# SOME AGRONOMIC ASPECTS OF FERTILIZER AND LIME APPLICATION

M P W FARIÑA, Soil Fertility Unit, Summer Grain Centre, Cedara College, Department of Agricultural Technical Services

## Introduction

Almost three generations ago it was stated that the best method of fertilizer application was such a controversial subject that it had been very difficult for equipment manufacturers to develop new machinery for fertilizer distribution (Jones & Rogers, 1949). Rapid advances in fertilizer technology and continuing changes in the philosophy of optimum plant nutrition have done little to reduce the controversy which surrounds fertilizer usage. All involved in agriculture at the field level are acutely aware of the wide diversity of opinion which exists on South African farms.

To a certain degree South Africa's climatic and pedological heterogeneity dictates considerably more diversity than would perhaps be found in the more homogeneous major cropping areas of the world, but undoubtedly much of the controversy stems from a dearth of local research in this field. It is, in fact, probably true that in South Africa, with the possible exception of certain specialised crops, equipment manufacturers have more influence on the evolution of fertilization practices than do crop and soils specialists.

The primary objective of this paper is to discuss some of the agronomic aspects of fertilizer application and in so doing to provide an introduction to the following paper. The philosophy underlying this discussion applies specifically to high potential cropping areas of the Republic. In the absence of adequate experimental data the views expressed in several instances reflect the writer's considered opinion rather than scientifically established fact.

Basically, the agronomic requirements of fertilizer application are twofold:

1 optimal utilization of fertilizer by plants should be promoted, and

2 applications should be convenient, economic, and accurate.

## Optimal utilization

Optimal utilization of fertilizer by plants is largely dependent upon plant root characteristics, soil physical and chemical properties, climate, and the type of fertilizer used.

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## Root characteristics

Nutrients reach the root by three mechanisms: root interception, mass flow, and diffusion. Interception plays a relatively insignificant role; N moves to root surfaces mainly through the action of mass flow, and P and K uptake are largely dependent upon diffusion. It is axiomatic, therefore, that optimum utilization of both P and K fertilizers will occur when application is to the soil volume in which maximum root development occurs. This varies considerably with plant species. Crops with limited root systems, such as potatoes and several other vegetable crops, will utilize fertilizer best when it is located relatively close to the plant, while crops like maize with extensive root systems will absorb nutrients from large soil volumes.

Plants cannot absorb nutrients from dry soil and it is logical to assume that incorporation of fertilizer in zones of high root activity should be an important consideration in dryland cropping. It is, however, general practice in South Africa to band-place the bulk of the P and K requirements of row crops at relatively shallow depths. While localised placement is perhaps unavoidable where wide-row spacings are considered necessary, it is questionable whether yield potential can be fully realised unless nutrients are also incorporated in zones of high root activity. There is at present no local experimental evidence to support this view, but striking beneficial effects of plough layer enrichment on moisture utilization have been noted in the field. Maize growers in the United States have generally abandoned the practice of band-placing total P and K requirements (Nelson & Hansen, 1968). It should be noted that it is not the intention here to infer that all fertilizers should be incorporated to plough depth. Localised placement of small quantities of fertilizer is advantageous for other reasons, which will be discussed later and the two systems of fertilizer application are not considered to be mutually exclusive.

The need to maintain high soil test values through the plough layer may appear to be at variance with reports of enhanced fertilizer usage in no-till maize (Moshler, Shear, Martens, Jones & Wilmouth, 1972). However, in experiments comparing no-till with conventionally treated maize, soil test levels have generally been high and treatment effects on moisture relationships and rooting patterns are frequently marked. Negligible P and K movement would be expected to reduce the efficiency of nutrient utilization where the surface few centimetres are not kept moist and the ability of no-till systems to sustain yields once the level of fertility in the plough layer has been depleted is questionable.

If it is accepted that nutrients are used more effectively when incorporated at depths with a consistently higher

moisture status, it might seem reasonable to expect greater efficiency of utilization from deep band placement. Although there are indications that such a system may have merit under low rainfall conditions (Koch, 1973) this has not proved to be the case in more humid areas (Phillips & Webb, 1971).

## Soil properties

Since chemical soil tests provide the only reliable assessment of total fertilizer and lime requirement, chemical soil properties play a particularly important role in determining optimum fertilizer and lime application methods.

Where soil tests indicate high fertility levels it may be possible to use nothing more than 'starter' applications of fertilizer at planting. However, low soil test levels which are the rule rather than the exception, will indicate a need to broadcast and incorporate quantities of fertilizer in most field crops. Similarly, high exchangeable acidity will indicate that a plough-down operation is necessary, as the low solubility of lime makes incorporation to plough depth essential. In such circumstances it will possibly be economic to incorporate fertilizer and lime simultaenously.

A problem of particular significance with regard to exchangeable acidity is the removal of toxic amounts of exchangeable aluminium from horizons below normal plough depth. Such situations are not uncommon and an inability to detoxify subsoil horizons seriously reduces the cropping potential of many soils which are physically well suited to intensive cultivation. It has been suggested that gypsum, which is somewhat more soluble than lime, be used in the amelioration of subsoil acidity (Reeve & Sumner, 1972), and Nardi ploughing offers another possible solution. However, the efficiency of gypsum under field conditions is still uncertain, and deep ploughing is a costly and not necessarily desirable operation. Is this perhaps not an area where engineers and agronomists could co-operate in the development of a more attractive alternative?

Where the general level of fertility is low or soils are acid, it is generally believed that fertilizer P is more efficiently used when band placed. Research in Natal, however, has not demonstrated any advantage in terms of final maize yields, even where soil test P was low and total P applications were as low as 10 kg/ha (Regional Research Projects N—Ce 106/19, N—Ko 2/7). These findings are difficult to reconcile with most comparisons of this nature, but it is possible that many results are confounded by indirect benefits which frequently result from enhanced early growth.

Physical soil properties are of lesser importance, but nevertheless are the root cause of one of the most controversial aspects of maize fertilization. It is known that N can be lost through leaching in sandy soils or through denitrification in soils which tend to become water-logged and it is common practice among maize farmers to apply a significant portion of the total N requirement as a top-dressing. However, as the necessity to cultivate decreases with the wider use of weedicides, farmers increasingly wish to avoid the cost and uncertainty associated with post-emergence tractor operations. The adequacy of single pre-plant N applications has been demonstrated in several of the drier parts of the Republic (Dijkhuis — personal communication), but the absence of research data make recommendations in this regard uncertain in the hgiher rainfall areas. While it seems likely that some N loss can be anticipated, the magnitude of this loss may be such that somewhat higher initial applications would be acceptable to farmers.

Ironically, while an increasing number of growers are experimenting with single pre-plant applications of N, more farmers are also applying portions of their K requirements as top-dressings with N. This practice has resulted from the commercial unavailability of zincated high K fertilizer mixtures, but the slow movement of K in all but very sandy soils makes split applications of K in annual crops a practice of questionable value.

It has also been suggested that split K applications might be economically justified on perennial pastures grown on very sandy soils. However, in Natal it has not been possible to demonstrate that split applications are in any way superior to single annual applications on Eragrostis pastures grown on sandy members of the Longlands series (Regional Research Project N—Dd 6/3).

## Climate

As has already been suggested, climate is intimately associated with optimal N usage. In the writer's opinion climatic considerations, together with weed competition, also constitute the most important reason for band placement of fertilizer in many field crops. Temperatures are frequently low during the early part of the growing season and the enhanced rate of early growth, which results from localised placement of small or 'starter' applications of fertilizer, can be advantageous where weed control is imperfect of where temporary conditions of water-logging are experienced.

Taking a broader view, it is also probable that the dry winters which prevail in most cropping areas of the Republic will eventually result in greater quantitites of P and K being applied ahead of planting. In cooler areas, where little winter weed growth occurs, it may also prove economic to incorporate nitrogenous fertilizers during the winter months and, indeed, this is already being done by a few growers. As more farmers move towards maximising profits such time-saving considerations will become more important.

### Fertilizer form

In several instances the method of application is determined by the form of fertilizer to be used. Rock phosphate and zinc fertilizers for example, work best when broadcast and incorporated, anhydrous ammonia requires to be knifed into the soil to avoid volatilisation losses, and enzymatic hydrolysis may result in marked ammonia losses from surface applied urea. Particle size and formulation may also influence the efficiency of application, but this aspect relates more to the mechanical aspects of fertilizer application and will be covered in the following paper.

## Application

As fertilizer applications move towards optimal levels the time required for their distribution becomes appreciable. Optimum annual fertilizer requirements in the high potential areas of the country commonly exceed 500 kg/ha and if for no other reason, the premium placed on time during planting must inevitably result in pre-plant incorporation of most fertilizer. It is considered that convenience, economy, and accuracy of pre-plant fertilizer applications will become increasingly important entrepreneural considerations.

Convenience and economy are associated with high-capacity equipment. Such equipment is costly and individual ownership is difficult to justify economically. However, the low capacity of applicators presently owned by farmers is wasteful in terms of fuel, labour, and time where large quantities of fertilizer are applied. A solution to the problem probably lies in custom application with high capacity distributors capable of applying fertilizer both rapidly and economically. Such services are presently available for specialised products in certain parts of the country and it seems likely that the role of custom applicators will increase in the future.

Accuracy and evenness of distribution are also important agronomic considerations. Generally, the equipment available today is capable of applying fertilizers with considerable accuracy, but low operator efficiency has a marked effect on the evenness and accuracy of application. If considerable quantities of fertilizer are being applied in the band at planting the results of inaccurate application may be disastrous, as was apparent when high-analysis fertilizers were first introduced in South Africa. Serious germination problems resulted from placement too close to the seed. The effects of poor operator quality are not considered to be serious where fertilizer is broadcast for row crops and soil test values are medium to high (Jensen & Pesek, 1962; Langdale, Myhre & Miller, 1971), but it is nevertheless probable that profitability will be affected in low fertility situations. In fact, the frequent occurrence of ragged row ends and edge rows in maize and unevenly top-dressed pastures suggests that the loss may be considerable.

## Conclusions

Although the agronomic aspects of fertilizer application have, in this discussion, been treated rather superficially, certain conclusions can be drawn.

- Band placement of large quantities of fertilizer is of questionable value and it is likely that greater percentages of total fertilizer needs will in the future be broadcast and incorporated.
- Only small 'starter' applications of fertilizer are warranted at planting. In some circumstances these applications may have little or no beneficial effect, but the value of enhanced early growth in combatting weeds and in overcoming the effect of cool, wet weather is frequently considerable.
- South Africa's dry winters are well suited to the early incorporation of fertilizers and considerable development in this direction can be anticipated.
- The rapidly increasing rates of fertilizer usage will generate a demand for increased custom application with high capacity equipment.
- The economic and agronomic merits of top-dressing N on annual crops in the moister areas of the Republic urgently require experimental assessment.
- Further research is required into ways and means of ameliorating subsoil acidity.

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