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ΠΡΟΕΔΡΙΑ ΣΟΛΩΝΟΣ ΚΥΔΩΝΙΑΤΟΥ

ΓΕΩΠΟΝΙΑ.— **Rational fertilization**, by the Academician *J. Papadakis**.

ABSTRACT

World population increased enormously during the 20th century: from 1.600 millions in 1900, to 2.500 in 1950, and a population of 6.000 millions is expected for 2.000. However consumption of food per capita has increased; and its quality too; as qualitative improvement, we consider the increase of the percentage of food of animal origin; however the quality of meat, etc. may have decreased. Such achievements are chiefly due to fertilizers and plant breeding; in past times only organic fertilizers were used. But although we owe to official research —that done by universities and public services— the discovery of mineral nutrition of plants and the invention of mineral fertilizers, we should confess, that official research contributed little to shape the technology of fertilizers application. Such technology has been shaped by farmers and private industry, in many cases against the opinion of specialized services; a notorious case is that of «green revolution». Moreover many outdated theories are still repeated in recent textbooks, etc.

The object of this communication is to point out these facts, underline some alternative theories —«potential» and «actual» fertility— propose some interesting practices —prefertilization in the case of nitrogen, phosphorus placement near the seed— underline the need of research on foliar fertilization; and recommend the establishment in fertilizers institutes of special sections, which collect farmers experience, and interprete it in close cooperation with laboratory scientists.

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1. INTRODUCTION

World population increased considerably, from 350 millions in 1,000 A.D., to 900 in 1,800. 1.600 in 1.900, 2.500 un 1.950, and a population of 6.000 millions is anticipated for 2.000. In spite of that the consumption of food per capita increased, even in «developing» countries; and its quality has been improved; the percentage of food of animal origin has increased. Moreover now great part of cereal production is consumed by the livestock, while such percentage was insignificant in past times.

Such a great achievement is due to agricultural technology, chiefly fertilizers and plant breeding. It is to be noted, that improved varieties respond better to fertilizers, so that the combination of these two advances gives excellent results. Consumption of mineral nutrients has increased from 2 millions tons in 1905, to 8 in 1945, 27 in 1960, 68 in 1971, and continues increasing.

We owe naturally these results to the discovery of mineral nutrition of plants, and the invention of mineral fertilizers later; the advances of chemical industry and petroleum production have helped enormously. But although official research —that done by universities and public services— contributed much to elucidate many problems, we should confess, that its contribution to shape the technology of fertilizers application has been little. Such technology has been shaped by farmers and private industry, in many cases against the opinion of specialized services; a notorious case is that of the «green revolution» of Borlaugh.

The reason is, that the problem of how much of each nutrient should be applied to each crop, according to soil, climate, etc. is very complex. Continuously soil microogranisms, in symbiosis or not with plants, fix atmospheric nitrogen in the soil, while other microorganisms release soil nitrogen in the atmosphere; unavailable nitrogen becomes available; and available nitrogen becomes unavailable; in a few months soil nitric nitrogen may vary from simple to decuple, or vice versa; something analogous happens with available phosphorus, potassium etc., although such processes are in this case slower, and better known. All these processes depend on climatic, soil and vegeration conditions. Moreover the influence of crop quality, prices, etc. should be taken into consideration.

At the beginning, more especially in continental Europe, scientists were not aware of such complexity; they were jumping too often to conclusions,

and the phrase «mais en pratique il arrive souvent le contraire» was too often repeated. Lawes and Cilbert in England founded the station of Rothamsted to test experimentally these theories. Cilbert has been invited in United States to organize the agricultural experiment stations, and in 1895 apppeared his «Agricultural Investigations in Rothamsted, England, during a period of 50 years», published by United States government, still today interesting, for the ideas he advances, and his way of thinking.

The experiments of Rothamsted and of American Experiment Stations have shown, that many of the prevailing theories were gratuitous; in Rothamsted plots are cropped during 150 years, without any fertilization, organic or inorganic, and their yields are today a little higher than 150 years ago; soil content in organic matter and nitrogen has not decreased Tillage acts only by eliminating weeds. When weeds are eliminated, sowing density may differ from single to more than quintuple, without any effect on yield. And so on. But Anglosaxons do not like speculation. They are cautious in advancing conclusions.

Then came the great crash of 1929. Roosevelt fighted it by buying agricultural production at high prices. Farmers were increasing continuously their production. Government could not manage the huge problem of surpluses. Congress has been obliged to recommend, to not carry out research, that may increase production. And that has been a blow to official research.

Private research naturally continued. And it is more efficient than the official. But it has its defects. It is chiefly interested in patentable results. When the result is important theoretically, but it has not immediate applications, it is maintained secret, fearing, that another firm could take advantage of it. Free discussion contributes much to scientific advance, but those working in private enterprises, should be cautious in their communications.

For all these reasons we have in «developed» countries the paradox, of an agriculture, that advances rapidly, and an out of date «official» science. Borlaugh, the author of «green revolution», has said in 1972, that he is afraid, with the situation of agricultural research in United States; and naturally the situation is not better in other countries. A little before (1968) he said, in the international symposium of Canberra, that young scientists of «developing» countries, going for postgraduate studies in «developed» ones acquire bad habits, that impede them to be useful.

The situation in «developing» countries is usually tragic. Private compagnies are not interested; and «official» research follows the example of «developed» countries. Afortunately came the «green revolution».

Borlaugh, an American agronomist, working in Mexico with the Rockfeller Foundation, used in his breeding program the dwarf highly productive wheats of Japan, and created varieties of wide adaptability very productive. He tried them in world wide experiments and recommended them to the governments of India and Pakistan. Although few trials had been done in these countries, he recommended to sow immediately millions hectares, with 120 kg N and 60 kg P_2O_5 per ha. The specialists of these countries, many of them of international prestige, opposed the measure; «we are experimenting during many decades, they were saying, and we cannot give any advice; how this man, who is not specialist in fertilizers, who has not carried out experiments in our countries, can give such prescriptions?». The international scientific establishment was also more than sceptic.

But the government accepted the proposition of Borlaugh; the farmers, although illiterate, adopted immediately the new technique. Annual wheat production of these countries increased by 18 millions tons immediately; such increase overpasses now 30 millions tons annualy.

Borlaugh thought as follows: the geographical distribution of crops shows, that good varieties have wide adaptability; and Borlaugh varieties had shown that, in world wide trials. Nitrogen increases yields almost everywhere, and high doses can be applied, when the crop is irrigated; phosphorus deficiency impedes sometimes the action of nitrogen; that is why it is prudent to add a moderate dose of P_2O_5; potash is seldom needed in young, not acid, soils.

A little later the International Rice Institute created dwarf rices of high productivity, crossing with japanese rices. The two colossi of «developing» countries, India and China, with a population of 1.800 millions, practice now the green revolution. Many other countries followed.

Concerning fertilizers it is evident, that laboratory scientists should pay greater attention to what farmers, and industry are doing. Edaphologic institutes should have a section, that follows, in each region, what farmers are doing, what results they are obtaining, interpret all that scientifically, in collaboration with laboratory scientists, and shape a science, that is based not only on laboratory research, but takes also into consideration what

happens in practice. Farmers experience is an immense experiment, that cannot be ignored. And one of the objects of this communication, is to emphasize such necessity.

2. LONG RUN VARIATIONS OF SOIL FERTILITY «POTENTIAL FERTILITY»

Universal experience shows, that when a virgin land begins to be cropped, and fertilizers are not used, at the biginning yields are high; but they drop gradually; and after a time, which varies from a few decades in cold climates, to a few years in the humid tropics, they are stabilized, fluctuating naturally from year to year. The level at which stabilization takes place depends on rotation etc.; with crops that receive little cultivation during the warm season, like wheat, the level is higher, than with crops, that receive cultivation during the warm season like maize; experiments have shown (Holtz and Vandecaveye, 1938), that the worse system is continuous barren fallow (the soil is maintained continuously barren of vegetation, but no crop is grown); on the contrary abandoning the soil to adventitious vegeration, or establishing a permanent prairie, mowed or grazed, restores gradually soil to its original fertility, when it was virgin.

When mineral nutrition of plants has been discovered, the foregoing drop of yields had been attributed to exportation of nutrients with cropping. But Rothamsted experiments, repeated later in many parts of the world, have shown, that such drop is not continuous; after a few years yields are stabilized, it seems for ever; after more than a century yields are now, without fertilizers, as high, or a little higher, than 100 years before. And this is easy to understand; soil is not a store, of which we have the keys, and we can do balance-sheets; nitrogen is continuously fixed, while other nitrogen is lost with denitrification; phosphorus is continuously released in available form, while other P is immobilized; and the same happens with all other nutrients; absorption by plants favours release, while addition of nutrients favours their immobilization. Finally with the passage of centuries soil changes; new materials are deposited on its surface; roots advance in new deeper soil, while surface soil disappears with slow erosion; rapid erosion, that destroys soil, is not taken in consideration in this discussion.

Determinations of organic matter have shown, that the foregoing variations of soil fertility are accompanied by losses or gains of organic matter.

And such fertility, that is related to organic matter content, and changes slowly with the passage of years, may be called «potential» fertility (Papadakis 1938, 1954, 1970, 1980).

3. RAPID CHANGES OF SOIL FERTILITY «ACTUAL» FERTILITY»

Universal experience has shown, that incorporations of organic matter with wide C/N ratio (straw f.i.) reduce yields. On the contrary after cultivated crops, like maize, cotton, or barren fallow, which favour organic matter decay, or crops like legumes, that leave residues with narrow C/N ratio, yields are higher.

Determinations of nitric nitrogen (Richardson 1931, Yancovitch 1933) have shown, that it varies from 12 Kg/ha after wheat harvest to 125 Kg/Ha at the end of a barren fallow. That explains the millenary rotation barren fallow-winter cereals, when fertilizers were not used; and the replacement of barren fallow by maize, where this crop can be grown. Nitric nitrogen desappears also after a humid winter, not by leaching as it was thought, but by denitrification; and that explains why in Nertherlands they increase the nitrogen given to wheat after a rainy winter. On the contrary wheat gives, without fertilizers, relatively high yields after a dry winter; in 1933 we had in Greece exceptionally high yields after a winter so dry, that we were fearing, wheat crops were lost; fertilizers were not used at that time. In Chile, where irrigation agriculture prevails, they have observed, that nitrates disappear after irrigation, but reappear some time later; we carried out experiments in long narrow pots; either the upper or the lower part was irrigated, leaving the rest dry; nitrates were disappearing from the irrigated part, due probably to denitrification; leaching was excluded. All that shows, that meteorological conditions also affect seriously actual fertility.

These facts conduced the author (Papadakis 1938, 1954, 1970, 1980) to introduce the concepts of «potential» and «actual» fertility. Potential fertility depends chiefly on the level of soil organic matter, and changes slowly with the passage of the years, affected by soil rotation, etc., as exposed in section 2; «actual» fertility depends on C/N ratio of recently incorporated organic matter, and is the chief cause of the influence od a crop on that which follows it immediately.

4. MINERAL FERTILIZERS

There is abundant evidence, that mineral fertilizers affect only actual fertility, but seldom affect the yield of following crops. In many countries high dosis of phosphorus are applied since one century, or something like that; soil analyses show an increase of available P; but farmers continue to apply high doses. Correlation between soil responce to P and different soil characteristics shows, that available P depends more on the capacity of the soil to fix P (sesquioxides, calcium carbonate, etc.) and less on the presence of minerals releasing P. The rapidity of P immobilization, is also shown by the fact, that P applied a few months before sowing increases less yields, than P applied at sowing (Papadakis 1946).

It seems, that added potassium is chiefly immobilized by adsorption by clay; but exchangeable potassium can be used by crops.

It seems, that deficiencies of some micronutrients are often due to the existence in soil of substances, that make them unavailable; and foliar application is recommended.

We know little about the variation of available nutrients other than nitrogen. Dormaar (1972) has shown, in Canada, that organic P increases 2 times from spring to autunn. In Tucumán, Argentina, winter crops respond better to P than summer crops. Research is needed. Naturally the decomposition of organic matter releases not only N, but other nutrients too; but in certain cases they may be immobilized rapidly.

It seems, that available soil nutrients are seldom sufficient for high yields; and this fact should be taken into consideration, when irrigated soils are fertilized.

5. NITROGEN FERTILIZATION

Since actual fertility (available nitrogen) changes so rapidly, we should adapt nitrogen fertilization to it. The influence of rotation is long ago taken into consideration by farmers; that of wet winters too. Determination of available nitrogen after incubation helps; but it is difficult to have the results in time. Italians were using foliar diagnostic of nitrates, carried out by the farmer, in wheat. The best method may be pre-test fertilization (Papadakis

1971); a narrow very long trip is fertilized; after 1-2 weeks the response is apparent; and the farmer decides. Naturally some experience is necessary, but it is acquired rapidly; in many cases the farmer makes the test and invites the consultant agronomist, to visit the land and give its opinion; in a few hours the consultant can visit a great number of lands; and he acquires a precious experience.

In periods of slow growth, f.i. winter, nitrogen fertilization can be postergated; but if for one or another reason crop growth is not satisfactory, it is fertilized. During rapid growth high doses of nitrogen are often applied; in this case the dosis is divided. The influence of nitrogen on quality, sugar content, gluten content, etc. should be taken into consideration.

6. PHOSPHORUS FERTILIZATION

Phosphorus is chiefly needed during the first growth of a plant; it accelerates seedlings growth, and helps them to overcome weed competition, etc.; in experiments, P fertilized plots look better at the beginning, but often such difference disappears later. On the other hand P is easily immobilized (see section 4). That is why localization permits to reduce considerably the doses applied. It seems, that the good results sometimes obtained with localization of fertilizers are chiefly due to P. Plants can absorb nitrogen with a part of their roots, P with another part, and water with a third part; and sometimes the results are so good as when N, P and water were applied to the entire root system (Papadakis 1954).

In the case of annual crops P can be placed near the seed; however contact with the seed seems injurious; phenomenal increases of yield, per P applied at the seed, have been obtained in the case of beet (Papadakis 1971). In perennial crops P can be placed in holes, a few per tree, or in furrows between plant lines.

There are methods, the best is resine, but it is difficult, to anticipate, with more or less acceptable probability, if a soil responds to phosphorus. But crops differ considerably in this respect, legumes and some other crops respond better. Pre-test fertilization, see paragraph 5, can be applied; the fertilizer may be covered with cultivation between plant rows.

When high doses of nitrogen are applied, and high yields are expected, it is usually prudent not omit P. It may be, see section 4, P availability varies with season.

7. POTASSIUM FERTILIZATION

Potassium is chiefly needed in intensely leached soils; spodosols (podsols), oxic soils of the humid tropics and subtropics, etc. There are laboratory methods, the best is resine, but it is difficult, to anticipate, with more or less acceptable probability, soil response to potassium.

It seems, that in many cases, competition with magnesium, is one of the causes K fertilization does not increase yields; and by applying in the same time Mg better results can be obtained; it is to be noted, that many «natural» (not purified) potassium fertilizers used in past times, were containing substancial quantities of Mg.

8. ORGANIC FERTILIZATION

Low prices of nitrogen made organic fertilizers too expensive, and their use has been reduced considerably, except for certain crops, that require a special, we might say artificial, soil. However they permit to maintain the soil at a high level of potential fertility; when mineral fertilizers are applied to soils poor in organic matter, attention should be paid to time and fractionnate duly the application. Organic fertilization is linked with that of the disposal of residues.

9. FOLIAR FERTILIZATION

Foliar fertilization permits to increase considerably the percentage of nutrients, that is recovered in crops; and that would result in considerable economy of fertilizers. But applications should be repeated frequently, and there are many problems, that have not yet been solved; some progress has been done in Japan. The prices of fertilizers are low in developed countries, compared to those of agricultural products, application costs are on the contrary high; moreover the industry is not anxious to reduce the consumption of fertilizers. The problem is important for «developing» countries, which do not earn sufficient foreign money, to buy the quantity of fertilizers they

need, or raw materials for their fabrication. Much research is needed on this question.

10. FERTILIZATION SURVEYS

Fertilization problems are usually faced as a particular problem of a soil, whose farmer asks advice, or as a question of correlation between analytical data obtained with a certain method and crop response. Such research is certainly useful, but the problem is broader. We urgently need to study the seasonal variation of available nitrogen (actual fertility) in different crops, rotations, soil moisture regimes, etc.; and it might be useful to do the same with other nutrients, P f.i., and potential fertility (organic matter content). The general trend of such variation is already known (see sections 2 and 3), so that no very numerous analysis are needed, and some data may exist in the archives; we should naturally take into consideration, that actual fertility may change, between sampling and analysis, and nitric nitrogen is not the only form of available nitrogen.

Farmers experience is now enormous in countries, where the use of fertilizers has been generalized; private industry takes certanly advantage of it; but academic research very little; much can be done in this respect. Naturally the information given by farmes is not exact; but proceeding adequately, not with questionnaires but with personal discussions, one can obtain valuable information; farmers try to interpret the facts they are observing; their interpretation is often defective for lack of knowledge; but interpreting their interpretations pays off sometimes. Correlating the response to fertilizers with the presumed level of actual fertility, soil moisture and the geopedologic history of the soil permits often interesting conclusions, which naturally should be continuously checked with facts, to improve them.

The term correlation is here meaning consideration of the relation between a factor and crop response; naturally it includes calculation of the correlation, but it is not limited to it; it needs sufficient understanding of crop physiology, soil chemistry and soil formation.

Concerning field experiements their planification is very important to give answers to the problem; they should be naturally statistically correct, but that is not sufficient. I shall quote a case. An important institute was sustaining, based on very exact experiments, that fertilizers do not increase

the yield of cotton; but farmers were fertilizing and spending much money in fertilizers; finally the institute has recognized, that farmers were right, cotton was grown in the institute under conditions very different from those of the farmers. We should be cautious to not discard information, that although not precise, is valuable.

Experiments in pots are extensively used; usually they are carried out with perennial grasses; but other plants, more sensible to one or another nutrient are sometimes preferable. Field experiments can be also carried out with the 1 plant per hill method, and distances between plants in all directions more that 50 cm in the case of wheat, more that 1m in the case of maize. In this way the response to fertilizers is magnified; observations during growth give useful information.

In agricultural services there is an excessive division of labour; the research man finds what should be done; the extentionist transmits it to the farmer, without sometimes understanding it; he is specialist in methods of extension; and the farmer applies the recommendations given. But speaking in medical terms, the extensionist is the general practitioner, and the farmer the patient; the research man has something to learn from the general practitioner and the patient.

11. DECISIONS MAKING

In the case of P and K, correlation between soil analysis and crop response is usually considered as sufficiently high, and fertilization is often decided on this basis. Naturally more attention should be paid to farmers experience, seasonal variation of available P and K, that may exist, crop physiology, and geopedologic history of soils. The survey mentioned in paragraph 10 may help much.

Concerning N the results of analysis are less informative; variations of available nitrogen are too important (see section 3). Determinations of available nitrogen, after or without incubation, or foliar diagnostic might help; pre-test fertilization may be applied. The survey discussed in section 10 is necessary.

In the case of micronutrients foliar diagnostics are often used; the geopedologic history of soils helps, and naturally farmers experience.

In the case of annual crops, a small dosis of phosphorus localised near

every seed may be sufficient; but some crops require higher dosis. Localization gives usually good results; seed fertilization serves also as pre-test fertilization for the application of higher dosis later.

In the case of K the possibility to improve the response with Mg should be taken into consideration.

Agricultural geography helps much; what happens in countries with analogous climate, soils and crops, may help, and should always be taken into consideration.

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ΠΕΡΙΛΗΨΗ

Ὀρθολογικὴ λίπανση

Ὁ πληθυσμὸς τῆς Γῆς αὐξήθηκε τρομακτικὰ τὸν εἰκοστὸ αἰώνα. Ἀπὸ 1.600 ἑκατομμύρια τὸ 1900, σὲ 2.500 τὸ 1950, καὶ ἀναμένεται νὰ φθάσει τὰ 6.000 ἑκατομμύρια τὸ 2.000. Ἐν τούτοις ἡ κατανάλωση τροφίμων κατὰ κεφαλὴ αὔξησε καὶ ἡ ποιότητά των ἐπίσης. Αὐτὰ τὰ ἀποτελέσματα ὀφείλονται κυρίως στὰ λιπάσματα καὶ τὴν καλλιτεύρευση τῶν φυτῶν, στὸ παρελθὸν μόνο ὀργανικὰ λιπάσματα χρησιμοποιοῦντο. Ἀλλὰ μολονότι ἡ ἀνακάλυψη, ὅτι τὰ φυτὰ τρέφονται μὲ ἀνόργανες οὐσίες, καὶ ἡ ἐφεύρεση τῶν ἀνοργάνων λιπασμάτων, ὀφείλονται στὴν ἐπίσημο ἔρευνα, δηλαδὴ ἐκείνη ποὺ γίνεται στὰ πανεπιστήμια καὶ δημόσιες ὑπηρεσίες, πρέπει νὰ ὁμολογήσομε ὅτι ἡ ἐπίσημη ἔρευνα συνέβαλε λίγο στὴ διαμόρφωση τῆς τεχνολογίας ἐφαρμογῆς τῶν λιπασμάτων. Ἡ τεχνολογία αὐτὴ διαμορφώθηκε ἀπὸ τοὺς γεωργοὺς καὶ τὴν ἰδιωτικὴ βιομηχανία, πολλὲς φορὲς ἀντίθετα πρὸς τὴ γνώμη τῶν εἰδικῶν ὑπηρεσιῶν· ἡ περίπτωση τῆς «πράσινης ἐπανάστασης» εἶναι πολὺ γνωστή. Ἐπὶ πλέον θεωρίες ξεπερασμένες ἐπαναλαμβάνονται σὲ σύγχρονα συγγράμματα, κ.λπ.

Σκοπὸς αὐτῆς τῆς ἀνακοίνωσης εἶναι νὰ τονίσει αὐτὰ τὰ γεγονότα· νὰ ὑπογραμμίσει μερικὲς θεωρίες μὴ ἀκόμη γενικῶς παραδεγμένες —δυναμικὴ καὶ ἐνεργὸς γονιμότητα— νὰ προτείνει μερικὲς ἐνδιαφέρουσες ἐφαρμογὲς —προλίπανση στὴν περίπτωση τοῦ ἀζώτου, τοποθέτηση τοῦ φωσφόρου κοντὰ στὸ σπόρο— νὰ τονίσει τὴν ἀνάγκη ἐρεύνης ἐπὶ τῆς ἐφαρμογῆς τῆς λίπανσης στὰ φύλλα· καὶ νὰ συστήσει τὴν ἵδρυση στὰ ἰνστιτοῦτα λιπασμάτων εἰδικῶν τμημάτων, τὰ ὁποῖα συλλέγουν τὴν πείρα τῶν γεωργῶν καὶ τὴν ἑρμηνεύουν, σὲ στενὴ συνεργασία μὲ τοὺς ἐπιστήμονας τοῦ ἐργαστηρίου.