BELOW-GROUND INPUTS OF CARBON BY CROPS AND PASTURES

M.C. Crawford[1,2], P.R. Grace[1], W.D. Bellotti[1,3], and J.M. Oades[2]

[1]CRC for Soil and Land Management, Glen Osmond, SA 5064
[2]Department of Soil Science, University of Adelaide, Adelaide, SA 5000
[3]Department of Agronomy and Farming Systems, University of Adelaide, Adelaide, SA 5000

Summary. To determine the annual input of carbon to the soil organic matter pool, the below-ground production of a faba bean crop, a grazed barrel medic pasture and a grazed barley grass pasture was quantified in a field trial at Roseworthy, South Australia. *True* root growth (which include living, dead and decomposed roots) was calculated from repeated, simultaneous measurements of living root biomass and dead organic material and disappearance rates of dead roots and old organic material. Maximum live root biomass for both the barley grass and medic pastures was similar (~1000 kg/ha), whereas faba beans were less (~250 kg/ha). True root growth was about 55-75% greater than maximum live root biomass for all species. Root-shoot ratios of both pasture species were 0.55 compared to 0.32 for faba beans, indicating that the pasture species are more efficient at contributing to the soil organic matter pool than the faba beans.

INTRODUCTION

The maintenance of, or addition to, soil organic matter (SOM) is considered to be necessary for sustainable agricultural activities, especially those involving some form of arable cropping (1). In most Australian agricultural ecosystems, one of the major input of organic carbon to the SOM pool comes from the below-ground growth, death and decay of the roots of crops and pastures. Because this root growth is hidden from us by the soil, it is difficult to quantify the annual inputs of organic C that occur by this process. Nevertheless, this information is necessary to develop sustainable farming practices and to assist in the validation of SOM models that attempt to estimate C turnover in agro-ecosystems (2). Many studies have reported figures for root biomass for a wide variety of crops and conditions. Often, however, these results cannot be used for an estimate of annual below-ground C input because net root biomass was measured, and no account was taken of root death, dead root decomposition and the exudation and secretion of C compounds from the roots throughout the growing season (3). In addition, where roots are sampled only once in a season (usually at flowering), it is uncertain whether root biomass is at or near the maximum (4).

An alternative approach is to measure net root growth plus root death and decomposition (‘true’ root growth) as an estimate of below-ground C allocation. This can be done by adopting a sequential biomass sampling technique (frequently used in ecological studies for determining production of plant communities) (4). It involves the calculation of true root growth from repeated, simultaneous measurements of living root and dead organic material and disappearance rates of dead roots and old organic material. This method accounts for root mortality and decomposition, thus avoiding underestimation of true root growth, and gives a figure more closely aligned to the true magnitude of the annual below-ground C input.

In this experiment, this procedure was utilised to determine and compare the true root growth of 3 annual species common in cropping systems of temperate Australia - a grain legume crop (faba beans), a legume pasture (barrel medic) and a grass pasture (barley grass).

MATERIALS AND METHODS

Theory

When an annual crop is grown, root production is the only major supply of organic material to the soil during the growing season. Old organic material (OOM) present in the soil at the beginning of the season decomposes as the season progresses, hence decreasing the amount of OOM remaining. If the amount of OOM at the beginning of the season is determined, and its decomposition rate is estimated by measuring the disappearance of OOM contained in nylon mesh bags buried in the same field in the same year, then the decreasing amount of OOM through the season can be calculated. At a number of times through the season, samples are taken and the macro-organic material isolated and separated into living roots (LR) and dead organic matter (DOM). DOM consists of both OOM and dead roots (DR) from the current season. As the amount of OOM is known, the quantity of DR can be calculated as the difference between DOM and OOM. However, this amount is potentially underestimated due to decomposition of DR during the season. Therefore, the decomposition rate of DR is also estimated by incubating root material from the current crop or pasture in nylon mesh bags. Consequently, root production can be estimated from the increase in LR between any two sampling periods plus a correction made for roots that have died plus a correction made for roots that have died and decomposed. True root growth for the season can be found by the summation of root production for each sampling period.

Trial Details

The experiment was located at the Roseworthy Campus of the University of Adelaide, approximately 60 km north of Adelaide on a red brown earth. In 1994, 3 treatments in 3 replicates were established in a randomised complete block design: a faba bean crop (*Vicia faba* cv. Fiord); a grazed barrel medic pasture (*Medicago truncatula* Gaertn. cv. Paraggio); and a grazed barley grass pasture (*Hordeum leporinum* Link). Each plot was 50x100 m. The faba beans were sown into a cultivated seedbed at 110 kg/ha on 20 June 1994, after the opening rains and grass and broadleaf weeds were controlled. The medic pasture was established by direct drilling seed at 50 kg/ha on 3 May. Seed did not germinate until after the opening rains in mid-June. The grass pasture consisted of volunteer annual grass species which also germinated in mid-June. The medic pasture was sprayed on 27 June to eliminate grasses and broadleaf weeds and the grass pasture was sprayed on 29 June to eliminate broadleaf species. Measurement of botanical composition on 20 October showed that the medic pasture was 95 % medic and the grass pasture was 99 % barley grass. The medic and grass pastures were grazed by sheep at 10 DSE/ha from 5 August to 20 October. The faba beans and medic pasture were 50 % in flower by 10 September and the grass pasture was 50 % in flower by 16 September. Growing season rainfall (May-October) was 176 mm (average = 291 mm).

Sampling and processing

Cores of 50 mm diameter were taken to 0.3 m depth at 6 weeks after germination (27 July) and to 0.5 m depth at 12 (6 September), 15 (27 September) and 18 (17 October) weeks after germination. Five cores were taken per plot with a hydraulically-driven corer and these were separated into 0.1 m segments. Segments of the same depth in each plot were bulked. Samples were stored at 3?C and processed within 2-5 days of sampling. Roots and DOM were washed from the soil using root washing buckets and captured on a sieve (0.5 mm mesh). Live roots were separated from dead roots and other DOM by hand (using tweezers). Separation was done on the basis of elasticity of the root, root colour and the presence or absence of lateral roots. Live roots were lighter in colour, more elastic and fleshier and possessed more lateral roots than dead roots. Live roots and DOM were dried at 50?C for 48 h and weighed. Subsamples of all material were combusted at 600?C for 4 h to obtain the ash percentage. All results are presented as ash-free.

To estimate the decomposition rate of OOM, material (> 1 mm) was separated from the soil at the beginning of the season using the same method as above and dried at 50?C for 48 h. Nylon mesh bags (10x10 cm, 1.0 mm mesh) were filled with ~1.5 g of OOM and were buried at 7.5-10 cm depth with as little disturbance to the surrounding soil as possible. Four bags were buried in each plot. When soil cores were taken, one bag per plot was retrieved. Bags were gently rinsed in water to remove adhering soil and the current season's roots were picked out with tweezers. The material was then dried at 50?C for 48 h, weighed, and the rate of disappearance calculated. To estimate the decomposition rate of dead roots, root material was obtained from each of the treatments from a depth of 0-0.2 m about one week prior to taking soil cores, washed free of soil and dried at 50?C for 48 h. About 1 g of this material was placed in mesh bags and 3 bags per plot were buried at the same time as taking soil cores under the same treatments from which they had come. Bags were then retrieved the next time soil cores were taken and subjected to the same procedure as the bags containing OOM. In this way, the rate of disappearance of dead roots was calculated.

RESULTS AND DISCUSSION

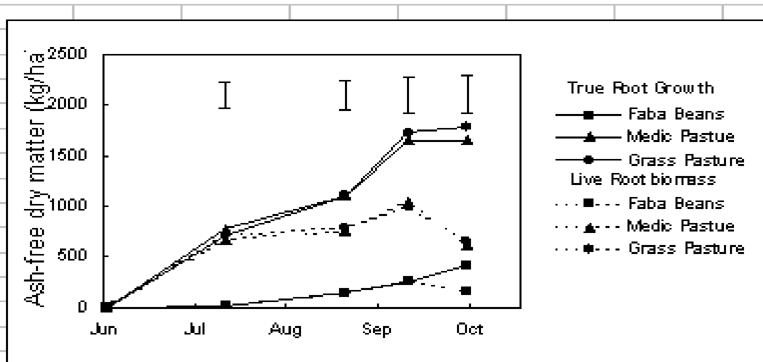

Figure 1. Live root biomass and true root growth for faba beans, barrel medic and barley grass. Error bars indicate least significant difference (*P*=0.05).

Live root biomass reached a maximum at flowering in all species and declined thereafter as plants matured and senesced (Fig. 1). The maximum live root biomass for both the barley grass and barrel medic pastures was similar at about 1000 kg/ha whereas faba beans were significantly less at 250 kg/ha. When true root growth was calculated, taking into account root death and decomposition, yields were 55-75 % greater than the maximum live root biomass. Again, there was no significant difference between medic pasture and grass pasture, yet they were both significantly greater than the true root growth of the faba beans. Some of this difference can be related to the above-ground production which was quite poor for the faba beans. However, the root/shoot ratios showed that both the medic and the grass pastures put a greater proportion of the net assimilated carbon into below-ground growth than did the faba beans (Table 1). Distribution with depth showed that 89 % of faba bean root growth was in the top 20 cm compared to 75 % for medic and 65 % for barley grass. These different percentages could be very important for subsequent decomposition. The deeper the input, the more likely the C will remain - unless the soil is disturbed.

Table 1. Shoot growth, true root growth, root/shoot ratio and true root growth as a proportion of total above- and below-ground growth.

	Shoot growth	True root growth	Root - shoot ratio	Root growth as a % of total growth
	kg/ha	kg/ha	g/g	%
Faba Beans	1330	410	0.32	23.1
Medic Pasture	3100	1650	0.55	35.0
Grass Pasture	3190	1780	0.57	35.1

l.s.d.	433	520	0.22	11.3

The 1994 was a dry season and the growing season rainfall was in the lowest 20% of rainfall years. In drier years, root/shoot ratios often increase as more resources are directed below-ground in the search for moisture (5). However, this may be offset by the effects of drought on the shoot (decreased photosynthesis and/or carbohydrate translocation). Data on root production of these species is being collected again in 1995 under more favourable soil moisture conditions.

In estimating annual inputs of carbon to the soil organic matter pool, this methodology fails to take into account rhizodeposition that occurs in the form of carbon compounds secreted and exuded from roots during the growing season. Whipps (3) reported that this can account for a further 5-40% of live root biomass depending on the species and environment. The methodology also fails to account for fine root fragments less than 0.5 mm in size that might have passed through the sieve. Measurements of root material caught on a 0.25 mm sieve indicate that this fraction could account for a further 10-30% depending on the species (data not shown). Total annual input of carbon, therefore, could be as much as 1.6-2 times the amount of carbon present in live roots at flowering.

The implications of this work are that pastures appear to put more carbon below-ground than a faba bean crop. Although there was little difference in absolute below-ground production between the barley grass and medic pastures, over time, a grassy pasture would become N deficient, which would in turn restrict both above and belowground growth relative to the medic pasture. In addition, there could be differences in the decomposition rates of the material. For example, C/N ratios were lower for the medic roots than the grass roots and the grass roots were found at greater depths. These findings all have implications for soil organic matter dynamics.

ACKNOWLEDGMENTS

Michael Crawford’s studentship is funded by the CRC for Soil and Land Management. The field trial was part of a project *Soil processes under grazed pastures*, funded by GRDC.

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