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# GRAIN YIELD AND YIELD COMPONENTS OF TRITICALE ON AN ACID SOIL DEPENDING ON MINERAL FERTILISATION AND LIMING

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## Summary

A field experiment with triticale cvs. ’Tango’, ’KG-20’ and ’Odyssey’ was established on a pseudogley (gleysol) in 2010/11 and 2011/12 to evaluate the effect of different rates of mineral fertilisers and lime on grain yield and yield components. Mineral fertilisation and liming led to a significant increase in grain yield components, notably grain number and grain weight per spike, thus resulting in increased grain yields in fertilised treatments. Liming gave a higher grain yield as compared to the increased P rate, mostly due to P immobilisation in the highly acidic environment. Growing triticale on very acid soils should involve liming, if considered economically feasible, to increase soil pH above the suboptimal level (pH 5.0) for the realisation of its yield potential.

**Keywords**: triticale, grain yield, mineral fertilisation, liming, acid soils

## Introduction

Triticale (*x Triticosecale*) is a small grain crop produced by crossing wheat (*Triticum sp*) and rye (*Secale cereale*) to combine the high yield potential and good grain quality of wheat with the resistance/tolerance to biotic and abiotic stresses of rye. The nutritional advantages of triticale over maize make triticale an increasingly preferred feed for all types of livestock (Đekić et al., 2011). Moreover, the potential use of triticale as a complete or partial substitute for commercially important cereal grains (wheat and maize) in fish (carp) feeds has been confirmed (Marković et al., 2012).

Through the improvement of the most important economic traits viz. grain yield, nutritional quality, early maturity and grain fill, triticale has become an increasingly attractive option, particularly for regions with cold climates and for low-fertility, degraded and low-pH soils.

It has been estimated that 30-40% of the world’s arable land is acidic, with a pH below 5.5 (von Uexkull and Mutert, 1995). There are many chemical limitations and interactions among chemical compounds in acid soils that constrain plant growth. Acid soils are deficient in Ca, Mg and Mo, low in available P, and have increased levels of toxic H, Al and Mn ions, with Al toxicity being the major constraint to plant growth.

Plant species and cultivars within species vary widely in their resistance to Al toxicity. A relatively wide range of Al resistance has been observed in wheat (de Sousa, 1998) and rye (Aniol et al., 1980). Therefore, triticale is also expected to show markedly different tolerance to soil acidity. Triticale has moderate soil requirements and good tolerance of low pH (about 5.0), and a large number of its strains show better adaptability to acidity compared to wheat cultivars (Oettler et al., 2000; Madic et al., 2013).

The objective of this study was to evaluate the effect of mineral fertilisation and liming on the grain yield and yield components of three triticale cultivars grown on an acid soil.

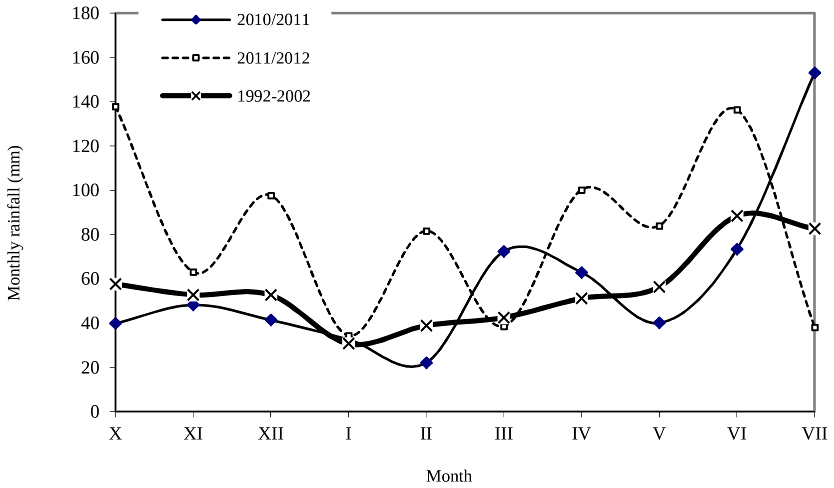
## Material and methods

The research was conducted at the experimental field of the Secondary School of Agriculture and Chemistry, Kraljevo, in 2010/2011 and 2011/2012. The experiment was established on an acidic pseudogley (gleysol), $pH_{H2O}$ 4.5, having a humus content of 2.2%. Triticale cultivars ’Tango’ (Agricultural and Technological Research Centre, Zaječar), ’KG-20’ and ’Odyssey’(Small Grains Research Centre, Kragujevac) and different fertilisation treatments were used (Table 1).

*Table 1. Fertiliser rates used in the experiment (kg ha$^{-1}$)*

| | Fertilisation ($P_2O_5$ kg ha$^{-1}$) : for the fertilised treatments = + 120 N + 53 $K_2O$ | | | |
|---|---|---|---|---|
| | $P_0$ (unfertilised) | $P_1$ | $P_2$ | $P_1$Ca |
| P2O5 (kg ha$^{-1}$) | 0 | 80 | 180 | |
| $CaCO_3$ (t ha$^{-1}$) | 0 | 0 | 0 | 5 |

The experiment was laid out as a randomised block design in three replications, with a plot size of 5m$^2$. Sowing was conducted in mid-October at a row spacing of 12.5 cm and a within-row spacing of 3 cm. Fertilisation involved the use of complex NPK fertilisers (8:24:16), superphosphate (17% P2O5) and ammonium nitrate (34.4% N) as a nitrogen fertiliser for top dressing. Prior to seedbed preparation, the whole amount of phosphorus and potassium fertilisers and a third of the nitrogen fertiliser were manually broadcast. Treatment $P_1$Ca included the broadcast application of "Njival Ca" lime fertiliser (98.5% $CaCO_3$,1% $MgCO_3$). The rest of the nitrogen was used as a single dressing in early spring. At full maturity, a sample consisting of 30 plants was collected from each plot for analysis of plant height, spike length, grain number per spike and grain weight per spike. After harvest, grain yield was weighed and calculated in kg ha$^{-1}$. The results were subjected to analysis of variance, using SPSS software (1995). The significance of differences between means was assessed by the LSD test.




Graph 1. Monthly rainfall during the experimental growing season, and the long-term average (1992-2002) for Kraljevo

The total rainfall in both growing seasons was comparable to the long-term average, with a rather uneven distribution across months (Graph 1). At sowing, emergence and other critical stages for plant growth, total rainfall was sufficient to ensure intensive plant growth and development.

## Results and discussion

The analysis of variance for all traits shows significant differences among cultivars (except for grain yield in the second year) and fertilisation treatments, as well as variations across cultivars in their response to fertilisation (cultivar/fertilisation interaction) (Table 2).

The differences among cultivars were mostly consistent across years; plant height, spike length and grain number/weight per spike were significantly lower in cv. ‘KG-20’ than in the other cultivars tested (Table 2).

Plant height in all cultivars was the lowest in the unfertilised treatment (P1), whereas spike length and grain number/weight per spike were significantly higher in all fertilised treatments than in treatment P0. In both years, spike length was significantly lower in treatment P0, compared to the other treatments. In the first year, grain number per spike was the lowest in treatment P0, significantly higher in treatment P1, and highest in treatments P2 and P1Ca; in the second year, significantly higher values were found in all treatments compared to treatment I. In both years, grain weight per spike was the lowest in treatment P0, significantly higher in treatment P1, and the highest in treatments P2 and P1Ca.

Regardless of fertilisation, differences in grain yield were observed only between ’Tango’ and ’Odyssey’ in the first year. Differences in grain yield in both years, regardless of cultivar, were significant across all treatments; the lowest yield was produced in treatment I, and the highest in treatment P1Ca.

In both years, the use of NP1K (treatment P1) led to an almost twofold increase in grain yield in all cultivars compared to the unfertilised treatment.

Increasing rates of P (treatments P1 and P2) resulted in 18.2% and 17.3% increases in grain yield in the first and second years, respectively. Liming (treatments P1 and P1Ca) increased grain yields by 36.6% in the first year and 32.1% in the second year. The marked response of the test cultivars to lime, compared to increased P application rates, is associated with P immobilisation in the very acidic environment (Edwards et al.1991). The cultivars showed consistent responses to increased P rates and liming in both years. Grain yield of triticale significantly increased with increasing combined N+P fertiliser rates up to 200 kg N+ 40 kg P $ha^{-1}$, whereas the positive response to further increases in NP rates progressively diminished, leading to a negative effect of overfertilisation (Moinuddin and Afridi, 2008). Harmoney and Thompson (2005) also reported a favourable response of triticale (grown for green forage) to increasing N and P fertilisation up to a certain rate, whereas StošoviC et al (2010) suggested positive effects of increased N rates on grain yield, with the rate of 80 kg N $ha^{-1}$ being the most cost-effective for large-scale production.

The average grain number per spike was higher in fertilised treatments than in treatment I by 40.6% in the first year and 41.3% in the second year, whereas grain weight per spike increased by 51.5% and 78.8%, respectively. The marked increase in grain weight per spike in fertilised treatments, compared to grain number per spike, was attributed to favourable conditions in the grain filling period, primarily sufficient soil moisture, particularly in the second year. Different environments can modify the expression of yield components, thus making changes in both grain yield and the relative contribution of yield components to grain yield (Wallace and Zobel, 1994). The results obtained confirm the finding of Giunta et al. (1999) that grain fill duration, moisture and assimilate supply during the period are the key determinants of grain weight.

*Table 2. Results of investigations*

Impacts of cultivar (factor A: A1 = Tango, A2 = KG-20, A3 = Odyssey) and fertilisation (factor B: B1 = unfertilised; B2 = P1, B3 = P2; B4 = P1Ca: Table 1) on plant height (PH), spike length (SL), grain number per spike (GNS), grain weight per spike (GWS) and grain yield (GY) of triticale

| Factor | | PH | SL | GNS | GWS | GY | PH | SL | GNS | GWS | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | B | cm | cm | | g | kg ha$^{-1}$ | cm | cm | | g | kg ha$^{-1}$ |
| | | 2010/2011 growing season | | | | | 2011/2012 growing season | | | | |
| A1 | | 110.8a | 10.6a | 45.9a | 1.82a | 4378 | 113.9a | 10.7a | 44.9a | 1.85a | 4378 |
| A2 | | 99.6b | 8.4b | 36.0c | 1.37b | 4046 | 101.9b | 7.7b | 34.2c | 1.15c | 4046 |
| A3 | | 107.4a | 10.9a | 39.4b | 1.43b | 4089 | 116.2a | 11.2a | 37.2b | 1.59b | 4089 |
| | P0 | 90.4c | 7.5c | 31.0c | 1.11c | 2101d | 99.2b | 8.0 bc | 29.3b | 0.96c | 2101d |
| | P1 | 102.5b | 10.1b | 40.2b | 1.50b | 4173c | 110.9a | 10.6 a | 43.0a | 1.61b | 4173c |
| | P2 | 114.2a | 10.7ab | 43.9a | 1.73a | 4895b | 117.5a | 10.7a | 41.4a | 1.67b | 4895b |
| | P1Ca | 116.8a | 11.6a | 46.7a | 1.82a | 5514a | 115.1a | 10.3a | 41.4a | 1.87a | 5514a |
| A1 | P0 | 89.3 | 7.1c | 32.7 | 32.7 | 2081 | 95.7d | 8.0bc | 1.17d | 1.17d | 2081 |
| | P1 | 108.4 | 11.1ab | 49.2 | 49.2 | 4175 | 117.2a | 11.8a | 1.94ab | 1.94ab | 4175 |
| | P2 | 122.0 | 12.0a | 51.3 | 51.3 | 4935 | 125.0a | 12.2a | 2.04ab | 2.04ab | 4935 |
| | P1Ca | 123.6 | 12.4a | 50.5 | 50.5 | 6301 | 117.8ab | 10.9a | 2.24a | 2.24a | 6301 |
| A2 | P0 | 85.8 | 7.2c | 29.5 | 29.5 | 1999 | 99.1cd | 6.9c | 0.86e | 0.86e | 1999 |
| | P1 | 96.0 | 8.2c | 35.3 | 35.3 | 3983 | 94.1d | 7.9bc | 1.17d | 1.17d | 3983 |
| | P2 | 106.6 | 8.1c | 36.9 | 36.9 | 4797 | 105.3cd | 7.5bc | 1.04de | 1.04de | 4797 |
| | P1Ca | 110.0 | 10.0b | 42.4 | 42.4 | 5404 | 109.1bc | 8.4b | 1.54c | 1.54c | 5404 |
| A3 | P0 | 95.9 | 8.3c | 30.9 | 30.9 | 2224 | 102.9cd | 8.6b | 0.86e | 0.86e | 2224 |
| | P1 | 103.1 | 11.0ab | 36.1 | 36.1 | 4360 | 121.5a | 12.2a | 1.72bc | 1.72bc | 4360 |
| | P2 | 113.9 | 12.1a | 43.6 | 43.6 | 4935 | 122.1a | 12.3a | 1.93b | 1.93b | 4935 |
| | P1Ca | 116.8 | 12.4a | 47.1 | 47.1 | 4838 | 118.3a | 11.8a | 1.84bc | 1.84bc | 4838 |
| ANOVA | | | | | | | | | | | |
| | A | ** | ** | ** | ** | ns | ** | ** | ** | ** | ns |
| | B | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| | AB | ns | * | ns | * | ns | * | * | ** | * | ns |

*Mean values designated with the same lowercase letter are not significantly different at the 95% level according to the LSD test*
*** F-test significant at 0.01; * F-test significant at the 0.05 level; ns non-significant*

## Conclusion

Mineral fertilisation and liming led to a significant increase in spike length, grain number per spike and grain weight per spike. These yield components are major determinants of grain yield; therefore, yield was significantly higher in fertilised treatments. Soil liming gave a higher grain yield as compared to increasing P rates, due to the greater availability of macro- and micronutrients at increased soil pH or due to P immobilisation in the highly acidic environment. Growing triticale on very acidic soils should involve liming, if considered economically feasible, to increase soil pH above the suboptimal level (pH 5.0) for the realisation of its grain yield potential.

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