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The relationship between phosphate absorption and root length in nine wheat cultivars

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Introduction

Because the diffusion coefficients of potassium and especially of phosphate ions in the soil are very small (Barber, 1974) the uptake of these nutrients is extensively dependent on the concentration gradient and the diffusion conditions (*e.g.* water content) of the soils (Römer and Schilling, 1987). For this reason the nutrients mentioned can only be exploited from a small soil cylinder around the roots (Jungk, 1984). Therefore plant species with a large root system like grasses are superior to others *e.g.* leguminous plants with regard to phosphate uptake (Steffen, 1984).

Hence the question arises whether the phosphate uptake of different wheat idiotypes correlates with their root surface or whether the uptake intensity per surface unit—*e.g.* by a smaller Michaelis-constant of the carrier system—can additionally compensate for the disadvantages of small root systems. As the P-supply influences root growth (Böhm, 1974), these relations should be investigated under conditions of low as well as high P-supply.

Materials and methods

From each of the 9 cultivars 4 groups of 10 plants were cultivated in polyethylene vessels (50 cm deep, diameter 5.6 cm) on quartz sand in a phytotron. The seed weight was 45 ± 5 mg. Nutrients (6 mg P·pot^{-1} and 44 mg P·pot^{-1} respectively, 0.2 g N, 0.3 g K, 0.07 g Mg, micro-nutrients) were mixed with quartz sand (1560 g). Phosphorus was applied as $CaHPO_4 \cdot 2H_2O$.

After 3 weeks the following parameters were determined: dry matter of shoots and roots, their P-content and the total root length, both main and of lateral roots (Augustin, 1984). The P taken up by plants within 3 weeks is the difference between the P-content of the plants and that of the seeds. Hence, the P-uptake intensity per cm root length in 3 weeks could be computed (μg P·cm^{-1}.[3 weeks]$^{-1}$).

Results

Table 1 shows that a higher P-supply causes a higher P-uptake in all cultivars. The concentration of P in shoots on the low P-level ranged from 0.32 to 0.41% P in dry matter and on the high P-level

Table 1. P uptake (μg P plant^{-1}) of 9 wheat cultivars within 3 weeks

	Low P level (6 mg P·pot^{-1})		High P level (44 mg P·pot^{-1})	
Cultivar	μg P	relative	μg P	relative
Fanal	365	81	838	100
Remus	369	82	696	83
Iljitschjowka	351	78	672	80
Compal	341	76	669	80
Durum wheat	450	100	616	74
14/44	324	72	554	66
Almus	304	68	540	64
Fakta	362	80	514	61
15080	396	88	504	60
$\bar{x}$	362	(100)	622	(172)
LSD 5% Tukey	43	10	77	9

Table 2. The dependence of total root length (cm/plant) and P-uptake intensity ($\mu g\,P \cdot cm^{-1}$ root. [3 weeks]$^{-1}$ in 9 wheat cultivars (high P-level = 44 mg P·pot^{-1}, low P-level = 6 mg P·pot^{-1})

	Total root length				P-uptake intensity			
	High P level		Low P level		High P level		Low P level	
Cultivar	cm·plant^{-1}	rel.	cm·plant^{-1}	rel.	$\mu g \cdot cm^{-1}$	rel.	$\mu g \cdot cm^{-1}$	rel.
Fanal	229	75	359	69	3.7	100	1.04	100
Remus	299	97	415	79	2.3	63	0.89	80
Iljitsch.	302	98	444	85	2.3	61	0.81	78
Compal	257	83	360	69	2.6	71	0.96	92
Durum w.	309	100	522	100	2.0	55	0.87	84
14/44	280	91	426	82	2.0	53	0.78	75
Almus	230	75	345	66	2.4	64	0.90	87
Fakta	226	73	363	69	2.3	62	1.04	100
15080	241	75	464	89	2.1	57	0.86	83
$\bar{x}$	263	(100)	410	(156)	2.4	(100)	0.91	(38)
LSD 5% Tukey	45	15	73	14	0.32	9	0.2	18

from 0.62 to 0.96% respectively. Therefore the experiment was principally suitable for testing the reaction of the cultivars with respect to their root growth and phosphate efficiency.

Table 2 shows that the P-supply significantly influenced the total root length and the uptake of P by the 9 cultivars. The root length of all cultivars increased at the lower P-supply at an average of 147 cm (from 263 to 410 cm), or 56%. Contrary to this the P-uptake intensity ($\mu g\,P \cdot cm^{-1}$. [3 weeks]$^{-1}$ decreased by more than 60%. The influence of these relations on the total P uptake of plants was tested by a linear correlation analysis (Table 3). At the high P-level the relation between total P-uptake and uptake intensity was close ($r = 0.88$) while the root length was relatively less important ($r = 0.39$). At the low P-level the significance of the root length clearly increased, r increased from 0.39 to 0.5 while the relation between total P-uptake and uptake intensity per root unit became unimportant ($r = 0.23$).

These general tendencies were modified by the behaviour of the cultivars. It was interesting that some cultivars adapted themselves well to the low P-supply while others were incapable of doing so. Although the absolute P-uptake was generally reduced in case of the low P-supply, the cultivars Durum wheat and 15080 were able to increase their total P-uptake in comparison with other cultivars like Fanal or Compal (Table 1). Under the same conditions Fanal reduced its P-uptake from 100% to 81%. The other cultivars responded in a less distinct manner.

Fakta, Durum wheat and 15080 increased their absolute root length by 61 to 93% under conditions of low P-supply. Besides, all 3 cultivars increased their P uptake compared to Fanal (Table 1). Fanal increased its absolute root length only by 57%. Consequently it lost its leading position regarding the total P-uptake at the low P level in favour of Durum wheat.

Discussion and conclusions

From these results we must conclude that the root length per plant is not important for phosphate uptake at a high P-supply. Obviously high P-uptake intensities per root and time unit enable sufficient P-uptake even when the root system is small. But these results are only relevant for 3 week old plants. Nevertheless, for high yields a high P-uptake up to the shooting phase is decisive

Table 3. Relations between P uptake per plant and the 2 parameters root length and P-uptake intensity per cm root length (linear correlation coefficient r)

y	x	High P level	Low P level
Absorbed P amount per plant	Total root length (cm)	0.39	0.50[a]
	Intensity of P uptake ($\mu g\,P\,cm^{-1}$ root length · 3 weeks)	0.88[a]	0.23

[a] Statistically significant at 1% level.

(Römer and Schilling, 1986). Under conditions of decreasing P-availability the P-absorbing root surface (root length) becomes more and more important. The cultivar spectrum showed that there are some varieties which can adapt themselves to this situation by extending their root system and/or developing a more effective P-uptake per root unit. If the heritability of such characteristics were high, types could be selected with a lower requirement for P-supply. Of course the adaptation capability should not be combined with a low yield level.

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