

*Droughts—The Soil As Reasons for Them

William A. Albrecht, Ph.D.

Professor of Soils
College of Agriculture, University of Missouri
Columbia



Dr. William A. Albrecht, chairman of the department of soils at the University of Missouri, has been a member of the Missouri staff since 1916. He holds four degrees from the University of Illinois, and has traveled and studied soils in Great Britain, Australia, and on the European continent.

Dr. Albrecht is the author of many scientific and popular articles on soils and soil fertility. For a number of years he has emphasized the need of proper soil treatment to insure healthy plants and healthy people, stressing the relation of soil fertility to human nutrition.

When one follows the meteorological reports rather regularly since most of us talk about the weather, at least when the radio reports it for us daily, one might well be asking with serious concern, "*How come that we keep on breaking flood records, heat records, past records for drought as long-time rain-free periods and other weather records?* While the meteorological conditions are changing are not the biological manifestations of droughts merely intensified as reciprocal to some other factor under serious decline through which the meteorological disturbances are magnified in their detrimental aspects? We have severer droughts as the records truly report. But should we not examine these in relation to the soil for more comprehensive understanding of them and our possible reduction of the disasters to plants and animals?

"Unfortunately, droughts may not be defined from standard meteorological records, since the intensity and the length of the drought depend on the kind of crops, the soil water, the soil fertility and meteorological parameters." It will be evident that we need to recognize the soil as a major factor in the disturbances to crops which we call "droughts." These are in reality dry periods extending themselves to lengths of time that bring about crop disaster. The drought then is more a performance measured by damage to crops than by meteorological indices.

Drought is then a time period during which there is a serious shortage of rainfall for the biological services to crop plants. These are exercised mainly after the rainwater has entered the soil, then the soil, which is more than merely a water reservoir, may be considered as influencing the effects of the shortage of stored water over an extended rain-free period through all of its services to crops beyond that of holding a supply of water. Those many services need to be considered before we use water shortage per se as the alibi for poor crops.

THE LAW OF CONTINENTALITY VS. THE LAW OF AVERAGES

The geographic-climatic settings for most of the droughts are the area between the humid and the semi-arid soil regions. These represent mineral-rich soils in general, since the low rainfall has not developed them excessively or removed the calcium, and minerals of similar soil behavior, from the profile and replaced them by hydrogen as acidity. These are the soils where agriculture grows protein-rich forages, where soils are windblown and where animals grow themselves more readily on what is apt to be called the prairie and the plains soils.

Droughts are also geographically located in the midst of larger land areas, where the effects of what is called "continentality" are more pronounced. This represents the degree to which the weather, or the daily meteorological condition, varies from the climate, which is the mean or the average of the weather for the longer time period of records considered. The larger the body of land, i.e. the more continental the area, the more the weather or the daily condition will vary from the climate or the average. This is "The law of continentality" in brief. Droughts, then, may be more commonly what we call "continental" manifestations. They are a variation from the mean and the expected, since climate is reported as the mean of such meteorological data. It is in the mid-continent of the United States, then, where droughts may be expected more commonly.

When the average, or mean, of weather records is used to describe the meteorological conditions of a region, Columbia, Missouri, for example, is reported to have an annual rainfall of 39.33 inches. For Springfield Missouri, the same figure is 41.42 inches. This rainfall figure, which is a mean total for the year obtained from records of nearly a half century, says nothing about how high or how low the amounts for any single year may be. Because of the continentality of Missouri

DROUGHTS—THE SOIL AS REASONS FOR THEM

—its location a thousand miles from any seacoast—we formerly considered that, from the previous data, Columbia, Missouri, had a continentality effect of 50 percent. That says that while the rainfall is reported to be roughly 40 inches, the precipitation might vary over a range of 50 percent, namely 25 percent, or 10 inches, below 40, and 25 percent, or 10 inches, above 40. It might range, then, from a low of 30 inches to a high of 50 inches of precipitation for the different years.

But that figure, once established for continentality, is no longer the fact. That record of continentality was broken in 1953 when because of the drought of that year the annual rainfall was but 25.12 in place of 39.33 inches. This annual weather in terms of a rainfall of 25.12 is 36.1 percent below the mean of 39.33 inches, or that much below the climate. Hence we may expect excess rain also of 36.1 percent, a high some time of 53.54 inches, or a continentality effect of twice

36.1, which is 72.2 percent. For Springfield, Missouri, the drought of 1953 gave but 25.21 inches of annual rainfall, or a deficiency of 39.1 percent to suggest a continentality effect there of 78.2 percent.

If one considers the rainfall for only the summer months, May to September 1953, inclusive, when the effects of the extended rainfree period on vegetation are exaggerated by high temperatures, Columbia, Missouri, suffered under a continentality effect amounting to 86 percent. At that same time, Springfield, Missouri, suffered one amounting to 135 percent. This latter was a most severe disaster to an agricultural area given largely to the dairy phase of that business with so much dependence on grass as the crop. Thus, the law of averages applied to Missouri may leave one content with averages, but the law of continentality is truly disturbing but highly revealing when such droughts as 1953 are experienced in record-breaking dimensions.

The Missouri Drought of 1953 Emphasized Continentality When the Records of the Weather Are Put in Contrast to Those of the Climate

	Columbia, Missouri	Springfield, Missouri
Annual rainfall—mean	39.33 inches	41.42 inches
Annual rainfall, 1953	25.12 inches	25.21 inches
Annual deficiency, 1953	36.1%	39.1%
Continentality effect, 1953	72.2%	78.2%
Summer rainfall, mean*	21.26 inches	21.62 inches
Summer rainfall, 1953	11.94 inches	7.02 inches
Summer deficiency, 1953	43.0%	67.5%
Continentality effect, summer	86.0%	135.0%

*May to September, inclusive

DROUGHTS ARE BECOMING URBAN

With 85 percent of our population collected into urban centers, while only 15 percent are still rural, we would scarcely expect the urban group to appreciate droughts, exhibiting the effects of rain-free time largely through the water shortage within the soil bringing crop disasters and livestock troubles. But droughts as water shortage through falling water tables and failing wells are not only rural troubles for thirsty livestock. They are coming to be serious troubles also for urban centers and areas of congested peoples. Where the per capita water consumption per day was formerly a few gallons—a pail-full carried from the spring—it is now estimated at 700 gallons per day on a national scale. When this increase per capita is coupled with the increase in population, our water consumption since “water-pail” days represents an increase of several thousand percent. This supply comes mainly from deep wells. For this the soil is the filtering, clarifying and bacteriicidal agency, in most cases, which gives us clean, health-supporting water to drink. We have taken water of this kind for granted. We have not seen the soil’s services

connected therewith. Droughts are making us become water-conscious, not only via disasters to crops as feed and livestock drink, but also even to the value of *water as the major liquid mineral we all drink*. When eastern Kansas in 1954, following a rain-free period of serious shortage in 1953, had 26 cities critically short of water, we have reason to become conscious of droughts of larger significance than of such to the rural population only.³

WATER SHORTAGES—A RESULT FROM EXCESSIVE EROSION AND DRAINAGE

Our urban centers are coming to see the soils as reasons for droughts in broader meaning of that loosely used term. We realize that we must either limit water consumption per capita, or we must raise the level of the groundwater, i.e. the water table, by getting more water per rainfall to enter the soil. The shortage in soil-stored water is a sequel to soil erosion. As the surface soils become shallower, they are less of a blanket to hold larger portions of each rainfall for increased amounts of it to filter or to soak down more deeply into the

soil to raise the water table there. Every little rill of erosion is a drainage ditch to hustle the rainfall off just that much more rapidly, and to leave that much less to enter the soil for storage there. With erosion, too, the structure of the remaining cultivated surface soil has become less granular and less stable. Less infiltration of water per rain is possible for that reason.

Our excessive drainage, increased more recently by the excessive surface runoff bringing about erosion, is now magnifying the shortage of water taken from and given out by the soil. In the mind of the pioneer, it was the surplus water and not the water shortage, against which he waged a constant struggle. He used drainage ditches, tiles, and all possible means of getting rid of what he considered too much water. We seem to have inherited the pioneer's animosity for water and delight in the extra speedy drainage. Instead, we now should encourage more standing water for infiltration because we have too much drainage for sufficient of that.

We have apparently lifted our soils too high out of the water when now nearly every acre is drained. Also, when all-weather roads are considered a necessity, almost every section of land is encircled by such. Each roadway under concrete cover is allowing no rainwater to enter that much soil. Also, by its sloping shoulders and parallel drainage ditches, each highway is hustling off to the rivers the rainwater falling upon acres and acres in roadways, while draining also more quickly the arable land adjoining them. When we are bringing about all these changes which reduce the rate and total of water infiltration into the soil while rates of water consumption are increased to lower the supply stored—both in the soil profile for our crops and in the water tables for our livestock and the people of our population—is it mysterious that droughts are getting worse and floods more disastrous? Are these new records other than man made? Are they coming other than by way of the soil?

We have then been bringing our droughts, as they represent shortage of supplies of water, upon ourselves. Droughts are disastrous in terms of deficiency of that liquid mineral in the soil and of the food it grows. The more fertile, high protein-producing soils are exhibiting the more serious drought disasters. Man is thus pushing himself off the soils which are better for nutrition. He is crowding himself to areas of higher rainfall and to soils giving feeds and foods of high-fattening rather than high-feeding values. He has not noticed that he was moving himself out of quality foods by soil exploitation, since hidden hunger is registering itself all too slowly. But now that he is crowding himself out of drink, that will register more quickly, since thirst is more speedily lethan than hunger, droughts take on more meaning. They, too, are moving from the country to the towns and the cities. Droughts register as disasters regardless of whether via humans or via vegetation. Since both routes for troubles of this nature go through the soil, they will finally lead us to the soil as the basis of creation in terms of both drink and food.

CONFUSION IN CONSIDERING WATER SHORTAGE IN THE SOIL BUT NOT RECOGNIZING FERTILITY SHORTAGE THERE

In seasons of water shortage for our crops, that shortage in the soil has too commonly been mistaken for the shortage of plant nutrition there. When the farmers said, "The drought is bad since the corn is 'fired' for four or five of the lower leaves on the stalk," he was citing a case of the plant's translocating nutrients, especially nitrogen, from the lower, older, nearly spent leaves in order to maintain the upper, younger, and growing leaf parts of the plant. Now that we can apply fertilizer nitrogen along with other nutrient elements, we know that in the confusion, and lack of knowledge about plant nutrition, we made so much of the drought in many cases where it was not the direct shortage of the water as liquid for the plants, but rather the more common shortage of nitrogen entering into protein and all it represents in crop production.

In this case, the soil as shortage of nutrition and not of water was responsible for what was called "drought." With a shallow horizon of surface soil to which the fertility of the entire profile was confined, and with an acid, infertile clay horizon beneath it, the drying of that surface layer compelled the roots to go out of the drying horizon originally providing both fertility and water, and into the subsoil where only water but little or no fertility was present. That shallow surface layer was dried, not only as the result of the heat from the sun but also because the roots of the growing crop like corn are estimated to be taking from .15-.25 of an inch of water by transpiration alone per day.* To miss recognizing the fertility shortage when emphasizing the water shortage in the surface soil during drought is a mental behavior of long standing. In that error of thought we have been blaming the drought via the soil water for a "fired" crop when it was plant starvation via that route from which also insufficient fertility for plant nutrition was coming.

If these fertility conditions cause the lower leaves of the corn stalk to "fire," in the case mistaken for drought, one needs only to note the growing tip of the corn stalk. If water shortage is responsible, then the growing tip of the plant will be wilted. If it is fertility shortage, the growing tip of the plant will not commonly be wilted since the roots going deeper into the subsoil are delivering water to maintain the active plant tip without its wilting. It is the wilting of the growing tip of the plant which tells us when water is needed, a question to which most any housewife knows the answer who cares for her house plants. Droughts may often be a case of infertility of the soil, or one of imbalanced plant nutrition, apt to be mistaken for shortages of rainfall and for bad weather.

*Some folks consider .10 inch of water transpired daily by a corn crop and define a drought for corn as rainfall of less than one inch every ten days. This gives no consideration to the soil concerned.

DROUGHTS—THE SOIL AS REASONS FOR THEM

PLANTS SPEND MOST SOIL WATER TO KEEP LEAF TISSUE MOIST FOR GASEOUS INTERCHANGE WITH THE ATMOSPHERE. THIS LOSS REPRESENTS COOLING EFFECTS.

Should we clarify some other confusions connected with the properties of water and its biochemical services to plants, animals, and man, we may simultaneously clarify more effectively our understanding of the soil's significance under what we call "droughts." In connection with our own body comfort during times of higher temperatures and longer rain-free periods, we appreciate the help by speedy evaporation of water from our own skin as a means of keeping us cool. It is a fortunate property of water that a tremendous amount of heat is taken up when water changes from its liquid form to a gas, or when it vaporizes. We can use melting ice to cool ourselves since about 85 calories of heat are taken up in melting one gram of solid water as ice into the liquid form at the same temperature. But Nature has been more efficient in using vaporization of water from our skin as a means of offsetting high temperatures or heat, since about 585 calories of heat are taken up when one gram of water is vaporized from the skin, or in the breath as discharged in the form of water vapor from the lungs.

This property of water, namely its high heat of vaporization, holds down—and to a considered regularity—the temperatures of small bodies of land surrounded by water. It offsets the effect of continentality as illustrated when Great Britain has a continentality of but 10 percent, or the Hawaiian Islands have almost none. Vaporization from the surrounding water mass spends the sun's heat which would otherwise raise the atmospheric temperature over the adjoining land were the air from there not exchanged by air from over the water. Soil water vaporizing from the soil's surface is then a cooling agent of the soil and air above it. So is the water vaporizing from the plant's leaf surfaces. Trees bringing up water stored much deeper in the soil to be vaporized from the tree's leaf surface are a means of spending the heat from the sun and thereby of cooling the atmosphere. Clearing areas of forests has done much in bringing about wider fluctuations in temperatures, first, because trees are help in getting rainfall into the soil for increased storage and less sudden fluctuation in soil temperature and moisture, and second, in lessened fluctuations in atmospheric temperatures within considerable heights from the soil because of their transpiration or vaporization of water from within their leaves. As crops grow taller, they ameliorate for themselves the effects of variations in heat from the sun by means of the water evaporated through them from the soil.

The water of transpiration from the plant's leaves demonstrates another of its vital biochemical properties, namely it services as a solvent of gases as well as of salts for their ioni-

zation. Water is lost from the leaf of a plant because the inner, moist tissue of the leaf is exposed to the atmosphere for the exchange of gases. Those gases are mainly carbon dioxide and oxygen. That inner, leaf surface must be kept moist since gases will not exchange through a dry one for help to the plants in taking in carbon dioxide for photosynthesis or oxygen for respiration. Plants lose water by transpiration according to the meteorological conditions vaporizing that water from the leaf surface much as water from any moist surface. The stomates of the leaf, through which gases exchange, may be partially but not completely closed for a living plant. The plant leaves may roll themselves for reduction in transpiration before they wilt. But moist leaf tissue exposed for exchange of the gases must be losing water to the atmosphere, or plants must be transpiring, if respiration and photosynthesis are to continue to keep the plant alive under most common conditions of the water. Only an atmosphere of humidity at 100 percent or one completely saturated, eliminates transpiration. In Nature this condition does not occur often.

PLANT'S TRANSPIRATION RATIO IS NOT AN INDEX OF EFFICIENCY OF USE OF WATER.

It was the classic work of Briggs and Shantz that measured the water of transpiration of crops in relation to the amount of dry weight in plant tissue resulting as growth.¹ The same soil was used for the many different crops under experiment. At that time, and by many folks today, it was believed that the kind of crop determines this relation and little significance was given the soil as control of it. Their work gave us many "transpiration ratios" apt to be called "water requirements" of different crops. These values are the pounds of water transpired to the air by the plant taking it from the soil to produce a pound of the crop's vegetative dry weight.

Unfortunately, crops have been classified by means of these values into different "efficiencies with which they use water from the soil to give us yields of crop," i.e. only vegetative bulk. "What difference is there in the quality of crop yield per pound of dry matter produced?" was not the question raised even when the transpiration ratios were widely different and the final figures were an average of them over wide range. Photosynthesis by the sorghum and sugar cane piling up rapidly their photosynthetic products, namely, sugars and starches as energy food for the plant, was emphasized. Biosynthesis, the production of the compounds like proteins which takes place without the direct service of light and uses some of the sugars and starches for starting compounds and for energy sources or fuel for the synthetic processes, was not considered. The ratio of the pounds of water transpired to the pounds of complete protein produced would have put this thinking on a truly nutritional basis. It would let us see water of transpiration used highly efficiently by alfalfa making a pound of very good protein per 8000 pounds of water transpired. This is high efficiency in contrast to sorghum,

*A medium-sized hardwood tree may lose 50 gallons of water through its foliage in a day, reports William B. Love, Michigan State College specialist in municipal forestry. Trees in lawn areas need more watering.

making a pound of incomplete, or very crude, protein per 10,000 pounds of water of transpiration. Alfalfa, a quality feed producer, is more efficient in using water for this purpose than is sorghum.

CROPS FOR DRY SOILS

But the crop specialists interested only in vegetative mass as a service by transpired water, remind us that sorghum uses water at the rate of 275 pounds per pound of dry matter grown, while alfalfa transpires 850. In his mind, which has not yet envisioned nutritional services by crops grown but clings to the criterion of vegetative mass produced per acre as the criterion of crop yield, the sorghum surpasses the alfalfa as the crop for droughty areas or those of lower rainfall. According to these folks using such simple transpiration ratios as their judgment of the crop's efficiencies in using water, low rainfall areas would call for growing bulky crops that starve our animals and ourselves rather than call for making the soils fertile in those low rainfall areas to use that water more efficiently for the creation of real nutritional values. Speculation in agricultural crops on the level of simple arithmetical thinking is more universal than is the creation of real food value demanding our thinking in terms of the science of physiology and all the other forms of organized knowledge undergirding growth, protection, and reproduction by the life forms that live to feed us.

Any crop uses water inefficiently for the possible biosynthetic services when the fertility supply in the soil represents an imbalance for the support of the physiological processes required for the maximum of nutrition of that crop. In that nutrition of the crop, any one element in low supply in the soil may cause inefficient synthesis, while the stream of water loss as transpiration runs on just the same. Elements like calcium, magnesium, potassium, phosphorus, and others held in place are *soil* fertilizers. Nitrogen, so mobile and not so held, is the *crop* fertilizer. Thus the confusion in this regard occasions inefficient use of the transpiration stream under Nature's control, because we fail to keep the supply of nutrients in the soil up to the high level, and in the proper ratio, for the biosynthetic processes of the crop functioning at high efficiency in giving us nutritional values in itself as our food.

The transpiration stream flows according to the meteorological conditions favoring evaporation of water balanced against the soil's conditions representing forces holding the water as a thinner film around the soil particles. The plant and its open, internally exposed, wet cells in the leaves are atmospherically exposed water surfaces connecting themselves through the plant, and its root contact, with the water film around the soil particles. According as that soil has less water and the film is thinner, the water is held there more firmly against liquid and gaseous transfers of it to the atmosphere via the plant which is the equilibrator of the atmosphere's taking water by evaporation from the leaves and the soil's holding it by surface adsorption. The poor plant is merely the innocent equal sign between the two opposing forces.

Even though the plant's leaves may roll, and stomates may nearly close, they must still permit carbon dioxide to enter and escape, and oxygen to do likewise for the continued respiration if the plant remains alive. Its wet, living tissue exposed cannot prevent the water loss any more than you can live and prevent the moisture loss in your breath by stopping your breathing. Plants lose water under variable weather according to the soil and meteorological conditions and not according to the plant species or plant pedigree.

TRANSPIRATION STREAM OF WATER FROM SOIL TO PLANT VS. NUTRIENT MOVEMENT ALONG THAT ROUTE.

The transpiration stream of water moving from the soil through the plant to the air obeys the meteorological conditions of the atmosphere controlling it. The nutrient elements move from the surface of the colloidal clay holding them to the colloidal surface of the root according to the energy changes required to bring that transfer about. This chemodynamic performance of nutrient activity follows its set of laws and conditions, including the *presence* of water but *not* the *movement* of the water. The nutrient, inorganic elements within the soil, like the fish in the stream, are not victims of the current. They move with or against it according to forces controlling them.

Experiments, using colloidal clay to measure more accurately the soil's stock, and changes, in the nutrient cations, have demonstrated that nutrient ions could go from the plant back into the soil while the plant was increasing its mass by growth and was having a normal transpiration stream of water flowing from the soil to the atmosphere. As a second case, using the seed planted into moist sand, for example, growth occurred with the transpiration stream moving water out of the sterile sand but no fertility elements from there. It was an empty transpiration stream then so far as nutrients hauled in by it are concerned, but it was, nevertheless, a flow of water. It was a moistener of the leaf tissue only for exchange of gases there, which is the normal function of transpiration.

In the desert where the soil is so dry, to cite a third case, the moisture condensing on the plants at night is enough to moisten the soil around the plant's roots by reversing the stream of transpiration. But this does not necessarily reverse the movement of fertility, which continues to go from the soil into the plants. Desert plants take fertility regularly even if the transpiration stream should be a diurnal reversal of its current. As another good case, one can demonstrate plant growth and nutrient movement into the root from the soil when the transpiration stream is not flowing. One can demonstrate growth by putting a potted plant under a glass bell jar into an atmosphere laden with moisture and carbon dioxide with a humidity of 100 percent and no transpiration. Given plenty of carbon dioxide and sunlight, we can have both plant growth and nutrient movement from the soil even when the transpiration stream is at a standstill. These four

DROUGHTS—THE SOIL AS REASONS FOR THEM

cases are the evidence that the transpiration stream is one activity, while the movement of the nutrients is another quite independent of it.

Our failure to study the plant nutrition within the soil, and our contentment with complaints about droughts, have left us growing bulk of plants rather than nutritional values in our agricultural crops. Water has been the great alibi. We have believed the plant concerned only about its drink. We have simply not seen the soil and the plant's concern about something that is truly plant nourishment for biosynthesis by it of proteins and higher food values. We have simply not diagnosed each specific case. We have been content with propagandized practices by the majority of prescribers. We have been running within the pack of humans in place of smelling out the trails of the things of Nature.

DROUGHT, EXCESS OF TEMPERATURE AS WELL AS THE DEFICIT OF SOIL WATER

When the absence of water for its services in vaporization from the soil and the vegetation as a cooling effect allows the temperature of the air to rise high, shall we not expect the plant's processes of life, centered in the proteins, to be disturbed by the increased heat? Those processes are doubled in their rate of activities for every 10°C. increase in temperature according to the Vant Hoff Law, until the protein itself may be destroyed by it. We may well expect many life processes to be interrupted long before the protein is coagulated or changes are visible. Eggs incubated near 100°F. give a hatched chick, but if they are held at a few degrees higher than that for even a short period of time, the physiological processes are so disturbed that the normal hatch of the healthy chicks does not result. The protein of the egg need not be coagulated, or even coddled, to upset the process. Life processes in the plant come under the same category as those within the egg. They deal with proteins within the plant cell. They are concerned also with enzymes which encourage the processes. These delicate catalytic combinations, resembling the proteins in many instances, fit into the same pattern of temperature requirements for regular, normal life processes. Low rainfall and accompanying irregular temperatures then, resulting in a drought, may be effects of the heat wave as well as of the shortage of water.

In the ecological pattern of plants distributed over the world, starch production and its storage in the seed occur under limited temperature ranges at certain physiological stages in the plant's growth period. Corn grows, for example, in the temperate zone for high starch output in the crop and that at certain months within the year. Other seeds of high-starch delivery are seasonally located similarly. For starch-producing crops in the tropical zone those seem to be given to storage of this compound in the roots, or underground, at lower temperatures. Seeds there seem to store their reserve energy supplies as oil. Shall we not visualize the plant injury, during a drought with the dry surface soil going to the higher temperatures, as an effect of the excessive heat changing the

physiology of the plant rather than the effect of only a shortage of water or this liquid nutrient?

Among the other plant manifestations suggesting effects of drought by high temperatures rather than by water shortage, there is the common change in a bluegrass lawn to one of crab grass or other species, for example when the lawn owners persist in keeping their lawns watered during the hot summer months. Where the lawn is dried and the bluegrass has disappeared in going dormant, this same grass species comes back with the break in the drought, namely, with the rain again and the lowered temperatures. Such is not the case of the watered lawn, shifted by that watering treatment during the heat to a crab grass flora. That flora persists and excludes the bluegrass during the rest of the season. A Bermuda grass lawn is undisturbed by the drought which displaces the bluegrass. Bermuda grass stays green during both the high temperature and water shortage.

Observations on Sanborn Field, Columbia, Missouri, under experimental soil studies since 1888, suggest that corn plants at a low level of physiological activity because of low soil fertility were not visibly injured by either the water shortage or the heat wave of the drought. But as more fertility, including nitrogen, raised the levels and diversities of the plant's activities, the drought damage became more severe. But this suggests itself as the result of the high temperature damaging the plant parts commonly rich in nitrogen and most active in tissue growth. The injury occurred in plant leaf parts where damages from nitrogen deficiencies are commonly observed, but the appearance of the plant parts injured was decidedly different than that exhibited under starvation for nitrogen. This suggests the simple fact that vegetation doing little but the elaboration of cellulosic mass is not subject to drought injury, but plants elaborating compounds of much nutritional value for animals are injured by the heat wave of the drought as well as by the soil's shortage of water.

As still another biological demonstration of the heat wave let us recall that the races of pheasants introduced into the United States came from a range of conditions quite unlike, for example, those in Missouri in which state the introductions of this game bird have not been so successful. These birds lay their eggs and incubate them too late in the season, or when the high temperatures we experience in the early summer have an adverse effect on the hatch. With the clutch of eggs on the ground, the soil temperatures rise too high and injure the incubating processes guaranteeing a good hatch. For this biological process, the "drought" damage results from the heat wave and not from the deficit of water as drink.⁴

As still another biological demonstration of the heat wave aspect of the drought of 1954, a hatchery reported the death of many chicks, and of more mature chickens and turkeys on its poultry farm during the high temperatures accompanying it. Likewise in some of our experiments using rabbits for biological assay of the differences in grains and forages resulting

from soil treatments with different trace elements, the first heat wave in late June and early July took over 70 percent of the rabbits in one set of the feed arrangements, while it took none of another set. All the animals of these two sets were in the same room and temperatures. This mounting of the fatalities of the one set was gradual and persistent as the drought continued and the temperatures mounted in killing even the replenishment of the dying stock from the adjoining surviving stock moved to the fatal feed. When the high percentage of fatality on this dried feed had been reached with eight deaths in one day of record heat, the assay was terminated with a shift in ration emphasizing the dried milk proteins. This shift prohibited any further fatalities and stopped the disastrous effects by the heat wave on these animals when considerable publicity of animal death by drought was common.

A repeat trial on the effects by the high temperatures on the rabbits, according to the original ration with increased grain mixture, duplicated the previous results. This trial was carried on for only three weeks or until only 31 percent of fatalities resulted during the succeeding heat wave. Here the deaths suggest themselves as due to the high temperatures, but only when the poor nutrition suggests itself as the route through which the high temperatures worked their damage. (It also casts reflection on the quality of the feed offered the public by some hatcheries along with their baby chicks.)

SUPERFICIAL POST-MORTEMS OF CROP FAILURES BLAME THE WEATHER. ACCURATE DIAGNOSES POINT TO THE SOIL.

It is only slowly that the factors in the agricultural production of our feeds and foods are being tabulated and evaluated. For too long a time has weather, especially rainfall as the supply of water for plant growth, been the alibi for irregularities in crop yields. "Drought" as a term including rain-free periods of extended time, has now broken all past records and become a national disaster. As such it deserves analysis of the problems it presents. Such analysis establishes the soil as a major factor in determining the severity of the disturbances to the plant's growth and reproductive processes by the water shortage and the high temperatures through which the plant is injured under the composite of conditions included in that term.

CONCLUSIONS

More soil knowledge through research progress has now pointed to a better understanding of the facts about soil water and the aspects through which some of the injuries by drought can be mitigated. The fertility of the soil as plant nutrition is decidedly significant in that respect. Now that we are separating the nutrition of the plant by the soil from the storage of water in it for the plant, the drought as water shortage is no longer so much of an alibi. Rather drought is more a damage by deficient plant nutrition. In soil management, which may include irrigation, the economy and sound service

to plant production demand that the supplying of the soil fertility should be the first concern and the addition of water the second.

Analyses of the problems of drought establish the fact that excessively high temperatures, per se, as disturbers of the physiological functions of the plants, and even of animals, are factors perhaps more lethal than the water shortage. Even when the high temperature is segregated as a factor of damage, it is significant that this is increased by imbalanced nutrition, or conversely, improved by proper nutrition.

Thus the problem of drought damage moves itself into the lap of agriculture as a problem either to be solved—at least in part—or tolerated with reduced disaster, via the management of the soil for better nutrition of the plants and the animals fed by means of it. In the case of what we call "droughts" we need to view them for possible prevention or reduction of damage via the wiser management of the soils under them.

*Read before the Eleventh Annual Meeting of the American Institute of Dental Medicine, The Desert Inn, Palm Springs, California, November 3, 1954.

REFERENCES CITED

1. Briggs, L. J., and H. L. Shantz. Relative water requirements of plants. *Jour. Agr. Res.* 3:1-64, 1914.
2. Decker, Wayne L. Sixth Annual Progress Rpt. Mo. Climatological Res. Project. Un. of Mo., and U. S. Weather Bureau Cooperating, July 1, 1954.
3. *Kansas City Star*, March 21, 1954. (Sunday Edition).
4. Steen, M. O. Missouri Conservation Commission, Jefferson City, Missouri. Private Communication, July 15, 1954.

SUMMARY

Droughts, as shortages of soil moisture, occur in regions where the daily meteorological conditions, considered as "weather," vary much from the mean of them which is called "climate." These variations are wider as the body of land is larger or more continental. Recent records showed that this continental effect has been increasing.

Excessive erosion and drainage have put less water into the soil to evaporate from there, hence droughts have been excessive heat waves as well as shortages of soil water. Temperatures rise when there is less water to evaporate and to spend the sun's heat. This heat has resulted in killing the enzymes in the plants and in prohibiting their functioning in regular growth.

While watching the plant under drought, little study has been given to the shortages in the soil of nutrition or fertility. We have not appreciated what was prohibiting more efficient use of the water in the soil. The transpiration stream is not a carrier of the nutrients from the soil into the plant root as is commonly believed. One set of laws holds for the movement of water from the soil into the plant; another set holds for the movement of soil fertility or plant nutrients in that direction.

With more study of plant nutrition, as our crops make nutrition for animals and man only as the fertility of the soil allows, we shall see that droughts are disastrous more because of shortage of nutrition via the soil than because of low supply of water from that source.