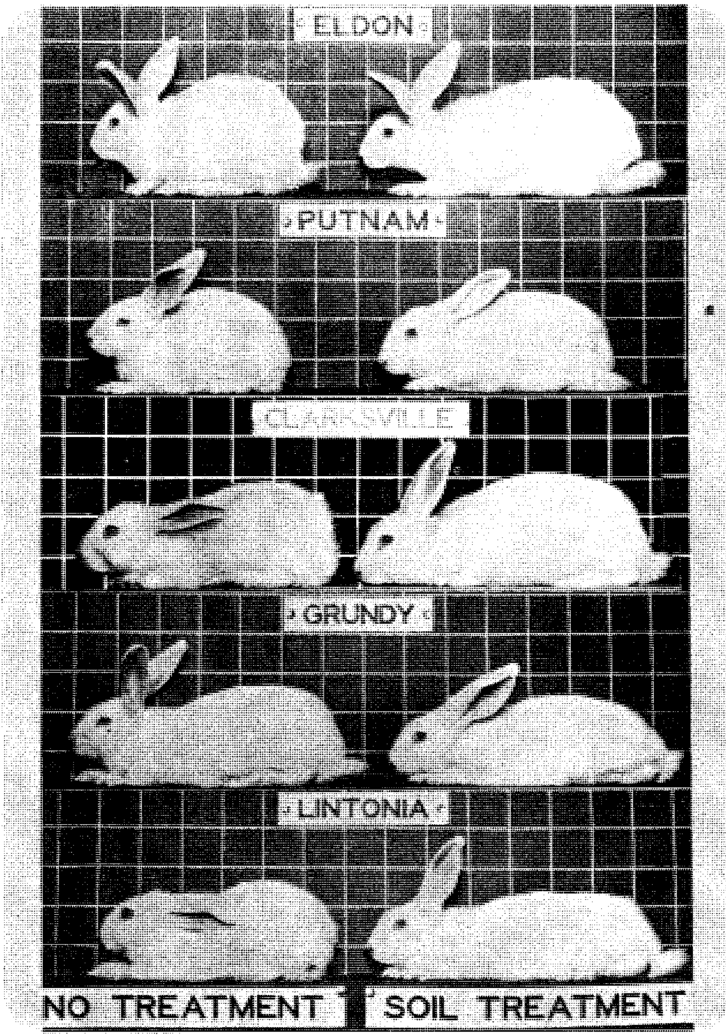
Reprinted from What's New in Crops & Soils, Vol. 6, No. 5 (February 1954)



These litter mate rabbits reflect the differences in feed coming from different soil types. They also reflect what happens when each soil gets fertility treatment. The animals were used in testing lespedeza hays grown on five Missouri soil types, each with and without soil treatment. The hays differed widely in their contents of the essential amino acids which go to make up proteins.

DO WE OVERLOOK *Protein Quality?*

by Wm. A. Albrecht and V. L. Sheldon

OUR struggle to get the inert nitrogen from the air and to compound it into our diet began even before agriculture itself came into being.

About four-fifths of every breath of air we take is nitrogen. Yet we cannot use this nitrogen in our bodies. Nor can we salt our food with nitrogen fertilizer to get what we need, for that too is in the wrong form.

We must rely on the work of microbes, plants, and animals. They only can build *inorganic* nitrogen into the *organic* forms we call proteins and which we can use as food.

The microbes in this trio are no longer as essential as they once were. It is now possible to manufacture synthetic nitrogen in factories. But as simple as this conversion may sound, we must still pay for it. It costs about 10 cents a pound to convert nitrogen into fertilizers.

From this point onward, the creative aspects of plants and animals become more significant. Our effort to eat resolves itself into a problem of obtaining nitrogen as protein. We like to have it come to us as meat, milk, or eggs. We like to get our nitrogen in beefsteak, selling for a dollar a pound.

We do not fully appreciate the fact that such animal proteins are products originally built by plants. Animals only assemble proteins. They must find the nitrogen in the vegetable or plant proteins they consume.

Plants can absorb nitrogen from the soil in simpler forms. Once they have

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taken it up, they unite it chemically with carbon compounds. The resulting nitrogen compounds are called amino acids, and there are 20 of these known to us. These amino acids in turn are used to build protein.

Amino acids have certain features in common. However, they differ in one main characteristic. This is in the nature of a group of carbon and other atoms which is attached at one point to the main amino-acid molecule.

This group is the so-called "side-chain." The complex side chains are built only by plants—not by animals. It is these different side chains which decide whether an amino acid is one which animals, and man, *must have to live.*

How the plant marshals these widely varied mixtures of amino acids into the huge protein molecule is still an unexplained mystery. Each living plant species has proteins with its own specific pattern. The structural difficulties encountered in making each of these proteins are complex.

We cannot distinguish the creation of protein from the process of growth. We must reason, then, that protein manufacture takes place where growth is taking place. Protein manufacture cannot be a simple adding together of the amino acids. It is a complete integration of them into the specific protein of the plant species.

We can separate a protein back into its amino acids—and we can again separate these acids into even simpler chemical elements. But even though we can do this, it gives us no clue regarding the processes by which the amino acids were put together in the first place.

In our digestive tract, the food proteins are broken down by enzymes such as pepsin and trypsin. If we do this chemically, in the test tube, we find a portion with the nitrogen in the amino form, holding the amino acids together.

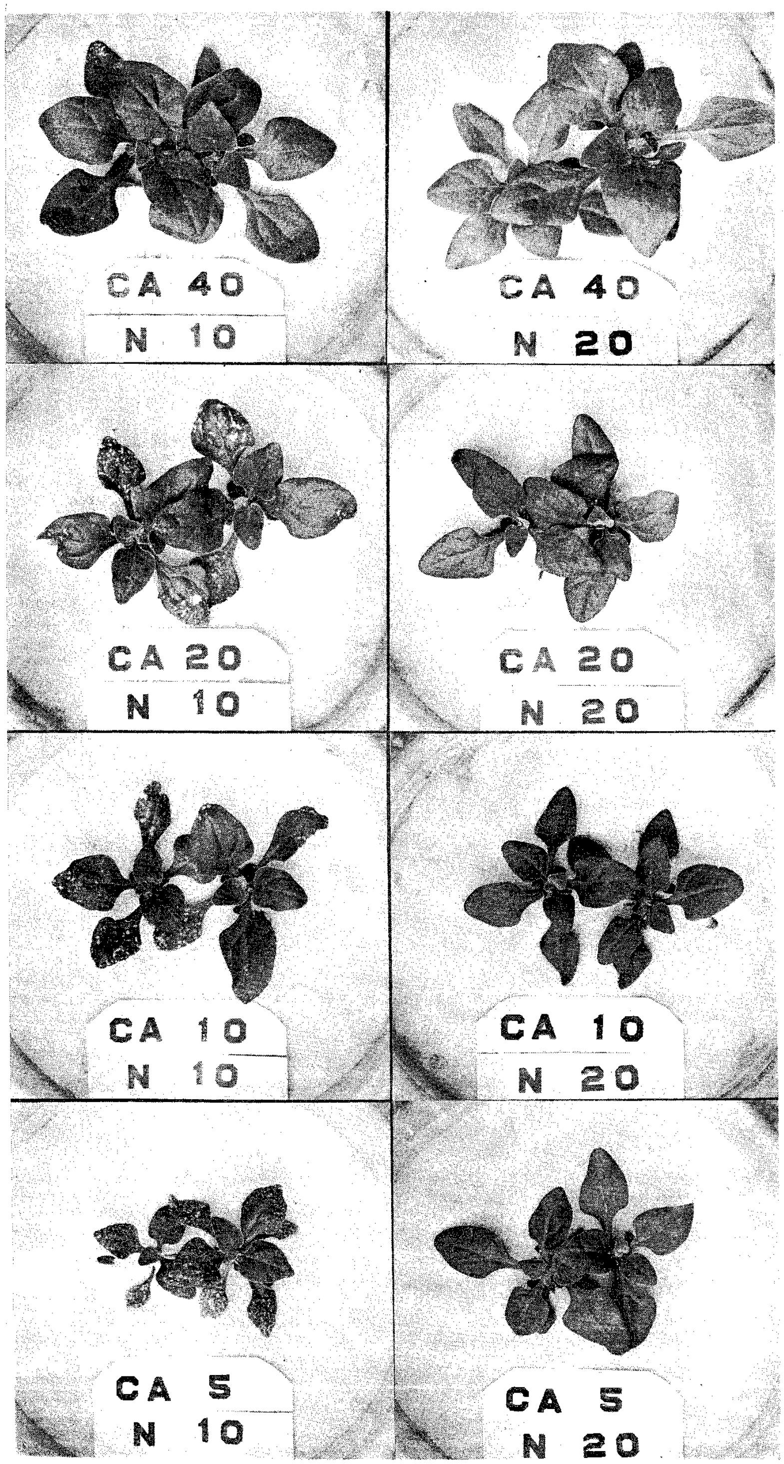
This particular form does not account for all the nitrogen in the protein. Some nitrogen is also stored away in another form, the amide, and still more is stored away in complex ring compounds.

Soil Regulates

The soil regulates the balance between these different nitrogen compounds inside the protein. It supplies the nitrogen which goes into the protein, and it also supplies the other substances which convert the nitrogen into protein.

One of these other substances is potassium. The way in which this element affects the conversion of nitrogen has been shown in experiments with alfalfa, grown on a sand medium.

When the potassium content of the sand was increased, the alfalfa responded by converting more nitrogen



Nitrogen at a low rate (10 M.E. per spinach plant) left the crop open to insect attack, though less so as there was more calcium applied to the soil (left, from lower to upper photo). But nitrogen at the higher rate (20 M.E. per plant) helped the plants build their own proteins for their protection at any calcium level (right, lower to upper photo).

So small a thing as a "fairy ring" affects the organic matter in the soil and provokes differences in the quality of the protein in the grass. The tall growth of grass in the "fairy ring" mushroom circle may be higher in amino acids than is the grass inside or outside of the circle.

into the complex ring structures mentioned above. Likewise, as the potassium increased, less of the total nitrogen went into the simpler forms.

These ring structures are not an exact measure of better protein; they are evidence that it is of higher quality. They do indicate that more of the kinds of protein needed by animals are present.

Sulfur, like potassium, is also needed in the manufacture of proteins. Analyses of over 250 plant samples which were grown on a wide variety of soils and nutrient solutions have given evidence of the effect of sulfur in this process.

Sulfur Affects Level

The simpler—and we think, the less useful—forms of nitrogen make up, on the average, about 50 percent of the total nitrogen in the forage, according to these analyses. Yet, in alfalfa, which was decidedly deficient in sulfur, this value jumped to over 80 percent. When more sulfur was offered to the plant, the relative amount of the simpler nitrogen compounds dropped back to normal.

Amide nitrogen in the protein is manufactured from the simple nitrogen compound, ammonia. It, too, has an agent which must be present before the manufacturing process can go on. Without adequate manganese, plants cannot produce this compound of nitrogen.

The 20 amino acids are the endpoints into which these other nitrogen compounds are assembled. Plants create amino acids as the products of a manufacturing process within the living plant tissue. This is their struggle to produce their proteins in order to make their growth.

These life processes require the soil-borne elements more than we yet appreciate. Much more is required for amino acid synthesis than the mere combination of nitrogen and sulfur from the soil with carbohydrates.

For these synthetic processes, plants need at least calcium, potassium, magnesium, boron, manganese, copper, and zinc. Should we not, then, expect a greater variety and a larger amount of amino acids in plants growing on soils which are well supplied with all of these nutrient elements?

Part of the answer to this question has been provided by a group of five Missouri soils. Each of these soils was treated to deliver differing quantities of the elements listed. Lespedeza was grown on these five soils, and we experienced wide differences in the array of amino acids within the lespedeza from each soil. A very minor difference in any of the substances mentioned above made a difference in the make-up of the lespedeza protein.

Similarly, a single soil was treated with varying amounts of the trace elements manganese and boron. Again, this time with alfalfa, it gave a marked diversity of the amino-acid pattern.

Animals consuming these forages need amino acids which they cannot make within their bodies. They need an assortment of the different kinds, and in turn, many elements of soil fertility will be needed before these various kinds of amino acids can be built.

Need to Know More

We are talking about going back to an agriculture which emphasizes forages and grasses. We need to know more about the proteins in these forages. Are the soils which grow them capable of producing proteins which contain the many kinds of amino acids needed by animals?

Among these amino acids, a typical one is tryptophane. It particularly demonstrates the complexity of those that are essential for human or animal nutrition. Here we find nitrogen bound with carbon to make a closed chain—what the chemist calls an "indole" ring.

Tryptophane is one of the complex amino acids which humans and animals must have to live. In addition to being required in the diet, it is also important because it can replace the B-vitamin, nicotinic acid, in the relief of the deficiency pellagra.

Yet, in corn, one of our most common feeds, the supply of this amino acid is so meager that its lack must be taken into account when corn is used in mixed feeds. If some other feed is not added to the mixture to make up for the lack, the mixed feed will fail to produce the results expected for it.

Soil Affects Protein Quality

The soil can help in building tryptophane, and this fact is of more than a little importance. We have found, at the Missouri Experiment Station, that soybeans getting low amounts of zinc, manganese, boron, magnesium, calcium, and phosphorus were always lower in tryptophane. As more of the zinc and the other inorganic elements were made available, more tryptophane appeared per pound of forage.

The same soybeans continued to show about the same amount of *total* protein, regardless of whether zinc and the other elements were provided. The total protein showed little if any relation to the amount of this essential amino acid, tryptophane.

So, by all our usual standards, we had a soybean plant high in protein. But we hadn't answered the question of whether this was good protein, and we don't know if it was high in tryptophane.

We dare not overlook this assistance of the soil in the build-up of nitrogen compounds. We must look to the end-product, the kind and quality of protein coming out of the soil, not the quantity.

Life chemistry is carried on by means of the compounds known as enzymes. These complex substances start and accelerate the chemical reactions in the plant. Their directing influences depend upon their three structural parts:

(a) A large, specific protein particle;
(b) A non-proteinaceous organic molecule, which when identified has often been found to be a vitamin; and
(c) An inorganic activator.

The manner in which these three are linked together remains obscure, yet each demands equal consideration. For when one of them is absent, the other two cannot function.

Enzymes Take Part

Herein lies the life-giving function of the soil. As the different soils deliver divergent quantities of the inorganic elements (activators)—calcium, zinc, and the like—so the enzymes in plants enable them to build better and more protein.

Biochemists as basic scientists may well busy themselves with studies of vitamins and proteins. But they dare not neglect the contribution made by the inorganic elements, or activators, from the soil. These substances serve in enzymatic roles, and if agriculture and medicine are to sustain or improve our health, then the two sciences must discover and interpret this enzymatic performance.

Food Value Improves

As the structural pattern of proteins presents more and varied amino acids, their values as food improve. In doing so, they make for what we call differences in quality. Improved quality of protein means improved health.

The nitrogen supplied by the soil can be a measure of protein only when we consider it in the array of specific organic nitrogen compounds. We dare not be content to count nutritional values of nitrogen only by crude protein.

Plants serve in the cycle of nutrition not as mere haulers of ash, but as biosynthetic creators of life with protein "not too crude" according to the more fertile soil. **END**

TABLE 1-RATES AND EFFICIENCIES OF ANIMAL GAINS AND YIELDS AS HAY AND AS ANIMAL GAINS PER ACRE ON DIFFERENT SOIL TYPES WITHOUT AND WITH SOIL TREATMENTS.

Soil Type	Rabbit Gains, Grams		Hay Consumed per Gram of Gain*		Yields of Hay, Lbs. per Acre		Yields as Lbs. of Gain per Acre*	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Putnam	315.7	419.9	13.23	9.41	2,180	3,800	116	254
Clarksville	419.0	616.6	7.85	5.49	520	2,020	39	233
Eldon	504.7	674.8	6.79	5.88	2,500	4,500	241	471
Lintonia	561.4	741.9	6.95	5.06	2,250	2,800	180	316
Grundy	637.1	593.9	7.43	6.47	2,400	3,760	180	303
Average	487.6	609.4	8.45	6.46	1,970	3,376	151	315
Range of difference, %	101.8	79.1	94.9	86.0	380.8	122.7	507.7	101.2

*Assuming all gains from the hay.

(From paper Biological Assays of Some Soil Types Under Treatments, Soil Science Soc. of Am., Vol. 8, 1944; McLean, Eugene O.; Smith, G.E.; and Albrecht, Wm.A.)