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Placement of Nutrients in Soil: A Review

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Review Article

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ABSTRACT

Placement of nutrients and fertilizer rates are important factors to be considered to produce maximum yield of crops. Particularly deep placement of nutrients might be beneficial to crop growth. Increased early growth has been observed with deeper P placement as well as by deep band placement of K when compared to broadcast application. The method of N, P and K placement has typically been found effective over broadcasting on the top of the soil, and it is also influenced by the amount of water used for irrigation. Normally fertilizers are broadcasted. Many a time, straight fertilizers are used as the source of nutrients. In order to manage the losses with these highly soluble fertilizers split application is recommended, particularly for urea. However, the entire quantity of P and K is applied basally at the time of sowing. Due to variations in their solubility and kinetics, the added nutrients are found to be available to plants at varying rates in different soils. In order to achieve the expected yields a comprehensive technology is required that can demonstrate an efficient use of added nutrients and irrigation water. Other than crop improvement aspects, this would be possible by switching over to nutrient management that employs methods like deep placement of fertilizer nutrients. Deep placement if can be done with simple tools and incidentally aim in the reduction in labour requirement then farmers can prefer to adopt easily. The literature pertaining to methods of fertilizer application on nutrient availability, response of maize and other crops to applied nutrients and nutrient use efficiency are reviewed.

INTRODUCTION

Optimum nutrient management has long been acknowledged as being critical for producing high yield in maize. However, there are multiple factors that cause decision making on fertilizer application to be a complex process. For instance, the rates of fertilizer application, the source of the nutrient and the associated availability to the crop, the time of application, and where the nutrient is placed are important considerations in nutrient management decisions. These parameters interact with many other factors such as tillage, soil type, variety, plant population and the environment. Banded starter fertilizer application, which places the fertilizer within close proximity to the seed furrow, can help to promote crop growth vigor of maize at early stages by overcoming these limitations.

Unless the supply of fertilizer nutrients to the crop is increased, low availability will remain as a serious constraint to increase maize production. One means of increasing the nutrient supply without increasing the fertilizer amount is to improve the efficiency of fertilizer, which can be achieved through deep placement of the fertilizers. Research on deep placement was meager due to difficulties associated with placing of fertilizer nutrient at a definite depth manually, since no suitable applicators are available.

Normally straight fertilizers are broadcasted in maize as the source of nutrients. In order to manage the losses with these highly soluble straight fertilizers split application is recommended particularly for urea. Compared to other cereals high rates of N is recommended to Maize. Of this, 50 per cent of N is applied as basal while the remaining dose is applied in two equal splits at 25 and45 days after sowing (DAS).

However, the entire quantity of P and K is applied as basal at the time of sowing. Even though fertilizer application in small furrow parallel to seed line is recommended, due to scarcity of labour farmers practice only surface band/ broadcast method. Due to variations in their solubility and distance from seed, the added nutrients are not available to plants uniformly, and result in differences in stature, growth rate, maturity and weight of cob.

Fertilizer placement

Band placement of urea reduced the N immobilization compared to broadcasted or incorporated urea, as in this method the contact between urea particles and soil is less [61]. According to Manickam and Ramaswami [32], application of urea supergranule at 10 cm depth in the soil produced low concentrations of NH_4-N in the flood water, consequently reduced the volatilization loss of ammonia. In no tillage maize production system ammonia volatilization and N immobilization are the process which causes low N use efficiency [33]. The type and amount of crop residue have been shown to affect immobilization potential.

Mohanty *et al.* [35] reported that efficiency of applied N could be increased by point placement of urea supergranule in the subsoil particularly in soils of low permeability. The loss of N was 20 per cent less from urea super granules than prilled urea. Natarajan and Manickam [38] also confirmed that more fertilizer N was utilized by rice with single deep placed urea supergranule than with split applied prilled urea. The ammonia loss was less than 5 per cent when fertilizer N was placed in soil at 10 cm depth by placement, or banding techniques compared to broadcast. Mohanty *et al.* [36] reported that deep placement of urea supergranules had greater benefit over surface split application in soils with moderate to fine texture, low permeability and percolation rate, and high CEC and pH.

Bautista *et al.* [6] concluded that placement of any N material with simultaneous soil cover was effective in minimizing floodwater ammonium-N losses and ammonia volatilization. Riedell *et al.* [51] reported that maize yield increased about 5 to 40 percent for knife-injected N compared with broadcasted N. Much of the yield reduction from N left on the soil surface without incorporation has been attributed to ammonia volatilization. Brad *et al.* [10] measured that 30 and 9 per cent of N from urea ammonium nitrate were lost due to broadcast in no till maize system.

Vibhu Kapoor *et al.* [66] recorded that deep placed N-P briquettes gave significantly higher grain yield, straw biomass, total P and K uptake, apparent P recovery, and agronomic N and P use efficiencies, when plant spacing was reduced from 20 x 20 cm to 20 X 10 cm. Closer plant spacing led to better utilization of P and K and provided opportunities for deep placement of N-P or N-P-K briquettes in soils with low available P. Combining site specific characteristics viz., high soil pH, low percolation rate, high rainfall and surface runoffs with plant spacing and N-P-K briquettes prepared based on site-specific nutrient requirements offered potential for higher yields, improved fertilizer use efficiency, balanced fertilization, and reduced nutrient losses.

Response of crops to fertilizer application

Effect of Placement of N

Placing fertilizer N at about 10 cm below the soil surface after puddling has long been known to improve plant uptake of N [34]. Partohardjono and Fitts [42] reported that 60 kg N ha^{-1} as sulphur coated urea applied as basal at significantly increased rice yields when compared to that of urea in three split application at same rate. Mahendran[27] observed that placement of urea supergranules in the reduced zone of soil recorded more grain and straw yield compared to the commercial urea application by broadcasting.

Further, Pillai [46] found that it was possible to get an extra grain yield as response of one t ha^{-1} by applying 38 kg N ha^{-1} by root zone placement of urea supergranules. To get the same yield with ordinary urea in split doses, it was necessary to apply about 56 kg N ha^{-1}. Surendra singh *et al.* [56] reported that placement of urea supergranules increased N use efficiency. The highest grain yield was obtained with 150 kg N ha^{-1} as urea supergranules with 489 panicles m^{-2} and 122 grains $panicle^{-1}$. Khattak *et al.* [25] reported that the maize is a nitrogen positive crop. Placement of fertilizer is an integral part of efficient crop management that can affect both maize crop yield and nutrient use Efficiency. Similar result was reported by Johnston and flower.

Bhuiyan [7] found that deep placement of urea supergranules resulted in significantly higher rice grain yield, better NUE and apparent N recovery than split application of prilled urea. Singh [55] reported that placement of urea briquettes at 3-4 cm depth resulted in significantly taller plants (78 cm), longer (23.3 cm) and heavier panicle (2.4 g), higher 1000 grain weight (18.6 g) and more grain (4.6 t ha^{-1}) and straw (5.7 t ha^{-1}) yield of rice than surface application. Zublena reported that plant growth and nutrient uptake can be influenced by placement method. In general, placing the fertilizer closer to the seed gives the greatest response to applied nutrients.

The band placement of urea solution recorded nearly 38 and 55 per cent higher grain yield than the researcher and farmer practices and similar to those with point placement of urea supergranules [53]. Placement of N as urea supergranules in the root zone and basal application of P and part of N as large granules of diammonium phosphate gave the best results for growth, yield performance and N use efficiency in maize under irrigated condition. Dhane *et al.* [15] reported that applying *Gliricidia* at 5 to 10 t ha^{-1} coupled with deep placement of urea at 25 or 50 kg N ha^{-1} at about 5-6 cm depth increased the rice yield significantly. The deep placement of N and P as pillow shaped urea briquettes (4:1 - N: P) using urea and DAP after transplanting was found to enhance the yield of rainfed rice [12].

Lehrsch *et al.* [26] showed that placement of N and P fertilizers at the time of planting directly in the seed furrow improved plant growth, crop uptake, and grain yield in maize. Many researchers have reported reduced maize yields with broadcast application of N compared with injected N sources or placements. Lehrsch *et al.* [26] reported that banded application of N increased grain yield and N uptake compared to broadcast application in maize. Peter *et al.* [44] found that incorporated or surface band-applied N produced considerably greater yields compared with broadcasted N.

Riaz *et al.* [50] found that furrow irrigation method with band placement of N considerably increased leaf area $plant^{-1}$, crop growth rate, net assimilation rate, number of grains cob^{-1}, 100-grain weight and grain yield (6.72%) than broadcast method.

Tewari *et al.* [58] found that the deep placement of slow release fertilizer kept nodule dry weight, higher in the maturing stage of seed, possibly through abundant supply of photo assimilate to the nodules by supporting leaf area and activity until late reproductive stages in the soybean plants, and the results indicated that deep placement of calcium cynamide or coated urea enhanced total amount of N_2 fixation activity 50 percent higher, which ultimately increased seed yield.

Trierweiler and Omae [62] recorded that the maize grain yield response to added N was very highly significant and the regression analysis predicted a maximum yield of 7.6 t ha^{-1} from 210 Kg N ha^{-1}. A consistent yield depression occurred at 320 kg N ha^{-1} rate in all placement treatments. Placement of urea on dry soil gave significantly higher yields than did placement on wet soil. The data indicated that substantial N losses occurred when urea was broadcasted on wet surface.

Kaiser *et al.* [23] reported that the starter fertilization increased the early growth of maize and P and K uptake more than broadcast fertilization. Deivanai [13] experimented with Nutriseed holder which contained seed on top cavity, manure in the middle tube and fertilizer at bottom cavity, which gave 42-58 per cent increase in ADT 36 rice yield grown in soil column, when compared to surface broadcast method, under submerged water regime. Deep placement using Nutriseed holder resulted in the grain yield increase to the tune of 81.8 per cent over surface broadcast [4].

Kaushal *et al.* [24] found that deep placement of a slow release fertilizer formulation (lime N) at 100 Kg N ha-1 was beneficial for promotion of soybean growth and N_2 fixation activity, which gave seed yield as high as 6.4 t ha^{-1}. Vengatesan [64] has conducted experiment with paper Nutriseed Pack and found that deep placement by Nutriseed Pack technique in maize increased the yield to about 55 per cent under surface irrigation with 660 mm (or) to about 35 per cent by micro sprinkler with 540 mm (or) to about 15 per cent by drip with 360 mm, over the conventional surface fertilizer broadcast - surface irrigation method. In this study the final form of Nutriseed pack was made with manure and fertilizer pellets using a hand operated machine.

Peterson [45] found that placement of compound NPK fertilizer increased the grain yield and the quality parameters like grain size and grade when weeds are controlled mechanically by harrowing in barley. The effect of fertilizer placement on grain yield and quality decreased in the order NPK> NP> N> P.

Upendra Singh *et al.* [63] reported that the deep-point placement of N, P and K briquettes significantly increased grain and straw yields, total N, P and K uptake, also N and P use efficiencies compared to broadcast incorporation of N, P and K in rice.

Golden *et al.* [18] reported that pre-plant incorporated polymer coated urea increased rice grain yield and N uptake in the direct seeded, delayed flood method compared with urea applied pre-flood at the five-leaf stage.

Rehm and Lamb [48] brought out that placement of fertilizer near the maize seed at the time of sowing increased early growth, P uptake and yield which can be an effective management practice with minimal risk, if soils are not sandy. Alley *et al.* [2] observed that during the first six weeks after sowing nutrients that are band-placed close to the maize crop were more available for plant uptake than the same amount of nutrients were broadcasted over the entire soil surface. Vetsch and Randall [65] reported that maize yields were greater in two of three years when fall applied environmentally smart Nitrogen (ESN) was banded than broadcast-incorporated.

Effect of Placement of P and K

Heckman and Kamprath [19] reported that stover yield and K concentration were increased in banded K than broadcasted K. Stover dry matter yield was increased in two of three years with 56 Kg ha^{-1}, but grain yield was increased in only one year. Yield increased linearly with K rate up to 112 Kg ha^{-1}. Mallarino and Murrell [31] found that deep band applications of K increased maize yield in no till maize compared with broadcast method of K application. Deep placement of P fertilizer at 15-cm increased early maize growth over broadcast [28]. Increase in early growth with a deep P placement was observed by Borges and Mallarino [9].

Deeper K placement often encouraged early growth of maize at low to medium soil nutrient levels. Placement of K seldom influenced early growth of maize at soil nutrient levels that were optimum or higher, and increased K uptake when applied by a planter band or 13-18 cm deep-banded [28]. This was similar to another study where early growth was increased by deep (15-20 cm) band placement of K as opposed to broadcast applications of K [9].

Likewise, Vyn *et al.* [67] reported that in a zone tillage system, deep-banding K increased early season maize dry matter relative to broadcast or broadcast plus shallow treatments. In addition, in the mulch tillage system, deep banding K was similar to the shallow placement, which resulted in increased early growth over the broadcast application. Potassium uptake by maize usually increased with a deep K band application. Applying K in strips (surface or 20 cm deep) significantly increased the K concentration of young plants and the ear leaf over the broadcast method [33]. Similarly, deep band placement of K improved K uptake in 11 out of 15 sites examined [9].

Riedell *et al.* [51] concluded that fertilizer placement at the time sowing was important for optimum maize growth and yield in irrigated no-till systems. Further Added K fertilizer did not interact with fertilizer placement to improve yield on the soils with high K status. Mallarino [29] reported that deep banding of K provided distinct yield advantages by making K more available in ridge-till and no-till fields, even on soils that test optimum to high in K. Deep banding of P and K produces higher yields and did not increase costs significantly compared with a separate broadcast P and K application.

When the initial exchangeable-K was 0.21 cmol L^{-1}, critical exchangeable K level was 0.35 cmol L^{-1} and the critical soil solution K concentration was 0.48 mmol L^{-1} the dry matter yield increased greatly. Vyn and Janovicek [67] found that deep placement of K resulted in higher early season K concentration as compared to a shallow or broadcast placement in both no-till and mulch tillage systems in maize. Vyn and Janovicek [67] found that corn yields in the no tillage and zone tillage systems were maximized by applying the high rate of deep band placement of K even when no K fertilizer was applied the to previous fall.

Yin and Vyn [68] reported that band placement of K increased leaf K content, yield (10 to 15 per cent) compared with zero K, while soybean seed yield was not significantly improved by surface broadcasting in any row-width system. Seed oil concentration was increased by band placement, and was often positively correlated with leaf K, seed K and seed yield in both wide and inter mediate row width systems.

Rehm and Lamb [48] reported that banded K produced changes in soil test K to a depth of 15 cm and at a distance to 15 cm from the row. Grain yield of maize at all sites were not affected by K application. Uptake of K by young maize plants was increased by K rate, but uptake was not directly related to yield.

Mallarino and Borges [30] found that deep band placement of both P and K (at 5 to 15 cm depth) resulted in higher concentration of phosphorus and potassium than for inter band row placement with no tillage and chisel disk tillage system. Jesse Grogan [22] found that the deep banding of K fertilizer increased maize yield in ridge-till and no-till fields even when soil test K was high but was not effective in chisel-disk tillage systems.

Zhang *et al.* indicated that drip irrigation in combination with fertilizer K application reduced of N pollution potential possible, while producing high yield of tomato with improved quality. Drip irrigation substantially increased marketable fruit yield and fruit size, and decreased green fruit yield, compared with non irrigation treatment. Drip irrigation increased N and P uptake by 29 to 38 percent respectively.

Yield Responses to Nutrient Placement

Appropriate methods of N, P and K fertilizer application to increase grain yield under intensive crop and water management systems are needed to optimize fertilizer input for high maize yields [49]. Although many studies have concentrated on potential crop yield responses to deep P and/or K placement, due to the relatively immobile nature of these nutrients in soils, results have been inconsistent. On the other hand several studies have reported yield benefits to deeper and banded nutrient placement in crops such as maize [9], and grain sorghum [59]. In some of these studies, yield benefits were seen with a deep-banded K placement, but not with a deep-banded P placement.

Phosphorus placement method seldom influenced maize grain yield for any tillage system, even with low testing soils. Deep banding of K (at 15 cm) increased maize yields slightly at several sites over the broadcast or planter-band placements [8]. The yield increase was observed even in soils that tested high for exchangeable K concentration. Broadcasting of P, when compared to a shallow N plus P band application, increased yields in both no-till and disk-till systems [21].

Vyn et al. reported that there were significant yield benefits to deep (15 cm) banding of K, particularly in zone-tillage systems, but not in a mulch tillage system. Deep banding K (15-cm) in a zone tillage system also increased maize yield when compared to broadcast method in conventional tillage and no-till situations .However, in continuous no-till maize with optimal soil moisture, surface broadcasting was found to be as good as deep banding of K despite soil exchangeable K stratification, and in some situations deep banding appeared to be detrimental relative to broadcast application [67].

Recovery of nutrients in fertilizer placement

The uptake pattern of various nutrients has been accepted as a criterion for fixing optimum time of fertilization. Yield and fertilizer recovery decreased in the order of ammonium phosphate> urea> calcium ammonium nitrate. Savant *et al.* [52] reported that negligible N uptake occurred during the first 20 days period in deep placement of urea supergranules. High solute concentration at placement site with urea supergranules or urea mud ball lumps might have also inhibited nitrification because of osmotic pressure of the solute. Placement methods lowered P fixation in soil and increased P availability at placement site which improved balanced nutrition of rice plants leading to increased nutrient utilization [37].

Chen and Zhusha [11] reported that the average N recovered from supergranules was 24 per cent higher than that from broadcast application of urea. The recovery of added N was 68, 34 and 27 per cent with placement, split application and broadcasting respectively [3].

Band placement of ^{15}N labeled urea resulted in higher recovery of the applied ^{15}N. Total recovery was slightly lower when a urea supergranule was point placed (95%). Total ^{15}N recovered was lowest when urea was surface incorporated (89%). ^{15}N balance data showed that with point deep placement of urea supergranule only 4-5 per cent of the applied N was not recovered even after harvest of both dry and wet season crops.

In contrast, when prilled urea was basally broadcasted or incorporated and top-dressed at panicle initiation, 11-35 per cent of the applied N was not recovered at harvest, indicating substantial loss of fertilizer N.

Urea applied at the rate of 60 kg ha^{-1} through any method other than surface broadcasting on to floodwater significantly increased grain and straw yield. The apparent recovery of applied N by rice crop was highest (47-61 per cent) with deep placement, moderate (41-48 %) with basal band placement and least (16 per cent) with surface broadcasting of prilled urea on to the floodwater [39].

Malhi and Nyborg found that placing urea in bands increased the recovery of applied N in plants and decreased the amount of immobilized N under zero tillage when compared to conventional tillage by using ^{15}N labeled urea as source. Rees *et al.* [47] found that the crop recovery of fertilizer N following point placement was 25 per cent of that applied, which was higher than that of surface application and also increased the grain yield, total N uptake, and dry matter yield as well as grain N contents in maize and wheat.

Thamir *et al.* [59] indicated that under current N fertilizer recommendation for maize, urea might have adverse effects on growth when applied in band. The banded application of urea and diammonium phosphate resulted in 19 and 24 percent increase in grain yield compared with the unfertilized plots. However, addition of lignosulfonate to the high rate of urea and DAP increased grain yield by 20 percent in band placement. In general, lignosulfonate significantly increased maize N uptake from urea. Mean recovery of ^{15}N in total dry matter of grain and stover was 51.9 and 47.9 per cent respectively.

Bandyopathyay and Biswas [5] reported the higher fertilizer use efficiency when urea supergranules and urea briquettes were used. The NUE was higher with band placement of urea compared to conventional split application of prilled urea at 100 kg N ha^{-1} in rice.

The ^{15}N recovery was 51.7 per cent with band placement compared with 47.8 per cent for neem-coated urea and 28.5 per cent for conventional split application of prilled urea [14]. Adjetey *et al.* [1] found that the total N recovery was 93.8 per cent in the deep placement of ^{15}N sources compared to shallow placement (79.9 per cent) in wheat, and these differences were due to differences in soil N recovery, as crop N recovery was approximately 48 per cent in both the treatments.

Shoji *et al.* [54] found that controlled release of fertilizers and a nitrification inhibitor showed the highest potential to increased N use efficiency and reduced N fertilization rate. Dotson *et al.* [16] reported that deep placement of N fertilizer has the potential to increase N use efficiency in maize. Noellsch *et al.* [41] found that pre-plant incorporated polymer coated urea increased N fertilizer recovery efficiency and grain yield compared to control in the clay pan landscapes. Nelson *et al.* [41] reported that slow-release N fertilizers, such as polymer-coated urea, increased crop N use efficiency and maize yield and also reduced NO_3-N leaching in clay pan soil compared to non coated urea.

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