^{15}N TRACER STUDIES ON NITROGEN UPTAKE BY RUSSET BURBANK POTATOES [1]

by
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Nitrogen (N) is one of the major essential nutrients required for potato production. Although the pioneer work of Dr. Kunkel has clearly demonstrated the need for N fertilization in achieving the high potato yields now obtainable, our knowledge on how potatoes use N is still scanty today. With N fertilizers becoming a major cost factor in production and with problems stemming from fertilizer N loss and in creating potential pollution hazards, we urgently need to know more about how to use fertilizer N efficiently. To improve N use efficiency in potato production, we must know how much N is needed by potatoes, how much and when N is taken up and utilized in plant growth and tuber production, and how much and when fertilizer N should be supplied to the crop during the growing season. These questions can best be answered by using the ^{15}N tracer technique which enables us to follow the uptake and utilization of ^{15}N-enriched fertilizer N by the potato plants. The purpose of my talk is to introduce to you the ^{15}N tracer technique and to illustrate with some experimental data how this technique can provide us information to answer those questions which I have just posed.

The chemical element N does not exist in nature by itself as atoms, but in combined forms as molecules. Some 79% of the air we breathe is composed of nitrogen gas, which is N_2 (2 atoms of N combined). This form of N is rather inert and cannot be used directly by plants. N_2 has to be first converted either synthetically to form ammonia (NH_3) or microbiologically by the process of nitrogen fixation. The N fertilizers commonly in use are in the forms of ammonium (NH_4^+), nitrate (NO_3^-), and urea. This is one way to differentiate various forms of nitrogen. Another way to classify the N element is by the mass of the atoms. Forms of the same element with different atomic weights are known as isotopes. Most of you are probably familiar with radioactive isotopes. Some radioisotopes have been used as tracers because one can readily differentiate radioactive from non-radioactive isotopes. Unfortunately all radioactive isotopes of N have very short half-lives (Table 1) and are not useful in fertilizer use efficiency studies. There are, however, two stable isotopes of N. Most of the N in nature is in ^{14}N form ($>$99.6%), and $<$0.4% is in ^{15}N form. The ^{15}N tracer technique is to enrich the source material with ^{15}N and follow the changes in ^{15}N concentration through various transformation processes. For instance, we can supply soil with a fertilizer N containing 10% ^{15}N. If all the N in the tubers comes from the fertilizer, then the tuber N should have an ^{15}N content of 10%. If tuber N contains only 5% ^{15}N, the fertilizer could only account for half of the N in the tubers, and some other sources in soil must have contributed to the other half. Data from a field experiment which we had initiated in 1981 will further illustrate the usefulness of the tracer tehhnique.

The experimental field was located on a sandy soil under sprinkler irrigation five miles west of Plymouth, Washington. Potatoes were planted on April 22, and all experimental plots received 100 lb. N/A as NH_4NO_3 on May 13, before potato emergence, followed by a supplemental application of 25 lb. N/A of NH_4NO_3 every ten days from June 10 to August 20, for a total supply of 300 lb. of fertilizer N/A. Eight miniplots were set up within each of the four replicate fields.

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Each time a 25 lb. N/A supplement was applied, at the same time a different miniplot received 25 lb. N/A of ^{15}N-enriched NH_4NO_3 fertilizer. Fertilizer N was sprayed on experimental plots and followed immediately by irrigation from solid-set sprinklers. Petiole samples were collected every ten days for nitrate and ^{15}N analyses. Whole plant and soil samples were collected every month for assessment of distribution of fertilizer N in plant tops, in tubers, and in the soil. The data collected from this study are useful in illustrating the extent of information obtainable by the tracer technique comparing with that from non-tracer analysis.

Let's first examine the petiole nitrate levels during the growing season, as they are commonly-used means to estimate plant N needs. The petiole nitrate levels in our experimental plots show a high level during the early season, and a sharp decline from 16,000 ppm to around 5,000 ppm in mid-season, and leveling off at this level until the end of the season (Fig. 1). We did not raise the level of nitrate in the petioles by the supplemental fertilization applied every ten days. Without the ^{15}N tracers, we were not able to determine whether or not the fertilizer added was taken up or utilized by the plants, nor to know how long the nitrate found has been in the petioles. However, the ^{15}N data show that throughout the growing season, fertilizer N was rapidly taken up by the plants (Fig. 2). The ^{15}N contents of the petioles were at the highest within ten days after fertilization with ^{15}N-enriched NH_4NO_3, and subsequently decreased rapidly with time and with additions of unenriched fertilizer, showing that the fertilizer N taken up was also rapidly translocated out of the petiole region. Both the uptake and the translocation activities appear to be active throughout the growing season. Thus the dynamic nature of fertilizer N use by potato plants was clearly demonstrated by the ^{15}N tracer technique.

More information on fertilizer uptake and utilization was also obtainable by analysis of the whole plants. Without ^{15}N tracers, one could only surmise that as the season progressed, the % N in plant tops decreased and the total amount of N accumulated in plant tops first increased and then decreased after mid-season, whereas the % N in tubers would remain constant although the total amount of N in tubers would increase with increasing growth of tubers (Table 2). The ^{15}N data reveal in addition that the fertilizer N taken up would first appear in plant tops and then gradually translocated into the tubers (Fig. 3 & 4). Most of the fertilizer N applied in June and July was translocated out of the tops into tubers, whereas more of the fertilizer N applied in August remained in the tops, thus revealing the relationship between time of fertilization and fertilizer use in tuber production. Furthermore, if we add together the amount of fertilizer N in the tops and that in the tubers, we can see that up to 60% or so of the fertilizer N was accounted for by the plant parts (Table 3).

These examples from our experimental data have clearly demonstrated the power of the ^{15}N tracer technique in providing useful information. Of course, we will still need to examine many variables in fertilization management before we can understand the N use processes and be prepared to recommend methods to improve N use efficiency by potatoes. You may wonder if the ^{15}N tracer technique is so useful, why we have not used it more extensively. Two major drawbacks are the costliness of ^{15}N materials and the time-consuming procedure for ^{15}N analysis. However, our experience this past year in the field study has shown that we could obtain meaningful data within reasonable cost. We are encouraged by the results we have obtained and will continue our research effort in the future.

Table 1. Isotopes of nitrogen.

Mass No.	Form	Abundance	Half-Life
12	radioactive	---	0.01 sec
13	radioactive	---	10.05 min
14	stable	99.634%	---
15	stable	0.366%	---
16	radioactive	---	7.38 sec
17	radioactive	---	4.14 sec

Table 2. Total N in plant tops and tubers of potatoes during the 1981 growing season.

Sampling Date	Total N in Tops		Total N in Tubers	
	%	g/plot	%	g/plot
6/30	3.56	27.2	1.58	11.0
7/30	2.85	31.0	1.52	43.4
8/31	2.55	23.7	1.60	67.4

Table 3. % ^{15}N-fertilizer recovered by potatoes (tops + tubers) during the 1981 growing season.

^{15}N Appln. Date	% of ^{15}N Recovered (Tops+Tubers)		
	Sampling Date		
	6/30	7/30	8/31
6/09	44.2	58.2	56.2
6/19	41.5	52.3	43.7
6/30		56.3	48.8
7/10		46.8	61.2
7/20		47.1	51.1
7/30			43.3
8/10			40.8
8/20			36.4

Figure 1. Petiole nitrate-N levels during the 1981 growing season.

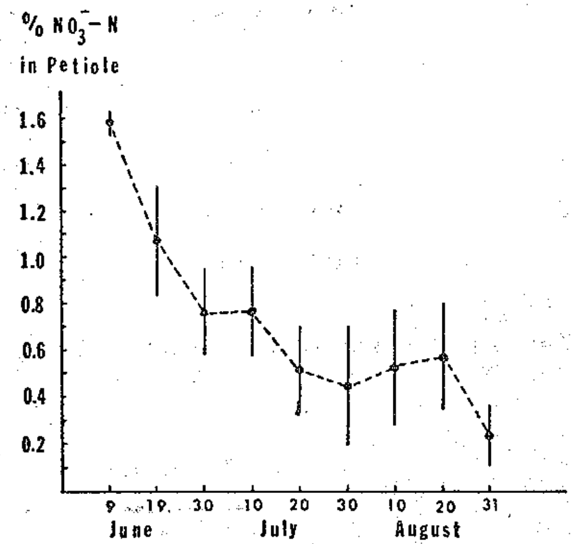

Figure 2. % ^{15}N in petiole nitrate following ^{15}N-fertilizer application during the 1981 growing season.

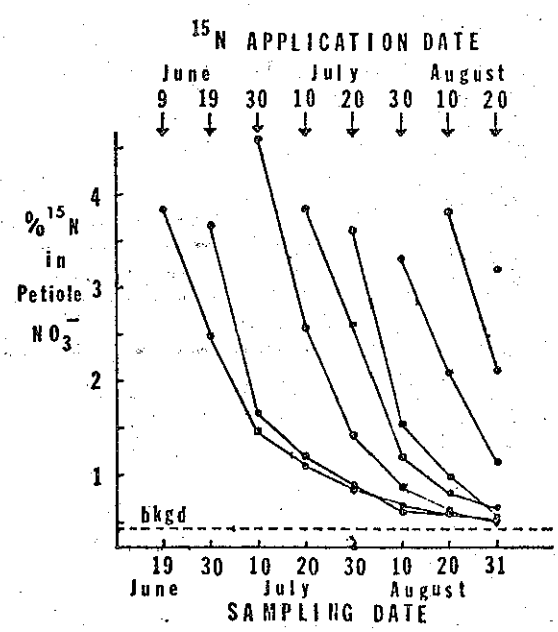

Figure 3. % of ^{15}N in plant tops following application of ^{15}N-enriched N fertilizer to potatoes, 1981.

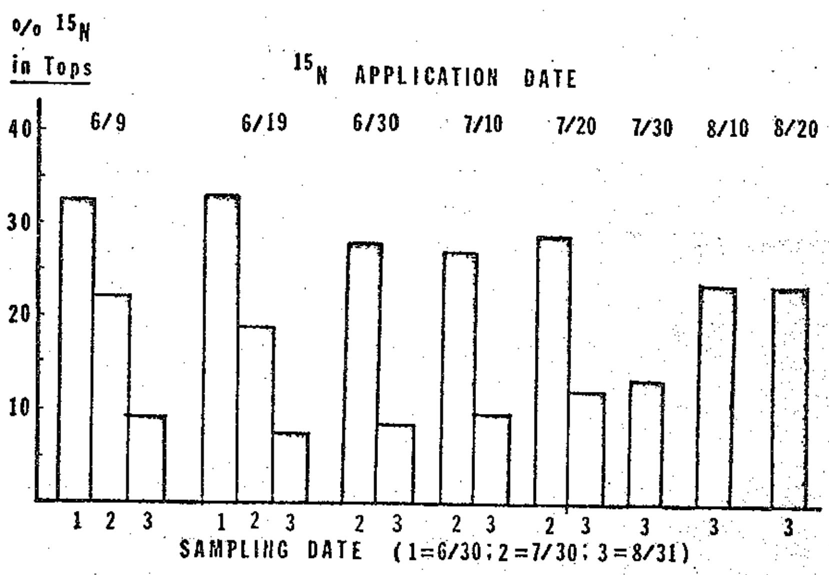

Figure 4. % of ^{15}N in tubers following application of ^{15}N-enriched N fertilizer to potatoes, 1981.