

6. Fertilizer Management

6.1 Balanced use of fertilizers

We are increasingly forced to meet up growing food needs from increases in yield from existing or even from shrinking land areas. In this process, we are moving away from the traditional and rather static “soil dependent” agriculture to a dynamic “fertilizer dependent” agriculture.

In a fertilizer dependent agriculture “balanced fertilization” is cornerstone of all activities. Balanced use of fertilizer should aim at:

- increasing crop yields
- increasing crop quality
- increasing farm income
- correction of inherent soil nutrient deficiencies
- improving soil fertility
- avoiding damage to the environment
- restoring fertility and productivity of land

In principle, balanced fertilization (regardless of fertilizer sources) is indispensable to avoid crop yield decline on cultivated land and to supplement nutrient loss from the soil ecosystem. Balanced fertilization ensures high productivity in accordance with nutrient demand by individual crops and for individual nutrient elements without causing harm to the environment.

Unbalanced fertilizer use at the expense of inherent soil fertility practices represent ‘soil mining’ as against ‘soil building’ that results from balanced fertilization. Only ‘soil building’ leads to a sustainable land use system in a world where most grains in food production must continue to come from existing agricultural land.

6.2 Efficient use of fertilizers

Fertilizer plays a crucial role in yield increase and is responsible for about 50 percent of the total production.

Nutrient use efficiency

Farmers are mostly concerned with the total profit and the marginal benefit-cost ratio from investment in fertilizers and soil conservation measures. The most relevant measure of nutrient use efficiency is, therefore, the partial factor productivity from investment in applied nutrients. The partial factor productivity from applied nutrients (PFP) is the ratio of grain yield to the quantity of applied nutrients.

Agronomic Efficiency (AE)

It represents the marginal benefit from investment in nutrient inputs.

The formula for AE is:

where, $AE = \frac{GY_{NA} - GY_{NO}}{N_R}$

AE = Agronomic efficiency

GY_{NA} = Grain yield (kg/ha) with addition of nutrient

GY_{NO} = Grain yield (kg/ha) without addition of nutrient

N_R = Rate of added nutrient (kg/ha)

Recovery efficiency (RE)

Crop management practices in general and nutrient management practices in particular have the greatest impact on the RE from applied nutrients. For example, competition from weeds, poor control of water, plant disease or insect damage can reduce the uptake of applied nutrients. Thus, improved crop management per se, including use of the best adapted variety, helps to maximize the RE from applied nutrients.

Physiological efficiency (PE)

Physiological efficiency (PE) represents the ability of a plant to transform a given amount of acquired nutrient into economic yield. For cereals, economic yield is grain yield. There are significant difference in PEs among genotypes. Most of the variations is associated with differences in harvest index (HI) which is the ratio of grain yield to total plant biomass, for example, traditional rice varieties typically have an HI of 0.33 while modern high yielding semidwarf rice varieties (MV) have an HI of 0.5. Therefore, with an equivalent quantity of N uptake and total biomass production MV will have greater PE than the traditional variety.

Deep placement of N fertilizers

Deep-placed N is in a chemically available form (NH_4^+ -N) in the proximity of the placement site. Uptake of deep-placed N can be elongated by placing the USG at lower depths and away from the plant. With USG, recovery of deep placed N in wetland rice is greater than the N recovery from surface applied and/or incorporated ordinary urea. The apparent recoveries of fertilizer N in the plant are 75% in the dry season and 85% in the wet season. Fertilizer recovery in the wetland rice plant tops is found significantly higher for deep placed as USG/UMG/ ^{15}N (50-60%) than for split – applied Urea ^{15}N (25-34%). About 40% nitrogen can be saved by using USG or UMG in rice and 20% in vegetable and fruit crops (viz. cabbage, cauliflower, tomato, potato and papaya).

Urea Super Granules (USG) and Urea Mega Granules (UMG) are used to increase nitrogen use efficiency. Urea Super Granules (USG) are small (0.9 g) and Urea Mega Granules (UMG) are large sized (1.8 or 2.7 g) pellets made of ordinary prilled/granular urea by compressing. The amount of USG or UMG should be adjusted to the recommended dose of N for different crops and soils. The granules (USG/UMG) need to be placed after 5-7 days of transplanting at 8-10 cm soil depth at the centre of every four hills between rows 1 and 2, between rows 3 and 4, and so on.

The main benefit of USG/UMG placement is that N losses through NH_3 volatilization, nitrification, denitrification and runoff are significantly minimized. Deep-placed N as

USG/UMG is less subject to algal immobilization and uptake by aquatic weeds than broadcast and/or incorporated urea. These two factors contribute to the improved nitrogen use efficiency (NUE=60%) of USG/UMG in the wetland rice.

6.3 Rationale

Fertilizers behave differently in the soil-plant system. Some fertilizers, namely those of P, S and Zn have considerable residual effect and only a fraction of the total applied amount is recovered by a single crop. In such cases, application of fertilizer in full dose at each crop is not economical. In view of this, as well as major variations in soil characteristics, the following points should be considered for making cropping pattern based fertilizer recommendations.

- i) Moderate yield goal has been assumed to be 75-85% of the high yield goal. In rainfed condition, the yield reduction would be 15% for rice & jute, 20% for potato & sugarcane, and 35% reduction for wheat, tobacco, oilseed, vegetables and spices.
- ii) As a source of nitrogenous fertilizer, urea is unstable and leaves very little or no residue in soil. Each crop, therefore, needs to be supplied with this fertilizer as per requirement. In a crop following a good green manuring crop, N dose may be reduced by 25-30 kg/ha provided 12-15 tons green biomass of GM (dhaincha) is incorporated, and in case of stover incorporation of grain legume, dose of N may be reduced by 8-10 kg/ha.
- iii) Availability of phosphorus is low at both low and high soil pH. Phosphorus recovery is usually very low (15-25%) and has considerable residual effect. Thus, the P rates for the second and third crops would be reduced by 40-50% for rice & jute, and by 30-40% for maize, vegetables, spices & pulses under moderately acid to slightly alkaline soil conditions. Such reduction would be 30-40% for rice & jute and no reduction for maize, vegetables, spices & pulses in strongly acid and calcareous soils.
- iv) Availability of potassium is high in soil with high K-bearing minerals. Generally, K supplying ability of light textured, terrace and piedmont soils are low. Again, the K requirement of crops, particularly rice, tuber crops, jute, sugarcane, many fruits, vegetables and spices are high. On the other hand, crop residues are not being recycled in the field. Consequently, most intensive cropped areas show a large K mining (130-165 kg K/ha/yr) which is about 80% of total nutrient mining (175-215 kg of N+P+K+S /ha/yr). Recently National Agricultural Policy (NAP) highlighted this large K mining and its possible measures. The following principles/rationales need to be followed in making potassium recommendation in crops and cropping patterns.
 - Response of crops to added K fertilizer is not clear in many cases, potassium application should be considered as maintenance dose even at optimum level of soil K.
 - Potassium application can be reduced by 30-40% in the subsequent crops after potato, maize, tobacco, sugarcane, vegetables and spices when high doses of K fertilizer are used.

- The K does may be reduced by 20-40% in subsequent crops if 2-4 ton of crop residues/rice straw per hectare are properly recycled with soils.
 - Since release of K is high in kharif season due to high temperature, potassium application may be reduced by about 10-15% of recommended dose.
- v) Sulphur availability is high under upland culture and low under wetland rice culture. The element has substantial residual effect. Crops grown under wetland condition should receive full dose of S. Upland crops (except oil seed, maize vegetables and spices) following wet condition (kharif-II season) may receive 50% of the recommended S dose. For oil seed, maize, vegetables and spices crops the full dose of S application is recommended.
- vi) Zinc availability is low in calcareous and wetland rice soils. Zinc should be applied to both rabi and kharif crops when grown in calcareous soils (AEZs 10, 11, 12, & 13). For 2 or 3 rice-rice cropping patterns, full amount of Zn needs to be applied to the 1st crop and 50% rate to the 2nd or 3rd crop. In non-rice- rice cropping pattern (except maize, potato, vegetables and spices) Zn should be supplied to rice crop only. For growing maize, potato, vegetables and spices, Zn needs to be added to a full rate.
- vii) In the cropping patterns where rabi is a fallow period, full recommended dose of nutrients should be applied to the kharif-I crop.
- viii) If organic sources (cowdung, FYM, poultry manure, pressmud, compost etc.) of nutrients except GM/grain legumes are used in the cultivation of field crops, certain quantity of fertilizer nutrients can be reduced from the recommended rates as per Appendix-5.
- ix) If bio-fertilizer (inoculum) is used in a leguminous crop, nitrogen fertilizer is not needed. One kg bio-fertilizer per hectare is enough for these crops.
- x) If two full layers of azolla are incorporated in rice field particularly in Boro, about 25-30 kg N/ha may be supplemented.
- ix) For rainfed condition, all the recommended fertilizer nutrients (i.e. N, P, K, S, etc.) should be reduced by 25-30% in comparison with irrigated condition

6.4 Time and methods of fertilizer application

Fertilizer efficiency depends to a great extent, on the time and method of application. This is particularly important in case of nitrogen fertilizers which are highly water soluble and are easily lost from soil in various ways. In certain situations, as much as 70% of the applied nitrogen may be lost from the soil, and thus, become unavailable to the crop. Fertilizers are now a very costly input. Therefore, efforts should be made to increase the efficiency of applied fertilizers.

In applying fertilizers, the following general principles should be kept in mind.

- i) Fertilizers should not be applied too close to seeds, young roots and stems of herbaceous plants

- ii) Fertilizers should not fall on leaves when they are young and wet.
- iii) Fertilizers should be mixed with the soil thoroughly as much as possible.
- iv) Urea should not be applied on high standing water.
- v) Zinc and phosphate fertilizers should not be applied together.
- vi) Organic manure/ fertilizers should be applied at least 15-20 days before planting/sowing and mixed thoroughly with the soil.
- vii) Rice should be transplanted immediately after incorporation of green manure
- viii) Foliar spray is good for trace elements, particularly for horticultural crops.

Methods of fertilizer application

For efficient use of fertilizers, an appropriate method of fertilizer application is very important. There are three methods of fertilizer application: broadcast, localized application and foliar spray. Broadcast method is most commonly used in field crops and the localized method is widely followed in horticultural crops.

In order to increase the efficiency of fertilizers, the following general guideline need to be followed.

- i) During rabi season, if there is no facility for irrigation, the full dose of urea should be applied and mixed with the soil during final land preparation.
- ii) If irrigation facility exists during rabi season, urea should be applied in 3 splits: basal (applied during final land preparation), rapid vegetative growth stage, and 5-7 days before primordial initiation.
- iii) In case of rice (except B. Aman rice), urea should be applied in three equal splits. In transplanted rice culture, the first installment of urea may be applied at final land preparation or immediately after seedling establishment and incorporated with soil through last puddling in a saturated field or first weeding and in case of broadcast rice culture, the first installment should be added before initiation of tillering and incorporated with soil along with weeding. The second installment of urea should be top dressed at rapid tillering and incorporated with soil along with the second weeding and the third installment should be applied 5-7 days before panicle initiation in saturated soil or soil with minimum standing water.
- iv) For vegetables, 2-3 split applications of urea should be adjusted with the growth periods of the crop. For short duration crops the full dose of urea may be applied during final land preparation.
- v) For most spices, urea application may be made in 2-3 splits.
- vi) The benefit of top-dressed urea application is best realized when the fertilizer is applied in late afternoon to the moist or just saturated soil and mixed thoroughly with the soil except at panicle initiation stage.
- vii) Phosphate fertilizer should be applied during ploughing, 1-2 days prior to final land preparation and zinc fertilizer should be applied during final land preparation.

- viii) The full doses of potassium and sulphur fertilizers should be applied during final land preparation. However, in coarse-textured soils, the potassium fertilizer may be applied in two splits: the first one-half at final land preparation and the second one-half at rapid tillering stage with the second application of urea.
- ix) For tobacco and onion crops, instead of KCl(MOP) K_2SO_4 should be applied.
- x) Sulphur and zinc fertilizers may be top dressed if necessary, especially if the recommended doses of these fertilizers have not been applied basally. Yellowing of younger leaves of the plants in spite of timely urea application indicates sulphur deficiency. In such cases, the recommended dose of sulphur fertilizer should be top dressed in full as soon as possible. Whitening of the younger leaves (progressively from the base of the leaf to the tip) followed by tiny brown spots points is the symptom of zinc deficiency. The full dose of zinc fertilizer should be top dressed immediately.
- xi) The method of application of fertilizer to an intercrop is the same as practiced for the particular sole crop.

Foliar application of fertilizers

Plants may absorb fertilizers directly when applied to their foliage as aqueous solution. This method can be used for any plant nutrient, but commonly employed in case of micronutrients which are required in relatively small amount. Foliar sprays should be done before dusk. On cloudy days, any time of the day is appropriate. Each species of plant has a maximum limit of tolerance of concentration of a particular dissolved fertilizer. The most commonly used chemical forms in which different nutrients are applied in the foliar method and the ranges of concentration are given below:

Nutrient	Chemical forms	Concentration(g//100 liter)
Iron	Ferrous sulphate	250-350
Manganese	Manganese sulphate	250-500
Zinc	Zinc sulphate	250-600
Copper	Copper sulphate	250-600
Boron	Solubor	250-600
Molybdenum	Sodium molybdate	30-60

6.5 Fertilizer management in multiple cropping

Multiple cropping is an important component to minimize risks and increase agricultural production. The philosophy of multiple cropping is maximizing crop production/unit areas of land with minimum soil deterioration and this philosophy is based on the modern concepts of soil management. As an approach towards planning of resources, existing as well as new ones, multiple cropping is a time dimension land use effort within a calendar year through repeated cropping. It is labour intensive highly productive cropping practices can lead not only to increased production and greater income but also to a more equitable distribution of income and an opportunity for diversified agriculture. Small land holders especially with limited land but high available labour resources can benefit from multiple cropping.

For intercrops fertilizer recommendations are made on the basis of the intercrop plant population in the field. Usually half or one-third of the recommended rates of fertilizers for a particular crop is recommended depending upon the number of rows, i.e. plant population of the crop. Fertilizer recommendations for different mixed and intercropping systems are given in the chapter 10.4 of this guide.

6.6 Fertilizer management in no-tillage/minimum tillage

No tillage may be defined as the introduction of seed into unploughed soil in narrow slots, trenches or bands of sufficient width and depth for seed coverage and soil contact. Minimum tillage refers to the introduction of seeds into least disturbed soil usually in furrows or with one to two ploughings followed by one disking/laddering.

In Bangladesh no-tillage/minimum tillage is generally practiced in potato and maize cultivation in low lying areas after recession of flood water, wheat cultivation just after T. Aman rice harvest, by relaying grass pea, mustard and wheat in standing T. Aman rice field. Soil moisture is one of the major constraints for crop production in Bangladesh in the winter. Minimum tillage can help achieve this objective since it conserves soil moisture. It has also the potential to reduce the turn around time between rice and winter crop and may thus allow planting in optimum time.

Nutrient requirement of crops grown under minimum/no-tillage is not greatly changed as compared to conventional tillage. However, there are changes and most of these arise from the fact that there is less disturbance of the soil. The extent of change is determined by the degree of reduction in tillage, amount of residue returned to the soil surface and length of the tie tillage system.

Mineralization, denitrification and leaching of N change with tillage. Nitrogen mineralization rate tends to be lower because the soil is not as greatly disturbed and the organic residues remain on the surface where decomposition is slower. Hence, there is usually less nitrate in the soil in unfertilized soil under no-tillage as compared to similar conventionally tilled soil. Since, nitrogen in the systems tends to be less available under no tillage. It has been found that delaying the application of nitrogen under no-tillage helps avoid early losses due to denitrification and leaching.

Phosphorus requirement of crops grown under minimum/no-tillage is very similar to conventional tillage. Minimum tillage affects soil temperature, soil water content and fertilizer placement. Under mulched surface, the mean temperature is lower than a soil that has been disturbed by conventional tillage. When this mean temperature is below the critical temperature for seedling growth and development, the uptake of P will be inhibited. The amount of P uptake depends mainly on the diffusion of this element. Diffusion of P increases with the soil water content. Therefore, it would be expected that under no-tillage, phosphorus diffusion rate would be higher than in the conventional.

Potassium fertilization in no-tillage systems is not a problem with most soils and climatic conditions. On soils where continuous no-tillage system is practiced, samples for soil tests should be taken from the upper 0-10 cm soil depth to better represent the available fertility. With

this adjustment recommendation for no-tillage corn (as with phosphorus) is similar to those made for conventional tillage.

6.7 Fertilizer management in problem soils

A problem soil is one in which certain unfavorable conditions restrict the growth of plants making crop production difficult and sometimes impossible. Special management practices need to be done for producing crops economically in such soils. In Bangladesh there are different types of problem soils occurring in various agro-ecological zones. A brief account of each of them is furnished below.

Saline soils

Saline soils have a high content of soluble salts. The EC value of saturated extract is more than 4 ds/m at 25⁰C, ESP value is less than 15 and the pH value is below 8.5. It is also called white alkali soils. The soluble salts are mostly chlorides and sulphates of Na, Ca and Mg.

Soil salinity develops in various ways: continuous accumulation of salts from tidal floodings, upstream withdrawal of the Ganges water, cyclone and tidal charges, shrimp cultivation and irrigation of saline groundwater. The saline soils exist in an area of about 1.0 million ha which occur in the districts of Khulna, Satkhira, Bagerhat, Borguna, Pirojpur, Cox's Bazar, Patuakhali, Bhola, Noakhali, Feni, Laxmipur and Chittagong. The salinity starts to increase from the month of December and reached its peak in March/April.

The crop production constraints include: reduction in absorption of water and nutrients due to high osmotic pressure, poor soil structure and damage of young plants due to salinity. Shallow rooted crops are more affected. The fertility status of this soil including organic matter content is generally low. Among the nutrients, the N, P and Zn contents of soil are especially low. Both cropping intensity and crop yield are low, cropping intensity being an average 60% and rice yield (mainly local Aman) 1.5 t/ha only. Barley and cotton have considerable salt tolerance. Due to temporal and spatial variation in soil salinity, location specific crop planning is rather important. Wheat, maize, potato, mustard, linseed and groundnut can be grown in low saline areas.

Acid sulphate soils

The potential of the acid sulphate soils for crop production is severely limited by some environmental factors like saline tidal flooding, tidal bores and probability of cyclonic storms. The soil pH is generally below 3.5. Its extent is about 0.23 million ha, occurring in Chittagong, Cox's Bazar, Khulna and Satkhira. In Chittagong, this soil is known as "Kosh" Soils.

These soils can be utilized for mangrove forest, salt production and shrimp culture. If protection from tidal flooding through embankment is possible T. Aman rice can be cultivated. Deficiency of P and toxicity of Fe and Al are a major constraint for crop cultivation.

Peat soils

These soils occur in about 0.13 million ha of land. They occur extensively in the Gopalganj – Khulna Bils, locally in some haors of the eastern Surma – Kushiyara Floodplain in Sylhet Basin and on the adjoining Northern and Eastern Piedmont plains. Organic matter may occupy up to

40 cm depth. Dark brown muck is the common constituent of the soil. Under wet conditions, these soils are near neutral in reaction and become acidic when drained. Some peat soils might be suitable for boro rice cultivation. The limitations for crop production include deep flooding, wetness throughout the year, low bearing capacity and poor availability of K, Zn and Cu.

Waterlogged soils

Inundation of land for long periods is harmful even for wetland crops, especially if the standing water is stagnant. Waterlogging restricts aeration of the soil creating an oxygen-free environment in the root zone. Under such conditions, activities of most of the useful microorganisms is hampered and the availability of S and Zn is reduced. Waterlogging also promotes the formation of gases like methane, H_2S etc. which pollute the atmosphere. Continuous inundation even in wetland rice culture should be avoided. The soil should be allowed to dry between two wetland rice crops. For the reason mentioned above, wetland rice is likely to respond to S and Zn fertilizers even in soils that are rich in these nutrients.

6.8 Fertilizer management in hill farming

Soil erosion is a serious problem in the slopping lands of the hilly areas. Erosion removes the fertile top soil and makes the root zone of the soil narrow. This creates the problem of nutrient deficiency, and water stress during the rain free periods. Clean cultivation should not be practiced in such soils especially when the slope is more than 45 degrees. Jhum cultivation should be discouraged. Erosion can be reduced by special practices like terracing, contour planting and stubble mulching. Steep slopes should better be left under perennial plants and permanent cover.

6.9 Liming

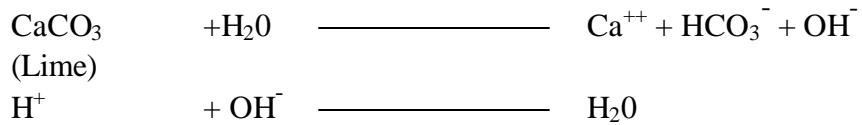
Soil acidity is largely controlled by ion exchange and other adsorptive reactions. The inorganic substances that cause acidity are the aluminosilicate clays, hydrous oxides of iron and aluminium, exchangeable aluminium, soluble salts and carbon dioxide. Al³⁺ ions on the surface of the clay can also generate acidity (H^+).

The organic substances have humus which contains reactive carboxylic and phenolic groups that behave as weak acid. Soil acidity develops during the decompositions of organic matter in peat soils. Uses of high rate of nitrogenous fertilizer result soil acidity. Nitrification contributes to soil acidification through the production of hydrogen ions.

Consideration of soil acidity or alkalinity is important because these conditions exert strong influences on root development as well as activity of soil bacteria and fungi, symbiotic nitrogen fixation by legumes and availability of a wide range of nutrients including phosphorous, iron, zinc, boron, manganese and copper.

Lime (calcium carbonate, calcium oxide, calcium hydroxide, magnesium carbonate, dolomite etc) reduces soil acidity by reacting primarily with the reserve acidity that results from hydrogen

and aluminium ions adsorbed on colloidal surfaces. The following illustration demonstrates the reaction between lime and soil acidity.



Calcium carbonate is dissolved in water forming a calcium ion, a bicarbonate ion and a hydroxyl ion. The Ca⁺⁺ ion is adsorbed by the soil colloids, replacing two hydrogen ions (H⁺) from the reserve acidity on the colloid. The hydrogen ions react with hydroxyl ions (OH⁻) from the calcium carbonate and bicarbonate producing water plus some carbon dioxide. Subsequently the amount of reserve acidity (which is in equilibrium with the soil pH) is reduced and soil pH is increased.

Except some Gangetic alluvial soils, all soils of Bangladesh are acidic to neutral in nature. The pH range for these acidic soils is around 4 to 7. Only when free acids are present, pH value may go below 4.

The amount of liming necessary to neutralize reserve acidity of a soil is determined depending on the soil pH, organic matter and clay contents

The most common liming agents are calcitic limestone (calcium carbonate) and dolomite. Dolomite is a mixture of calcium carbonate and magnesium carbonate and can also serve as a good source of magnesium as well. The rate of dolomite application would be 3-5, 2-3 and 1-2 t/ha for soils having pH 3.5-4.5, 4.5-5.5 and 5.5-6.5, respectively