ROMANIAN AGRICULTURAL RESEARCH, NO. 35, 2018
Print ISSN 1222–4227; Online ISSN 2067–5720

# VARIABILITY OF SEMINAL ROOTS ANGLE IN SOME EUROPEAN WINTER WHEAT CULTIVARS

**Monica David**

National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania.
Corresponding author. E-mail: davidmonica233@gmail.com

## ABSTRACT

**Root system traits are important for soil exploration and using soil resources. Wheat root system architecture is closely related to seminal roots axis angle in the seedlings stage. We tested several wheat cultivars with previously known different responses to drought. There was a significant variability between the studied genotypes for seminal roots angle. Western Europe cultivars had angles above 84º, while Romanian cultivars showed a large variability. The simple technique that we used allows breeding to improve wheat root architecture, for a better use of water and nutrients in different water availability conditions.**

**Key words:** drought, root system architecture, seminal roots angle, adaptation.

## INTRODUCTION

Root angle axis is a main component of root system architecture, strongly associated with efficient use of soil resources, in many crops. Genotypes with a good resistance to drought distribute relatively large number of roots in the soil volume located directly below the plant (Manschadi et al., 2006). The root system traits, expressed in the early development stages (seminal roots angle and number) are associated with the extraction of water at different depths in the soil (Richard et al., 2015).

Seminal roots are important for adaptation to drought, due to their early development and association with the root system architecture of the mature plants (Richard et al., 2015). The differences in the seminal roots angle are related to the horizontal and vertical exploration of the soil, which may affect the absorption of water and nutrients in mature wheat plants (Blum et al., 1977; Blum and Arkin, 1984; O'Toole and Bland, 1987; Oyanagi, 1994; Fukai and Cooper, 1995; Kato et al., 2006; Manschadi et al., 2006, 2008; Hund et al., 2008 (a, b); Hammer et al., 2009).

Several studies on wheat, rice, sorghum, etc. have shown that a small root angle in seedlings is a precursor of a deep root system and large branches in soil depth. These characteristics are advantageous for terminal drought conditions, when there is water stored deep in the soil (Manschadi et al., 2006; Uga et al., 2011; Mace et al., 2012; Christopher et al., 2013). Every extra millimeter of water extracted during filling grain produces a plus yield of 55 kg ha$^{-1}$ (Manschadi et al., 2008). In sorghum, a small root angle was associated with the phenotype "stay-green", improving the access of water in the soil depth profile (Singh et al., 2012).

On the other hand, wheat genotypes with a wide root angle can be very well equipped to use the rainfalls in the vegetation season, as a result of a dense but shallow root system (Liao et al., 2006). The selection for a shallow rooting had a positive effect on phosphorus use (in vegetables). The gene DRO1 (Deep rooting 1) increased the yield in rice under drought conditions (Uga et al., 2013 (b)).

Selection for root traits in wheat breeding has been limited by the lack of appropriate methods of phenotyping. Richard et al., (2015) proposed a rapid method for the characterization of the seminal root traits in wheat breeding programs. Their study focused on spring wheat.

Received 21 August 2017; accepted 15 January 2018. First Online: February, 2018. DII 2067-5720 RAR 2018-17

We used their methods to explore the variability of seminal root angle in European winter wheat.

## MATERIAL AND METHODS

We tested 62 winter wheat genotypes, including:

- 12 Romanian released cultivars, with previously known different responses to drought;
- 4 Western European cultivars;
- 1 Russian cultivar;
- 1 Austrian cultivar;
- 44 common and durum breeding lines from the NARDI Fundulea breeding program.

The seeds were allowed to imbibition for 4 days and then planted at equal distances in transparent pots, provided with the same amount of soil and water. Each genotype grains were sown by 3 seeds x 3 repetitions. Then, the transparent pots were placed in other pots with opaque wall. The roots were photographed at 5 days after planting and the seminal roots angle was measured.

Data were analyzed using the statistical analysis software ANOVA in Microsoft Excel.

## RESULTS AND DISCUSSION

There was a significant variability between the studied genotypes for seminal roots angle index, as shown by ANOVA (Table 1).

*Table 1.* ANOVA for seminal roots angle values

| Source of variation | DF | MS | F | F crit. | P-value |
|---|---|---|---|---|---|
| Wheat cultivars | 61 | 261.10 | 2.63 | 1.42 | 2.61E-06 |
| Within cultivars | 124 | 99.16 | | | |
| Total | 185 | | | | |

Seminal roots angle varied in the analyzed winter wheat cultivars between 69 and 111º (Table 2). In the study conducted in Australia, the seminal roots angle has ranged between genotypes with values from 36 to 56º (Richard et al., 2015). This could preliminary suggest that seminal roots angle in European winter wheat could be larger than that found in Australian spring wheat. This would be in agreement with the drier climate of Australia.

The analyzed Western Europe cultivars had seminal roots angles between 84 and 88º, while the Austrian and Russian cultivars had angles of 79 and 85º respectively.

Romanian varieties showed a large variability, with the cultivars Fundulea 133 and Izvor having relatively small angles (74-75º). Both cultivars have been previously described as being more resistant to drought, and this might be possibly associated with a deeper rooting, improving the access to water in the soil depth profile during severe drought periods (Mustăţea et al., 2003, 2009).

The largest wheat seminal roots angle values among Romanian cultivars were found in Dumbrava and Fundulea 4. Dumbrava was released by the Agricultural Research & Development Station Turda for the more humid area of Transylvania, while Fundulea 4 has been known as a high yielding cultivar in favourable years, but relatively susceptible to drought. The larger angles of seminal roots can be considered in agreement with a better use of rainfall during the vegetation season.

A wide variability of seminal roots angle values was found among the common wheat breeding lines. Some wheat lines were identified with angle values equal to or less than Izvor cultivar's value.

The analyzed winter durum breeding lines also showed a wide variability of seminal roots angle values, from 75 to 105º.

The large amplitude of seminal roots angles among the Romanian wheat germplasm might reflect the large variation in water availability patterns, which lead to selection of different root architecture types, complementing each other in different years.

*Table 2*. Classification of wheat genotypes analyzed for seminal roots angle

| No. | Genotype | Group | Angle value |
|---|---|---|---|
| 1. | GDD 3-18 | Breeding line | 69.44 |
| 2. | GDD 1-16 | Breeding line | 72.22 |
| 3. | IZVOR | Romanian cultivar (NARDI) | 73.89 |
| 4. | GDD 1-5 | Breeding line | 74.11 |
| 5. | Fundulea 133 | Romanian cultivar (NARDI) | 75.5 |
| 6. | DIN 204 | Durum breeding line | 75.56 |
| 7. | Miranda | Romanian cultivar (NARDI) | 76 |
| 8. | Litera | Romanian cultivar (NARDI) | 76.7 |
| 9. | GDD 1-22 | Breeding line | 77.22 |
| 10. | GCO 3-3 | Breeding line | 77.78 |
| 11. | GDD 4-5 | Breeding line | 77.78 |
| 12. | Andrada | Romanian cultivar (ARS Turda) | 78.2 |
| 13. | Dropia | Romanian cultivar (NARDI) | 78.3 |
| 14. | Delabrad | Romanian cultivar (NARDI) | 78.6 |
| 15. | Ai II 107 | Breeding line | 78.89 |
| 16. | Capo | Austrian cultivar | 78.9 |
| 17. | GDD 1-9 | Breeding line | 81.56 |
| 18. | Bi II 47 | Breeding line | 81.67 |
| 19. | Bi II 108 | Breeding line | 83.33 |
| 20. | Glosa | Romanian cultivar (NARDI) | 83.8 |
| 21. | DDU 147 | Durum breeding line | 83.89 |
| 22. | Adelina | Romanian cultivar (ARS Simnic) | 84.1 |
| 23. | GDD 1-15 | Breeding line | 84.44 |
| 24. | Apache | West European cultivar | 84.5 |
| 25. | GCO 1-9 | Breeding line | 84.78 |
| 26. | Bi II 89 | Breeding line | 85 |
| 27. | DDU 21 | Durum breeding line | 85.28 |
| 28. | Bezostaia | Russian cultivar | 85.5 |
| 29. | GDD 1-17 | Breeding line | 86.11 |
| 30. | GCO 3-5 | Breeding line | 86.44 |
| 31. | Aerobic | West European cultivar | 86.6 |
| 32. | Exotic | West European cultivar | 86.9 |
| 33. | Ai I 69 | Breeding line | 87.22 |
| 34. | DDU 45 | Durum breeding line | 87.22 |
| 35. | DDU 83 | Durum breeding line | 87.22 |
| 36. | GDD 1-13 | Breeding line | 87.22 |
| 37. | GCO 1-5 | Breeding line | 87.78 |
| 38. | Falado | West European cultivar | 88 |
| 39. | Ai II 201 | Breeding line | 88.89 |
| 40. | Ai I 75 | Breeding line | 90 |
| 41. | Ai I 77 | Breeding line | 90 |
| 42. | GDD 4-13 | Breeding line | 90.56 |
| 43. | Faur | Romanian cultivar (NARDI) | 90.8 |
| 44. | Bi II 125 | Breeding line | 92.78 |
| 45. | GDD 4-8 | Breeding line | 93.61 |
| 46. | DDU 143 | Durum breeding line | 93.89 |
| 47. | Fundulea 4 | Romanian cultivar (NARDI) | 95 |
| 48. | Bi I 3 | Breeding line | 95.56 |
| 49. | GDD 1-7 | Breeding line | 95.56 |
| 50. | DDU 167 | Durum breeding line | 96.39 |
| 51. | AiII 55 | Breeding line | 96.67 |
| 52. | DDU 179 | Durum breeding line | 98.33 |
| 53. | Ai II 123 | Breeding line | 98.89 |
| 54. | Ai II 126 | Breeding line | 99.44 |
| 55. | GCO 1-7 | Breeding line | 99.44 |
| 56. | GDR 203 | Breeding line | 101.67 |

| | | | |
|---|---|---|---|
| 57. | AiII 223 | Breeding line | 104.44 |
| 58. | Ai II 193 | Breeding line | 105 |
| 59. | DDU 174 | Durum breeding line | 105 |
| 60. | Dumbrava | Romanian cultivar (ARS Turda) | 105.1 |
| 61. | Ai II 183 | Breeding line | 107.78 |
| 62. | AiII 172 | Breeding line | 111.11 |

The variation in seminal roots angles was not correlated with other physiological indices describing water stress response, such as osmotic adjustment or response of seedlings to gradual drying of the substrate (data not shown). This could open the perspective of combining different mechanisms that can contribute to better performance under drought.

## CONCLUSIONS

We found significant differences between the analyzed genotypes. This diversity can assist in selecting new cultivars, with root system architecture better adapted to different patterns of water availability. These could include genotypes with deep roots for good performance under drought, when water is only available deeper in the soil, but also genotypes with shallower rooting system for better use of smaller amounts of rainfall during the vegetation period.

## REFERENCES

Blum, A., Arkin, G.F., Jordan, W.R., 1977. *Sorghum root morphogenesis and growth. I. Effect of maturity genes.* Crop Sci., 17: 149-153.

Blum, A., Arkin, G.F., 1984. *Sorghum root growth and water-use as affected by water supply and growth duration.* Field Crops Res., 9: 131-142.

Christopher, J., Christopher, M., Jennings, R., Jones, S., Fletcher, S., Borrell, A., Manschadi, A.M., Jordan, D., Mace, E., Hammer, G., 2013. *QTL for root angle and number in a population developed from bread wheats (Triticum aestivum) with contrasting adaptation to water-limited environments.* Theor. Appl. Genet., 126: 1563-1574

Fukai, S., Cooper, M., 1995. *Development of drought-resistant cultivars using physiomorphological traits in rice.* Field Crops Res., 40: 67-86.

Hammer, G.L., Dong, Z., McLean, G., Doherty, A., Messina, C., Schussler, J.C., Zinselmeier, Paszkiewicz, S., Cooper, M., 2009. *Can changes in canopy and/or root system architecture explain historical maize yield trends in the U.S. Corn Belt?* Crop Sci., 49: 299-312.

Hund, A., Fracheboud, Y., Soldati, A., Stamp, P., 2008a. *Cold tolerance of maize seedlings as determined by root morphology and photosynthetic traits.* Eur. J. Agron., 28: 178-185.

Hund, A., Ruta, N., Liedgens, M., 2008b. *Rooting depth and water use efficiency of tropical maize inbred lines, differing in drought tolerance.* Plant and Soil, 318: 311-325.

Liao, M., Palta, J.A., Fillery, I.R.P., 2006. *Root characteristics of vigorous wheat improve early nitrogen uptake.* Australian Journal of Agricultural Research, 57: 1097-1107.

Kato,Y., Abe, J., Kamoshita, A., Yamagishi, J., 2006. *Genotypic variation in root growth angle in rice (Oryza sativa L.) and its association with deep root development in upland fields with different water regimes.* Plant Soil, 287: 117-129.

Mace, E.S., Singh, V., vanOosterom, E.J., Hammer, G.L., Hunt, C.H., Jordan, D.R., 2012. *QTL for nodal root angle in sorghum (Sorghum bicolour L. Moench) co-locate with QTL for traits associated with drought adaptation.* Theor. Appl. Genet., 124: 97-109.

Manschadi, A.M., Christopher, J., de Voil, P., Hammer, G.L., 2006. *The role of root architectural traits in adaptation of wheat to water-limited environments.* Funct. Plant Biol., 33: 823-837.

Manschadi, A.M., Hammer, G.L., Christopher, J.T., de Voil, P., 2008. *Genotypic variation in seedling root architectural traits and implications for drought adaptation in wheat (Triticum aestivum L.).* Plant and Soil, 303: 115-129.

Mustăţea, P., Săulescu, N.N., Ittu, Gh., Păunescu, G., Stere, I., Tanislav, N., Zamfir, M.C., Voinea, I., 2003. *Diferenţe genotipice în rezistenţa grâului la secetă, evidenţiate în condiţiile anului 2002.* Analele ICDA Fundulea, 70: 7-16.

Mustăţea, P., Săulescu, N. N., Ittu, Gh., Păunescu, G., Voinea, L., Stere, I., Mîrlogeanu, S., Constantinescu, E., Năstase, D., 2009. *Grain yield and yield stability of winter wheat cultivars in contrasting weather conditions.* Romanian Agricultural Research, 26: 1-8.

Richard, C., Hickey, L., Fletcher, S., Jennings, R., Chenu, K., Christopher, J., 2015. *High-throughput phenotyping of seminal root traits in wheat.* Plant Methods, 11(1): 13.

Oyanagi, A., 1994. *Gravitropic response growth angle and vertical distribution of roots of wheat (Triticum aestivum L.). Plant and Soil,* 165(2): 323-326.

O'Toole, J.C., Bland, W.L., 1987. *Genotypic variation in crop plant root systems.* Adv. Agr., 41: 91-143.

Singh, V., van Oosterom, E.J., Jordan, D.R, Hunt, C.H., Hammer, G.L., 2011. *Genetic variability and control of nodal root angle in sorghum*. Crop Sci., 51: 2011-20.

Uga, Y., Okuno, K.,Yano, M., 2011. *Dro1, a major QTL involved in deep rooting of rice under upland field conditions.* J. Exp. Bot., 62: 2485-2494

Uga,Y., Sugimoto, K., Ogawa, S., Rane, J., Ishitani, M., Hara, N., Kitomi, Y., Inukai, Y., Ono, K., Kanno, N., 2013a. *Control of root system architecture by DEEPER ROOTING 1 increases rice yield under drought conditions.* Nat. Genet. 45: 1097-1102.

Uga,Y., Yamamoto, E., Kanno, N., Kawai, S., Mizubayashi, T., Fukuoka, S., 2013b. *A major QTL controlling deep rooting on rice chromosome 4.* Sci. Rep., 3: 3040.