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**Phosphorus use efficiency, grain yield, and quality
of triticale and durum wheat under irrigated
conditions**

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Abstract

After nitrogen stress, phosphorus is the second most widely occurring nutrient deficiency in cereal systems around the world. The objectives of this study were: (1) to look at the effect of changes in phosphorus use efficiency and responsiveness on grain yield and quality of triticale and durum wheat with respect to an old tall durum wheat of the early 1940s, Barrigon Yaqui. A two-year field experiment was established at the CIANO research station in Cd. Obregon, Sonora, Mexico. The experimental design used was a split-plot, main plots were two levels of phosphorus (0 vs 80 kg P₂O₅), and subplots were 20 genotypes [10 durum wheat (1-10) and 6 triticale (11-20)] with three replications. The effect of phosphorus deficiency was severe: only 43% of the achievable yield was obtained with no P application. The modern durum wheat and triticale genotypes included in this study equaled Barrigon Yaqui in phosphorus use efficiency (performance under low P conditions). In contrast, all modern durum wheat and triticale genotypes (except for Tehuacan 60, Tehuacan 67, and Beagle_1) were more responsive to P applications with grain yields in some genotypes almost three times higher in the 80 kg P₂O₅ application treatment. Percent grain protein on average was higher in durum wheat than in triticale. Within durum wheat, compared to Barrigon Yaqui, most durum genotypes were the same except for Cocorit 71, Mexicali 75, and Altar 84, which had lower percent grain protein when well fertilized with P. Compared to Barrigon Yaqui, all triticale genotypes had lower percent grain protein. Under high P conditions, the early durum Cocorit 71 and all durum genotypes from Aconchi 89 onwards had higher sedimentation values than Barrigon Yaqui. In contrast, all triticales were not significantly different from Barrigon Yaqui.

Introduction

After nitrogen stress, phosphorus is the second most widely occurring nutrient deficiency in cereal systems around the world. Durum wheat (*Triticum turgidum* var. *durum*) and triticale (\times *Triticosecale* Wittmack) genotypes can be classified as phosphorus efficient (higher yielding than other cultivars under low phosphorus supply) and/or responsive (higher yielding than other cultivars under high phosphorus supply) (Gerloff 1977). Many soils have large reserves of total phosphorus, but low levels of available phosphorus. Al-Abbas and Barber (1964) reported that total P is often 100 times higher than the fraction of soil P available to crop plants. Most cereal growing areas in the developed world will overcome the problem of low P availability through management practices such as the application of phosphorus-based fertilizer/manure. In those areas, together with the supply of phosphorus nutrients, farmers would benefit most by also adopting genotypes that are responsive to high P levels. However, there are areas in the developing world, particularly in Africa, where use and availability of fertilizers and manure is very limited or non-existent. It is in these areas where farmers will benefit most from triticale and durum wheat genotypes that are more efficient at utilizing the low levels of available P in the soil. Due to the widespread adoption of CIMMYT's triticale and durum wheat cultivars around the world (high input and low input environments), it is important that new releases be evaluated under low as well as high P levels to ensure that they are efficient as well as responsive to phosphorus. The objective

of this study was to look at the changes in phosphorus efficiency as well as the responsiveness of modern triticale and durum wheat cultivars compared to Barrigon Yaqui, an old tall durum wheat variety from the early 1940s.

Materials and methods

Site

A two-year field experiment was sown in block 710 of the CIANO research station in Cd. Obregon, Sonora, Mexico, during the 1999-2000 and 2000-2001 crop cycles. The soil was a fine montmorillonitic Chromic Calcitorrert; soil texture was clay sand. The site had some problems with salinity and sodicity mainly in the subsoil (Table 1). The experimental design used was a split-plot; main plots were two levels of phosphorus (0 vs 80 kg P₂O₅) and subplots were 20 genotypes [10 durum wheat (1-10) and 6 triticale (11-20)] with three replications. The low phosphorus environment was created by continuous cropping of wheat in the winter and maize in the summer, without adding P fertilizer and removing all plant biomass from the field for three consecutive years prior to trial establishment. Experiments were planted within the optimum planting date of November 15 to December 15. Seed rate was 120 kg of seed per hectare for both crops. Plot size was 4 beds, 80 cm apart, 3.2 m wide and 5 m long. The harvested area (4.8 m²) consisted of the middle 3 m of the 2 middle beds. Weeds were controlled by a combination of chemical herbicides and hand weeding. Rust pathogens were controlled with the application of fungicides (triadimefon at 0.5 kg ha⁻¹). Plots were harvested by hand and threshed using a Pullman thresher; grain yield was expressed at 12% moisture.

Table 1. Some soil chemical characteristics of the experimental site

Depth (cm)	pH	E.C. (dS/m)	SAR	Organic Matter
0-15	8.8	1.50	10.46	0.81
15-30	8.9	1.40	13.75	0.72
30-60	8.7	2.15	17.43	0.48
60-90	8.0	6.85	13.18	0.34

Grain Quality Analysis

Durum wheat pasta making quality was determined by measuring protein quantity (NIR analysis), protein quality (as indicated by SDS sedimentation, mixograph dough mixing time and mixograph height), and yellow pigment content (as determined by endosperm yellowness).

Data Analysis

Data were analyzed using SAS statistical program, applying the PROC MIXED procedure (SAS 1991). The variables (genotype, phosphorus, and phosphorus x genotype interactions) were considered as fixed effects in the model, while year, replications and all their interactions were considered random. If any of the variance components resulted in zero variance, the component was removed to achieve a more parsimonious model. The means and significance of genotype and phosphorus x genotype interaction were obtained using the LSMEANS/PDIFF procedure.

Results

Grain yield

There was a strong P deficiency in the experimental area. Average yield under no P application was only 2,185 kg/ha across both years and all genotypes, which was only 43% of the yield obtained with P application (5,075 kg/ha). Compared to Barrigon Yaqui, all durum wheat cultivars except for the two early releases Tehuacan 60 and Tehuacan 67 (which had the same yield) were higher yielding with 80 kg P₂O₅/ha (more responsive to phosphorus). Similarly, compared to Barrigon Yaqui all triticale genotypes were also higher yielding when P was applied (more responsive to phosphorus applications) except the genotype EDA_5/Tapir. In contrast, under conditions of P deficiency (no phosphorus applied as fertilizer) among all durum and triticale genotypes only the triticale Eronga 83 had significantly higher yield than Barrigon Yaqui.

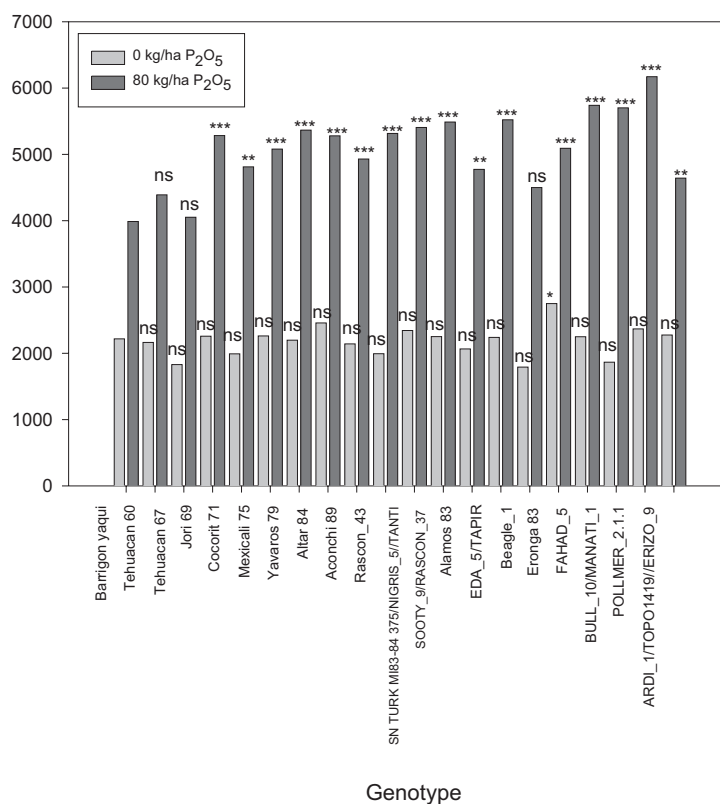


Fig. 1. Grain yield of twelve durum wheat and eight Triticales with and without P application

- * — significant at 5 % level compared with Barrigon Yaqui
- ** — significant at 1% level compared with Barrigon Yaqui
- *** — significant at < 1% level compared with Barrigon Yaqui
- ns — not significant compared with Barrigon Yaqui

Percent grain protein

On average durum wheat genotypes had higher percent grain protein than triticale. Compared to Barrigon Yaqui, most durum genotypes were the same except for Cocorit 71,

Mexicali 75, and Altar 84, which had a lower percent grain protein when well fertilized with P. All triticale genotypes had lower percent grain protein than Barrigon Yaqui. Under low P conditions, differences among genotypes were very similar to those under high P. Higher protein levels were achieved under low P conditions probably as a result of the lower yields associated with low P levels.

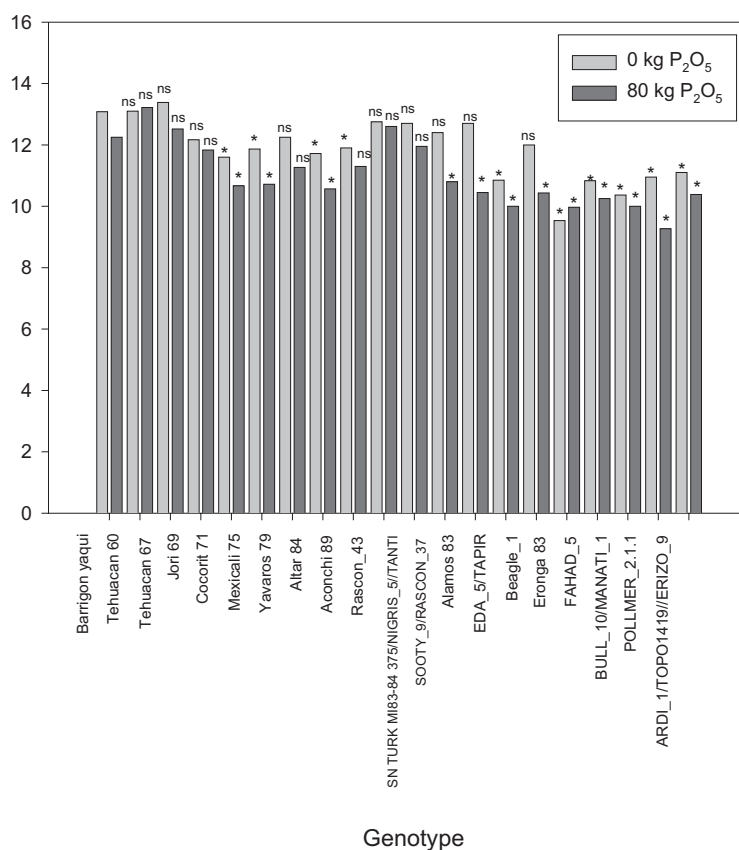


Fig. 2. Percent grain protein of twelve durum wheat and eight Triticales with and without P application

* — significant at 5 % level compared with Barrigon Yaqui

** — significant at 1% level compared with Barrigon Yaqui

*** — significant at < 1% level compared with Barrigon Yaqui

ns — not significant compared with Barrigon Yaqui

Sedimentation

Under high P conditions, the early durum Cocorit 71 and all durum genotypes from Aconchi 89 onwards had higher sedimentation values than Barrigon Yaqui. In contrast, all triticales were not significantly different from Barrigon Yaqui. These differences were very similar under low P conditions.

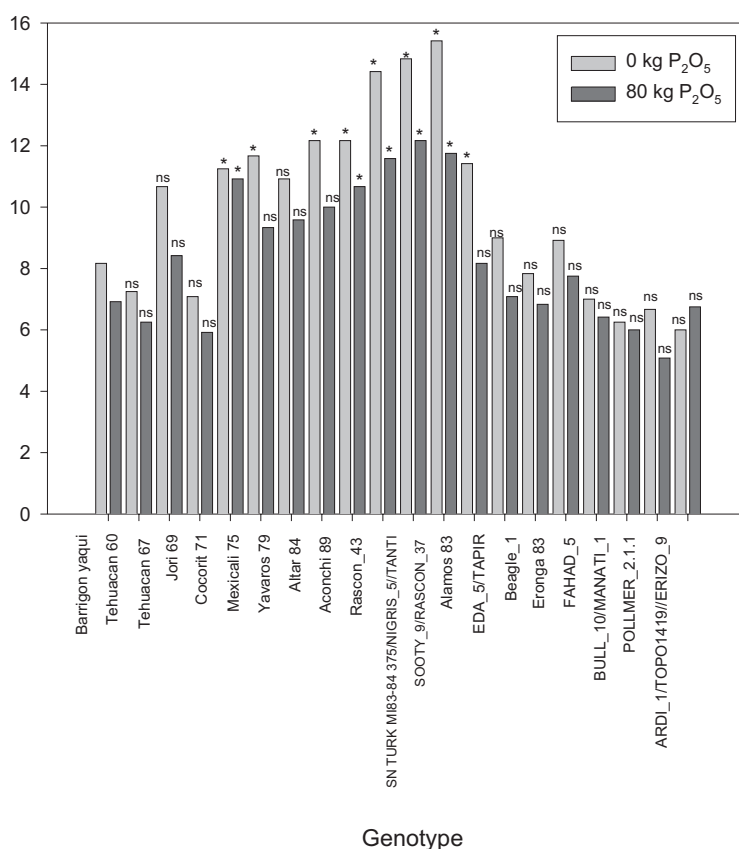


Fig. 3. Sedimentation of twelve durum wheat and eight Triticales with and without P application

* — significant at 5 % level compared with Barrigon Yaqui

** — significant at 1% level compared with Barrigon Yaqui

*** — significant at < 1% level compared with Barrigon Yaqui

ns not — significant compared with Barrigon Yaqui

Conclusions

Grain yield

These results suggest that generally there has been substantial improvement (e.g., genetic gains) in terms of P responsiveness in both triticale and durum wheat with respect to Barrigon Yaqui. In contrast, there has been no progress on phosphorus use efficiency (performance under low P conditions) within durum wheat, and only one triticale was better than Barrigon Yaqui. This suggests that the current breeding strategy allows selecting only for P responsiveness but not for P use efficiency. When selection for P use efficiency is an important breeding objective, breeders will have to look at alternative breeding strategies to meet this objective.

Grain protein

There is better discrimination among genotypes for grain protein under high P fertilizer conditions. Therefore, breeders should ensure that their segregating populations and their

yield trials are well fertilized with P. On average triticales had a lower protein level than durum wheats.

Sedimentation

Progress in sedimentation values (type of protein) has occurred mainly in more recent durum wheat germplasm. There has been a net improvement in durum wheat quality mainly associated with the type of protein, rather the amount of protein. There has been a significant achievement in terms of improving quality in durum wheat but not in triticales. This improvement in quality has been achieved while at the same time increasing grain yield.

References

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