.01.

28. **Rokupr Agricultural Research Centre (RARC) and Japan International Cooperation Agency (JICA).** Soil Analysis Manual June 2014.

29. **Ozturk L, Eker S, Torun B and I Cakmak** Variation in phosphorus efficiency among 73 bread and durum wheat genotypes grown in a phosphorus-deficient calcareous soil. Plant Soil 2005; **269:** 69–80. https://doi.org/10.1007/s11104-004-0469-z

30. **Gadaleta A, Lacolla G, Giove SL, Fortunato S, Nigro D, Mastro MA, De Corato U, Caranfa D, Cucci G, de Pinto MC and F Vita** Durum Wheat Response to Organic and Mineral Fertilization with Application of Different Levels and Types of Phosphorus-Based Fertilizers. *Agronomy*. 2022; **12(8):**1861. https://doi.org/10.3390/agronomy12081861

31. **Boukhalfa-Deraoui N, Halilat M and A Mekliche** effet d'un apport de phosphore sur une culture de blé tendre conduite en conditions irriguées. 2011. Revue des Bioressources. **1:** 39-46.

32. **Garba A** Etude des possibilités d'amélioration des systèmes de production à base de légumineuses alimentaires (niébé-arachide)) dans la zone agro-écologique du Fakara, sud-ouest du Niger. mémoire de fin d'études.gestion des ressources animales et végétales en milieux tropicaux: université de Liège.belgique. (2007).

33. **Beebe S, Lynch J, Galwey N, Tohme J and I Ochoa A** Geographical approach to identify phosphorus-efficient genotypes among landraces and wild ancestors of common bean. *Euphytica*. 1997; **95(3):** 325-338. http://doi.org/10.1023/A:1003008617829

34. **Belaid D** etude de la fertilisation azotée et phosphatée du blé dur en conditions de déficit hydrique. annales de l'institut national agronomique. 1998; 31-42. http://www.asjp.cerist.dz/en/downArticle/12/12/2/8802 *Accessed September 2019.*

35. **De Tafur S, El-Sharkawy M and L Cadavid** Response of cassava (*Manihot esculenta* Crantz) to water stress and fertilization. Photosynthetica. 1998; **34:** 233–239 https://doi.org/10.1023/A:1006892607834

36. **Batten G** A review of phosphorus efficiency in wheat. Plant and soil. 1992; **146:** 163-168. http://doi.org/10.1007/BF00012009

37. **Sattelmacher B, Horst WJ and HC Becker** Factors that contribute to genetic variation for nutrient efficiency of crop plants. Z Pflanzenernähr Bodenk. 1994; **157(3):** 215–224. http://doi.org/10.1002/jpln.19941570309

38. **Van de Wiel C, Van der Linden G and O Scholten** Improving phosphorus use efficiency in agriculture: opportunities for breeding. Euphytica. 2016; **207:** 1-22. http://doi.org/10.1007/s10681-015-1572-3

39. **Lynch J** Roots of the second green revolution. *Aust. J Bot.* 2007; **57:** 493-512. http://doi.org/10.1071/BT06118

40. **Richardson AE, Lynch JP, Ryan PR, Delhaize E, Smith FA, Smith SE, Harvey PR, Ryan M, Veneeklas E, Lambers H, Oberson A, Culvenor RA and R Simpson** Plant and microbial strategies to improve the phosphorus efficiency of agriculture. *Plant Soil*. 2011; **349(1-2):** 121–156. https://doi.org/10.1007/s11104-011-0950-4

ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 2
February 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

41. **Syers J, Johnston A and D Curtin** Efficiency of soil and fertilizer phosphorus use. FAO Fertilizer and plant nutrition. 2008; Bulletin 18.

42. **Germeier CU and S Unger** Modeling Crop Genetic Resources Phenotyping Information Systems. *Front. Plant Sci. Sec. Plant Breeding.* 2019 ;**10 :**728. https://doi.org/10.3389/fpls.2019.00728