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Bhupendra Kumar
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

P Kumari
Institute of Animal Health and Production, Kanke, Ranchi, Jharkhand, India

Asha Kumari Sinha
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

Shashi Bhushan Kumar
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

Asisan Minz
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

Kumari Prerna Deep
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

Correspondence
Bhupendra Kumar
Department of Soil Science and Agricultural Chemistry, B. A. U, Ranchi, Jharkhand, India

A review on increasing fertilizer use efficiencies: Problems and their management

Bhupendra Kumar, P Kumari, Asha Kumari Sinha, Shashi Bhushan Kumar, Asisan Minz and Kumari Prerna Deep

Abstract
Acid soils are very prone to the losses of clay particles, nutrient and organic carbon. It is well saturated with sesquioxides. All these factors are greately harmfull to the soil fertility, and use efficiency of the water and nutrient particularly N, P, S and some micronurients. Many researchers have tried well to find out the effects of soil constraints on the efficiency of the nutrients in acid soil. They has also suggested for its remady. Soil test based fertilizer application is highly beneficial for enhancing use efficieny of the nutrient and keeps the resource healthy for ever. Other has suggested that liming as well as ample supplementation of the soil organic matter (SOM) more beneficial and sustainable not only to the soil but also for crop and environment. These two inputst increases nutrient use efficiency very much. Liming is beneficial for quick resolution of the soil acidity whereas SOM is slowly effective but permanent solution of all the problems associated with the acid soil. Fertilizer use efficiency can be optimized by fertilizer best management like proper rate, time, and place of uses has also been suggested. Various traditional methods such as halting of sheep and other techniques of soil restoration also have been suggested. The highest nutrient use efficiency always occurs at the lower parts of the yield response curve, where fertilizer inputs are the lowest, but effectiveness of fertilizers in increasing crop yields and optimizing farmer profitability should not be sacrificed for the sake of efficiency alone. Nano fertilizers are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. There must be a balance between optimal nutrient use efficiency and optimal crop productivity.

Keywords: organic matter, nutrient use efficiency, acid soil, liming, sesquioxides.

Introduction

Modern agricultural production system is fertilizer based because importance of fertilizer cannot be ignored or in other word it can be said that there is no alternative of fertilizer in achieving such a high yield to meet the economic growth as well as food requirement for present and future. Credit for first green revolution goes to the introduction of chemical fertilizer in India. Presently due to the fertilizer, fertilizer responsive varieties and irrigation facility, death of huger has been eradicated from the country. However, many abuses are presently found to the fertilizer application like, low efficiency, availability, detrimentale effects on natural resources. All these drowbacks of sole use of fertilizer are threatening people. But more discussion among the people about the safety measures of using fertilizer is very essential. Such kind of discussion sould be done continuously and frequently to eradicate the fear about the harmfull effect of the fertilizer. It will also be advantagious for increasing fertilizer cunsumption and achieving higher target of crop production without harming environment soil, water and environment. Low efficiency is the key factor in reducing income to the farmers. Increasing efficiency is concerned to the soil scientist and it is our responsibility. If this problem will be solved cost will be reduced and per unit gain income will be higher. Fertilizers create various kinds of problems if not used properly but, there is a number of solutions that can be used to sustain the resources and go ahead without fear of the future. The topic has been planned to discuss the methods that could be used to solve the above mentioned threats.

For coastal acid sulfate soils of Sundarbans, application of lime, superphosphate and rock phosphate have been found useful **(**Bandyopadhyay, 1989) [4]. Since 1970 in India, there has been significant commercial development using various desalination technologies, including distillation, reverse osmosis and electrolysis **(**Kumar *et al*., 2005). Desalination mostly uses fossil fuels. Many facilities in coastal region are using reverse osmosis for desalinization. For example, at Kalpakkam reactor, Tamil Nadu, 1.8 million liters of water is being produced per day. Installation of one-way sluice gates on the river banks or any other suitable location to drain out excess water from the land during low tides in river, use of subsurface tile drains combined with moling perpendicular to the former **(**Moukhtar *et al*., 2003) [22]**,** and open surface drains along with moling perpendicular to it **(**Abdel-Mawgoud *et al*., 2003) [1] are some of the practices.

There are a number of factors involved in reducing the fertilizer use efficiency in the soil and correction is essential to enhance the soil fertility and productivity. Major problems associated are imbalanced use of fertilizers, Mechanization, avoiding soil testing and amelioration, rapid soil degradation, leaving indiginous technology (ITK), unscientific crop rotation, overgrazing and deforestation, etc. Solutions for all these problems are going to be discussed here in detail.

Balance use of fertilizer: Scientists are involved continuously in motivating to use at least balanced fertilizers to check over or application of any nutrient through field demonstration, publication and other extension methods. But after 70 years of independence Indian farmers are not using balanced nutrient in their field. Covering 100 per cent of the farmer's field under balanced fertilization is a great challenge till today. Imbalanced use of fertilizers is the great problem of soil and water degradation. It's not only detrimental to the soil but unexpectadly affect the fertilizer and water use efficiency in acid soil

Integrated Nutrient Management: The effect of balanced and imbalanced nutrient use on crop yield and availability of plant nutrients over the years is being studied in a *Paleustalf* of Ranchi under long-term permanent manurial trial. The present paper reports the long-term effect of organic manures, fertilizers and lime on secondary and micronutrient status of an acid soil. Results revealed that the yield of maize under the treatments decreased in the order: NPK+lime> FYM+PK > NPK > NP > control > N. Lime application with NPK resulted in significantly higher uptake of P, Ca, Mg, S and B. Imbalanced use of N alone had a depressing effect on soil pH and Ca uptake by maize. The pH of acid soil (5.5) increased by 0.9 units with lime and fertilizer use, while it decreased in unlimed plots. Farmyard manure treated plots had a favourable influence on soil pH and organic carbon content. Application of N, NP and NPK fertilizers did not increase exchangeable Ca status of acid soil. The DTPA-extractable micronutrients in acid soils increased in N, NP and NPK treated plots while a decrease was recorded in limed plots. Liming decreased the DTPA-Cd in soil while FYM increased its content (Singh *et al.*, 2009) [30].

Highest grain yield (17.5 q ha-1) was recorded withthe application of supra-optimal dose of NPK i.e. 150% which was at par with 100%NPK + FYM (16.7 q ha-1) but significantly higher than other treatmentsincluding control(9.4 q ha-1). Application of organics along with chemical fertilizers improved soilphysicalenvironment (water transmission properties i.e. Ks and IR and soil aggregation) and optimized maize productivity (Garg *et. al.*, 2006) [15].

Integrated nutrient management, *i.e.*, the application of NPK mineral fertilizers along with organic manure, increases crop productivity, improves SOC content, and decreases soil loss. In the northwestern hill region, integrated nutrient management improved soil health and SOC storage in all cropping systems. Bhattacharyya *et al.* (2009) [7] observed that about 19% and 25% of gross C input contributed to greater SOC content after 30 years of rainfed or after nine years of irrigated soybean-wheat production, respectively. Annual farmyard manure addition improved labile (movable; short-lived) and long-lived C pools (Bhattacharyya *et al.*, 2011) [8]. In the drylands, Srinivasarao *et al.* (2009) [32] found that integrated nutrient management could improve C accumulation rates up to 0.45 ton $ha^{-1}year^{-1}$ in a groundnut based cropping system. Integrated nutrient management also decreases soil loss. Runoff and soil loss increased with increase in slope from 0.5% to 2.0% at Bellary (Source: CSWCR&TI Annual Report (CSWCR & TI, 2012) [11]. However, in the treatments with application of recommended rate of fertilizer along with farm-yard manure, it was comparatively low.

Soil testing and amelioration: The soil of the state Jharkhand is acidic out of which 10 lac hectares is highly acidic having pH <5.0 (Sakar *et al*., 2000) and without its management better yield and fertilizer response is not possible. Fertilizer response is very poor in those soils. Some of the crops fail 100 per cent if acidity is not managed in time properly as for example cauliflower. In Jharkhand cauliflower cultivation is very popular in vegetable crop. Farmers grow it whole year in this state but its quality and productivity sometimes do not meet to the market choice.

Using fertilizer without soil testing is another problem in reducing nutrient and water use efficiency. What nutrient is below or above the critical limit without soil testing no one can decide. A single nutrient deficiency may affect productivity anourmously. Liming is the most desirable practice for amelioration of acid soils as it raises soil pH and their by which increases nutrients availability to the plant and reduces toxicity of Fe and Al (Sharma and Sarkar, 2005) [29]. Bhat *et al.* (2007) [5] recommended low dose of lime (*i.e.*, one-tenth to one-fifth of lime requirement) applied along with fertilizers in furrows at the time of sowing. Bhat *et al.* (2010) [6] also tested low-cost locally available basic slag, a by-product of a steel factory as an ameliorant for acidic red and lateritic soils of India. Management of saline soils involves tillage, irrigation and leaching. Inversion tillage can decrease potential soluble salt accumulation in the root zone compared to zero tillage (Wilson *et al*., 2000) [34] However, deep tillage may bring more salts to the soil surface and root zone. The most efficient method is through application of high quality irrigation water (low electrical conductivity) and growing of salinity tolerant crops. Tolerant crops also support formation of stable soil aggregates, which help to improve soil tilth. Rice is the potential crop for reclamation of sodic soils.

Reclaiming acid sulfate soils may follow approaches like: (i) pyrite and soil acidity can be removed by leaching after drying and aeration; (ii) pyrite oxidation can be limited or stopped and existing acidity inactivated by maintaining a high water table, with or without (iii) additional liming and fertilization with phosphorus, though liming may often be uneconomical in practical use. For coastal acid sulfate soils of Sundarbans, application of lime, superphosphate and rock phosphate have been found useful (Bandyopadhyay, 1989) [4]. Since 1970 in India, there has been significant commercial development using various desalination technologies, including distillation, reverse osmosis and electrolysis (Kumar *et al.*, 2005) [18]. Desalination mostly uses fossil fuels. Many facilities in coastal region are using reverse osmosis for desalinization. For example, at Kalpakkam reactor, Tamil Nadu, 1.8 million liters of water is being produced per day. Installation of one-way sluice gates on the river banks or any other suitable location to drain out excess water from the land during low tides in river, use of subsurface tile drains combined with moling perpendicular to the former (Moukhtar *et al.,* 2003) [22], and open surface drains along with moling perpendicular to it (Abdel-Mawgoud *et al.,* 2003) [1] are some of the practices.

Right methods for inputs supply: The fertilizer industry supports applying nutrients at the right rate, right time, and in the right place as a best management practice (BMP) for achieving optimum nutrient efficiency.

Most crops are location and season specific depending on cultivar, management practices, climate, etc., and so it is critical that realistic yield goals are established and that nutrients are applied to meet the target yield. Over- or under-application will result in reduced nutrient use efficiency or losses in yield and crop quality. Other techniques, such as omission plots, are proving useful in determining the amount of fertilizer required for attaining a yield target (Witt and Dobermann 2002) [36]. In this method, N, P, and K are applied at sufficiently high rates to ensure that yield is not limited by an insufficient supply of the added nutrients. Target yield can be determined from plots with unlimited NPK.

Greater synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency, especially for N (Johnson *et al.* 1997) [16]. Split applications of N during the growing season, rather than a single, large application prior to planting, are known to be effective in increasing N use efficiency (Cassman *et al.* 2002) [9]. Tissue testing is a wellknown method used to assess N status of growing crops, but other diagnostic tools are also available. Chlorophyll meters have proven useful in fine-tuning in-season N management (Francis and Piekielek 1999) [14], and leaf color charts have been highly successful in guiding split N applications in rice and now maize production in Asia (Witt *et al.* 2005) [35]. Precision farming technologies have introduced, and now commercialized, on-the-go N sensors that can be coupled with variable rate fertilizer applicators to automatically correct crop N deficiencies on a site-specific basis.

Application method has always been critical in ensuring fertilizer nutrients are used efficiently. Determining the right placement is as important as determining the right application rate. Numerous placements are available, but most generally involve surface or subsurface applications before or after planting. Prior to planting, nutrients can be broadcast (i.e., applied uniformly on the soil surface and may or may not be incorporated), applied as a band on the surface, or applied as a subsurface band, usually 5–20 cm deep. Applied at planting, nutrients can be banded with the seed, below the seed, or below and to the side of the seed. After planting, application is usually restricted to N and placement can be as a topdress or a subsurface sidedress. In general, nutrient recovery efficiency tends to be higher with banded applications because less contact with the soil lessens the opportunity for nutrient loss due to leaching or fixation reactions. Placement decisions depend on the crop and soil conditions, which interact to influence nutrient uptake and availability.

Crop use nutrient in solution form therefore sufficient soulte is essential for proper fertilizer use. Platnt use maximumum nutrients during the maximum physiological growth stages. If water is not provided quickly and sufficiently at this stage plant suffer greately and do not use pportunities exist for improving irrigation systems to allow site-specific application of water and nutrients across a field. This improvement would result in microzones that could be independently controlled to allow spatially appropriate application of water, meeting any specific crop or soil condition (Evans *et al.,* 2013) [13]. Delivering a site-specific volume of water through an irrigation system is relatively simple by opening and closing valves. This practice can be done electronically, or field workers can make manual changes. Controlled delivery of nutrients with water is a larger challenge since it involves injecting fertilizer during the irrigation event (Coates *et al.,* 2012) [10]. Separate systems for water and nutrient delivery may be required to achieve independent control of each input. It is clear that large-scale improvements in the use of water and plant nutrients can be made for crop production with more careful management. Any improvements in water use efficiency for irrigated agriculture must be simultaneously coupled with advances in nutrient management. There are many examples of how these improvements can be implemented in irrigated crop production, but they all require a greater level of education and significant improvements in crop management skills. The outreach by local and regional experts on water and nutrient management can speed the adoption of these important concepts to achieve these pressing goals.

Quality and quantity improvement of composts: Quality compost is not available to the farmers. Even the locally available compost is not sufficiently available to the soil to maintain their good health. The gap between need and accessibility of the farmer is very wide and increasing year by year due to the machanization cost involved in cattle management. Commercial cattle manegement by the farmers as well as by the private farm are using enriched feeds, medicines and hormones that are harmfull to the soil and the environment.

Crop rotation: Improper crop rotation coupled with lack of proper soil and water conservation measures are important reasons contributing to soil erosion in lands under cultivation. In addition, cultivation of marginal lands on steep slopes, in shallow or sandy soils, with laterite crusts, and in arid or semi-arid regions bordering deserts has resulted in land degradation. Agricultural production in marginal areas with low SOM due to unsuitable cropping patterns has been the major cause of accelerated wind and water erosion. Wind erosion is a serious problem in arid and semi-arid regions, in coastal areas with sandy soils, and in the cold desert regions of Leh in the extreme north of India.

Managing soil degradation and loss: The severity and extent of soil degradation in the country has been previously assessed by many agencies. According to the survey data of National Bureau of Soil Survey and Land Use Planning about 146.8 Mha is land found to be degraded, (NBSS & LUP, 2004) [23]. Water erosion is the most serious degradation problem in India, resulting in loss of topsoil and terrain deformation. Based on first approximation analysis of existing soil loss data, the average soil erosion rate was 16.4 ton ha^{-1} $year^{-1}$, resulting in an annual total soil loss of 5.3 billion tons throughout the country (Dhruvanarayan and Ram, 1983) [12].

Overgrazing and deforestation have caused degradation in eight Indian states which now have >20% wasteland (NRSA, 2000). Loss of vegetation occurs due to cutting beyond the silviculturally permissible limit, unsustainable fuelwood and fodder extraction, encroachment by agriculture into forest lands, forest fires and overgrazing, all of which subject the land to degradation forces. A cattle population of 467 million grazes on 11 Mha of pastures, implying an average of 42 head per hectare of land compared to a sustainable threshold level of 5 animals per hectare (Sahay, 2015) [26].

High livestock density in arid region causes overgrazing and resulting in decreased infiltration and accelerated runoff and soil erosion. Due to overgrazing, soil loss is 5 to 41 times greater than normal at the mesoscale and 3 to 18 times greater at the macroscale (Sharma, K.D. 1997) [28]. Tendency of cultivation on slopes in the 1990s led to deforestation and land degradation (MoEF, 1999) [21].

To meet the future need of food are of cultivation should be increaesed but due to fast expantion of in urbon and industrial areas, road way, rail way, etc. is reducing the cultivated area day by day. Therefore productivity of the soil needs to be increase enoumously and it is a great challenge.

Optimum cattle population per hectare cultivable land: Mechanization is advantageous for reducing cost, time and getting higher crop production but, it may create inaccessibility of the manure due to the reduction in the cattle population. The gap between demand and availability of the manure is very high. Traditionally all the agricultural operations by the Indian farmers were being done through chattels like ploughing, threshing, crushing, transportation, etc. therefore, people had great importance of cattle in their life. Each of the farmer was keeping at least one bull and at that time bulls were more valuable for the farmers as compared to the milk animal. The population of cattle decreased by 3.14%, Yaks by 8.15%, Sheep by 8.37%, Goat by 3.18%, Donkeys by 28.09%, and Camels by 22.09% in rural areas within last decade (All India Report, Livestock Census-2012). In the states like Panjab, Haryana and UP farms are fully mechanized and producing huge mass of the crop residues but due to the less cattle population to consume it creating disposal problem thus, farmers are forced to burn it on their farm. In such situation organic wastes are not being converted to the valuable compost. On the other hand residue burning is creating pollution seriously to the cities by their smokes.

Cattle population must be fixed according to the land area or carbon trading rule should be made so that afarmer who are not able to keep cattle must procure organic sources from the other farmer to meet the requirement. The suggestion cited above para of this chapter may also be helfull for such kind of farmers. Other improvement techniques like green manuring, Azolla cultivation, vermicompoding, etc. can be done by the farmers at their own farm which requres very less area and cost.

Promotion and protection of the mobile shepherd (as ITK): During the past shephered population was higher. They were moving place to place to graze their shees and the farmers were allowing them to halt their sheep on their land by paying some amount to the shephered. It was a great technique to sustain the soil fertility but presently it is not happening due to various constraints. Thus it is very essential to attract the attention of the authority, agencies and environmentalists over this point.

One example is the Deccan Plateau region in Maharashtra that spans across numerous dis-tricts and is home to a variety of different human communities. A well known example of a transhumant group is the migratory dhangars who travel large distances with large flocks of sheep and goats (Anonymous. 2007) [3].

The Planning Commission report of 2011, states that India's pastures have reduced from 70 million ha in 1947 to 38 million ha in 1997. Furthermore, grazing lands are also planted with invasive species which cannot be eaten by the livestock thereby decreasing the productivity of the lands. Despite focus by the MOEF and recommendations by the Planning Commission and the Grassland Task Force, on ground there is no concerted action on grassland management (Abi Tamim Vanak. 2013) [2].

Recycling of the various kinds of organic wastes: A huge mass of agricultural wastes where farmers are cultivating land commercially is produced and creating problem in their disposal. They are burning vigrously on their farm and increasing pollution as felt recently during 2017 in New Delhi. This practice is also wasting the valuable, recycable and good quality source of carbon and nutrient. If producer use better, cheep and quick transformation technique for compost preparation from it they may add national income as well as able to manage hazards. By this technique the volume will be reduced and transported to the other states. Many other weeds like, ipomia, water hycinth, aquatic weeds, shrubs, Karanj and Neem caked may be utilized for good quality compost preparation.

Inclusion of new technologies: Nano fertilizer, soil and water conservation. Nano fertilizers are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. Nano-fertilizers are very effective for precise nutrient management in precision agriculture with matching the crop growth stage for nutrient and may provide nutrient throughout the crop growth period (Singh *et al.*, 2017) [31].

Nano-fertilizers increase crop growth up to optimum concentrations further increase in concentration may inhibit the crop growth due to the toxicity of nutrient. Nano fertilizer have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer. Fertilizers encapsulated in nano-particles will increase availability and uptake of nutrient to the crop plants (Tarafdar *et al*., 2012) [33]. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizers which leads to more penetration and uptake of the nutrient (Liscano *et al*., 2000) [19].

Soil and water conservation Approach like integrated watershed management, which involves soil and water conservation coupled with suitable crop management, is another excellent strategy for mitigating soil erosion. Development and management of watershed resources to achieve optimum production without causing deterioration in the resources base is integrated watershed management. It involves construction of check dams along gullies, bench terracing, contour bunding, land leveling and planting of grasses. These strategies will increase percolation of water, decrease runoff and improve water availability. Several reviews are available on the performance of watershed development projects (Palanisami *et al.*, 2002, Joy *et al.*, 2005) [25, 17], as well as their limitations.

Conclusion: Increasing the inputs of nutrients has played a major role in increasing the supply of food to a continually growing world population. In contrast, food exports from the developing to the developed world are depleting soils of nutrients in some countries. It will be essential, therefore, to increase the efficiency of nutrient use in all management systems so that nutrients from all sources, i.e. those supplied through the mineralization of SOM, animal excreta and manures as well as fertilizers, are fully taken into account and used efficiently. Much progress can be made by better use of existing knowledge, but continued research and development will be necessary for more efficient plants and animals and nutrient management. Better management of all essential nutrients is required that delivers sustainable agriculture and maintains the necessary increases in food production while minimizing waste, economic loss and environmental impacts. However, for most of the developed world, and in the developing world where an ever-growing population demands more food, it will be essential to increase the efficiency of nutrient use in conventional systems. Sustainable agricultural intensification using innovative farming practices have tremendous potential of increasing productivity and conserving natural resources, particularly by sequestering SOC (both labile and recalcitrant) and improving soil quality. Fertilizer nutrient use efficiency in crop production can be enhanced with effective use of nano-fertilizers. Nano fertilizers improve crop growth and yield up to optimum applied doses and concentration but they also have inhibitory effect on crop plant if concentration is more than the optimum which result reduces growth and yield of the crop.

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