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Plant Nutrients and the Environment

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Sixteen nutrient elements are essential for plant growth and they are : Non-mineral Elements - C, H, O; Macro Mineral Elements - N, P, K; Secondary Elements - Ca, Mg, S and Micronutrients - B, Cl, Cu, Fe, Mn, Mo, Zn. All the essential nutrients required for food, feed and fiber production are involved with the quality of our environment. Collectively, they enhance both the productive potential and environmental integrity of farm enterprises when used in adequate and balanced amounts.

Plant nutrients promote a more vigorous, healthy and productive crop; one which develops greater root systems, more above-ground vegetation, quicker ground cover, greater water use efficiency and higher resistance to crop stresses produced by drought, pests, cold temperatures and date of planting.

Although the essential plant nutrients play a vital role in providing adequate food supplies and protecting our environment, some pose an environmental risk with improper management. The two nutrients most often associated with mismanagement and non point source environmental concerns are N and P. This is especially so because of low use efficiency which is 30-50% for N and 10-30% for applied P.

Nitrogen : Nitrogen is subjected to plant removal, leaching volatilisation and denitrification. For environment concern, the forms of N involved through different processes are:

Leaching	....	as NO_3
Volatilisation	....	as NH_3 and
Denitrification	....	as gaseous forms of N like NO, N_2O, N_2.

Most of the concern about N in the environment is due to the potential movement of unused or excess nitrate-N through the soil profile into groundwater (leaching). Because of its negative charge, nitrate N is not attracted to the various soil fractions. Rather, it is free to leach as water moves through the soil profile Figure 1 illustrates relative movement of nitrate-N through different kinds of soils.

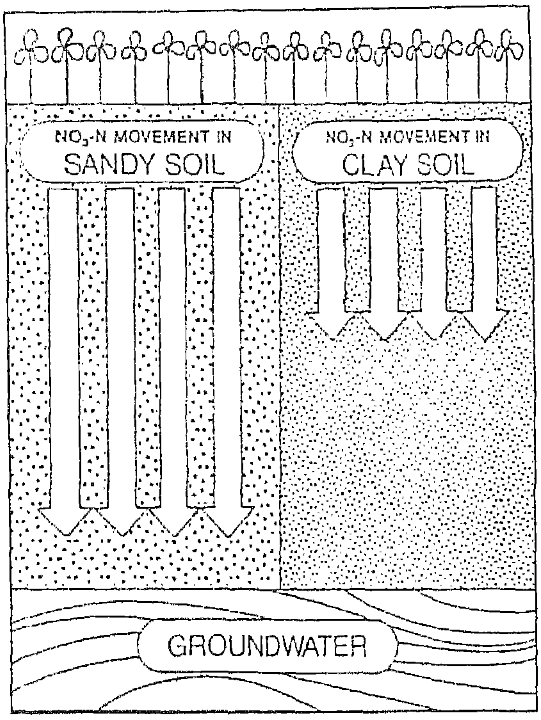

Fig. 1. Nitrate is more likely to move downward in sandy soil than in clay soil

All N sources (commerical, legumes, crop residues, animal manures and soil organic matter) are readily converted to the nitrate form in soils. Thus, all are subjected to leaching into groundwater unless utilised by a growing crop or retained in the ammonium-N form through management practices.

Fertiliser nitrogen undergoes transformation in soil depending upon several factors, including moisture, temperature, soil pH, soil aeration, etc. The overall result is no net gain or loss of N in nature. The total process is known as the "nitrogen cycle".

Cultural practices can largely control N losses from agricultural soils. This is both economically and environmentally desirable. Reducing N loss means more is available for crop production, less *for movement into surface water and groundwater.*

Phosphorus : Phosphorus has been associated with environmental effects primarily through the euthrophication of lakes, bays and non-flowing water bodies. Eutrophication is the response of a water body to over-enrichment by nutrients. The enrichment may be natural or man made. Eutrophication symptoms are algal blooms, heavy growth of aquatic plants, algal mats and deoxygenetion (exclusive of oxygen).

The fact is that P is extremely immobile in soils. It is held (adsorbed) very strongly by surfaces of iron (Fe), aluminium (Al), and Manganese (Mn) oxides and hydroxides in acid soils. It is also adsorbed by clay particles and in calcareous soils it is precipitated by calcium (Ca) ions to produce calcium phosphates of various types.

The non point agricultural P additions to water bodies are almost wholly associated with erosion. Phosphorus movement is associated with erosion because P has a very low solubility; it moves very little in most soils and very low P concentrations are found in most drainage waters.

Where erosion and sediment loss are stopped, P losses are minimised. It has been estimated that 50% of soil loss from erosion occurs in 10% of the crop land. More cultivation creates more risk for erosion and increases nutrient losses.

Potassium, Calcium, Magnesium and Sulphur : Potassium (K) in water has no detrimental health or environmental effects. Potassium is essential for human and animal health. Normal human dietary intake is from 2,000 to 6,000 milligrams of K per day, far above the content of water supplies. Potassium plays a vital positive environmental role because adequate supply is essential for efficient utilisation of N and P, helping to keep these nutrients from water losses.

Calcium (Ca), Magnesium (Mg) and Sulphur (S) are not cosidered to be of environmental concern from agricultural sources. They are essential plant nutrients and must often be supplied by liming and fertilisation based on soil and plant testing. As with other essential nutrients in short supply, they can decrease N and P use efficiency.

Micro-nutrients : Micro-nutrients are essential for crop growth and to human health. Application of micro-nutrients, based on soil tests or plant analysis, have a positive environmental impact through their effects on improved crop yields and more efficient use of other nutrients. Importance of micro-nutrients is increasing as crop yields increase and as sustained agricultural production requires that they be replaced in the soil.

There is often confusion over chloride (Cl), one of the essential micro-nutrients. It has been confused with chlorine, which is a poisonous gas and never found free in nature. Chloride occurs in nature as sodium chloride (NaCl), potassium chloride (KCl) and salts of other metals. Chloride has not been associated with environmental or health problems. Potassium chloride (muriate of potash) is an important K fertiliser. It contains about 47 per cent Cl. Sodium chloride (common table salt) has over 60 per cent Cl.

Principal objectives for profitable production and environmental safety

The distinct crop management objectives must be considered to assure that adequate amounts of nutrients are used in agriculture for maintenance of profitable production levels while minimising any potential negative effects on the environment.

Objective One : Managing crops for optimum nutrient efficiency through the use of best management practices (BMPs) and an integrated crop management (ICM) system in which all production inputs are balanced at optimum levels.

Objective Two : Managing crops for optimum nutrient efficiency through the use of BMPs that utilise site-specific soil and water conservation techniques to provide optimum soil retention and minimum losses to groundwater.

BMPs involve both conservation and agronomic practices. Incorporating BMP technology into a cropping system plan is the key to both economical and environmental success. They are definitely site-specific. A BMP for one location is not necessarily the same at another. They vary for different crops, soils and climates. They are practices which have been proven in research and tested through farmer implementation to give optimum production potential, input efficiency and environmental protection.

Practices that ensure environmental safety for nitrogen

Leaching Losses : To avoid leaching loss, applied N must be either utilised by crop or retained in the soil. Another approach is that there should be regulated nitrification. It is to be remembered that N from all sources (including commercial fertilisers, legumes, crop residues, animal manures, sewage sludge and soil organic matter) is readily converted to nitrate form in the soil. When fertiliser N is applied at rates that do not exceed the economic optimum, its direct contribution to nitrate leaching is small.

Nitrogen stabilisers block the conversion of NH_4 to NO_3 and thus keep the more stable NH_4 form in the soil. Nitrification inhibitors retard the conversion of ammonium N to nitrate N. When used with appropriate rates of commercial N fertiliser or animal manure, they can increase N uptake by the crop. The inhibitors hold N in the crop rooting zone, so it is available for crop uptake even under wet soil conditions that move nitrates deeper into the soil and out of the reach of crop roots. Research shows that corn, wheat, cotton, grain, sorghum and many other crops use ammonium readily and tend to take up more total N when ammonium is available along with nitrate. In addition to the environmental benefit, nitrification inhibitors increase yield potential and the efficient use of N applications an economic benefit.

The practices that reduce the potential for NO_3-N leaching are use of NH_4 - N fertilisers, incorporation of fertilisers and use of nitrification inhibitors.

Denitrification Losses : The practices to reduce denitrification are avoiding use of NO_3 sources, use of nitrification inhibitors, use of slow release N sources or coated N materials and in rice, N is to be applied in soil in reduced zone.

Volatilisation losses : Method of application is one single most important practice that controls volatilisation losses of applied N. In an experiment, drilling of urea reduced volatilisation to 5% against 30-40% with broadcast.

Practices that ensure environmental safety for phosphorus

When erosion is stopped, P loss is minimised. Therefore, approach has to be to control erosion and thereby P loss to environment will be minimised. Therefore, practices that increase residue in soil should be followed. This will reduce run-off and soil erosion and thereby P losses.

The soil erosion losses in India are estimated as 6000 m.t. per year resulting in nutrient loss of 5.37-8.4 m.t. and 30-40 m.t. of food-grain loss. In this, soil loss per unit area is 16.3 t/ha/year against permissible limit of 5-12.5 t/ha/year.

Management plans to achieve production and environmental goals

A BMP fertiliser recommendation allows crop yields to be expressed at the economic optimal level which for most crops is also the point of greatest environmental protection. The following planning is recommended.

(1) Setting yield goals : Optimistic, yet realistic goals for each crop and for each field are to be determined. Nutrient requirements increase with yield. It is a BMP to be sure that adequate, but not excessive, nutrients are readily available to the growing crop from seeding through to maturity.

(2) Adoption of BMPs : BMPs of all controllable inputs to achieve higher yields are to be adopted. Well-fertilised soils, alongwith other good management practices, lead to higher crop yields. Higher yields, with their associated increase in crop residues, have a tremendous positive effect in reducing water runoff and water and wind erosion losses. Higher soil fertility levels have many benefits :

- A more rapid crop canopy closure results from better plant nutrition. It reduces the erosive energy of raindrops, improves moisture use efficiency, and reduces weed pressure. Phosphorus available at early growth stages is especially important for early canopy development.
- Vigorous growth of plants both above and below ground helps to hold soil in place, improves water infiltration and water use efficiency and increases yields.

(3) Application timing : Nitrogen efficiency and yield potential are increased when applications are made close to the time of greatest uptake. Split N applications at growth stages which correspond to the N demands of the crop is to be considered. On some coarse-textured (sandy) soils, split applications of K, S and some micro-nutrients may also be a BMP because yield potential is increased and environmental protection is enhanced through more efficient utilisation of other inputs.

(4) Fertiliser placement plans : Higher crops yields are not only a matter of fertiliser rates and methods of application, but fertiliser placement as well. Proper fertiliser placement improves nutrient availability to plants, which means higher yields and

greater nutrient efficiency, particularly in conservation tillage systems.

Starters, banding, strip or dribble, deep injection and knifing are just some of the terms used for various methods of fertiliser placement. The increased use of conversation tillage systems has increased the need to consider the most efficient methods of applying fertiliser nutrients. For example, the injection or banding of N in conservation tillage systems helps to prevent tie-up of nutrients with the surface residue, minimises the volatilisation losses of N and improves positional availability. New fertiliser equipment technology makes it possible to place nutrients correctly with increased accuracy and with a minimum of delay.

Early growth response to band or row applications of fertiliser especially P, is very common

(5) Use soil testing and plant analysis : These are the best tools available to determine the amount and availability of soil nutrients and the amount of nutrients which should be applied to achieve the yield goal. Nutrient needs with frequent soil tests, especially for P, K, S, Mg, micro-nutrients and pH should be monitored. Plant analysis helps confirm diagnosis of nutrient needs and can identify needs during the growing season.

Tissue analysis for N is a good tool to help determine the amount of N to apply during the growing season when more accurate rates and more efficient utilisation of applied N can be expected.

(6) Following a conservation plan : BMPs for soil and water are site-specific. They include conservation tillage, terracing, contour strip cropping, grass water-ways, contour and grass head lands, crop rotation and cover crops and water control basins and diversions.

A good soil and water conservation plan for each farm can be the single most important factor in decreasing erosion and the potential loss of soil, water and nutrients especially P attached to sediment and organic particles. Some form of conservation tillage can be practised in almost all types of farming systems.

Summary

The use of adequate amounts of plant nutrients for optimum crop yields and profitability is a key to environmental protection. BMPs developed through research, modified and adopted for specific site conditions, are keys to both efficient use of nutrients and protection of our soil and water resources.