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Effect of Imazaquin on Absorption, Translocation, and Pattern of Distribution of Chlormequat Chloride in Winter Wheat

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Abstract. The role of imazaquin in the absorption, translocation, and distribution of chlormequat chloride in CYCOCEL* CL has been studied in winter wheat. Three treatments were applied to the 5th leaf of the main stem at growth stage 5 (Feekes Large scale): (1) ^{14}C-chlormequat chloride, (2) CYCOCEL* CL containing ^{14}C-chlormequat chloride, and (3) CYCOCEL* CL containing ^{14}C-imazaquin. Tracing of the radioactivity was followed in the treated leaf, main stem, tillers, and roots. Results showed that more than 85% of the radioactivity absorbed remained in the treated leaf. Ten days after the application of chlormequat chloride alone, 94.4% of the ^{14}C-chlormequat was found in the treated leaf, 2.9% in the main stem, 1.2% in the tillers, and 1.4% in the root system versus 88.2, 8.2, 2.1, and 1.4%, respectively, for the chlormequat chloride plus imazaquin treatment. It was concluded that imazaquin increases the mobility and the pattern of distribution of chlormequat chloride in the plant.

Chlormequat chloride is a plant growth regulator (PGR), which is used mainly for control of lodging in cereals due to antigibberellic activity (Bruinsma 1980). Chlormequat chloride is the active ingredient of the commercial product, CYCOCEL* 5C. In 1985, a different CYCOCEL* type product was registered in France, CYCOCEL* CL. This compound differs from CYCOCEL* 5C by the addition of imazaquin.

Imazaquin is a member of the imidazolinone chemical family. These compounds are generally used at higher rates as herbicides, but at very low rates, they show PGR activity, particularly when combined with chlormequat (Ferriere et al. 1987).

In addition to lodging control properties, CYCOCEL* CL may increase yield also in absence of lodging (Couvreur 1987). Phytotron studies have shown that a foliar application of CYCOCEL* CL resulted in an increase in the root size of the treated wheat (Guckert et al. 1987).

Comparison of the mode of action of CYCOCEL* 5C and CYCOCEL* CL was conducted by a comparative study of the dynamics of distribution of chlormequat chloride and imazaquin using ^{14}C-labeled compounds applied to the foliage.

Material and Methods

Compounds

CYCOCEL* CL is a co-formulation of chlormequat chloride (2-chloroethyl trimethylammonium chloride) plus choline chlorure plus imazaquin (nicotinic acid 2[4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl]). The labeled components, chlormequat chloride (70.6 μCi) and imazaquin (38 μCi) were supplied by American Cyanamid Company (Agricultural Research Center, Princeton, New Jersey, USA).

Methods

Winter wheat seeds (*Triticum aestivum* L., cv. Fidel) were germinated at 4°C in blotting paper and in the dark. After 20 days, uniform seedlings were selected and transplanted individually into PVC tubes (diameter, 5 cm; length, 30 cm) containing sandy soil of pH 7. Plants in PVC tubes were grown in a greenhouse with a day/night temperature of 30/20°C and a photoperiod of 16 h. Plants were watered using a drip irrigation system with a nutrient solution (Hoagland and Arnon 1950) supplied with micronutrients. Total nitrogen supply equivalent to 0.0125 g N per pot at emergence and 0.025 g N per pot at tillering stage was provided.

Wheat plants were grown up to growth stage 5 (Feekes Large scale). Then, 36 seedlings with similar leaf size and number of tillers were taken and divided into three batches.

Each batch of 12 seedlings was first treated with 90% of the total rate of the active ingredient equivalent to 2 L FP ha^{-1} of CYCOCEL* 5C for batch 1 (200 seedlings m^{-2}) and 2.2 L FP ha^{-1} of CYCOCEL* CL for batches 2 and 3. Each batch was

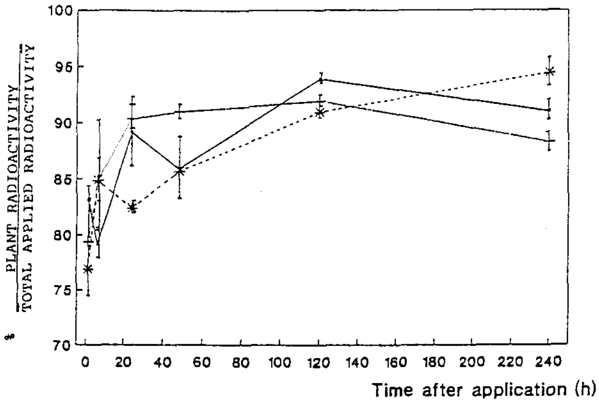

Fig. 1. Absorption of ^{14}C-labeled compounds: ^{14}C-chlormequat (.—.); CYCOCEL* CL ^{14}C-chlormequat (+. . .+); CYCOCEL* CL ^{14}C-imazaquin (*. . . . . *). In batch 1, plants were first treated with unlabeled chlormequat chlorure and in batches 2 and 3 with unlabeled CYCOCEL* CL. The 5th leaf of the main stem was then treated with ^{14}C-labeled chlormequat chlorure for batches 1 and 2 and ^{14}C-labeled imazaquin for batch 3. The vertical lines indicate the 2 SE limits.

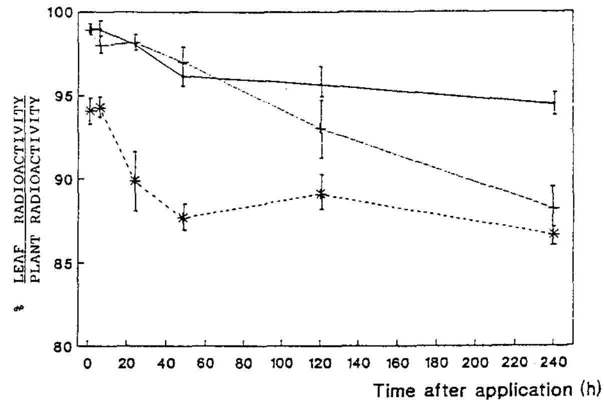

Fig. 2. Translocation of ^{14}C from the 5th leaf of the main stem. See Fig. 1.

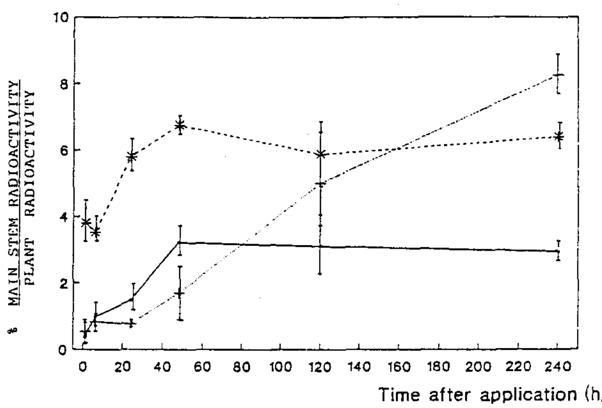

Fig. 3. Influence of imazaquin on the translocation of chlormequat chlorure to the main stem. See Fig. 1.

then treated with ^{14}C-labeled compound applied on the 5th leaf of the main stem of each wheat plant as follows: batch 1, 10 μl chlormequat chloride (45.5 μg ^{14}C-chlormequat chloride equivalent to a radioactivity of 667 Bq); batch 2, 10 μl CYCOCEL* CL containing ^{14}C-chlormequat chloride (0.47 μg imazaquin and 45.9 μg chlormequat chloride with a radioactivity of 663 Bq); and batch 3, 10 μl CYCOCEL* CL containing ^{14}C-imazaquin (46.1 μg chlormequat chloride and 0.47 μg ^{14}C-imazaquin with a radioactivity of 672 Bq).

At 1, 6, 24, 48, 120, and 240 h after the application of labeled compounds, two seedlings per treatment were sampled. The treated leaf was rinsed with 10 ml distilled water. Then the treated leaf, main stem, tillers, and root system were separated. Each part was then processed (deep freeze, freeze drying, grinding) and weighed. Then it was mineralized under an oxygen flow in a "oxymat" Kontron (Intertechnique IN 4101) oven. The CO^2 released was retained in a scintillating liquid ("Carbomax" by Kontron). One milliliter of the water used for washing the treated leaf was placed in 10 ml of "instagel". Radioactivity was measured in liquid scintillation (Tri Carb Packard counter, model 3003).

Results and Discussion

Absorption of labeled compounds was determined by comparing the total activity in the plant, after rinsing the treated leaf, to the total radioactivity found (plant + rinsing water) (Fig. 1). It can be noted that the rate of absorption and total absorption are very much the same in the different treatments. Ten days after application, absorption varied between 88 and 94%.

The evolution of the percentage of radioactivity contained in the labeled leaf compared to the entire plant is shown in Fig. 2. The remaining activity was over 85% even 10 days after application of the labeled compounds. Evolution was different between chlormequat and imazaquin. Translocation of imazaquin from the treated leaf was more rapid. Moreover, imazaquin doubled the translocation of chlormequat 10 days after treatment (from 6–13%).

The radioactivity found in the main stem was, in all cases, lower than 9% (Fig. 3). This represents the major part of the radiocarbon which had left the treated leaf. It can also be noted that the mobility of imazaquin was greater than that of chlormequat: 3.8% of the activity found 1 h after application of ^{14}C-imazaquin compared to 0.4% for the ^{14}C-chlormequat. Also, the presence of imazaquin modified the translocation of the chlormequat; the percentage of radiocarbon found in the main stem continued to increase and reached 8% after 240 h, whereas with chlormequat alone, the percentage found was only 3.2% after 48 h and remained stable thereafter.

Table 1. Translocation of ^{14}C to tillers (T) and roots (R).

Batch	1		2		3	
Pretreatment	Chlormequat chlorure		CYCOCEL* CL		CYCOCEL* CL	
Labeled compounds	^{14}C-Chlormequat chlorure		^{14}C-Chlormequat chlorure		^{14}C-Imazaquin	
Time after application (h)	% roots or tillers radioactivity / plant radioactivity					
	T	R	T	R	T	R
1	0.35a	0.15a	0.37a	0.16a	0.73a	1.37b
6	0.24a	0.22a	0.73a	0.44a	1.02a	1.60a
24	0.27a	0.16a	0.56a	0.47a	2.54b	1.77b
48	0.33a	0.26a	0.52a	0.65a	3.07b	1.65b
120	0.76a	0.43a	1.15a	0.83a	3.46b	1.53a
240	1.19a	1.38a	2.14a	1.38a	3.91a	3.02a

The results are given as means. Values within the same row (horizontal) with common letter postscripts are not significantly different at $p = 0.05$ according to Newman-Keuls test.

Radioactivity measured in the tillers and roots was relatively low: less than 4% for the tillers and less than 3% for the roots (Table 1). However, the radioactive content found in the tillers and roots after application of ^{14}C-imazaquin was higher than with ^{14}C-chlormequat treatment. When the ^{14}C-chlormequat alone and the ^{14}C-chlormequat + imazaquin treatments were compared, there was an increase in the transfer of radiocarbon in presence of imazaquin in the tillers and, to a lesser degree, in the roots.

Studies of the absorption and translocation of chlormequat chloride in wheat show that this plant growth regulator, in foliar application, is not very mobile and is located principally in the treated organ (Alcock et al. 1966; Lord and Wheeler 1981). The rate of transfer of chlormequat chloride is low, less than 19% of the total radioactivity found 1 week after application on the 3rd leaf of wheat (Lord and Wheeler 1981). Our results confirm the low mobility of chlormequat chloride and show that chlormequat chloride applied to a wheat plant reaches, principally, the main stem. However, as already observed on winter barley (Belzile et al. 1972), a low proportion was found in the tillers and roots.

Shaner and Robson (1985) and Wilcut et al. (1988), reported from their studies on soybean, groundnut, and various weed plants, that after application of ^{14}C-imazaquin, more than 73% radioactivity was found in the treated leaf 3 days after treatment. Our data with wheat confirms their observations.

The addition of a low dose of imazaquin to chlormequat chloride, which corresponds to the formulation of CYCOCEL* CL, caused a reinforcement of the regulator's efficacy (Ferriere et al. 1987). Our results indicated that imazaquin increases the mobility of the chlormequat and modifies its translocation in the plant by increasing the percentage of radioactivity found in the main stem and tillers. These assessments also help to explain the differences observed on wheat after foliar application of CYCOCEL* CL compared to CYCOCEL* 5C.

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