

Higher Productivity and Profitability in maize systems by nutrient management

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NUTRIENT requirement of the crops depend mainly on soil fertility status and the farmers' targets yield. At each harvest, nutrients taken up from the soil by the growing crop are exported from the field in the form of grain or stover which further depletes the productive capacity of the soil. Thus, soils require external nutrient replenishment in the form of organic and inorganic fertilizers. Soils having low inherent fertility status would require more fertilizer nutrients compared to those with higher fertility to get same level of targeted yield. Nutrient mining, imbalanced nutrition and under/insufficient supply of plant nutrients are some of the major problems contributing to declining crop yields. Maize like most of the field crops, require a good amount of primary nutrients, *i.e.* nitrogen (N), phosphorus (P) and potassium (K) with the addition of other essential elements *e.g.* zinc (Zn), sulfur (S) and boron (B) in smaller quantities wherever necessary.

Besides, the current nutrient management practices in the high input maize systems indicates imbalance plant nutrition with very high use of N and less use of P and

negligible use of K and micro nutrients. This has led to nutrient imbalances in soils and lower nutrient-use efficiency and farm profitability under the scenario of decontrolled fertilizer prices that increased the cost of this input in recent years. As the all three macronutrients *i.e.* NPK having synergistically increases the crop yield and hence needs to apply in balance amount to get higher efficiency of each other. Moreover, the crop performance depends on sufficient supply of each of the 17 essential nutrients required for crop growth and development while it is limited by the nutrient in shortest supply. Thus, it is required to have adequate and balanced use of plant nutrients to achieve better efficiency and increased farm productivity and profitability in our country.

Fertilizer use in maize systems aims at providing crop with balanced proportions of essential nutrients when required with all available organic and inorganic sources. To determine fertilizer needs for the crop, it is essential to know which nutrients are required for the desired target yield. In this article, the authors have tried to enumerate

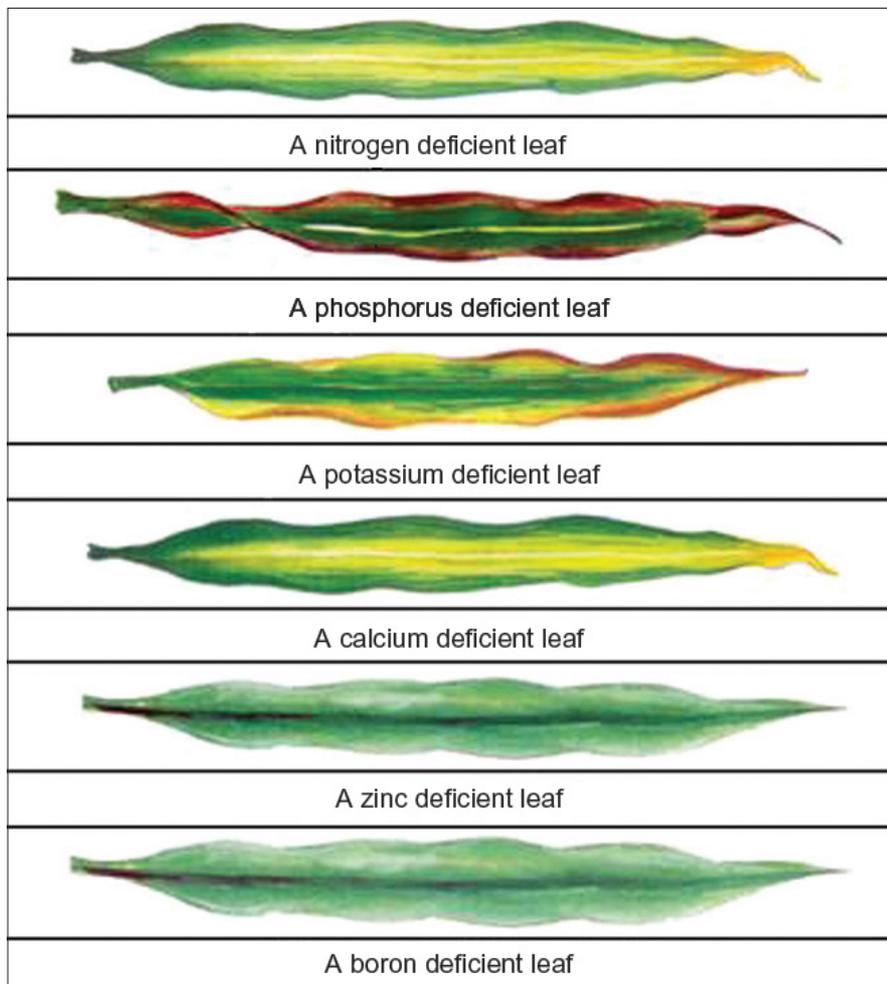
answers for nutrient hunger assessment in crop, factors affecting nutrient requirement and best fertilizer management practices in maize towards increasing productivity and profitability.

How to assess nutrient hunger of maize crop?

The nutrient hunger symptoms of maize showed as stunted growth in general appearance as well as the faded green colour of the plant. Typical symptoms are small (stunted) plants, pale green leaves, and spotting or striping on leaves. Deficiency symptoms for most important nutrient elements are identifiable normally. However, in some complex cases, where there is no clear distinction, a specialist needs to identify the problem. Some pest and disease damage symptoms are quite similar to those of nutrient deficiencies (*e.g.* striping or spotting), so it is important not to confuse the two.

Primary nutrients: Nitrogen is the most important nutrient for plant involved in all major processes of plant development and yield formation. Loss of green color is the most typical hunger symptom of N

In several states of the country particularly hill ecologies (North Eastern Himalayas, Uttarakhand, Jammu and Kashmir and Himachal Pradesh) and rainfed tribal states (Madhya Pradesh, Chhattisgarh, Rajasthan, Gujarat and Odisha), large area under maize production still remained untreated with fertilizers. This extant of no fertilizer application goes up to 90 % especially in areas where farmers are not sure to harvest their crop due to frequent drought and floods during monsoon season. After adoption of hybrids at farmers field further emphasize the need of change in nutrient management in maize substantially due to higher plant stand and yield potential.



Nutrient deficiency symptoms in maize

which appears on lower older leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base resulted in premature death of lower leaves. In the early plant growth stages P is important in laying down foundation for its productivity required for good root system. The dark bluish-green and purple discolouration of lower leaves caused marked reduction in plant growth under P deficiency. Symptoms of K deficiency include drying along the tips and edges of lower leaves. The K deficiency is accompanied with weakening of the stalk, resulting in lodging and crop loss as this nutrient provides strength to plant and helps in fighting with diseases. However, in most maize systems of northern India, K deficiency is rare because of its abundance in most of the soils whereas there is a need to apply it in peninsular India.

Secondary nutrients: Calcium deficiencies in maize, often called

“buggy whipping,” are fairly common in a greenhouse or in crop grown under acidic soil conditions. The most common and troublesome calcium disorder occurs in the seedling stage where emerging leaves are damaged and don’t unfurl. Distortion and twisting results in as newer leaves try to push through the damaged leaves. The plant recovers sometimes, if not the farmer must carefully unfurl the leaves manually to save the crop. Inadequate supply of magnesium appears as definite and sharply defined series of yellow/green streaks on all leaves due to a general loss of green color which starts with the bottom leaves and later moves up the stalks. Sulfur deficiency symptoms in maize are similar to those of nitrogen in which plants show a pale green colour but it appears first on younger leaves.

Micronutrients: Micronutrient deficiencies are usually apparent on the new leaves of maize except molybdenum since these are

immobile in plant. The zinc deficiency symptoms may appear within the first two weeks after crop emergence as a broad band of white to yellow bleached tissue on one or both sides of the leaf midrib. These deficiency symptoms are called as white bud of maize, a physiological nutritional disorder.

A stunted appearance and yellow stripes between green veins along the entire length of the leaf blade are distinct hunger symptoms of iron. Boron deficiency may easily be mistaken for iron deficiency where there is a general stunted growth and leaves fail to uncurl properly. Boron availability reduced under low rainfall/drought conditions or in soils with low in organic matter.

The deficiency of molybdenum and manganese cause dwarfing of maize plants. Maize grown under soils low in molybdenum develops yellowing of older leaves and younger leaves usually fail to unroll, while with manganese deficiency, maize seeds may fail to germinate entirely. Copper deficiencies, typical symptoms include a general yellowing (chlorosis) of younger leaves while in older leaves, leaf tips curl like pig tails and dies.

Important factors affecting nutrient requirement in maize crop

The recommended fertilizer application rates depend on a number of factors and the most important ones are:

Cultivar and yield potential: Varieties differ in their response to fertilizers depending on their yield potential. Improved hybrid cultivars in maize with high yield potential will require more nutrients in order to achieve their yield potential. Their yields will be significantly reduced if fertilizer rates are low. Moreover, the nutrient use efficient cultivars may require less external inputs for same level of yields compared to inefficient genotypes. On the other hand application of higher nutrient doses in low yielder composites will decrease nutrient-use efficiency and farm profitability.

Crop rotations: The continuous cereal base rotation like maize-wheat

requires higher amount of nutrients compared to legume in rotation with maize. The inclusion of legumes as intercrops (like soybean, mungbean, urdbean, pigeonpea, groundnut, etc) or in rotation considerably reduces N requirement in maize as carry over legume effect. Moreover, it recycles other macro and micronutrients from lower sub-soil layer to upper root zone in the form of leaf falls and thus helps in enhancing applied nutrient-use efficiency. The green manuring of legumes like dhaincha/sunhemp also reduces the nitrogen requirement in maize crop substantially. If the previous crop is cereal like wheat than full dose of recommended fertilizer is needed to get same yield.

Crop management: Efficient use of applied nutrients depends on soil and crop management practices and fertilizer application methods and timing. Timely weeding reduces competition for nutrients by weeds which otherwise removes large amount of nutrients. Availability of moisture/water both in terms of amount and timing also influences nutrient movement in the soil and the uptake by crop in synergistic manner.

Soil type: Soil fertility is determined by soil type, which in turn is based upon its depth, organic matter content and texture. N, P and S reserves are poor in soils with low organic matter content; coarse texture and a history of continuous cropping for many years are usually very low while there may be sufficient K for crop needs. Coarse texture soil with higher sand proportions requires higher nutrients to produce same level of yields compared to those with fine textured clay soils.

Soil reaction: Maximum availability of essential nutrients occurs at pH 6.0-7.0 where maximum availability of fertilizer nutrients is also maintained. Thus, the differed pH may require higher amount of the nutrient to be supplied. A sufficient supply of all nutrients (including micronutrients) is important for a good, healthy crop and the efficient use of each applied nutrient. If the nutrient is present in soil, but insufficient in quantity, the plant growth and uptake of other nutrients is limited. Soil with higher organic matter requires less external input of the nutrients

Climatic conditions: Response of rainfed crops to fertilizer also depends on soil moisture and its availability during critical crop growth stages like seedling, knee high and reproductive. The erratic rainfall patterns make optimum yield and fertilizer requirements difficult to predict, so fertilizer use is a risky investment. When drought risk is high, split applications of nitrogen fertilizers may be advisable, with adjustments throughout the season based upon evolving weather conditions. Generally P applied in the previous season retains some residual availability for the next crop since it is not easily leached, if drought occurs after fertilizer application resulted in crop failures.

Residue management: Maize with the grain yield potential of 6.3 t/ha removes 178 kg/ha of NPK in its straw beside sizeable quantity of other nutrients. With the introduction of improved cultivars, the productivity has increased up to 5.0 t/ha in some of the states like Tamil Nadu and Andhra Pradesh in our country. Maintaining crop

residues in the field contributes to natural cycle of nutrients and reduces the need for fertilizer nutrients specially K, Mg, Mn and Zn (Table 1). Thus the fertilizer requirement will be different in residue incorporated field compared to residue removal. The straw which is generally 4 to 5 times of the maize grain produced in the field, if not required for cattle feeding can be used for nutrient recycling in field itself under conservation agriculture based management practices. The straw retention in field will be beneficial for potassium management.

Nutrient management practices for higher productivity and profitability

Maize is grown in almost all states of the countries in various seasons. The crop is largely grown under rainfed conditions where soils are not only thirsty but also hungry for nutrient too. The less consumption of fertilizer in maize with traditional varieties was one of the major reasons for low maize productivity and profitability in such ecologies. The better nutrient management will synergistically act with water to improve the maize productivity in the country. Moreover, with the adoption of single cross hybrid technology there is need of proper nutrition of the maize crop for harnessing benefit of the hybrids at farmers' field. The application of organic and inorganic sources of nutrient in right amount, at right time and right place will further enhance the maize productivity in different soil types and agroecologies.

NPK recommendation: Among all the cereals, maize in general and hybrids in particular are responsive to nutrients applied either through organic or inorganic sources. Blanket nutrient recommendation packages for different agro-ecological zones based on a 'normal' season's yield potential are available from most national agricultural research institutions. For raising good kharif season crop the application 150:75:50 kg/ha of N:P₂O₅: K₂O required for hybrids of medium and late duration while for early duration hybrids and composites can be grown

Table 1. Nutrient uptake by maize crop

Grain yield (t/ha)	Macronutrient uptake (kg/ha)						
	Part	N	P ₂ O ₅	K ₂ O	MgO	CaO	S
6.3	Grain	100	40	29	9.3	1.5	7.8
	Stover	63	23	92	28	15	9
	Total	163	63	121	37.3	16.5	16.8
Micronutrient uptake (g/ha)							
Grain yield (t/ha)	Part	Mn	Cu	Zn			
6.3	Grain	70	40	110			
	Stover	940	30	200			
	Total	1010	70	310			

Table 2. Recommended dose of nutrients for maize cultivation in various states

Season	Recommended dose of nutrients (N: P ₂ O ₅ :K ₂ O kg/ha)	States
Kharif	100:60:40	Odisha, Bihar and Madhya Pradesh
Kharif	120:40:0	Rajasthan and Gujarat
Kharif	120:60:40	Himachal Pradesh, Maharashtra, Punjab, Uttar Pradesh and Uttarakhand
Kharif	150:80: 60	Chhattisgarh, Haryana, Karnataka, Jammu and Kashmir, West Bengal and Tamil Nadu
Rabi	120:75:50	Bihar and Rajasthan
Rabi	175:60:50	West Bengal
Rabi	225:80:80	Andhra Pradesh and Tamil Nadu
Spring	80:40:30	Bihar
Spring	120:75:50	Punjab and Uttar Pradesh

with 100:40:25 kg/ha of N:P₂O₅:K₂O. During rabi season for cultivation of medium and late duration maize hybrid, it requires 180:80:60 kg/ha of N:P₂O₅:K₂O. However, these recommendations vary in different agro-ecological situations as given in Table 2.

Timing and method of fertilizer application: One of the most important aspects of fertilizer usage is to know when and how fertilizers should be applied to improve the efficiency of the nutrients applied. It primarily depends on the mobility of the particular nutrient applied to soil. With nutrients that are stored efficiently in soil (i.e. P, K, S), fertilizers can be applied before planting, or banded below/side of the seed. P is immobile in soil and it should therefore be applied into the root zone during sowing. N application should be timed to coincide with periods of peak demand and rates adjusted according to rainfall received during the season via split application to reduce leaching losses. The following points must be kept in mind for NPK management in maize cultivation:

- Apply NPK fertilizers as per soil test recommendation as far as possible. If soil test recommendation is not available adopt a blanket recommendation.
- The 20% N in irrigated and 34% N in rainfed conditions with full dose of P₂O₅ and K₂O should be applied as basal before sowing.
- Nitrogen is the most important in maize production but it faces losses of leaching, volatilization and fixation results in lower use efficiency. So, studies on N

scheduling in maize were carried out at Delhi, Karnal, Pantnagar, Udaipur, Bahraich, Chhindwara and Srinagar. Results show that the application of N in 5-split (20% Basal, 25% V₄, 30% V₈, 20% V_T and 5% GF) resulted significantly higher yield of QPM, sweet corn and pop corn over to 3-splits (33% at basal, 33% at V₈ and 33% at V_T) at Srinagar. However, the degree of yield increase varied across locations (2.5 to 22%) being lowest at Karnal and highest at Arbhavi. So, this can be used as strategy for enhancing N-use efficiency.

- Apply rest 80% N in four splits as top dressing in following proportions:

Crop Stage	Nitrogen rate (%)
V ₄ (four leaf stage)	25
V ₈ (eight leaf stage)	30
V _T (tasseling stage)	20
GF (grain filling stage)	5

- The top dressing may be done in two equal splits for rest 66% N under rainfed conditions at around knee high and tasseling stage of the crop according to the moisture availability in the field.

Integrated nutrient management (INM): The application of the organic manure enhances soil fertility and improves water retention besides supplying vital macro and micronutrient for crop growth. All type of maize respond well to organic manuring and it is recommended to apply 10 to 15 tonnes/ha of organic manures before planting of crop will enhance maize productivity and profitability. This is very much

necessary for seed production plots as inbred are lesser nutrient efficient with weak root system.

INM is the best way of utilization of the farm waste and the enhancement in fertilizer nutrient-use efficiency apart from providing good soil health. Studies on INM in quality protein maize (QPM) and other specialty corn (Baby Corn and Sweet Corn) were conducted at various locations involving varying levels of organic and inorganic sources of nutrients. Integration of FYM and 100 to 125% recommended doses on nutrients through chemical fertilizers resulted in significantly higher yields of QPM, Baby Corn and Sweet Corn almost at all the locations. Application of FYM @ 6 tonnes/ha resulted in 3 to 20% higher grain yield of QPM at different locations.

Biofertilizers: The seed treatment with *Azotobacter/Azospirillum* @ 600 g/ha found beneficial in maize production. When biofertilizer alone or cocktail is used for seed treatment in maize and soil application, 10 to 15% reduction in the total N is recommended.

Micronutrient application: Zinc is the major limiting factor for maize production in our country and 25 kg/ha zinc sulphate is recommended as basal application for higher maize productivity. Beside this, maize crop also respond to sulphur application @ 30 kg/ha and boron application @ 1.5 kg/ha in deficient soils.

Slow release fertilizers: The one time or split application strategies of the fertilizers like neem/sulphur coated urea are having potential for decreasing the labour cost incurred in fertilizer application. Further these products will help greatly under zero-till maize cultivation as portion of the split applied urea remained on the surface of the residue which may volatilize or immobilised. An improvement of 18% in the agronomic nitrogen-use efficiency was found with application of sulphur coated urea over prilled urea application.

Precision nutrient management: There is huge variation in Indian soil with respect to the nutrient various nutrients content and the respond to

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varied fertilizer application. The 4R principles of applying right nutrient source, at right rate, at right time and at right place is expected to increase nutrient use efficiency, productivity and farm profit from maize production and provides opportunity for better environmental soundness.

In-season N application adjustments of maize can be done using leaf colour charts (LCC), SPAD and Green-Seeker sensors. The N requirement of crops at initial growth stage (V3 in maize) is comparatively less. It has been well established that maize begins to rapidly take up N after V6, with the maximum rate of uptake occurring near silking and the diagnostic techniques to monitor crop N status, such as the chlorophyll meter (SPAD-502), were found to be good for N management. As a in-season crop N management strategies, skipping basal application and application of nitrogen as per critical SPAD values was found beneficial for improving

crop productivity.

The trails on site-specific nutrient management (SSNM) in two major maize systems i.e. maize-wheat at eight locations (Delhi, Bajaura, Udhampur, Dholi, Ludhiana, Pantnagar, Banswara and Ranchi) and rice-maize at three locations (Jorhat, Banswara, Hyderabad) were conducted in two consecutive *kharif* season. Significantly higher yield of maize was recorded under SSNM compared to state recommendations almost at all the locations. So, the SSNM can be adopted instead of blanket recommendation of nutrients for higher resource-use efficiency. In this connection a farmer and extension worker friendly tool 'Nutrient Expert on Hybrid Maize™' is being developed by International Plant Nutrition Institute which is going under validation through AICRP on Maize. It gives recommendation of the nutrient for field specific in absence or presence of the data on soil nutrient

availability. This software of nutrient expert can be free access from <http://seap.ipni.net>.

SUMMARY

Maize was traditionally grown as subsistence crop in rainfed ecologies till 2000 and hence there exist large management yield gaps in which large proportion was contributed by imbalance and inappropriate plant nutrition with multiple nutrient deficiencies. After 2005, maize grew at very faster rate in terms of area expansion in non-traditional assured ecologies replacing less remunerative crop due to higher productivity. In this context, for enhancing and sustaining higher maize productivity and profitability will be based on balanced adequate fertilization in maize systems using all available organic and inorganic sources with proper crop rotations and timing of application.

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