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Short communication. Nitrogen content of residual alfalfa taproots under irrigation

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Abstract

The decomposition of alfalfa (*Medicago sativa* L.) residues can provide significant amounts of N to subsequent crops, but most of the data on this subject has been obtained from 1-2 year old alfalfa stands. The objective of this study was to determine the biomass of alfalfa taproots and their N content in irrigated alfalfa stands that are more than 2 years old. Twenty-two commercial irrigated alfalfa fields were evaluated in the Ebro Valley (Northeast Spain) from 2006 to 2010. The taproot biomass in the arable layer (0 to 30 cm depth) ranged from 1.8 to 10.1 Mg ha^{-1} and averaged 4.8 Mg ha^{-1}. In contrast, the N concentration in alfalfa taproots was constant among fields and averaged 24.6 g N kg^{-1}. The total amount of N contained in alfalfa taproots (0-30 cm depth) ranged from 47 to 96 kg N ha^{-1} in 55% of the fields, ranged from 97 to 200 kg N ha^{-1} in 22% of the fields, and exceeded 200 kg N ha^{-1} in 23% of the fields. The N content of the irrigated alfalfa taproots studied here is in the upper range previously reported in other areas, mainly with younger alfalfa stands. Based on the current finding, a classification of the quality of irrigated alfalfa stands is proposed to improve the estimates of the residual-N effects of alfalfa on subsequent crops.

Additional key words: root biomass; alfalfa stands.

Alfalfa (*Medicago sativa* L.) is one of the main forage crops in the irrigated areas of the Ebro Valley (Northeast Spain). In this region, alfalfa crops are usually grown for periods of at least 3 years, receive 5 to 7 cuts per year, and yield from 11 to 23 Mg ha^{-1} of dry matter per year, depending on such factors as cultivar, stand age and the method of irrigation, etc. (Delgado *et al.*, 2005; Lloveras *et al.*, 2008). In the area studied, a good alfalfa stand includes about 400 plants m^{-2} at emergence and is ploughed when the visual plant density falls to below 50 plants m^{-2} (Delgado *et al.*, 2005).

After ploughing, the mineralization of alfalfa roots and crowns can provide significant amounts of N to the subsequent crop (Morris *et al.*, 1993; Kelner *et al.*, 1997). However, there is little information regarding the N content of residual alfalfa roots at the end of the crop. Previous works conducted in different areas of the world reported that the N content in alfalfa roots ranged from 21 to 259 kg N ha^{-1} (Heichel *et al.*, 1984; Pettersson *et al.*, 1986; Bruuslema & Christie, 1987; Kelner *et al.*, 1997; Justes *et al.*, 2001; Hakl *et al.*, 2007). Nevertheless, most of the existing information was obtained from one- or two-year old alfalfa crops, but the N contributions of older alfalfa stands could be higher than those previously reported in the literature (Kelner *et al.*, 1997). A better assessment of the N content of alfalfa roots and crowns at the end of the crop could help growers to better estimate the N credits of alfalfa for subsequent crops. The main objective of this study was to quantify the N returned to the soil by alfalfa taproots in irrigated commercial fields that were more than 2 years old.

The biomass of residual alfalfa taproots and their N content was determined in 22 commercial alfalfa fields located in Lleida and Huesca provinces (Northeast Spain) from 2006 to 2010. The alfalfa fields studied were between 3 and 7 years old and had been ploughed (usually with chisel plus disk) within one to three weeks of root determination. The cultivars included in this study were 'Aragón' (sown in 21 fields), and 'Ampurdán' (sown in one field). Both cultivars have a fall dormancy rating of 7-8 (non-dormant). The alfalfa-taproot biomass (Mg ha^{-1}) was calculated by multi-

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Figure 1. On the left: determination of alfalfa taproot density. On the right: dry alfalfa taproots.

plying the taproot density (roots ha^{-1}) by the average taproot weight (g root^{-1}). The taproot density was determined by digging between 6 and 10 holes per field, with areas of 0.36 m^2 and depths of 30 cm. Average taproot weight was determined for each field by collecting between 10 and 30 alfalfa taproots (roots plus crowns, without any regrowth) that were representative of each field, washing them with pressured water, and oven drying them at 60°C for 48 h (Fig. 1). The dry taproots were then ground (1-mm sieve) and their C and N concentrations were measured by the dry combustion method, using a CN analyzer (TruSpec CN, LECO, St. Joseph, MI, USA). The amount of N in the alfalfa taproots in the arable layer (kg N ha^{-1}) was calculated by multiplying the alfalfa-taproot biomass by its N concentration.

The alfalfa taproot density at the end of the crop varied widely among fields, ranging between 19 and 67 roots m^{-2} (Table 1). However, the average taproot density (41 pl m^{-2}) was similar when alfalfa stands of different ages were compared. The weight of alfalfa taproots also varied greatly among fields (Table 1). The biggest roots were mainly observed in the oldest and youngest stands. Unexpectedly, plant density and average taproot weight were not negatively related. The biomass of alfalfa taproots in the arable layer (in the upper 30 cm of the soil) ranged from 1.8 to 10.1 Mg ha^{-1} (Table 1) and was related to both taproot density ($R^2 = 0.44$, $p < 0.001$) and to average taproot weight ($R^2 = 0.56$, $p < 0.001$). If the aged 6 and 7 year old alfalfa stands (which are rare in the region) are removed from the analysis, the relationship between taproot density and taproot biomass improves significantly ($R^2 = 0.56$, $p < 0.001$), as does that between taproot weight and taproot biomass ($R^2 = 0.70$, $p < 0.001$).

The N concentration in alfalfa taproots was very constant among fields and averaged 24.6 g kg^{-1} (Table 1). As a result, the amount of N returned to the soil with alfalfa taproots (0-30 cm) ranged from 47 to 237 kg N ha^{-1} (Table 1). About 55% of the commercial alfalfa fields evaluated in this study had between 47 and 96 kg N ha^{-1} in their taproots. The other 45% of fields had more than 100 kg N ha^{-1} in their taproots, whereas almost one in four fields had more than 200 kg N ha^{-1} in the taproots in the arable layer (Table 1). An estimation of the total volume of the alfalfa taproots was carried out in ten commercial fields by measuring the crown and the lower taproot diameters and the recovered taproot length and by considering the alfalfa root as a "cone". The results obtained showed that in our soils, we recovered between 71 and 91% of the total taproot volume in first 30 cm of the soil, with the value varying according to the field.

Under irrigated semiarid conditions, alfalfa taproots derived from 3 to 7 year old stands can return large quantities of N to the soil (from 47 to 237 kg N ha^{-1}). These values are greater than most of the values reported in previous studies (21-79 kg N ha^{-1}) (Heichel *et al*., 1984; Bruuslema & Christie, 1987; Justes *et al*., 2001; Hakl *et al*., 2007) and similar to those reported by Pettersson *et al*. (1986) in Sweden and by Kelner *et al*. (1997) in Canada (from 107 to 259 kg N ha^{-1}). In the present study, we estimated a rate of taproot recovery of 70-90%, omitting the lateral roots. This estimation is feasible given that 'Aragon', the most common variety of alfalfa grown in the area, does not normally branch. These results are in line with those of various other authors who reported that most of the alfalfa root biomass was present in the upper 20-40 cm of the soil profile (Lamba *et al*., 1949; Upchurch & Lovvorn, 1951; Abdul-Jabbar *et al*., 1982).

Table 1. Main characteristics of the different irrigated commercial alfalfa fields at the end of the crop. All fields had alfalfa cultivars with a fall dormancy rating of 7-8

Commercial alfalfa field	Stand age (yr)	Alfalfa taproot						
		Density (roots m^{-2})	Weight (g root^{-1})	Biomass (kg ha^{-1})	C (g kg^{-1})	N (g kg^{-1})	C:N ratio	N content (kg N ha^{-1})
1	3	24	9.4	2,256	452	24.2	18.7	55
2	3	42	12.9	5,418	452	26.3	17.2	142
3	3	56	14.5	8,120	446	26.1	17.1	212
4	3	47	19.6	9,212	458	25.7	17.8	237
5	4	48	4.1	1,968	449	23.9	18.8	47
6	4	33	6.0	1,980	461	24.5	18.8	49
7	4	37	7.1	2,627	456	25.2	18.1	66
8*	4	39	7.5	2,948	440	23.4	18.8	69
9	4	35	16.3	5,705	460	24.7	18.6	141
10*	4	60	14.1	8,460	440	23.8	18.5	201
11	5	25	7.4	1,850	454	25.6	17.7	47
12*	5	19	10.7	2,037	447	26.3	17.0	54
13	5	47	5.0	2,350	457	25.0	18.3	59
14	5	27	10.9	2,943	448	21.0	21.3	62
15*	5	48	5.6	2,698	439	26.3	16.7	71
16	5	34	9.9	3,366	446	23.3	19.1	78
17	5	66	9.8	6,468	445	26.9	16.5	174
18*	5	60	13.3	7,980	464	26.5	17.5	212
19	5	67	15.1	10,117	460	23.4	19.7	237
20	6	29	18.5	5,365	455	22.7	20.0	122
21	6	32	21.3	6,816	461	24.2	19.0	165
22	7	28	15.3	4,284	456	22.5	20.3	96
Average	4.5	41	11.6	4,771	452	24.6	18.4	118
SD	1.1	14.2	4.9	2,706	7	1.5	1.2	68

SD: standard deviation. *: Fields reported in Cela *et al.* (2011).

Table 2. Proposed quality of alfalfa stands as a function of the taproot biomass and the taproot-N content in the upper 30 cm of the soil. The N concentration of alfalfa taproots was considered as 25 g kg^{-1}

	Alfalfa stand quality			
	Poor	Regular	Good	Very good
Taproot biomass (Mg ha^{-1})	<2.5	2.5-5.0	5.0-7.5	7.5-10
N in taproots (kg N ha^{-1})	<60	60-120	120-180	180-240
N credits of alfalfa* (kg N ha^{-1})	<40	40-80	80-120	120-170

* Assuming that ≈ 70% of the N in alfalfa taproots mineralizes during the first year after ploughing (Fox & Piekielek, 1988).

The N content in alfalfa taproots was closely related to the taproot biomass ($R^2 = 0.99$, $p < 0.001$). Then, we propose classifying irrigated alfalfa stands into four categories (Table 2), based on the average, lowest and highest taproot biomasses reported in Table 1. It is important to mention here that the N content in alfalfa taproots is not immediately available for crops. A study conducted in the US Midwest (Fox & Piekielek, 1988) reported that up to 70% of the N contained in alfalfa roots can be mineralized within the first year after the end of the alfalfa crop. According to this classification, about half of the alfalfa fields evaluated in this study would be 'poor' or 'regular' (they had less than 5 Mg ha^{-1} of taproots and would provide less than 80 kg N ha^{-1} to a subsequent crop). On the contrary, the other half would be classified as 'good' or 'very good' (they had more than 5 Mg ha^{-1} of taproots and would provide more than 80 kg N ha^{-1} to a subsequent crop). The N credits of alfalfa for following crops estimated in this study (from ≈40 to ≈170 kg N ha^{-1}, Table 2) are in line with the results reported by Cela *et al.* (2011), who found that N applications for maize succeeding alfalfa could be greatly reduced (> 100 kg N ha^{-1}) compared to the rates normally applied in irrigated conditions. The proposed classification could help to better evaluate the residual-N effects of irrigated alfalfa on subsequent crops. More research is needed to improve our estimate of the rate of N mineralization from alfalfa roots under irrigated semiarid conditions.

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