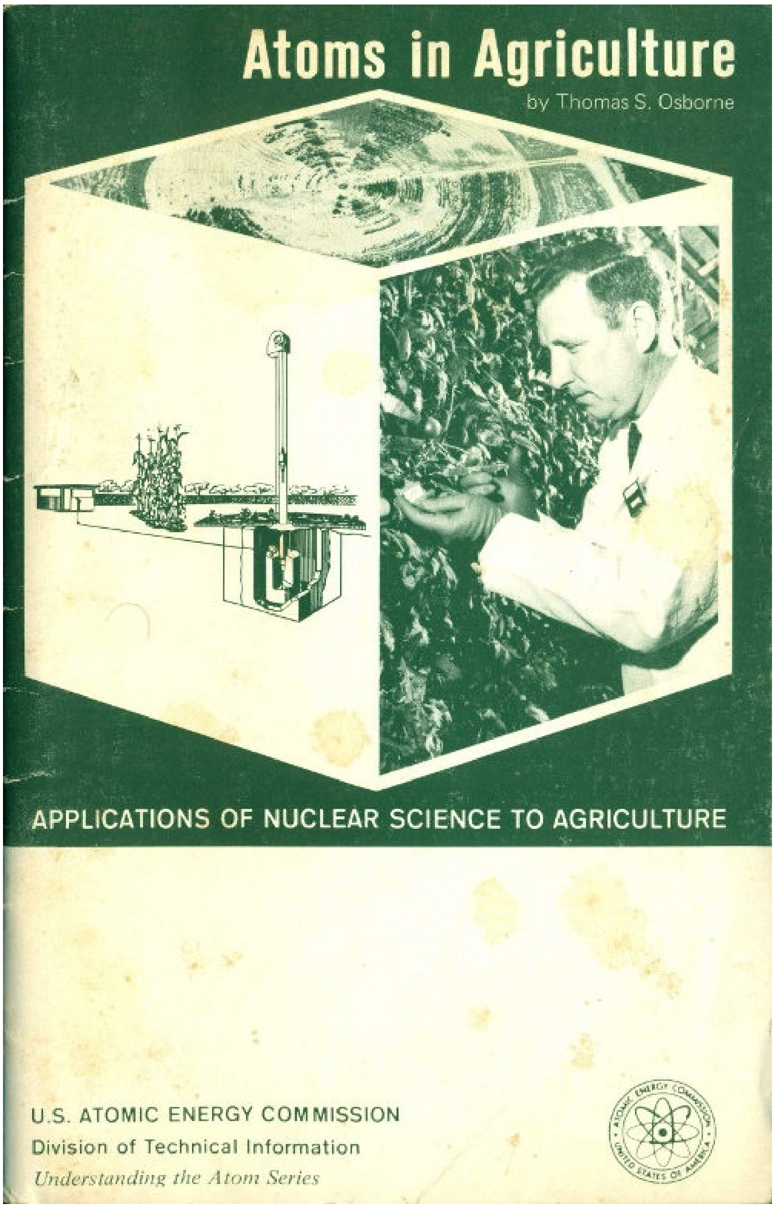

Atoms in Agriculture

The Understanding the Atom Series

Nuclear energy is playing a vital role in the life of every man, woman, and child in the United States today. In the years ahead it will affect increasingly all the peoples of the earth. It is essential that all Americans gain an understanding of this vital force if they are to discharge thoughtfully their responsibilities as citizens and if they are to realize fully the myriad benefits that nuclear energy offers them.

The United States Atomic Energy Commission provides this booklet to help you achieve such understanding.

Edward J. Brunenkant, Director
Division of Technical Information

Atoms in Agriculture

by Thomas S. Osborne

CONTENTS

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ABOUT THE AUTHOR

Thomas S. Osborne is in charge of plant-breeding research being conducted by the University of Tennessee's Agricultural Research Laboratory for the Atomic Energy Commission. He has been in this work since 1953.

But Dr. Osborne is a teacher at heart. Hence when students wrote inquiring about the effects of radiation on seeds, he took great interest in replying. From these replies grew mimeographed literature suggesting experiments for students; then this and other booklets.

Dr. Osborne received his undergraduate degree from Oklahoma State University and his doctorate from Washington State University.

1

Atoms in Agriculture

by Thomas S. Osborne,
Associate Professor of Agronomy, University of Tennessee.

To know what questions to put to Nature—that is 95 per cent of scientific research.

—Whitehead

If man's existence on the earth is compared to a calendar year, then he began farming in the very early morning of December 30 and began applying systematic knowledge to agriculture at 10:15 p.m. on December 31.

The first traces of man on the earth are dated at about one and three-quarter million years ago. Plant life then was very much like plant life today, but the animal population was quite different. Man became a producer of plants and animals instead of merely a gatherer and hunter about 8000 years ago. He has applied systematic study to cultivated plants and animals for only 300 years.

Research in the United States

Estimates of crop losses in the United States each year are approximately $5 billion to weeds, $4 billion to insects, and $3 billion to diseases. This total loss of $12 billion a year is about $22,500 a minute.

In an effort to reduce these losses and to raise the standard of living, agricultural research has become more 2
specialized and more complex. Over the years it has gradually changed from trial-and-error attempts to increase production to the actual study of basic questions. To study such intricate systems as the leaf of a plant or the liver of an animal, agricultural science has had to draw from every other science. The use of radioactive tracers and radiations in research looks especially promising to agriculture.

In fact, agriculture has already begun to benefit from the applications of such research. Radioactive techniques have been used to study soils, plants, microbes, insects, farm animals, and new ways to use and preserve foodstuffs. Radioactive atoms are not used directly by farmers but are used in research directed by the U. S. Department of Agriculture and Atomic Energy Commission, by the agricultural experiment stations of the various states, and by numerous public and private research institutions. From such research come improved materials and methods which are used on the farm.

In more highly developed countries agricultural research has brought a shift of emphasis from production to utilization. In the United States today, each farmer produces enough food for himself and 25 other people. Moreover, for every person who works on a farm, there are two or three other people who sell him goods and services or process and distribute the things he produces.

In agriculture, as in all areas of research, the number of questions to be asked of Nature seems infinite. Future generations seeking to answer these questions will probably rely more on techniques using radioactive isotopes than on any other methods known today.

How Are Radioisotopes Used in Research?

They May Be Used as "Tracers"

Man's attempts to describe the universe consist of finding answers to the questions he puts to Nature:

How deep is a well? Toss in a rock. 3
Where is the cat? Hang a bell on him.
How far does a wild duck fly? Put a marker on his leg.
Where are the fireflies? Just watch at dusk.
Is our satellite still up? Listen for the radio signal.

Other questions arise in agricultural research:

How fast do roots grow? How deep? How soon does water get to them after a rain?
When does a mouthful of hay reach a cow's stomach?
How long until nutrients get into her blood? Her milk?
How far will pine pollen travel on the wind?
How deep does an earthworm burrow?

To answer these questions, scientists need some kind of miniature genie, one who will shout at the proper moment, "I'm here!" When the root has reached the fertilizer or the water has reached the root; when the hay becomes transmuted to milk, or the earthworm arrives at a particular spot—then this invisible little servant who has made the trip could announce, "I'm here!"

Such a helpful genie exists as the radioactive atom: he is invisibly small, obedient, transportable, digestible, immune to fire, flood, or famine, able to travel under his invisible cloak to the secret hiding places of Nature's creatures and announce to waiting Geiger tubes, "I'm here!"

The physically unstable radioactive atom behaves chemically exactly like its stable counterpart until the instant it emits its radiation and becomes stable. For example, radioactive phosphorus behaves, biologically and chemically, like stable phosphorus until it emits a beta particle and becomes stable sulfur. If the beta particle enters a gas-filled Geiger tube, it produces a tiny burst of electrical energy which is registered by the counter.

Like fireflies which reveal themselves at dusk by flashes of light, radioisotopes announce their numbers and locations to sensitive Geiger tubes by flashes of invisible "light."

How Effective Are Radioactive Tracers?

One way to see how valuable radioactive tracers are is to compare them to standard chemical techniques. A sensitive chemical test can perceive molecules as dilute as 10^{-7}; that is, it can detect a molecule surrounded by 10 million molecules of another kind. A good radioactive tracer technique, by comparison, can distinguish concentrations of 10^{-11}; that is, it can trace one in 100 billion. 4

In other words by the chemical test you could find a person in metropolitan New York with a secret tattoo on the roof of his mouth. By the tracer method you could find this same person anywhere in the world, even if the world population were multiplied fiftyfold.

In the chemical test you could distinguish the equivalent of one kernel of corn in one-tenth of a boxcar load; in the tracer, one kernel in 850 boxcars.

Plant Nutrition and Metabolism

Most studies of plant nutrition and metabolism pertain to the following questions. What do plants need for their best growth? How do they take in the materials they need? What things are absorbed by roots and what things by foliage? How does the plant turn water and other simple compounds into carbohydrates and proteins?

Specific problems that atomic energy has helped to solve are listed.

What Happens to Fertilizer in the Soil?

Early research indicated that only 10 to 12 per cent of phosphorus fertilizers was taken up by plants in the first year; the rest was "locked into" the soil or washed away. With radioactive phosphorus-32 scientists found that as much as 50 to 70 per cent of the phosphorus in a plant came from the fertilizer during the first two or three weeks of growth.

Do Plants Absorb Through Roots Only?

Fertilizer applied to soil is largely wasted because it is either bound by soil particles or is washed out of the root zone. If chemical elements could go directly into leaves and bypass the wastefulness of soils, a tremendous saving would result. 5

Botanists have learned in recent years that the foliage of plants can take in some nutrients much as roots can. With tracers they discovered that many nutrients are readily taken up by foliage, including bark of dormant trees, even at temperatures below freezing. As shown by isotopic tracers, elements such as phosphorus, nitrogen, and potassium move both up and down from the point of application at rates similar to those following root absorption. Urea (a nitrogen compound) is now used as a nutrient foliar spray for many fruit and vegetable crops in this country.

Where Should Fertilizer Be Placed?

Even before the use of tracers, agronomists realized the inefficiency of spreading fertilizer uniformly over a seed-bed. They know the fertilizer should be placed somewhere near the seed, but where? Above? Below? Beside? Below and beside? How far away? They had conducted some research, but the methods were slow and tedious.

Using tracers, the researchers confirmed earlier findings that roots within two or three days reached fertilizer placed less than two inches directly below seeds, but the roots tended to congregate there. When the fertilizer was two inches below and two inches to the side, roots reached it within a week and a better root system developed. With three inches between seeds and fertilizer, the desired seedling "boost" was delayed three or four weeks. (See Fig. 1.)

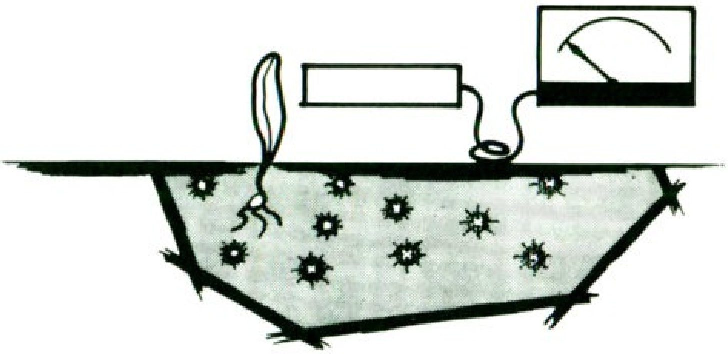
Do Fertilizers Move Fast in Plants?

The movement of radioactive phosphorus from root to leaf was found to be remarkably fast, sometimes requiring less than twenty minutes. (See Fig. 2.)

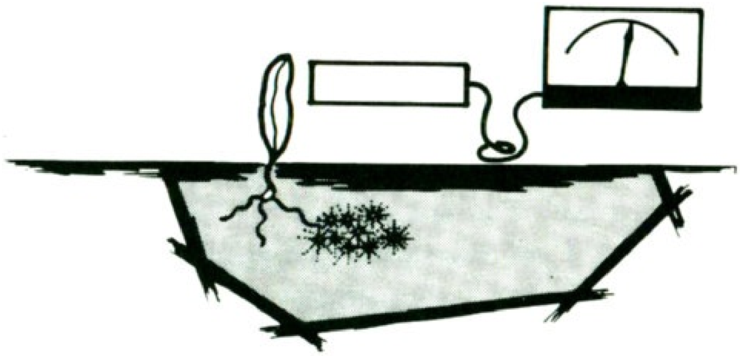
What Else Do Radioisotopes Tell Us?

Some plants take in chemicals that the plant probably cannot use: for example, the so-called locoweeds accumulate enormous amounts of selenium. With tracer techniques, we can see that the root uptake process has poor powers of discrimination.

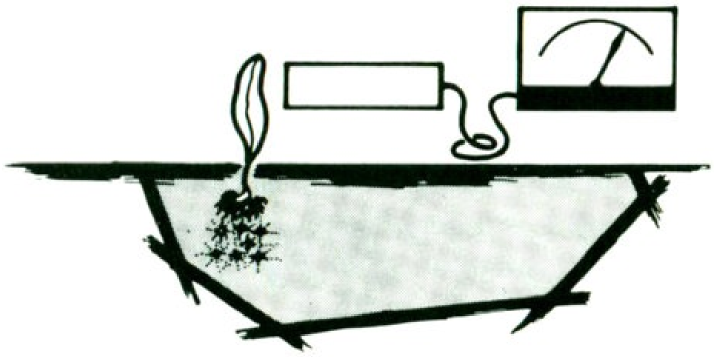
Fig. 1—Soil tests tell *how much* of each fertilizer element is needed but not where to put it to give seedlings the much-needed "push." With tracers it is found that: [6]



(A) Fertilizer mixed throughout the soil gives the least benefit to seedlings.

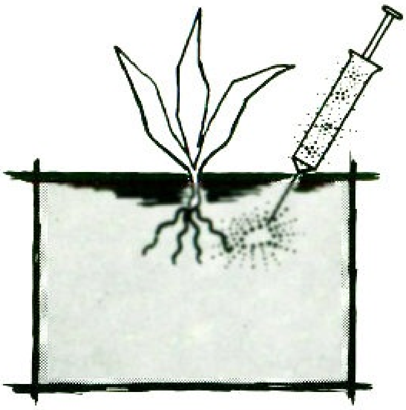


(B) If placed in a band below and beside the seeds, the fertilizer gives high uptake and good root distribution.

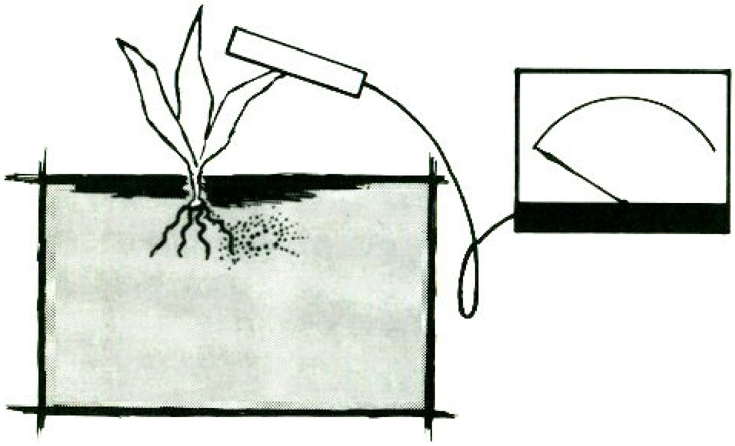


(C) If the fertilizer is placed directly beneath the seeds, highest uptake occurs but roots tend to "bunch"—a handicap to later growth.

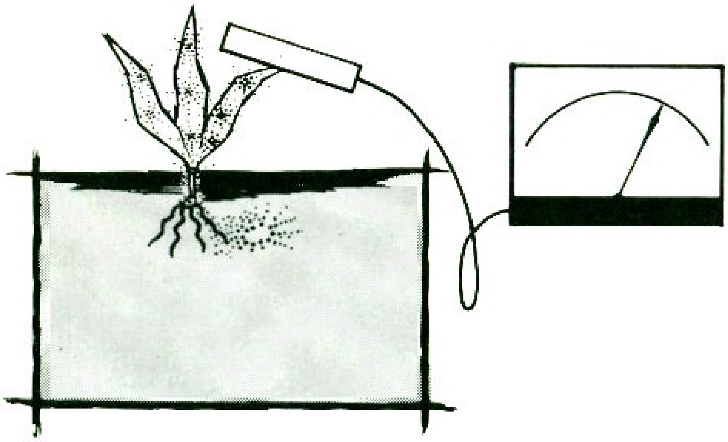
Fig. 2—Radioactive plant nutrients injected in soil roots [7]



have not reached above ground parts in 5 minutes



but have, as indicated by Geiger counter, reached these parts in 20 minutes.



Tracer experiments reveal that roots cannot distinguish potassium (needed in large amounts) from other 8
elements which are chemically similar but quite different in size. Once inside the plant, only potassium can be metabolized and similar but heavier elements (rubidium, cesium) are useless. This is like an absentminded builder who buys brick, boulders, and gravel indiscriminately for his wall and then finds he can use only part of his materials.

The process called photosynthesis whereby green plants use energy from the sun to convert simple compounds from air and soil into complex, energy-rich substances has been termed the most important chemical reaction in the world. It is the basis for man's entire food supply and, except for nuclear energy, all significant fuel as well. Tracer techniques have multiplied the research efforts on photosynthesis tremendously.

When only chemical tests were available, food manufacturing in green leaves had to progress for hours before scientists could measure the products. But with tracers and other new techniques they have narrowed the experimental time to minutes and finally to seconds. Today they know that a green leaf has formed sugars more complex than fructose, "fruit sugar," after exposure to light for only *one second*!

When the incredible complexities of photosynthesis are finally unraveled, radioactive tracers, especially radioactive carbon-14, will have provided the significant clues.

Plant Diseases and Weeds

How Can We Combat Plant Diseases?

At one time to stop epidemic spread of plant diseases was virtually impossible; farmers had to abandon fields and crops. Such catastrophes caused by microbes have changed the course of history. For example, the Irish famines of the 1840's resulted from the potato blight and caused mass emigrations from Ireland. 9

In this country today plant diseases result in losses estimated at $3 billion a year. So far, the most economical means of reducing the ravages of plant diseases has been to breed resistant plant varieties. Although such a variety may cost $100,000 to develop, its cost is usually repaid within a year or two.

But the victory is only temporary. Although plants are bred to resist the pathogen (fungus) of the moment, Nature is constantly changing the microbial population by mutation and hybridization. Within a few years virulent strains of fungi which can attack the "resistant" variety increase to such an extent that the new variety must be replaced.

For crops that provide high per-acre income such as some vegetables and vine and tree fruits, chemical control of fungous diseases is economically possible; in fact, it is a real necessity. But such treatment is too costly for most field crops, unless some cheap seed treatment or fertilizer additive can be found.

A general breakthrough in control of plant diseases is yet to come. Because of thousands of pathogenic species, with hundreds of strains, it does not seem possible that the following questions could be answered about each one. What is the life cycle of the microbe? What conditions of temperature and humidity encourage it to spread? What plant species does it attack? How does it enter? What chemical changes within the cells of the plant determine whether they resist or succumb to the invader? How long can germs remain potent? How far can they travel by wind or water? What combination of resistant varieties, cultural methods, and chemical treatment will control the disease?

With tracers it is possible for the first time to measure chemical uptake in single spores and to follow chemicals through the plant. Perhaps the most enlightening information from such studies is that some fungicides are 10,000 times less effective per unit of "body weight" than are other chemicals used to destroy weeds and insects. Obviously the breakthrough in chemical control of plant diseases is yet to come.

Why Do Chemicals Destroy Some Plants? 10

Weeds cost this country an estimated $5 billion annually, which is more than the loss to either plant diseases or insects. Selective chemical weed killers such as "2, 4-D" have become so widely used that more than $135 million worth was sold in the United States in 1959. In proper concentration these compounds will destroy many unwanted plants without harming lawn grasses or crop plants.

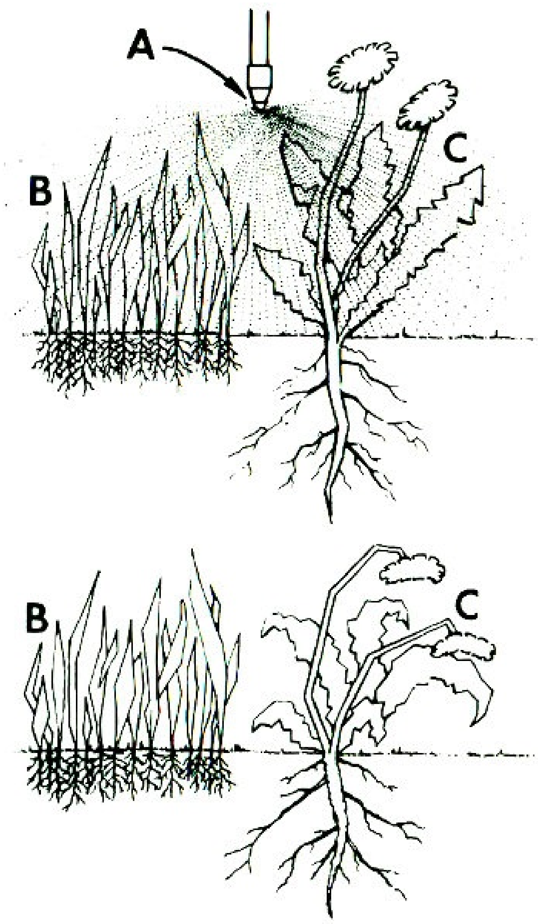


Fig. 3—Tagged weed-killing chemicals (A) are taken in and transported alike in grassy (B) and broad-leaved (C) plants,

but only in the latter are killed.

As in many other instances, beneficial use of the chemicals has far outreached an understanding of how they work. The still scanty knowledge of the process has come almost entirely from tracer studies.

All plants readily absorb selective weed killers (“herbicides”), which are not destroyed within the plants. Resistant
plants show no effect of the chemicals, but sensitive plants suffer damage in actively growing roots and 11
shoots. Sugar formation during photosynthesis is disrupted in these plants, and phosphorus movement is
retarded. In order to predict what new classes of chemicals might be of value as herbicides, we must await the results of research using radioactive tracers.

Animal Nutrition and Metabolism

How Nutritious Are Various Feedstuffs?

An endless phase of animal nutrition research deals with efficiency of rations, that is, the pounds gained by the animal per pound of feed consumed. The standard form of such research is to feed groups of animals on different rations for several weeks or months and determine average change in weight per pound of feed used.

In recent years scientists have used chemical tests to compare the amount of calcium in the diet against the amount excreted. The apparent digestibility of such minerals has thus been computed for different rations. Yet one important source of error in these chemical tests plagued researchers.

There is a “turnover” in nutrients fed to animals; elements in feed are absorbed into the animal’s body, retained for a time, and later excreted. For example, a cow actually loses more calcium (through milk and excreta) during the first six months of milk production than her normal ration contains. As long as the amount of recycling was unknown, scientists could not tell, for instance, how much calcium in alfalfa hay could be digested by simply measuring incoming and outgoing calcium.

Formerly scientists could study the problem only by withholding all calcium from the diet. Under this unnatural condition all outgoing calcium came from the animal’s body.

With radioactive calcium in a steer’s diet (or injected into the blood), scientists can quickly tell how much of the
excreted calcium comes from the animal’s blood and organs under normal conditions. In a typical instance a 12
ration thought to have 24 per cent digestible calcium, chemically determined, was found to have 38 per cent
by the tracer technique.

The tracer method shows that milk contains phosphorus, only 20 per cent of which may come from the feed and 80 per cent from the cow’s bones. With eggs, about 65 per cent of the phosphorus is provided by feed and 35 per cent by the hen. Radioactive tracers permit measurement of such “biological pathways,” as the biochemist calls them.

Can Lean Meat be Estimated “on the Hoof”?

The proof of the ration, one might say, is in the cutting. That is, the worth of a particular feed was formerly unknown until the carcass had been cut and priced.

Because of the time and expense, researchers in the past have merely tested groups of animals on a ration for a few weeks and then estimated the total gain by weighing and measuring. The main drawback to such a method is that it measures total growth only. In meat animals, knowing total growth is less important than knowing how much gain is in the more valuable lean meat, how much is in fat, and how much merely water. Techniques based on atomic energy have provided a new approach without adding radioactive contamination to the animal.

Of the “background radiation” that has existed since the earth was formed, part comes from cosmic rays (from outer space) and part from radioactive materials in the earth itself. One of these naturally radioactive isotopes is radioactive potassium, which is present to a small but significant extent in food, in human bodies, and in construction materials.

While some chemicals such as carbon, hydrogen, and oxygen go into almost every kind of substance in living things, potassium plays a special role in animals: it lodges almost exclusively, not in bone or fat or water, but in lean meat.

Biological and medical researchers are now cooperating to build “whole-body” radiation counters. A human being
or an animal is actually enclosed by these huge devices, some of which are so sensitive they measure nearly 13
every ray that emerges from the body. These counters will help answer many questions, but here only their
use to measure radiopotassium in meat animals is explained. The animal is fed a test ration containing no added radioactivity. At intervals of a week or more, the animal is weighed and is also tested for natural radioactivity. Weighing tells total gain, while radiopotassium counting shows how much gain is in the desired lean meat. This method is remarkably simple, and since no radioactivity is added to its diet, the animal can still be marketed.

Does Thyroid Affect Milk—Egg Production?

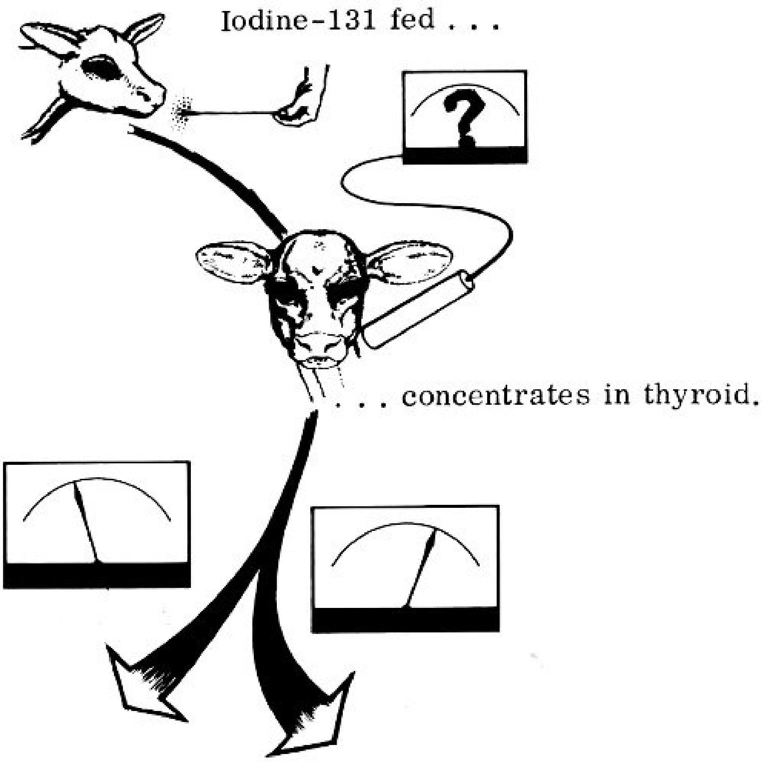
Recognition of the significance of the thyroid gland in animals, the association of iodine with the thyroid, and the availability of an excellent radioisotope of iodine have resulted in increased study of this important gland. Chemical tests had hinted at a link between the thyroid gland and the production of milk and eggs. Using radioactive iodine, scientists learned that thyroid activity increases with the onset of milk and egg formation. In hot weather, when yield of milk and eggs decreases, activity of the thyroid gland diminishes.

It may be that a dairy breeder can soon select calves for potential milk production because of thyroid activity as measured by radioactive iodine. At present he must let the animals grow and produce milk for several years before he chooses those to use in herd improvement. (See Fig. 4.)

More Tracers in Animal Nutrition Research

Female hormones in microgram amounts[1] accelerate fattening of cattle and sheep. Before this method can be used on animals for human consumption, however, it must be determined that no possible human injury can result from any residue. With chemical tests the measurement of such tiny amounts was impossible. Even with 14
radioactive carbon-14, doses of hormone 1000 times normal dosage were required before the hormones in the flesh were measurable.

Fig. 4—Future high-producing milk cows may be selected as calves, because of the measured activity of their thyroid glands. A minute amount of iodine-131 is fed and within minutes has concentrated in the thyroid. High concentration means high thyroid activity, which in older animals means high milk production.



Recently an isotope of hydrogen (tritium or H^3) was linked to hormones, and these were fed in normal amounts to cattle. Tests 90 days afterward showed less than one part per billion in the meat, a big step toward cheaper fattening of meat animals with hormones.

The use of tranquilizers has been proposed for reducing the customary loss of weight in cattle being shipped to market. These chemicals, also, are used in such minute quantities that residues could not be detected except with radioactive tracers. Tritium can now be used by health officials to study the effects of tranquilizers.

Insects 15

Where and How Fast Do Insects Travel?

Radioactive isotopes have been used to study insects, their life cycles, dispersion, mating and feeding habits, parasites, and predators. Several hundred such studies have been made on dozens of insect species.

With radioactive tracers even the smallest insect becomes more easily followed. As one example, nearly half a million mosquito larvae were tagged with radioactive phosphorus in Canada. Some of the adults from these larvae were later found as far as seven miles away, but most were recovered within one-eighth mile.

In a companion study grasshoppers were labeled with the same isotope. Their average rate of movement was only twenty-one feet per hour, and after seven days their position was based entirely on random motions plus prevailing winds. It seems that grasshoppers have no ability to move toward food.

How Far Do Insects Carry Pollen?

This question is of practical importance in knowing how far to separate seed-fields to maintain pure varieties of plants. In the past it was studied by the laborious method of growing a plant having a dominant “marker” gene for some visible trait surrounded by plants without the marker. Seeds from plants at various distances from the marked plant were grown the following year to see how far the genetically marked pollen had been carried. Since such plants are normally cross pollinated, it was difficult to obtain strains genetically pure for presence or absence of the marker gene. Also, considerable testing and bookkeeping were involved.

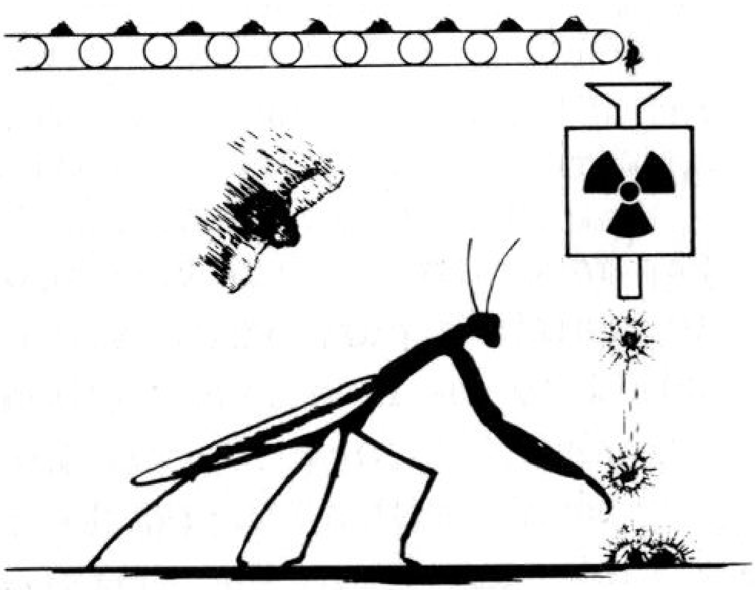
With tracers the answer may be found in a few days. A plant is injected with radioactive phosphorus; after a few days its pollen is highly radioactive. Flowers at various distances from the tagged plant may be checked daily for radioactivity. In one study with alfalfa, radioactive pollen was carried as far as thirty feet by bees, but more than one-third was deposited on plants adjacent to the labeled one. 16

Are Predators Used to Destroy Insects?

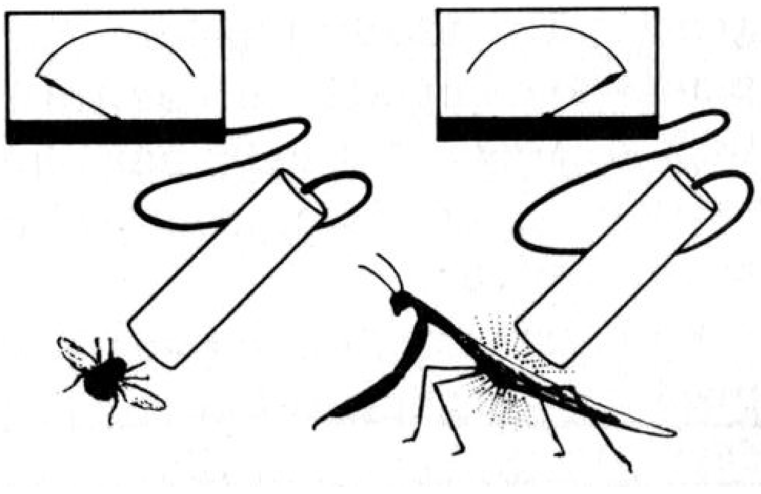
With insect pests, as with plant diseases, biological control is more economical than artificial control. The use of insecticides too often results in destruction of helpful insects along with pests. Limited success has been achieved in breeding certain plants for resistance to insects.

Two important uses of biological control in agriculture have been made in recent years: importing an insect from Australia to eradicate a weed in California and disseminating ladybird beetles to control certain scale insects.

Fig. 5—Identifying predators that destroy unwanted insects.



Aphids are made radioactive.



Larger insects found nearby are checked for radioactivity.

Bumblebee has not eaten radioactive aphids, but mantis has.

Helpful parasites and predators must first be identified before they can be used. In the case of small or nocturnal insects, this can be exceedingly troublesome. Tagging the pests with radioisotopes in order to identify the predators which consume them is much simpler because the most efficient predators contain the most 17
activity.

With such techniques entomologists have studied insects and animals which prey on unwanted aphids, mosquitoes, blackflies, and roaches. Such experiments may lead to a deliberate increase of certain predators to control injurious insects.

Radioactive labeling is also valuable in studying helpful insects. In one case the indolence of drone bees was indicated by finding that even with adequate syrup in their cage they still received identical syrup from worker bees in an adjoining cage!

Can Tracers Measure Spray Residues?

Any material used on plants or animals to kill insects or disease organisms must pass rigid inspection to be sure it does not accumulate in foodstuffs. This is particularly true of the “systemic” poisons, those which are fed to plants via leaves or roots and are carried internally to all parts of the plant. Such chemicals can be used widely with nonfood plants such as cotton to kill insects feeding on them.

Combining radioactive labeling with other techniques has permitted the researchers to show that some compounds are soon broken down into harmless chemicals—a big step toward acceptance for their use on food plants.

Radioisotopes as Radiation Sources

Earlier in this booklet radioisotopes were compared to fireflies because they emit flashes of “light.” Isotopes serve research in another important way, other than as tracers.

Suppose you collected all the fireflies within a 100-mile radius and put them into a glass jar. Instead of an occasional twinkle, you would now have a steady glow of light. Similarly immense numbers of radioactive atoms can be compressed into a small volume to produce steady, intense sources of radiation. Agricultural research has answered many questions with the use of such radiation sources.

Can Radiation Produce New Plants? 18

Perhaps no biological aspect of atomic energy has so caught the fancy of the public as the prospect of creating new plant varieties. There is something mysterious about pouring invisible energy into seeds or buds and watching for changes in the emerging leaves and flowers. There is also the challenge of the lottery in being unable to predict where, when, or in what form the alterations will appear.

Although the claims of over-enthusiastic gardeners and seed dealers about astonishing new plants “created” by atomic radiation are doubted, clear proof exists even in the restrained scientific journals of hereditary changes caused by radiation.

From more than 30 years of scientific study, certain conclusions have emerged. High-energy radiations can cause sudden hereditary changes (mutations) in any living thing: man, animal, microbe, or plant. Any feature of a plant subject to hereditary control—root, shoot, leaf, flower, or fruit—can be altered by radiation. Most of these changes are undesirable; they interfere with the normal state of biological affairs. A very small percentage of mutated organisms is improved in some way. So far changes cannot be controlled or predicted.

To date fourteen new strains of crop plants improved by radiation have been put into production in various parts of the world. These varieties with their places and dates of release follow:

1. “Primex” white mustard, Sweden, 1950
2. “Chlorina Mutant” tobacco, Indonesia, about 1950
3. “Shafer’s Universal” bean, Germany, about 1950
4. “Regina II” summer oil rape, Sweden, 1953
5. “Weibull Stralart” fodder pea, Sweden, 1957
6. “Sanilac” navy bean, Michigan, 1957
7. “Pallas” barley, Sweden, 1958
8. “N. C. 4X” peanut, North Carolina, 1959
9. “Florad” oats, Florida, 1960
10. “Seaway” bean, Michigan, 1960
11. “Alamo-X” oats, Texas, 1961
12. “Gratiot” bean, Michigan, 1963
13. “Pennrad” barley, Pennsylvania, 1963
14. “Yukon-1” carnation, Connecticut, 1963

In these instances no desirable changes appeared in the plant grown directly from treated seeds, but they 19
appeared several generations later. In most cases hundreds of thousands of plants were examined before the desirable ones were found. The desired changes were almost always accompanied by undesirable ones, and years of cross-breeding and “purifying” were necessary to obtain usable varieties.

The technique of radiation breeding can be used on any form of life where large numbers can be grown and discarded at little cost. The output of penicillin has been increased a thousandfold by repeated mutations caused in the microorganism producing this antibiotic. Several studies on radiation breeding of poultry have been started.

An ingenious reverse twist of induced mutation is being applied in the field of plant diseases. While some scientists are irradiating seeds and plants in an effort to obtain disease-resistant mutations, others are irradiating the fungi which cause the diseases. They hope in this way to foresee the new strains of pathogenic microbes that will occur naturally in order to breed resistant plants before the new diseases appear.

Some claims have been made that radiation can stimulate plant growth, germination, earlier maturity, and so on. Similar benefits are sometimes claimed for human health. These allegations are almost never proved in reputable laboratories. It seems likely that radiation is stimulating, in the words of one authority, “only in the sense that a pruning knife is stimulating.”

Can Radiation Destroy Germs and Insects?

Food technologists have studied ways of preserving food with radiation for more than ten years. Their findings indicate that complete sterilization of food with radiation requires doses so high (2 to 6 million roentgens[2]) that cost is prohibitive at present, and the food often becomes distasteful. These amounts of energy completely 20
destroy the microbes and enzymes which normally cause food to putrefy.

If radiation is to be used in preserving food, it will probably be as a supplement to conventional methods of heating and freezing. “Pasteurizing” with radiation to destroy most (but not all) of the microbes in meat or fruit or vegetables is accomplished with less than five per cent of the dosage required for sterilizing. Such treatment does not alter flavor or texture appreciably and could be used to prolong the refrigerated “life” of many fresh foods. It is the responsibility of the Federal Food and Drug Administration to determine that no threat to human welfare could possibly result before approving the use of high-energy radiation to preserve foods.

With agricultural products stored dry, such as grain, tobacco, and wool, the chief agents of damage are not microbes, but insects. The loss of stored field crops caused by insects is estimated at $200 million annually in the United States. Deinfesting such goods with radiation doses in the “pasteurizing” range promises to be practical and causes no apparent change in the product.

Like many other foodstuffs, potatoes are often stored for months between harvest and use. Precaution must be taken to prevent their deterioration during storage not only from decay but also from sprouting.

Cold storage inhibits sprouting but is costly and has another serious drawback. In the making of potato chips, tubers held at low temperature contain excess sugar and result in darkened chips. Storage at higher temperatures prevents conversion of starch to sugar but encourages sprouting.

Atomic energy promises to resolve this dilemma. Given low doses of gamma rays (5000 to 10,000 roentgens), potatoes may be kept at room temperature for a year or more without sprouting. Similar doses inhibit sprouting of onions. The estimated cost of irradiating tubers and bulbs at such doses is as low as 14 cents per ton. No chemical changes have yet been found in irradiated potatoes that would make them unsafe for eating. In fact, health officials in Canada have recently approved the use of gamma rays on potato tubers that will be stored 21
and later used for human food. Our own Food and Drug Administration has given similar approval for applying gamma rays to bacon and fast electrons to wheat (for killing insects).

An ingenious application of atomic energy to agriculture concerns the screwworm fly, which inhabits large areas of southern United States, Mexico, and the Caribbean. The fly lays eggs in open wounds of livestock, including navels of newly born, and the burrowing maggots inevitably kill the animal. In the southeastern United States, damage from this insect amounted to $15 to $25 million annually.

In the years 1958 and 1959 more than two billion screwworm flies were deliberately released from airplanes over the entire state of Florida and parts of Georgia and Alabama. This astonishing act was a major step in successful eradication of the pest from southeastern United States.

The entomologists who conceived this remarkable scheme had the following information from basic studies: the insect produces a generation about every three weeks. In the pupal stage males can be sterilized by 2500 roentgens of X or gamma rays, females by 5000 roentgens. The insect can be reared in large numbers. Sterile males are fully competitive with normal males for mates. And, of course, sterile eggs do not hatch. (It was helpful, though incidental, that females mate only once.)

After initial tests on an island in the Caribbean, a large fly-producing plant was set up. Flies were grown to the pupal stage, irradiated with 8000 roentgens of gamma rays, permitted to mature, and released from airplanes. With 50 million flies being released weekly over Florida, Georgia, and Alabama, the area was smothered with sterile flies, and the number of eggs that hatched (from the normal native flies) rapidly diminished to zero. The program was continued for 18 months, and in this time the insect was completely eliminated.

Certain other insects are being considered for the sterility-eradication technique. Among them are the boll weevil, European corn borer, mosquito, and tsetse fly. Oriental scientists are using gamma rays instead of the conventional heating to kill silkworms inside cocoons.

How Does Radiation Affect Farm Animals? 22

At a few colleges of agriculture in this country, radiation effects on farm animals are being studied.

Although it may not be flattering to be likened to a pig or a donkey, the fact remains that human beings are physiologically very similar to swine and burros. These animals are mammals with simple stomachs and have the same general size, shape, and placement of organs as do humans. Radiation studies with swine and burros, although slow and expensive, should give information more applicable to humans than the more rapid and inexpensive studies with small laboratory animals.

What Else Can Radiation Tell Us?

Two characteristics of soils besides fertility are vitally important and difficult to measure. These characteristics are moisture and density. Moisture must be determined frequently for efficient irrigation. Density controls the pore space available for water and oxygen; the possible damage to the soil from tillage and harvesting machines is revealed by before-and-after tests of density.

Both soil moisture and density were formerly determined by laboratory methods, which had two drawbacks: the methods were laborious, and they tested soil in an unnatural state. Today a sort of double-barreled radiation method can be used to measure these two soil characteristics.

Neutrons are readily scattered by water but not by soil; gamma rays are absorbed by both soil and water. In practice the experimenter drills two holes in the soil a few feet apart. Into one he puts a gamma-ray source; into the other, a radiation detector. The reading on his detector dial tells him the amount of gamma rays absorbed by both soil and water. Replacing the gamma-ray source with a neutron source, he obtains a reading on absorption by water only. The difference between the two readings is ascribed to the density, or degree of compaction, of that soil in its native state.

Conclusion

Radioactive tracers and radiation sources have become indispensable to all phases of agricultural research. They have helped answer questions that seemed unanswerable. But there will always be more questions to put to Nature. The physicists-philosophers of 1890 were confident that they had obtained all significant knowledge of the physical universe. Discoveries of the next twenty years revealed the immaturity of that conviction.

The modern poet Archibald MacLeish has dramatized the meagerness of knowledge:[3]

I will tell you all we have learned ...
  the lights in the sky are stars
We think they do not see
  we think also
The trees do not know nor the leaves of the grasses hear us....

Perhaps the most characteristic realization of the scientist today is that the universe is too complex to be fully described, that concepts must change repeatedly to absorb new findings, and that the recurring miracle of life is more majestic than any formula, any computer, or any rocket that man’s brain can devise.

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Motion Picture

(Available for loan without charge from the Division of Public Information, U. S. Atomic Energy Commission, Washington 25, D. C.)

Harvest of an Atomic Age, 20 minutes, 16mm, color and sound, 1963.

Footnotes

[1]A microgram bears the same relationship to a 1000-pound steer as a penny does to $4½ billion.

[2]The roentgen is a measure of ionizing radiation, as the foot-candle is a measure of light. In simple terms the roentgen is that amount of X or gamma radiation which produces one electrostatic unit (esu) of electricity in one cubic centimeter (cc) of dry air at standard conditions of temperature and pressure. This may sound like a trivial amount of energy, but it amounts to more than two billion ionizations in each cubic centimeter.

[3]From “Epistle To Be Left in the Earth.”

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