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A Novel Technique for Measuring Root Activity of Small Crops in Mixtures Using Lithium as a Non-Radioactive Tracer

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Abstract: A novel method of studying root interactions in mixtures of small crops (eg. cereals and peas is discussed. The technique involve the measurements of root activity using lithium, a non-radioactive tracer and using a mixture of cereal and peas as an example of a mixed crop where the technique is applicable. Results of studies on root activity of cereals and peas by Tofinga, Tofinga and Snaydon and Tofinga were used in the discussion and to explain how the technique works. The total lithium uptake by cereals was tenfold that of peas and for both species, the uptake decreased with placement depth. Semi-leafless peas absorbed more lithium than leafy peas, by about sixteen times. Lithium uptake by peas was significantly more in monoculture compared with mixtures, in cereals.

Key words: Lithium, mixed cropping, root activity, tracers, root interactions

INTRODUCTION

Much research attention has been focussed on the canopy structures and light interception patterns of mixed-species stands, both of pastures[1] and of crops[2,3], despite the fact that in many cases, light is not a limiting factor[4-6] in mixed cropping. On the other hand, much less research attention has been given to the root distribution and nutrient uptake patterns of pasture and crop species when grown in mixtures, though information is available on root distribution of trees and semi-natural grasslands and the way in which this affects competition for nutrients and water[7,8], even though in many studies nutrient and water were the limiting factors in crop mixtures[6,9]. One of the reasons for the relative deficiency of data on root distribution in crop mixtures is the difficulty of measurement. It is quite easy, though time-consuming, to measure the root distribution of pure stands in the field, by soil excavation and soil-coring methods; it is more difficult to measure the root distribution of the components of species mixtures, because of the difficulties in separating the root systems.

Measures of root distribution do not necessarily provide evidence of root activity at various depths, because root activity depends on

- The age and physiological status of the root and
- The soil conditions. Since agronomic interest is usually centered on root activity, rather than on root distribution per se, techniques have been developed to measure root activity. For example, radioactive isotopes have been widely used to measure root activity in pure stands[10-12], but the technique requires sophisticated analytical equipment, skill and care in handling. Radioactive tracers could also be used in mixtures, though there seem to be few published examples. Non-radioactive tracers have a number of advantages, compared with radioactive tracers, for studying root activity; they are generally cheap, simple to use and generally less hazadous.

Lithium has been used as a non-radioactive tracer in both monocultures[13] and crop mixtures[14]. Lithium fulfills the main requirements of a suitable tracer, since it is normally present in low concentrations in soils, is absorbed freely by plants, is toxic only at high concetrations and can be eluted from plant materials easily, without acid digestion. This paper describes the use of lithium as a tracer to determine the root activity of crop mixtures and pure stands using results of appropriet experiments[15,16].

MATERIALS AND METHODS

The field equipment is very simple and consist of the following:

- A steel tube (10 mm diameter), open at both ends, containing a steel rod (9 mm diameter) of at least one metre (m) in length. The length depends on how deep one wishes to measure the root activity of the plants. These can and have been made locally.

- A fine plastic tubing (0.5 mm diameter) equal in length to the steel rod.
- A syringe of over 10 mL volume.
- A container, containing 10% lithium chloride solution.
- A heavy weight steel hammer.

The procedures of the technique are as follow for a mixed crop experiment[15].

- Decide the depths at which to measure root activity, for example, 0, 15, 30 and 70 cm from the soil surface.
- Decide where on the plot the planned root activity measurements are to be taken. It is advisable to take the measurements at the corners of the plot, leaving the middle for yield and other data measurements. This also ensure that the sites are not too close to each other.
- For the 0 cm placement, inject lithium on the surface of the soil between rows of the two crop types. The injections at the various placement depths are achieved by using a steel tube (10 mm diameter), driven into the soil to the placement depth using the hammer on the flat end of the steel rod contained in the steel tube.
- The steel rod is removed to insert a fine plastic tube in the steel tube, through which 10 mL of 10% lithium chloride solution is injected using a syringe at the placement depth.
- Five plants of each component or crop type (eg. A and B) should be harvested immediately adjacent to the placement site, 30 days after lithium was injected.
- The plants should be dried at 85 degrees centigrade for 72 h and milled into powder. A sub-sample of 500 mg of the milled plant material should be shaken (in a suitable shaker) for 8 h in 50 mL of warm distilled water and filtered.
- The lithium content of the filtrate is then determined by atomic absorption spectrophotometry.
- The data obtained should be transformed to logarithms before analysis of variance is carried out; this homogenises the variance and allows proportionate comparisons to be made. Lithium uptake is measured as mg per square metre, log scale.

RESULTS AND DISCUSSION

Results are best presented in graph form where the Lithium uptake (mg per square metre, log scale) is plotted on the X-axis and the Depth of placement (cm) is plotted on the Y-axis and LSD values ($p = 0.05$) are indicated by bars. An example from the results of a 4×2×2 factorial mixed cropping experiment with 2 replicates is given Fig. 1[15]. The experimental factors were:

- 4 planting arrangements (pure stands, same-row mixtures, alternate-row mixtures and cross-row mixtures
- 2 cereal species (barley, cv. Jericho and wheat, cv. Corniche)
- 2 pea cultivars (leafy, cv. Bohatyr and semileafless, cv. Countess). Binary mixtures of the cereal species and pea cultivars were used. The interpretation of the results is based on the information contained in the graph Fig. 1 and discussed as follow.

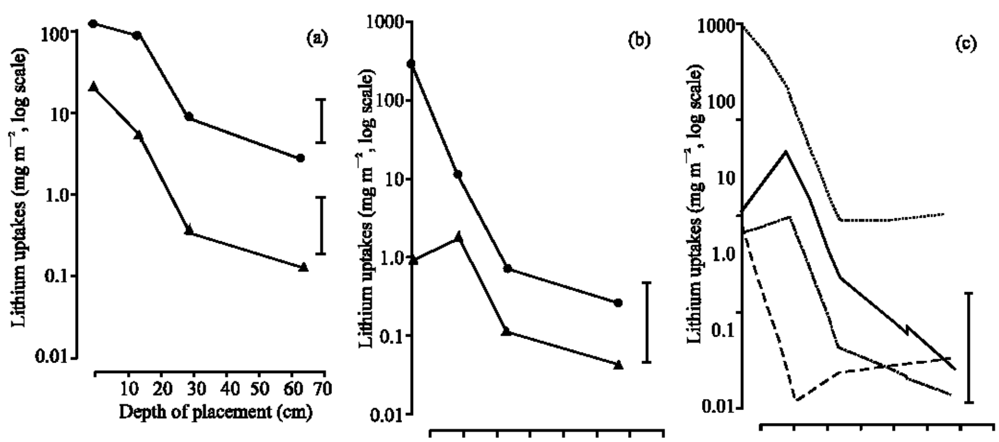

Fig. 1: The uptake of lithium (mg m^{-2}) form various soil depths by cereals and peas. (a) Li uptake by cereals (●–●) and peas (▲–▲) and various mixtures, (b) Li uptakes by leafy pea (▲–▲) and semi-leafless peas (●–●) in mixtures with cereal species (barley or wheat); each value is the mean of three planting patterns. © Li uptakes by peas when grown in pure stands (........) In samerow mixtures (----------) in alternate-row mixtures (----- -----) and in cross-row mixtures with cereals (---- . -----); each value is the mean of two cultivars. Bars indicate LSD ($p = 0.05$)

From Fig. 1, it can be seen that the total uptake of lithium (mg m^{-2}) by cereals was ten times higher than that by peas. The Li uptake of both cereals and peas decreased progressively with depth in a similar manner Fig. 1a.

On average, semi-leafless peas absorbed about sixteen times more lithium (5.6 mg m^{-2}) than leafy peas (0.3 mg m^{-2}) ($p<0.001$). However, there was also a significant pea cultivar x soil depth interaction ($p<0.05$); leafy peas absorbed proportionately less lithium close to the soil surface, compared with other depths, than did semi-leafless peas Fig. 1b. The uptake of lithium by peas was significantly higher ($p<0.05$) when grown in monoculture (1.5 mg m^{-2}) than when grown in same-row mixtures with cereals (1.4 mg m^{-2}), which in turn was higher ($p<0.001$) than when grown in cross-row mixtures (0.40 mg m^{-2}), or alternate-row mixtures (0.1 mg m^{-2}) with cereals. Wheat and barley reduced the lithium uptake of peas by similar amounts. There was a planting arrangement x soil depth interaction ($p<0.05$), mainly because peas grown in pure stands and alternate-row mixtures had a different pattern of uptake with depth than did those grown in same-row and cross-row mixtures Fig. 1c.

CONCLUSION

Lithium can be used successfully to measure root activity of small crops in mixtures. This method is less laborious than soil coring methods used in studies of root distribution, which do not necessarily give evidence of root activity at various depths, which is believed to be more important in putting together complementary and thus high yielding mixed cropping systems. In addition, lithium is non-radioactive and environmentally friendly and its use is highly recommended.

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