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The Partitioning of Sulfur following Fumigation of Wheat, Bean and Cabbage with $H_2{}^{35}S$ and $CO^{35}S$

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Summary

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Wheat, bean and cabbage plants were fumigated with $H_2{}^{35}S$ and $CO^{35}S$. The subsequent movement of the labelled sulfur was followed to crop maturity. The results indicated that the sulfur followed source-sink relationships. The implications for sulfur metabolism are discussed.

Introduction

During the routine operation of gas-cooled nuclear reactors small quantities of $H_2{}^{35}S$ and $CO^{35}S$ are released to the atmosphere. Nuclear Electric, the nuclear power generator in England and Wales, is required to quantify these releases to calculate the radiological dose to man. As a consequence of this predictive models are being developed to provide information on the partition of radioactive sulfur (half-life 87.4 days) to the edible components of the crop through the growing season. At present there are few data describing the movement of sulfur within plants over a long time scale (COLLINS 1992), and it is this aspect of the model development that is described in the following paper.

Materials and Methods

Wheat (cv. Riband), bean (cv. Sutton) and cabbage (cv. April) were sown into pots containing John Innes no. 2 compost on 13/10/89, 17/4/90 and 23/4/90 respectively. 3 l pots were used for the wheat and 2 l for the cabbage and bean. After sowing the pots were placed outside in

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a standing area. Crops were fumigated with $H_2{}^{35}S$ on the following dates: wheat, 19/7/90; bean, 31/5/90 and cabbage 27/9/90 with $CO^{35}S$ fumigation the following day. The final harvest dates were: wheat, 3/8/90; bean, 9/8/90 and cabbage, 11/11/90.

One day before fumigation plants were placed in a perspex chamber within a controlled environment cabinet. The plants were well watered and then the chamber was sealed. The perspex chamber had an internal volume of 0.72 m^3 and was under negative pressure such that there was one air change per minute. The exhaust of the chamber was passed through a charcoal filter containing 5 % KI to remove the active sulfur. Within the chamber the temperature was maintained at 20 ° C and the RH at 60 %. At the uppermost part of the crop the light intensity was 150 $\mu mol\ m^{-2}\ s^{-1}$.

Fumigation commenced at 11 a.m. and was carried out for 30 mins. The concentration of the radioactive gases within the chamber was 0.04 ppm and 0.009 ppm for the H_2S and COS respectively. This level of H_2S was not found to be deleterious even under continuous fumigation (THOMPSON & KATS 1978). The COS concentration in the atmosphere is 500 ppt (SZE & KO 1980), which is well below the experimental concentration, but the author is unaware of any detrimental effects of COS on vegetation.

Immediately after fumigation 2 plants were removed from the chamber, dissected into their component parts and oven dried at 60° C. This was repeated at 24 hrs. At final harvest, crop maturity, 4 replicate plants were used.

Sulfur analysis of the plant material was conducted using the method of KLUCZEWSKI & al. (1986), such that the material is digested in conc. HNO_3, evaporated with $Mg(NO_3)_2$ and then ashed. The ashed material is rehydrated in diluted HNO_3 and then added to Hi-Safe 3 (LKB, Wallac) scintillant for counting. All counting was done on an LKB 1219 Rackbeta, counting efficiency was 95 %. Data were calculated as the total activity in each component and then expressed as the percentage of the total activity in the whole plant.

Results and Discussion

Both gases were partitioned between plant organs in the same pattern (Fig. 1,2,3), which would suggest that the labelled sulfur is being metabolised by the same pathway for translocation. It is proposed that the translocation of labelled sulfur occurs as glutathione. Glutathione is known to accumulate following fumigation with H_2S (DE KOK & al. 1989, BUWALDA & al. 1988). COS is assimilated by carbonic anydrase releasing H_2S (PROTOSCHILL-KREBS & KESSELMEIER 1992). This H_2S is then expected to be metabolised by the same pathway as when it is directly exposed to plants. Following fumigation with $CO^{35}S$ BROWN & al. 1986 recovered 67 % of the labelled sulfur in buffer extracts of foliage as glutathione.

In cabbage (Fig. 1a,b) translocation occured from the leaves to the stem and roots. This partition continued upto 100 days with COS (Fig. 1a) and upto 56 days with H_2S (Fig. 1b). The high proportion in the stem at 48 h following fumigation with H_2S is thought to be an spurious result.

Following exposure to $CO^{35}S$ and $H_2{}^{35}S$ the bean plants demonstrated differences in the partition pattern between 0.5 h and 24 h (Figs 2a,b) with a more rapid import to the pods following exposure to COS. At maturity when the seeds had developed inside the pods and the weight of the reproductive parts had increased tenfold, significant import was recorded with the seeds and pods account-

ing for 72 % and 73 % of the label following fumigation with COS and H_2S respectively.

The ear was the main sink component between 0.5 h and 24 h after fumigation with $CO^{35}S$ to wheat (Fig. 3a) and the ear and roots with H_2S (Fig. 3b). Subsequent movement did not indicate a continued partition to the ear, this may be because of these plants being close to maturity and a reduced accumulation rate with time as the grain go from filling to the ripening stage.

The stems and not the leaves were the primary sites of uptake with the wheat plants. This was because the leaves were visibly senescent upon fumigation unlike with cabbage and bean. This result is important because wheat remains in the field for several weeks in the senescent condition before being harvested. Thus any uptake of radioactivity by the grain at this time will have less time to decay than radioactive sulfur partitioned to the grain earlier in the growing season. However, COPE & SPEDDING 1982, related uptake of H_2S to the metabolic activity of the plant, senescing plants may well have a lower metabolic rate. Future work will need to look at the differences in the flux of the labelled gases to the plant at different growth stages, to determine at what part of the lifecycle the most labelled sulfur is accumulated in the grain.

The rapid partition of labelled sulfur to other components from the leaves of bean and cabbage supports the translocation rates of 40 cm h^{-1} recorded by BIDDULPH & al. 1956 and 30 cm h^{-1} by BONAS & al. 1982 for $^{35}SO_4^{2-}$. However, they run contrary to those of BRANDLE & SCHNYDER 1970 who observed little movement from leaves after 15 h following fumigation with $H_2{}^{35}S$, but agree with BROWN & al. 1986 who recovered 17 % of the labelled sulfur in the roots of ryegrass 24 h. after fumigation with $CO^{35}S$.

Finally, these data add further to the debate of sulfur immobility in mature leaves as discussed by CRAM 1990. In all cases here there was sulfur movement from the leaves to other plant components and it is suggested that some of this must come from mature leaves. In the data for cabbage this movement continued for some time. ADIPUTURA & ANDERSON 1992 also observed movement of labelled sulfur from mature leaves.

These preliminary experiments have elicited some thought provoking data, but more experiments will be needed for sound conclusions. Generally, it can be stated that labelled sulfur assimilated after fumigation with $H_2{}^{35}S$ and $CO^{35}S$ follows source-sink relationships and is apparently readily mobile within the plant.

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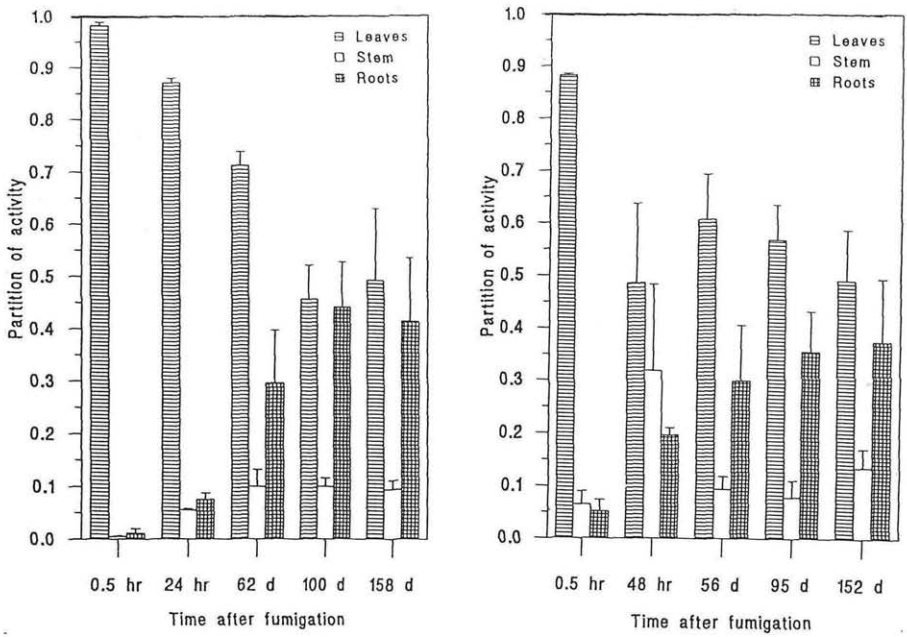

Fig. 1. The partitioning of labelled sulfur in cabbage following fumigation with (a) COS (b) H_2S (vertical bars indicate standard errors).

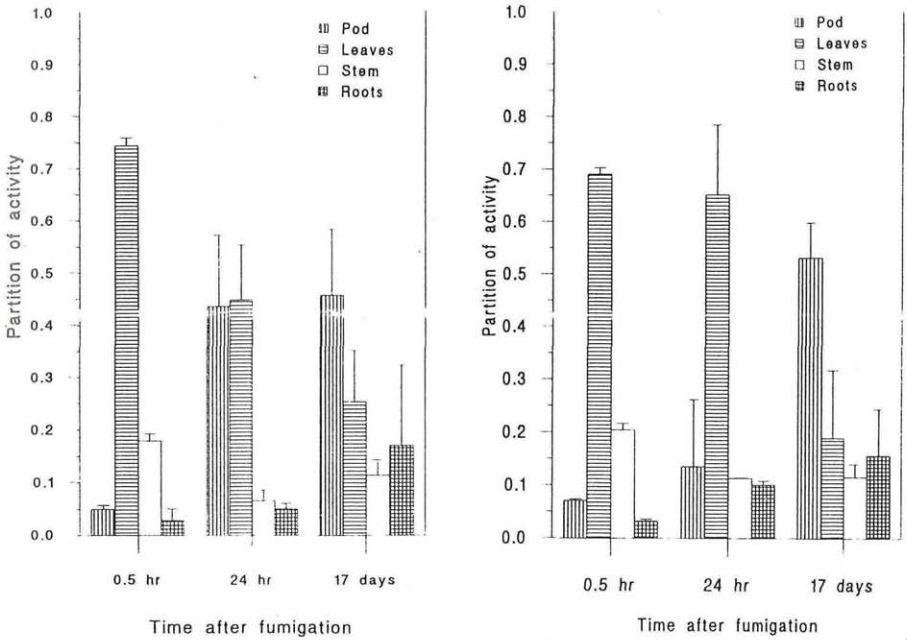

Fig. 2. The partitioning of labelled sulfur in bean following fumigation with (a) COS (b) H_2S (vertical bars indicate standard errors).

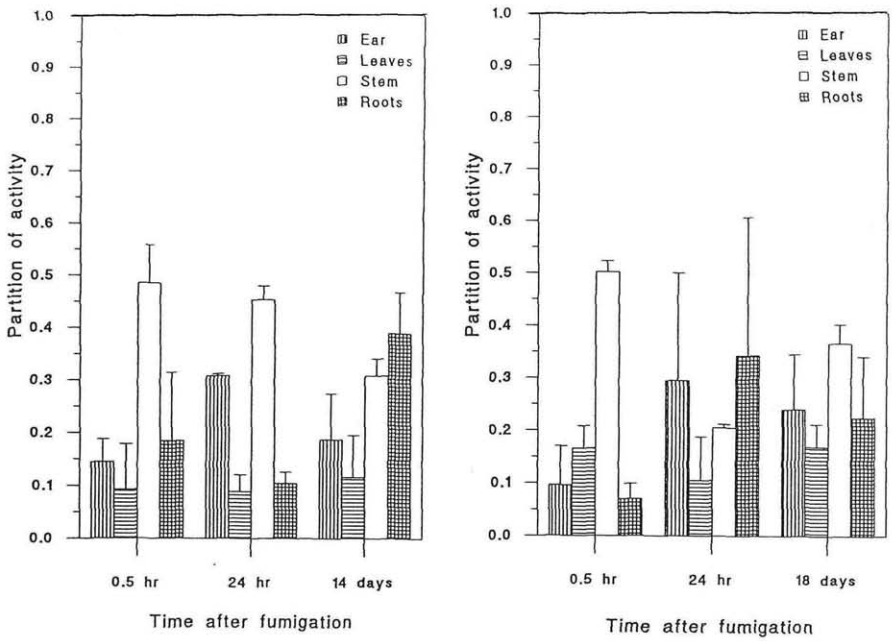

Fig. 3. The partitioning of labelled sulfur in wheat following fumigation with (a) COS (b) H_2S (vertical bars indicate standard errors).