ROOT MORPHOLOGY AND NITROGEN EFFICIENCY IN NEW HYBRIDS OF WINTER OILSEED RAPE

Federica Zanetti[(1)], Enrico Rampin[(1)], Stefano Loddo[(1)], Teofilo Vamerali[(2)] and Giuliano Mosca[(1)]
[(1)]Dept. of Environmental Agronomy and Crop Sciences, University of Padova, Agripolis, Viale dell'Università 16, 35020 Legnaro (PD), Italy. E-mail: federica.zanetti@unipd.it
[(2)]Dept. of Environmental Sciences, University of Parma, Viale G.P. Usberti 11/A, 43100 Parma, Italy

Key words: semi–dwarf hybrid, shoot biomass, root system, N uptake, root length density, root diameter.

Oilseed rape (OSR) (*Brassica napus* L.) is the most widespread oil crop in Europe and its production has increased rapidly in recent decades. Yield rises are mainly due to genetic breeding and higher applications of inputs, especially nitrogen. OSR is characterized by low N efficiency, leading to high N balance surpluses (Berry et al., 2010). Consequently, integrated N management, based on highly N efficient genotypes, is needed to prevent environmental pollution (Sieling et al., 2008). New semi-dwarf hybrids, being less tall but with high yield potential, may meet this requirement, as they have deeper root systems and higher root densities from early growth stages onward. Many studies (Kage et al., 2000; Vamerali et al., 2000; Kamh at al., 2005) have reported how the root system may be a good indicator of N uptake potential. In this regard, two experiments were set up with OSR: one in open field, lasting 2 years, monitoring crop growth throughout its cycle, and the other in pots, to study the early growth stage.

Materials and Methods

A semi-dwarf (PR45D01, Pioneer Hi-Breed) and a conventional OSR hybrids (Excalibur, Dekalb) were compared during plant establishment and flowering phases in terms of root growth and N uptake efficiency.

Plant biometry was investigated in pots through weekly samplings, from emergence until 40 days after sowing (DAS). A two-year field trial (2007-2009) was also set up at the Experimental farm of the University of Padova at Legnaro (45°21'N, 11°58'E, NE-Italy) to study root growth and N uptake in conditions of decreasing N fertilisation. Three N rates were compared: unfertilized controls (0 N), a high dose (100 N) and an intermediate rate, the latter defined each year by applying the "Reglette Azote" criterion (CETIOM, 1998).

In both experiments, shoot N was monitored with the Kjeldahl method. At root level, length, root length density (RLD) and diameter were assessed by destructive sampling: for pot plants, the entire root system was sampled weekly (10 pots at each date); for the field experiments, auger sampling was applied at full flowering (n = 4). The root system was sampled to a depth of 1 m and cores were cut into 10-cm long subsamples. All samples were stored at –18°C until processing. After 2 hours soaking in oxalic acid solution (20 g L^{-1}), roots were separated from soil particles by a hydraulic sieving-centrifugation device (500-µm mesh) (Cahoon and Morton 1961). Coarse sand was separated by flotation. Roots were stored in ethanol solution (10% by vol) at 4 °C, until 1-bit 400-DPI resolution (11.8 pixel mm^{-1}) TIFF format images were acquired by digital scanning. Large extraneous objects (e.g., organic debris) were removed from samples with tweezers, and mages were processed by KS 300 Rel. 3.0 software, interfaced with a spreadsheet for recording data. Root length was determined by the *FbL* algorithm (fiberlength) available in the software and modified by Vamerali et al. (2003). In order to discriminate roots from residual extraneous objects, an elongation index ($perimeter^2$ $area^{-1}$) value >70 was adopted during processing.

Results of the examined parameters were analyzed by ANOVA with Statgraphics Centurion XV software. Mean separation was at $P \leq 0.05$, according to Tukey's test.

Results and conclusions

In pots, at early growth stage, as expected, the semi-dwarf genotype produced smaller shoots and root systems, and had lower N uptake than the conventional hybrid, although shoot N concentration was slightly higher (3.72 vs. 3.59 % of Excalibur, P>0.05). Shoot fresh biomass was found to be significantly (P<0.05) and positively correlated with root length in both genotypes (Fig. 1), so that it seems possible to estimate the size of the root system by simply weighting the shoots.

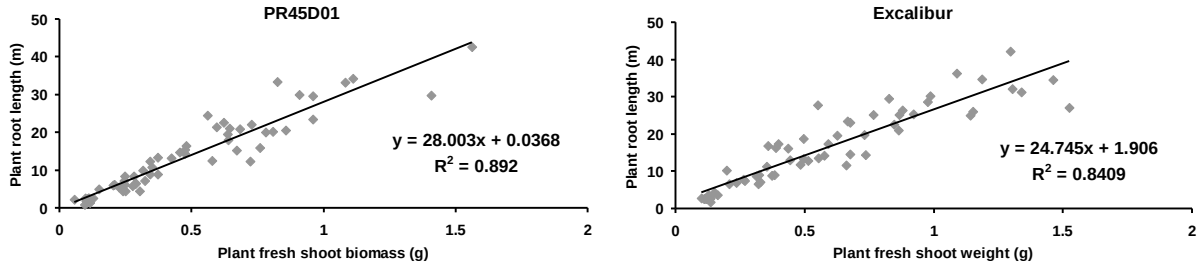

Fig. 1. Correlation (n= 60, P<0.05) between shoot fresh weight (g) and root length (m) in two OSR hybrids in pot experiment.

At this early stage, a significant positive relationship (P<0.05) between root length and shoot N content for each sampling, was found: the longer the root system, the higher the N accumulation in shoots (Fig. 2).

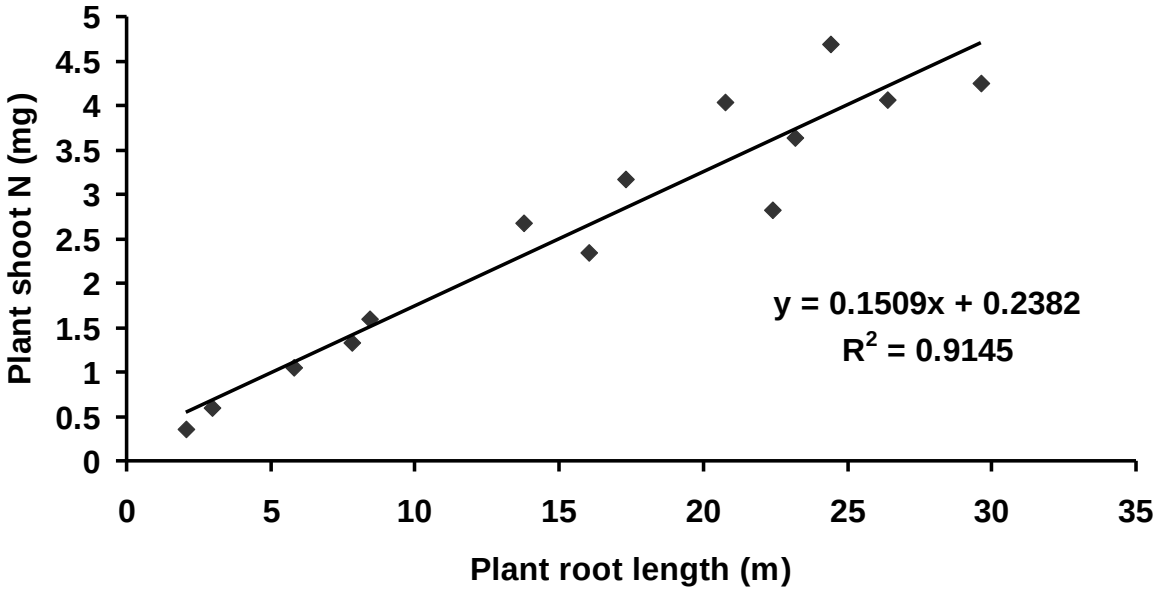

Fig. 2. Pot investigation: correlation (n= 14, P<0.05) between root length and shoot N content, monitored in two OSR hybrids every 7 d, until 40 DAS.

In open field, at flowering, the semi-dwarf genotype compensated its limited early growth by showing significantly higher RLD (P<0.05) (Tab. 1) (average of 1-m profile), although this was mainly due to significantly higher growth in the arable layer (0-50 cm). Instead Excalibur exhibited deeper growth, and significant was the "genotype × depth" interaction (P<0.05).

RLD was also influenced by N fertilisation and higher values were generally found in fertilised plots (Tab. 1), the significantly highest ones (P<0.05) being associated with Reglette doses. The highest N dose (i.e., 100 kg ha^{-1}) led to RLD increases in the upper soil (to a depth of 30 cm), whereas the opposite occurred downward.

Tab. 1. Two-year field experiment: mean RLD (cm cm^{-3}) of whole profiles (1 m depth) at flowering of two OSR genotypes. Letters: significantly different values. (P<0.05, Tukey's test).

	2007-2008				2008	
	0N	Reglette	100N	Mean	0N	Reglette
PR45D01	3.01a	3.25a	3.33a	**3.19a**	2.10ab	3.12a
Excalibur	2.37a	3.08a	2.70a	**2.72b**	2.73ab	2.21ab

In open field, root diameter was influenced by genotype, the conventional hybrid Excalibur having higher values (348 vs. 340 µm of PR45D01, P<0.05). No differences between the two hybrids in early stages in pots were detectable.

PR45D01 showed greater shoot N concentration in open field (1.84 vs. 1.66 %, full flowering, 2-year mean). However, in view of the larger shoot biomass of the conventional hybrid, N uptake of both genotypes was comparable throughout the monitoring period (flowering time in both years) (P=0.80). N uptake was very high (grand mean: 184 kg N ha^{-1}), indicating good ability in N recovery even without N supply. As expected, N uptake was influenced by N fertilization (P<0.05), higher values being found at 100 N (213 vs. 181 vs. 158 kg N ha^{-1}, respectively, at 100 N, Reglette and 0N dose, main effect "fertilisation"). Excalibur showed more stable N uptake in response to fertilization and in the two years, compared with PR45D01. This behavior was also reflected in stable seed yields, which were higher and less fluctuating in both years and input levels in the conventional hybrid than the semi-dwarf hybrid.

Conclusions

The higher RLD of the tested semi-dwarf genotype in the upper soil may be interestingly exploited for increasing nutrient acquisition during winter in rainy environments. Right in shallow layers, N is more available and a greater uptake may reduce the potential nitrate leaching. This finding was also observed under increased N supply, as PR45D01 had greater RLD than Excalibur under 100 kg N ha^{-1}, demonstrating a greater rooting potential and stable response. Instead, for the parameters examined, Excalibur had a behavior which was less influenced by the environment and N rate.

References

Berry et al., (2010). The physiological basis of genotypic differences in nitrogen use efficiency in oilseed rape (*Brassica napus* L.). Field Crops Res. 119, 2-3: 365-373.

Cahoon & Morton, (1961). An apparatus for the quantitative separation of plant roots from soil. Proc. Am. Soc. Hortic. Sci. 78: 593-596.

CETIOM, (1998). Nitrogen and rape in spring. Oleoscope 48: 9-26.

Kage et al., (2000). Root growth of cauliflower (*Brassica oleracea* L. *botrytis*) under unstressed conditions: measurement and modelling. Plant Soil, 223: 131-145.

Kamh et al., (2005). Root growth and N-uptake activity of oilseed rape (*Brassica napus*) cultivars differing in nitrogen efficiency. J. Plant Nutr. Soil Sci., 168: 130-137.

Sieling et al., (2008). The potential of semi-dwarf oilseed rape genotypes to reduce risk of N leaching. J. Agr. Sci., 147: 77-84.

Vamerali et al., (2000). Is the root system the key to higher nitrogen uptake in rapeseed? In: The supporting roots of trees and woody plants: form, function and physiology, A. Stokes (ed.): 397-404.

Vamerali et al., (2003). Analysis of root images from auger sampling with a fast procedure: a case of application to sugar beet. Plant Soil. 255 (1): 387-397.