CULTIVAR VARIABILITY IN ACIDIC (AL/MN) STRESS TOLERANCE IN TRITICALE

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Abstract

Acidic soil stress, often induced by high levels of aluminium (Al) and/or manganese (Mn), can severely reduce the productivity of cereal crops, including triticale. This study summarises the results obtained from three experiments in which several triticale cultivars were subject to a range of pH values or to low pH combined with Al or Mn stresses imposed in nutrient solution. Triticale cultivars showed normal seedling growth at a wide range of pH values, and H^+ toxicity occurred at an extremely low pH (around 3.5). The Al pulse method indicated differential response and considerable cultivar variabilities in Al tolerance based on root regrowth characteristics at 10 mg/g Al imposed. Mn tolerance responses were assessed by relative plant dry root weight. There appeared to be some association of Mn tolerance and Al tolerance in nutrient solution.

Key words: Aluminium tolerance, cultivar variability, hydrogen ion, manganese tolerance, root growth and regrowth, soil acidity, triticale (x Triticosecale Wittmack)

In large areas of the world, including Australia, crop production is limited by soil acidity (2, 3). Soil acidity decreases plant growth in many ways, but toxicities of hydrogen ions (H^+), aluminium (Al) and/or manganese (Mn) have been recognised as common causes of reduc-ed yields. Tolerance of soil acidity is an important component of acid soil management. Since triticale is grown largely on acidic soils throughout the world though on a small scale (3), it is necessary to screen and investigate the acidic stress tolerance response so as to maximise its yield in marginal situations. Our objectives were to characterise the differential responses of some major Australian and overseas triticale cultivars to a range of pH, Al or Mn stresses imposed in nutrient solution, and to evaluate cultivar variability for genetic improvement for acidic stress tolerance in future triticale breeding.

Materials and methods

The following three experiments were conducted with triticale (? *Triticosecale* Wittmack) using nutrient solut-ion culture techniques (refer to Aniol (1) for components of nutrient solution) in a growth cabinet with temperat-ure maintained at 24~25^{o}C/19~20^{o}C under 12-hr light/ 12-hr darkness.

Experiment 1: Differential responses of three cultivars to a range of pH values

Tahara, Empat and G4-95A (a South African select-ion) were exposed to six pH treatments; there were T1 (pH 3.5), T2 (4.5), T3 (5.5), T4 (6.5), T5 (7.5) and T6 (8.5). The different pH values were obtained using 1 *N* HCl or 1 *N* NaOH for adjustment.?? Pre-germinated seedlings were cultured in each treatment solution for four days; after which they were transferred to their respect-ive fresh nutrient solutions with each of the specified pH values for another four days, with daily pH adjustment. Ten seedlings were sampled at the 4th day and 8th day, respectively, for measurement of seedling growth.

Experiment 2: Comparison of Al tolerance of Australian and South African (SA) triticales

Following the standard Al tolerance screening system modified by Aniol (1) the Al tolerance response of eight Australian/SA genotypes was tested in terms of root regrowth. The varieties were designated as V1, Tahara (a well adapted Australian triticale with Al tolerance at 10 mg/g Al from previous tests in nutrient solution, used as a standard); V2, Empat; V3, Abacus; V4, G4-95A; V5, 894-94A; V6, 896-94A; V7, 892-94A; and V8, 886-94A. V4 ~ V8 are of SA origin. The Al stress imposed was 10 mg/g (approximately 0.37

mM Al as $AlCl_3$?$6H_2O$) at pH 4.5 for 24 hr. Ten seedlings were measured for root length and regrown root length. Percentage of seedlings showing root regrowth (longer than 0.6 cm) was also recorded.

Experiment 3: Investigation of Mn tolerance response of two cultivars

Pre-germinated seeds of two cultivars (Tahara and G4-95A) were cultured for four days in nutrient solution (without Mn, pH 4.5); seedlings were then transferred to individual plastic trays containing 600 mL nutrient solution of Mn (as $MnSO_4$) imposed at a range of Mn concentrations of 0, 5, 10, 20, 50, 100, and 200 mg/g (designated as T1~T7). Nutrient solutions containing Mn were renewed every three days with daily pH adjustment (pH 4.5). On the 15th day following Mn treat-ments, a 5-seedling sample for all treatments was remov- ed while the remaining five seedlings were harvested on the 25th day. The longest root length of each seedling was measured; shoots and roots (separated from each other) were then dried in a forced air heater at 75^{o}C for 48 hr, and weighed. The dry weight at 0g/g was then used as a basis to calculate the root weight index (RWI) as proposed by MacFie *et al.* (5).

All three experiments used a complete random block design with three replicates for Exp. 1 and 2, and two replicates for Exp. 3. Data were subject to ANOVA us- ing plot mean of the five or ten seedlings; multiple comparisons were made if significant effects existed.

Results

Experiment 1: Differential responses of three cultivars to a range of pH values

Shoot length increased as H+ concentration decreased (*ie.* pH value increased from 3.5 to 8.5). Significant differences in shoot length among cultivars occurred at pH 4.5, 7.5 and 8.5 (Fig. 1). Similarly, the longest root length of the three cultivars increased as H+ concentrat-ion decreased (pH value increased from 3.5 to 7.5). A? much greater difference occurred between pH 3.5 and 4.5, while root length decreased from pH 7.5 to 8.5. On average, G4-95A produced significantly longer roots than Tahara or Empat. Similar but more marked results were also observed on 8-day-old seedlings, particularly for the longest root length.

Greater differences among the pH treatments (data meaned over cultivars) were indicated on a percentage basis using length at pH 7.5 as the standard (Table 1).? Shoot at pH 3.5 accounted for 51.3% and 57.9% of the growth at pH 7.5 respectively for the 4-day-old and 8-day-old seedlings; root growth was only 28.6% and 22.7% respectively, suggesting that the roots were more susceptible to the low pH (hence the H+ toxicity) than the shoots. The indicator root length to shoot length ratio (R/S) showed similar results to the shoot growth data.

Experiment 2: Comparison of Al tolerance of Australian and South African (SA) triticales

Results indicated the existence of considerable vari-ability of Al tolerance among the eight Australian and SA varieties tested in terms of root regrowth characteristics (Fig. 2). Abacus (V3), G4-95A (V4) and Tahara (V1) had the longest regrown root length (1.8-2.0 cm) and a similar high percentage of seedlings with root regrowth (100%, longer than 0.6 cm), those three varieties could be classified as Al-tolerant at 10?mg/g Al.? Furthermore, these three varieties produced longer roots. Conversely, V2, V5 and V6, which had few seed- lings with root regrowth (10-40%) and produced very little root regrowth (0.2-0.5 cm) after the imposition of Al stress, were classified as intolerant to 10?mg/g Al. V7 and V8 could be considered moderately Al-tolerant as most seedlings showed root regrowth and they produced a mid-range of root regrowth (0.8-1.0 cm). It should be noted that regrown root length was greatly correlated with total root length in those eight varieties.

Experiment 3: Investigation of Mn tolerance response of two cultivars

Highly significant differences among the seven Mn treatments were detected at both sampling stages. Mn-affected seedlings generally produced few roots, few lateral roots and shorter roots. Roots were a little brown under toxic conditions; affected leaves were generally chlorotic.

The longest root length was recorded at 10?mg/g Mn for both cultivars. Root length decreased markedly at Mn levels greater than 50?mg/g for Tahara, and from 100 to 200?mg/g for G4-95A. The greatest differences between cultivars occurred at 100?mg/g Mn; root dry weight per plant (Fig. 3) was similarly affected. However, no significant differences could be found at 200?mg/g Mn which appeared to be highly toxic for seedling growth.

Tahara showed normal root growth at 0-50?mg/g Mn but root growth was retarded by 60% at 100?mg/g compared with that at 0?mg/g (*ie.* 40% for RWI); its critical concentration for Mn toxicity was apparently between 50-100?mg/g. G4-95A showed improved relative Mn tolerance at 100?mg/g; only at 200?mg/g, was its root weight greatly reduced (40.9% for RWI). With an apparent critical Mn toxicity concentration between 100-200?mg/g, it appears that G4-95A was more Mn-tolerant than Tahara.

Discussion

Triticale has been considered a relatively suitable crop in regions where other cereals are less productive or poorly adapted in marginal situations (3). However, triticale still suffers reduced yields under acid soil conditions and retarded seedling growth in acid nutrient solutions. Nevertheless, varietal differences do exist and acidic stress-tolerant genotypes are available for further evaluation as can be seen from the differential tolerance responses in seedling growth in this study.

Triticale showed normal seedling growth at a wide range of pH values under nutrient solution culture, from pH 5.0 up to pH 8.5 (Fig. 1). Decreased lengths of shoots and roots were similar among the three cultivars as pH decreased, indicating a uniform response of triticale cultivars to excess H+ concentrations in the nutrient solution. Similar results have been reported in wheat by Johnson and Wilkinson (4), but differences in experimental methods make direct comparison of relative tolerances of these two crops impossible.

In acid mineral soils, Al and/or Mn are major factors limiting plant growth. Differences in Al and Mn tolerance have been demonstrated in many crops (2); cultivar variability in Al tolerance has also been detected in triticale (3). Other studies (X. Zhang and R. Jessop, unpublished data) have also showed the availability of considerable genetic variability of Al tolerance in both Australian and South African genotypes. Apparent Al tolerance of triticale can be assessed through the determination of root regrowth characteristics of seed-lings in nutrient solution by the Al pulse method to facilitate the screening of tolerant germplasm. Conversely, relative root dry weight per plant seemed to be a better index to assess Mn tolerance of triticale cultivars under nutrient solution culture although other indices of dry matter production have been proposed (5). Triticale cultivars showed varying levels of plant growth at different Mn concentrations, indicating the existence of a range of Mn tolerance (Fig. 3). G4-95A was found to be more Mn-tolerant than Tahara in terms of seedling growth and dry matter production. In addition, G4-95A is one of the most Al-tolerant genotypes tested so far.? There appeared to be some association of Al and Mn tolerance, but co-adaptable responses in acid stressed environments (as in both field and in nutrient solution) and the possible mechanisms of Al and/or Mn tolerance warrant further investigation of a range of triticale genotypes.

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