

FORECAST AND CONTROL OF NUTRITIONAL DISEASES IN PLANTS

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The soil nutrient supply is a natural resource whose measurement is of interest in forecasting and control of nutritional imbalance in plants. Nutritional imbalance is known to cause marked disturbance in the normal metabolic process of plants. Some of these disturbances are very well-defined and are exhibited as clear-cut symptoms of nutrient deficiency in plants. These disturbances are known by specific names such as 'white bud' of maize and 'little leaf' of apple caused by Zn deficiency, 'whiptail' of cauliflower and 'yellow spot' of citrus by Mo, 'marsh spot' in peas and 'speckled yellow' in sugarbeet by Mn, 'witches' broom' of citrus and 'reclamation disease' of cereals by copper, and 'tea yellows' by sulphur.

Control of these diseases by the application of nutrients is based on the predictions made on soil and plant tests. Nutrient supplying power of the soil is assessed through the use of chemical extractants, microbiological methods, tracer techniques, tissue test, foliar test and yield response relationship. The merits of various methods for predicting nutrient supply to plants have been discussed.

INTRODUCTION

A number of nutritional diseases are caused in the plants due to either a deficiency in soil of a particular nutrient element or its unavailability to the plants. Nutritional diseases in plants follow some particular pattern which is unique to a nutrient element deficient in plant. The unique pattern of deficiency symptoms of specific nutrient in plants can be helpful in diagnosing and correcting the deficiency of that element, but it has its own limitations. Firstly, multiple deficiencies produce complicated patterns which are hard to recognize. Secondly, the crop undergoes considerable damage before any corrective measures can be undertaken.

For precise recommendations and more reliable predictions, the nutrient content both in soil and plants needs to be calibrated for various agro-climatic soil regions. These studies involve laboratory as well as greenhouse and field measurements.

Laboratory measurements are based on shaking the soil sample with a hypothetical extracting solution for a certain specific time. A definite chemical fraction for a nutrient extracted in this way gives a measure of availability of that nutrient. The greenhouse and field trials actually show the amount of nutrient available to the plants. Field trials give a measure of nutrient reservoir for a plant species grown on a soil under natural environmental conditions.

Greenhouse and field techniques are time-consuming and expensive as compared to laboratory techniques. On account of their rapidity and precision, the laboratory techniques make it possible to undertake an extensive soil-testing programme. However, the greenhouse and field studies are still required for determining the suitability of a particular laboratory method for evaluating the nutrient supply.

USE OF CHEMICAL EXTRACTANTS

Macronutrient elements

Most of the N in the soil is present in organic combination and becomes available to plants on mineralization of organic matter. The most common method for determining total nitrogen is wet digestion of the soil and for measuring the readily available N, alkaline permanganate method of Subbiah and Asija (1956) is used. But rapid fluctuations in the mineral N content of the soil are responsible for wide variations in the data for the same soil tested at different intervals (Harmsen and Lindenberg 1949). Harmsen and Schreven (1955) suggested that to measure the nitrogen supply of a soil, it is more useful to measure the rate of N-mineralization rather than the mineral N itself.

Behrens (1935) and Pauw (1956) described the use of citric acid of varying concentrations as extractant for phosphorus. The action of citric acid in releasing P is associated with complexing iron and aluminium under low pH conditions and dissolution of calcium phosphates at higher pH. Bray and Kurtz (1945) suggested the use of a combination of acid and complexing agents such as mixture of HCl and ammonium fluoride of varying strengths adjusted to various pH levels. HCl with high strength is suggested where most of the P is associated with calcium. Olsen *et al.* (1954) suggested the use of 0.5 M NaHCO_3 , pH (8.5) for estimating the phosphorus supply in cases where the P associated with the exchange complex is more dominant. However, Olsen's method is more useful for calcareous soils where the surface-bond P is more important. Chang and Jue (1963) reported that all the methods including resin extraction of P (Amer *et al.* 1955) correlated well for soils which are rich in iron. On the other hand, acid extractants gave similar results in soils containing P bond with calcium. But in soils in which P is associated both with Ca and Fe, Olsen, Morgen and Bray P_4 (high fluoride) gave similar results.

Potassium in the soil solution is in equilibrium with that associated with solid phase. A part of the K is also slowly released by clay minerals. In general, it has been found that readily exchangeable potassium gives better correlation with yield. Dilute acids or salt solutions are used to extract potassium representing a combination of K in solution and exchangeable form.

Sulphur in the soil behaves similarly as nitrogen. Its mineralization results in an increase in its availability. Both sulphur in solution and that associated with solid phase as exchangeable sulphate are taken into consideration for measuring soil S supply. A number of extractants have been suggested by various workers ((Barrow 1961; Williams and Steinberg 1962), but use of phosphate ions either from KH_2PO_4 (Ensminger 1954) or from $\text{Ca}(\text{H}_2\text{PO}_4)_2$ (Fox *et al.* 1964) are more preferable because phosphate ion readily displaces the sulphate from exchange sites. Little (1953, 1957, 1958) suggested the use of 0.001N HCl. Kilmer and Nearpass (1960) used 0.5 M NaHCO_3 adjusted to pH 8.5 for extracting available S and found a good correlation with 'A' value (Fried and Dean 1952).

Micronutrients

Iron supply to the plants depends upon the soil pH and drainage conditions. So, iron supply is subject to continuous changes and any method for extracting available

iron gives results which may be erroneously interpreted. However, exchangeable iron with ammonium acetate adjusted to a suitable pH has been suggested as indicative of iron supply (Kanwar and Dhingra 1962; Randhawa *et al.* 1967). Easily exchangeable or readily reducible Mn has been used as a measure of Mn supply of the soil (Kanwar and Dhingra 1962; Venkataswarlu 1964; Sharma and Shinde 1968; Dikshit and Verma 1968). Reduction with hydroquinone (Jones 1951 and Finck 1954) has been used to measure its supply. Mehta and Patel (1969) reported the highest correlation ($r=0.913$) between plant-uptake and 1M $\text{NH}_4\text{H}_2\text{PO}_4$ extractable Mn.

Copper in the soil exists as tightly bound with organic and clay colloids. EDTA and other complexing agents such as KCN or EDTA have been used to extract substantial amounts of Cu (Kanwar 1954; Smidh-Brun 1945). Ammonium acetate-acetic acid buffer (Neelkantan and Mehta 1961) adjusted at neutral pH has also been often used for extracting available Cu in the soil. Strong acids such as 1N HNO_3 and HCl have been suggested by Henriksen (1956) for extracting exchangeable Cu.

Zinc like copper exists as tightly bound Zn^{++} , ZnOH^+ and ZnCl^+ ion on clay or organic colloids. Neutral salt solutions such as ammonium acetate, pH 7.0, can extract only a part of the adsorbed Zn. Strong acids and organic complexing agents like EDTA and diphenyl thio-carbazone have been used to extract strongly-adsorbed or complexed zinc (Shaw and Dean 1952, and Nearpass 1956). Ranadive *et al.* (1964) reported a good correlation between the bioassay method and 0.02M EDTA extractable zinc of soils other than alkali soils. Grewal *et al.* (1967, 1968) reported a good correlation between zinc-uptake and amount of zinc extracted with dithizone-ammonium acetate mixture.

Boron availability measurement is carried on either with hot water extraction (Singh and Singh 1967) or from saturation extract (Kanwar and Singh 1961).

Molybdenum supply to plants is affected by soil pH. Its low availability is common in acidic soils. Grigg's (1953) ammonium-oxalate, (pH 3.3) is the most common extractant. It has given good correlations with plant-uptake of the nutrient at many places in different parts of the world (Jha 1964; Walsh *et al.* 1953; Davies 1952; Ebeling *et al.* 1966 and Pasricha and Randhawa 1971).

In case of soil analysis, one limitation is that generally upper 6" soil is considered for studying the nutrient-supplying power of soils, but under field-grown conditions, sub surface horizons may also contribute appreciably, particularly in case of deep rooted crops. Pasricha and Randhawa (1971) reported a higher correlation between oxalate extractable Mo from 15 to 30 cm layer ($r=+0.63$) than for Mo extractable from 0 to 15 cm layer ($r=0.57$). They showed that barseem grown in pots in greenhouse on the same soil contained less Mo as compared to field-grown crop.

Microbiological techniques

Use of micro-organisms in determining the soil-nutrient supply is based on the assumption that amount of growth is a function of concentration of the limiting element. This method is useful for estimating the minute quantities of the nutrients as the micro-organisms—fungi, bacteria or aglae; they are most sensitive to minute quantities. *Azotobacter* has been used for Ca, P and K (Vandecaveye 1948). *Aspergillus niger* has

been used for determining Zn, Fe, Mo, Cu, B P and K (Tanaka and Yatazawa 1965; Nicholas and Fielding 1950; Omer 1964; Henkens 1960). In the nutrient culture of *Aspergillus niger*, 1 per cent citric acid is used, so it may be the extraction of nutrients with citric acid and their subsequent measurement in terms of microbial growth. Moreover, with the growth of micro-organism, the medium becomes more and more acidic resulting in the increased release of a nutrient measured.

On the basis of research work reported above, the threshold values of available soil nutrients for predicting responses to the application of micronutrients have been worked out and presented in Table I. These can be used for rapid delineation of nutrient-deficient areas; however, for more precise prediction, each of these methods has to be calibrated for agro-climatic soil region and for the type of crops grown in the region.

TABLE I

Threshold values of available nutrients in soils as determined by various methods

Method	Threshold value (ppm)	Author
<i>Zinc</i>		
<i>Aspergillus niger</i> method	5.0—6.0	Bould <i>et al.</i> (1953)
Dithizone-ammonium acetate extractable	0.5 (pH 6.5 or less)	Brown <i>et al.</i> (1962)
<i>Copper</i>		
<i>Aspergillus niger</i> method	2.0	Bould <i>et al.</i> (1953)
NH ₄ OAC extractable	0.6	Grewal <i>et al.</i> (1967)
0.02 M EDTA extractable	2.55	Dakhore <i>et al.</i> (1963)
<i>Manganese</i>		
Exchangeable Mn	2.0	Kanwar and Dhingra (1962)
Hydroquinone extractable	65.0	Hammes and Berger (1960)
<i>Iron</i>		
N-NH ₄ OAC (pH 3.0) extractable	15.0	Randhawa <i>et al.</i> (1967)
<i>Aspergillus niger</i> method	4000.0	Omer (1964)
<i>Boron</i>		
Hot water extractable	0.2—0.5	Mandal <i>et al.</i> (1956) Bucher (1957)
Saturation extract	0.7	Kanwar and Singh (1961)
<i>Molybdenum</i>		
Acid-oxalate extractable	0.14 (pH 6.3 or less)	Grigg (1953)
Acid-oxalate extractable	0.2 (pH 5 and below)	Davies (1952)
	0.05 (pH 6.5 and above)	
<i>Aspergillus niger</i> method	0.01—0.03	Nicholas and Fielding (1950)

Nutrient-uptake methods

The uptake of nutrients by plants is more important where we are interested in the study of soil-nutrient supply and in such cases the yield of dry matter is only a

secondary consideration. Such methods carried out in the greenhouse are subjected to many limitations including the levels of other nutrients, light intensity, temperature, season and moisture.

Neubauer and Schnieder (1923) suggested a technique based on the nutrient uptake of plants, it consists in the determination of a nutrient extracted by a large number of plants grown for a certain time period. The limitations of this method include the high density of plant population, and in certain cases, for example, N contained in the seeds of some crop species may be sufficient to support the growth of the plant for shorter periods proposed in these investigations.

A method similar to Neubauer technique has been proposed by Stanford and DeMont (1957, 1959a, 1959b) which involves an initial growth of mass seedlings in fine sand to form a mat of roots. These seedlings are then kept in contact with the soils whose nutrient supply is to be estimated. Amount of nutrients absorbed by plants within a short period of 5–7 days is measured. This method is better than Neubauer technique in one respect that in this case, we have not to deduct the amount of nutrient supplied by the seed, but basically, it suffers from limitations similar to Neubauer technique.

Dean (1954) used the nutrient-uptake curve for measuring soil nutrient supply and is based on the logic suggested by Steinbergs (1951) that P-uptake is an ascending straight line curve. The nutrient-uptake curve is extrapolated to give 'A' value which measures the amount of nutrient available in terms of fertilizer standard. Of course, this is valid only when applied nutrient does not affect the uptake of native nutrient.

'A' value technique with the use of radioisotopes first given by Fried and Dean (1952) is based on the assumption that when two sources of a given nutrient are present in the soil, the plant will absorb from each of these sources in proportion to their relative amounts present. Similar 'A' values have been obtained with variable doses of applied nutrients from fertilizers and with different crops (Fried 1957). But this method suffers from the fact that applied fertilizer interacts differently in different systems.

Methods involving nutrients uptake are time-consuming and cannot be adopted for routine analysis. However, these have a definite place in calibration and determining the suitability of different chemical methods.

Foliar test

Leaf analysis is more widely used for perennial or tree crops. It gives a measure of adequacy of supply of a nutrient at a given time. Broeshart (1956) and Hanway (1962) suggested the importance of sampling conditions with regard to time of the year and position of the leaf. Based on the leaf analysis results, critical limits have been set for various nutrients in different crop species. Baird *et al.* (1962) reported that 2.4 to 2.5 per cent N in the corn leaf is associated with optimum yields. Bhajan Singh *et al.* (1969) gave 2.0 per cent N in the leaf blade of sugarcane for optimum yields. The critical limit of N being 1.6 per cent. They suggested July sampling of leaf blades for measuring N status of the plant. Although leaf analysis technique is more useful for perennial crops, but the technique has been applied to annual crops such as cereals (Lundegardh 1943), tomatoes (Malcolm 1955, 1959) and to groundnut (Prevot and Ollagnier 1951, 1953).

The threshold values of nutrients for important crop species at deficiency, adequacy and toxicity are shown in Table II. The nutrient requirement varies not only between different plant species but also between different varieties of the same plant species. We can use the information already available for important crop species with advantage. However, for crops for which this information is lacking, we can utilize the threshold values developed in other countries.

TABLE II

Threshold values of micronutrients for different crops at deficiency, sufficiency and toxicity
(Agarwala *et al.* 1969)

Crop	Plant part	Age of the plant (days)	Micro-nutrient	Tissue concentration (ppm) at		
				Deficiency	Sufficiency	Toxicity
Wheat (Kalyan Sona)	Leaves	68	Boron	11.0	29.0— 60.0	140.0
	Tops	35	Copper	4.0	4.0— 10.0	40.0
	Tops	26	Iron	110.0	100.0—125.0	170.0
	Tops	36	Manganese	9.0	21.0— 64.0	150.0
	Tops	61	Molybdenum	0.4	0.4— 4.0	320.0
	Tops	36	Zinc	8.0	19.0— 40.0	90.0
Maize (Ganga-1)	Leaves	46	Boron	10.0	20.0— 60.0	200.0
	Leaves	32	Iron	60.0	60.0— 70.0	150.0
	Tops	45	Manganese	10.0	10.0— 26.0	144.0
	Tops	60	Zinc	13.0	60.0— 70.0	—
Paddy (IR-8)	Leaves	48	Boron	18.0	20.0— 72.0	400.0
	Leaves	32	Iron	80.0	100.0—240.0	600.0
	Tops	23	Manganese	32.0	90.0—190.0	600.0
Barley (K-19)	Leaves	68	Boron	3.0	14.0—126.0	476.0
	Tops	35	Copper	4.0	8.0— 9.0	19.0
	Leaves	88	Iron	130.0	200.0—240.0	250.0
	Leaves	56	Manganese	12.0	17.0— 74.0	190.0
	Leaves	63	Molybdenum	0.31	0.58— 3.88	140.0
	Tops	36	Zinc	6.0	20.0— 35.0	40.0
Tomato	Tops	28	Copper	3.0	5.0	—
	Tops	40	Manganese	5.0	58.0	—
	Tops	56	Molybdenum	0.2	6.50	—
	Tops	40	Zinc	11.0	20.0	—
Citrus	Leaves	—	Zinc	15.0	25.0—60.0	—

It is quite evident from the preceding discussion that a single diagnostic technique involving the use of hunger signs or soil analysis or plant analysis cannot provide definite information for sound fertilizer recommendations. For increasing the predictability of recommendations, it is very important to compliment the information of one method with that of the other.

Corrective measures

Based on the results obtained for the nutrient supply of the soil, nutritional disease can be controlled by application of the required nutrient in a suitable form and amount.

The nutritional diseases caused by iron in the crops can be corrected through foliar application of iron salts. Three per cent ferrous sulphate solution, neutralized with CaCO_3 in the presence of some wetting agents, gives good results.

A common method of correcting Mn deficiency in soils is by applying manganese salt, usually MnSO_4 . The amount to apply is determined by soil type and its fixation capacity. One general recommendation is to add 50–100 kg/hectare of MnSO_4 .

Boron is added either as such or through mixed fertilizers. Borax at the rate of 5–10 kg/hectare is the general recommendation. Soil application of zinc sulphate is recommended at the rate of 10 to 25 kg/hectare. Randhawa *et al.* (1970) reported that soil application of zinc is more effective than foliar application. Molybdenum salts are applied to effectively correct the deficiency either as a solid to the soil or by spraying an appropriate solution on the foliage or by treating the seed. The most commonly recommended compound used for the purpose is sodium molybdate, dihydrate applied at the rate varying from 1/16th to 4 kg/hectare depending on the established needs. Copper deficiency in citrus and in cereals grown on peat soils can be corrected by applying 50 to 100 kg copper sulphate/hectare in the soil.

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