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VARIATIONS OF ^{14}C IN OATS GROWN FROM 1957 TO 1978 IN QUEBEC

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ABSTRACT. Annual atmospheric radiocarbon concentrations for the year 1957 to 1978 are measured through oat seeds grown in the rural region of La Pocatière, Québec (70° W, 47° N). Results follow the general pattern of other curves obtained from grains elsewhere in the northern hemisphere. Some disagreements suggest a non-uniform mixing process with faster response to stratospheric contamination in definite regions.

INTRODUCTION

Human activity has notably modified the ^{14}C concentration of the atmosphere and, hence, of other parts of carbon reservoir with both welcome and ill-advised consequences. These modifications must, however, be precisely evaluated if one expects to take all the benefit from their positive aspects.

METHOD

With the aim of participating in this evaluation and, hence, improving the world-wide interpretation of related phenomena, we have undertaken a study of ^{14}C variations in the Quebec region from the year 1957 to 1978. Atmospheric radiocarbon concentration is calculated through the use of oat seed reserves from the Canadian Agriculture Department experimental farm at La Pocatière, Québec (70° W, 47° N). The grains were grown in a rural region from the middle of May to the end of August with a grain formation period from the end of June to the middle of August. After harvesting, the grains were stored in a dry place for preservation.

Before transformation for ^{14}C analysis, collected specimens were pretreated with warm 0.1N hydrochloric acid, washed three times with warm demineralized CO_2 free water, then dried at 90°C in an oven. The 15 to 20g pretreated samples were burned in a high pressure combustion bomb and synthesized to benzene. The 4ml benzene samples plus 1ml of scintillation cocktail (PPO and POPOP in toluene) were counted in a liquid scintillation counter (Beckman LS-230) either for 25,000 counts or for 1000 to 1500 min, depending on the series (Samson and others, 1977).

RESULTS AND DISCUSSION

Atmospheric ^{14}C concentrations are presented in table 1 (the presence of one barley sample for 1961 will be explained later). They appear as Δ (Stuiver and Polach, 1977) over AISA (absolute international standard activity). The present results follow the general pattern of other curves obtained from grains elsewhere in the northern hemisphere as shown graphically in figure 1. Local results are identified by black marks corresponding to the different oat seeds series and by a plus sign for the barley sample. Saskatchewan wheat results (McCallum and Wittenberg, 1962;

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1965; Rutherford, Wittenberg, and Wilmeth, 1979) are identified by open circles. Copenhagen different cereals (barley, wheat, rye, or oats) results (Tauber, 1967) are represented by open squares. Open triangles symbolize Glasgow malt whisky samples (Baxter, Ergin, and Walton, 1969).

Some disagreements are distinctly noted. They can be classified in two categories: those corresponding to high test activity period and those of low test activity. The discrepancies related to the high test activity period are irregular and difficult to deal with. The differences in place, time, and intensity of bombing, as well as atmospheric instability, preclude direct cause-to-effect relationship. A somewhat coarse agreement is, nevertheless, generally maintained between curves. A major disagreement is observed between present results and others for the year 1961. This peculiarity has been seriously investigated. The first result obtained, QU-541: $\Delta = 0.894 \pm 0.022$ has been cross-checked by QU-876: 1.019 ± 0.017 and QU-897: 1.042 ± 0.015. The consistency between those oat seeds' ^{14}C concentration results confirm their accuracy but is of no help in their interpretation. These measurements were then compared with a value obtained from barley, QU-890: 0.364 ± 0.011, which has an earlier

TABLE 1

Radiocarbon concentration in oats grown from 1957 to 1978 in La Pocatière, Québec

Year of harvesting	Laboratory no.	Oat species	^{14}C concentration Δ*
1957	QU-879	Abegweit	0.132 ± 0.010
1958	QU-871	Victory	0.210 ± 0.011
1959	QU-872	Victory	0.345 ± 0.012
1960	QU-875	Rodney	0.354 ± 0.011
1961	QU-541	Garry	0.894 ± 0.022
	QU-876	Rodney	1.019 ± 0.017
	QU-897	Dorval	1.042 ± 0.015
	QU-890	(Fort)**	0.364 ± 0.011
1962	QU-873	Victory	0.483 ± 0.014
1963	QU-542	Garry	0.818 ± 0.022
	QU-874	Victory	0.971 ± 0.015
1964	QU-543	Garry	0.918 ± 0.022
	QU-877	Garry	0.990 ± 0.015
1965	QU-544	Garry	0.775 ± 0.020
1966	QU-545	Garry	0.821 ± 0.019
	QU-878	Garry	0.747 ± 0.013
1967	QU-546	Garry	0.690 ± 0.018
1968	QU-547	Garry	0.635 ± 0.017
1969	QU-548	Garry	0.621 ± 0.017
1970	QU-549	Garry	0.609 ± 0.016
1971	QU-550	Garry	0.560 ± 0.016
1972	QU-551	Garry	0.535 ± 0.016
1973	QU-552	Garry	0.482 ± 0.015
1974	QU-553	Garry	0.443 ± 0.015
1975	QU-554	Garry	0.426 ± 0.015
1976	QU-555	Garry	0.375 ± 0.014
1977	QU-842	Garry	0.379 ± 0.013
1978	QU-843	Garry	0.373 ± 0.013

* An assumed -0.023 $\delta^{13}C$ correction based on Stuiver and Polach (1977) has been applied.

** Barley sample.

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seed formation period than oat. This result, slightly higher than those reported by other laboratories, fits satisfactorily in the general trend suggested by preceding and subsequent results. Further investigation through dendrochronology is in progress in our laboratory and may help to explain this anomaly.

From 1967 to date is a relatively low yield test period with only 7 Chinese atmospheric tests in the 0.5 to 4 megaton range in the northern hemisphere. The delay since the high yield bombs of 1961 and 1962 permitted ^{14}C concentration in the atmosphere to equilibrate uniformly. The recovery rate of the atmosphere can then be observed. This is tentatively done in figure 2, where Δ for Quebec and Saskatchewan results is presented for the year 1967 and the following years on a lorgarithmic scale. Chinese test times are indicated above time scale by vertical lines whose heights represent the magnitude in megatons related to the right hand side vertical axis calibration. The experimental ^{14}C concentration measurements are hand fitted and the estimates are represented by straight segments. Consequences of Chinese tests are recognizable through breaks in the curves. Parallelism between curves is sufficient to conclude at an 8.7 ± 0.9 year half period value for atmospheric recovery rate during the corresponding time.

The fact that thermonuclear activity consequences seem delayed by one year on Saskatchewan results relative to Quebec can be explained partly by differences in growth periods. Former grains grow earlier and are then less affected by the early summer ^{14}C increase induced by favored

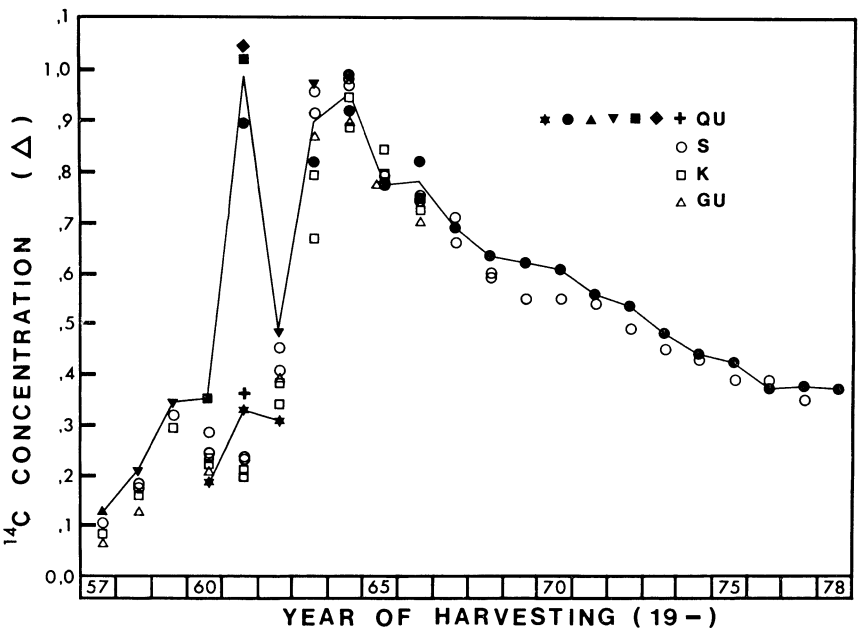

Fig 1. Tropospheric ^{14}C concentrations measured from plants by Saskatchewan (S), Copenhagen (K), Glasgow (GU), and Quebec (QU) radiocarbon laboratories.

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stratosphere-troposphere mixing. But this should not be considered as the only possible explanation. Short-term heterogeneities in atmospheric ^{14}C concentration, induced by local mixing patterns, must be suspected.

Whichever the cause, it is evident from the observation of figure 1 that Quebec results are consistently higher than others. Systematic error in measurements must not be considered because all measurements are made relative to same modern standard (0.95 activity of NBS oxalic acid). Local heterogeneities and/or delayed seed formation periods are more likely to be true explanations.

The physics of the atmosphere is complex and even if it is impossible at this time to explain each observed phenomenon, it is important to report them for possible later interpretation and for immediate evaluation of safe imprecision factors that must be dealt with. Any attempt to generalize local perturbations to the whole hemisphere should be made with these facts in mind.

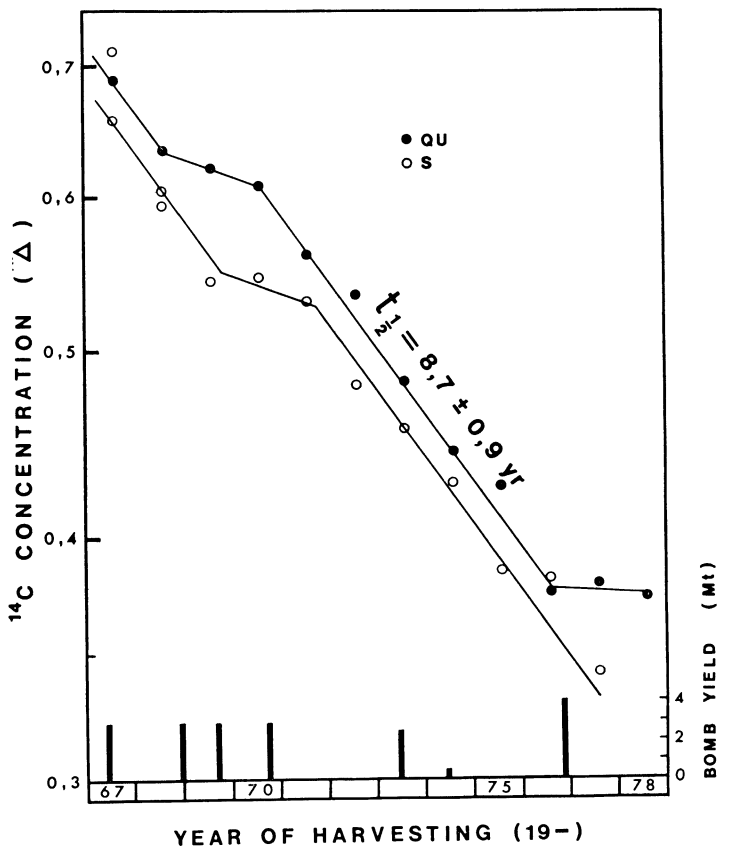

Fig 2. Comparison of Quebec (QU) and Saskatchewan (S), tropospheric ^{14}C concentration measurements on a logarithmic scale.

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Note added in proof: Further results have been obtained on tree rings from a spruce cut on the experimental farm where cereal samples come from. They are presented below in table 2 and appear as black stars in figure 1.

TABLE 2

Radiocarbon concentration in 1960 to 1962 spruce tree rings from La Pocatière, Québec

Year of growth	Laboratory no.	Species	^{14}C concentration Δ
1960	QU-918	Spruce tree ring	0.187 ± 0.015
1961	QU-916	Spruce tree ring	0.325 ± 0.010
1962	QU-917	Spruce tree ring	0.305 ± 0.016

The high 1961 value confirms similar results obtained from oats. Different growth periods explain lower wood values whereas short time perturbation may explain different peak amplitudes.

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