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Are Mineral Fertilizers Panacea for Increase in Crop Yield? Review

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Abstract: *Fertilizers are important in increasing crop yield and many of the increases in world food production are attributed to the judicious application of mineral fertilizers. Among the 18 essential elements, nitrogen, phosphorus and potassium are the major ones and the first two are imported to and used in Ethiopia. Nitrogen is the most limiting nutrient in plant growth. It is a constituent of chlorophyll, plant proteins, and nucleic acids. Phosphorus is essential component of Adenosine triphosphate, deoxyribonucleic acid and ribonucleic acid, whereas potassium is useful in activation of enzymes, photosynthesis, starch synthesis, nitrate reduction and sugar degradation as well as helping plants withstand stresses like drought, winter hardiness, tolerance to diseases, insect pests and frost damage. The other macro and micro nutrients are also important in the various physiological processes of plants. Mineral fertilizers have been responsible for an important share of worldwide improvement in agricultural productivity and fertilizers account for more than half of the increase in yield worldwide. The yield increase recorded in Ethiopia has been attributed mainly to the use of mineral fertilizers together with improved seeds. It is, however, important to note that fertilizers will be effective if other conditions are fulfilled. These factors include soil factors (soil reaction, clay mineralogy and clay content, moisture regime of the soil, impermeable soil layer, soil texture and bulk density and availability of other nutrients in the soil, availability of moisture;climatic factors (temperature, light intensity and length of the day); crop factors (crop adaptability to local conditions, fertilizer requirement, resistance to disease, pests, drought and other stress factors); fertilizer characteristics and management practices (erosion control, land preparation, planting date and practice, weed, and pest and disease management). Crop yield, therefore, can be improved not by application of mineral fertilizers alone but by the combination of genotype (G), optimum environmental condition (E), appropriate management practices (M) and yield = G x E x M.*

Keywords: Crop yield, environment, genotype, management, interaction

1. Introduction

Tremendous population growth, food shortage and malnutrition have been a major challenge in Ethiopia. Hence, the importance of increasing agricultural productivity to secure sufficient food for growing population is obvious (Havlin *et al.*, 2005). One of the major factors responsible for increasing crop yield is judicious application of mineral fertilizers.

Mineral fertilizers are concentrated sources of essential nutrients in a form that is readily available for plant uptake. Since the invention of mineral fertilizers in the 19th century until the 1980s, fertilizer use, improved seeds and planting materials have been the major drivers of improved productivity in agriculture; and increased use of mineral fertilizers has been responsible for an important share of worldwide improvement in agricultural productivity

(Handbook of Integrated Fertility Management, 2012). Fertilizers account for more than 50% of the increase in yield worldwide (FAO, 1984). Yield increase in Ethiopian agriculture has been mainly due to application of mineral fertilizers to different crops (Yesuf and Duga, 2000a; Getachew Alemu, 2001; Amare et al., 2005; Getachew et al., 2007).

Although mineral fertilizers increase crop yield, they have also negative consequences. In some cases, excessive mineral fertilizer use in industrialized countries has resulted in leaching of N and P into water bodies, causing water contamination and eutrophication. Care must be taken, therefore, to avoid the negative effects that accompany excessive fertilizer use. Moreover, application of mineral fertilizers cannot be taken as panacea to boost agricultural production. Increase in crop yield is possible only through the integrated availability of optimum conditions for crop performance besides the judicious application of fertilizers. These include soil factors, climatic factors, crop factors, fertilizer characteristics and management practices (Ignatieff and Page, 1968; Mortvedt at al., 1999). In this paper, a review of the factors that affect efficiency of applied mineral fertilizers is presented.

2. Methodology

This article is based on intensive literature review of published materials like books, articles and other scholarly materials.

3. Results and Discussion

3.1. Role of Mineral Fertilizers in Crop Yield

Mineral fertilizers are substances that are synthesized by fertilizer industries and that carry essential elements required for growth and development of plants. There are 18 essential elements for growth and development of plants (Brady and Weil, 2000). Among these nutrients nitrogen, phosphorus and potassium are the major ones ranking from first to third. Nitrogen is the most limiting nutrient in plant growth. It is a constituent of chlorophyll, plant proteins, and nucleic acids (Brady and Weil, 2000) and useful for vegetative development (Pocock et al., 1988; Scott and Jaffard, 1993; Yihenew, 2007). However, nitrogen is believed to be the most frequently deficient nutrient in crop production (Havlin et al., 2005; Yihenew and Suwanarit, 2007). Phosphorus is an essential component of Adenosine triphosphate (ATP), deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) (Brady and Weil, 2000). Potassium is useful in activation of enzymes, photosynthesis, starch synthesis, nitrate reduction and sugar degradation (Askegaard et al., 2004). It is also important in helping plants withstand stresses like drought, winter hardiness, tolerance to diseases, insect pests and frost damage (Brady and Weil, 2000).

Results of several researches conducted in Ethiopia demonstrated that fertilizer applications increased crop yield in Ethiopia. Yesuf and Duga (2000a) reported that judicious application of N increased yield and protein content of wheat at farmers' fields. Phosphorus fertilizer also improved yield of field pea (Amare et al., 2005) and faba bean (Getachew et al., 2007). Wassie Haile (2009) showed that integrated application of NPK fertilizers (at the rate of 110/40/100 kg ha^{-1}, respectively) increased potato yield by 208% over the control. Daniel et al. (2008) emphasized that integrated use of 75% of recommended fertilizer rate along with farmyard manure improved tuber yield of potato by 29.59 ton ha^{-1} over the control. Getachew Alemu (2001) also showed that combined application of N and P significantly improved grain yield and yield components of barley in Welo highlands of Ethiopia. Nevertheless, yield cannot be increased to the maximum unless other conditions are fulfilled (Ignatieff and Page, 1968).

3.2. Other Conditions Determining Efficiency of Mineral Fertilizers

Factors affecting crop response to fertilization can be grouped into five categories. They are soil factors, climatic factors, crop factors, fertilizer characteristics and management practices (Ignatieff and Page, 1968; Mortvedt *at al.,* 1999).

3.2.1. Soil Factors

3.2.1.1. Soil Reaction

Two fundamental features limit the fertility of acid soils: impoverished nutrient status and the presence of toxic levels of some elements such as Al and Mn (Hynes and Naidu, 1991). Nitrogen availability is affected by soil pH. It has been reported that nitrogen is more available at a pH of 6.5 and 5.5 for mineral and organic soils, respectively (Miller and Donahue, 1990). Foth and Ellis (1997) also indicated that nitrogen availability is greatest between pH 6 and 8. Soil reaction has a tremendous effect on the activity and growth of microorganisms involved in mineralization of organic matter, hence it affects the availability of nutrients to plants (Robson and Abbott, 1989). Cornfield (1953) reported that acidification of a neutral soil (pH = 6.5) to pH 4.0 decreased ammonification and almost completely suppressed nitrification. Dancer *et al.* (1973) also has shown that nitrification did not occur when soil pH (1: 2.5, soil: water) was less than 4.1. Moreover, Morrill and Dawson (1960) indicated that the optimum pH values for the growth of *Nitrobacter* and *Nitrosomonas* were greater than 6.6 and 7.6, respectively. Soil acidity has also long been recognized as harmful to symbiotic (Tisdale *et al*., 1985) and non-symbiotic (Granhall, 1981) nitrogen fixation.

Alkaline pH reaction also has a detrimental effect on availability of nitrogen. When ammoniacal nitrogen fertilizers are spread on the surface of the soil with pH values greater than 7, ammonia could be lost by volatilization (Blackmer, 2000; Tisdale *et al*., 1985). It was also reported that absorption of NH_4^+ increases as pH increases (Lumbanranja and Evangelou, 1994), because 2:1 clay minerals dominate at higher pH values.

Soil reaction plays a tremendous role in availability of phosphorus. Phosphorus availability in most soils is at a maximum in the pH range of 6.0 - 6.5 (Hynes and Naidu, 1991). At low pH values, the retention of P results largely from the reaction with iron and aluminum and their hydrous oxides. A study conducted on some Paleudults of Southern Nigeria indicated that phosphate sorption at high P additions generally decreased with the increase in soil pH (Eze and Loganathan, 1990). The continuous decrease in phosphate sorption with increase in pH was due to the increased concentration of hydroxyl ions as pH increased and resulted in greater competition of these ions with phosphate ions for sorption. Ignatieff and Page (1968) indicated that the availability of phosphorus in superphosphate as well as the ability of plant roots to absorb it is lower in acid soils and thus higher applications are needed. In acidic soils, roots appear coralloid with many stubby lateral roots and branching of fine roots is restricted, which limits plants’ ability to absorb water and nutrients (Prasad and Power, 1997).

There is also some evidence to show that phosphate sorption decreased with increase in pH up to 5.0 - 6.0, beyond which it increased. This is related to the availability of Ca and Mg, which forms precipitates (Barrow, 1987; Sims and Ellis, 1983; Tisdale *et al*., 1985). Chen and Barber (1990) also reported that P in soil solution decreased with an increase in pH, which was explained by the formation of calcium phosphate with increase in solution Ca. Chen and Barber (1990) also studied the effect of change in pH by liming acid soils of three soil orders (Mollisols, Ultisols and Oxisols) on soil solution, P concentration, labile P content and P uptake by maize. Results showed that increasing soil pH generally decreased soil solution P concentration and P uptake by the crop but increased labile P for all soils. The decrease in solution P was attributed to the formation of Ca phosphates. High soil pH values of about 7.5 to 8.0 and above favor the conversion of water soluble fertilizer phosphorus into less soluble forms of lower availability to crops (Tisdale *et al*., 1985). Likewise, the availability of P especially in fertilizers containing no water-soluble phosphate is less in calcareous or alkaline soils (Ignatieff and Page, 1968).

Some reports also indicated that liming highly weathered soils above pH approximately 5.0 does not usually lead to increased P solubility although it may lead to increase in P uptake by plants (Fox *et al*., 1991). Similarly, an equilibrium study of Lucedale sandy loam soil (fine loamy, silicious, thermic Rhodic Paleudults) with an initial pH of 5.2 showed that solution P levels increased with liming up to a pH of 5.7 then decreased at pH 6.2 and decreased further at 6.6 if the lime was added before the P (Soltanpour *et al*., 1974).

In general, as soil pH increases from 4, the root and microbial environment changes. Therefore, there is a tendency for plant growth to increase with an increase in soil pH as the factors that limit growth were ameliorated. A plateau yield is reached where further increase in soil pH has little if any effect on plant growth (Foth and Ellis, 1997). The optimum soil pH for crop production is generally considered to be between 6.5 and 7.0 (Prasad and Power, 1997). The results of the experiment designed to investigate the effect of soil pH on maize grain yield on acid Ultisols indicated that grain yield was significantly reduced ($p < 0.05$) when the pH was less than 5.5 (Fox, 1979). Similarly, Pearson (1975) reported that in the humid tropics liming, when the soil pH falls below 5.0 or the Al concentration exceeds 15%, increased maize yields. Foy (1984) also reported that in acid soils toxicities of aluminum and manganese and deficiencies of calcium and molybdenum might be as important as effects of hydrogen ions *per se*. Increasing pH of variable charge soils increases the cation exchange capacity of the soil, precipitates Al that otherwise competes for exchangeable sites (Fox *et al*., 1991).

3.2.1.2. Clay Mineralogy and Clay Content

The clay mineralogy of the soil plays a tremendous role in affecting the availability of nitrogen. Ammonium is fixed between the lattice of 2:1 expanding clays like illite and montmorillonite (Prasad and Power, 1997). Up to 10% of the total N in surface soils and 30% in sub-soils is reported to be adsorbed as NH_4^+ in soil clay minerals in a non-exchangeable (fixed) form (Lumbanranja and Evangelou, 1984).

The more clay content the soil has, the more the CEC and the more the adsorption of NH_4^+ will be (Anon, 1979). Prasad and Power (1997) also reported that most ammonium fixation occurs in the clay fraction of the soil, while some may occur in the silt fraction. Jensen *et al*.

(1989) separated clay and silt fractions of four Danish soils by ultrasonic technique and found that fixed ammonium in the clay fraction it varied from 255 to 430 μg N g^{-1}, while in the silt fraction varied from 72 to 166 μg g^{-1}. Similarly, for a Canadian soil with 37% clay, Kowalenko and Ross (1980) reported ammonium fixation of 35 μg g^{-1} for clay and 8.3 μg g^{-1} for silt.

Owusu-Bennoah and Acquaye (1989) indicated that P sorption maxima of Ghanaian soils was significantly correlated with clay content (r = 0.894), free Fe_2O_3 (r = 0.830) and free Al_2O_3 (r = 0.912) contents. Soils high in clay content and kaolinite clay minerals retain or fix more added P than other soils (Anon, 1979). The presence of amorphous materials such as allophane on the exchange complexes is also often associated with high P-fixation capacities and reduced P use efficiencies (Sanchez, 1976).

3.2.1.3. Moisture Regime of the Soil

The growth of many plants is proportional to the amount of water present in the soil since growth is restricted both at very low and very high levels of soil moisture (Tisdale *et al*., 1985). A very close relationship exists between the continuous availability of soil moisture and the response of a crop to fertilizer applications. If soil moisture becomes a limiting factor during any stage of the growth of a crop, the addition of fertilizer may even adversely affect the yield. This is because, the more vigorous early growth while moisture is available in the soil may cause the limited water supply to be exhausted more rapidly (Ignatieff and Page, 1968).

Nutrients will only be recovered efficiently if the crop has sufficient water. The amount of rainfall captured and made available to crops can be increased in areas that are prone to drought. Most approaches aim to harvest extra water by installing structures that decrease runoff (e.g., the Zaï system used in the Sahel or the use of planting basins in Southern Africa), or by maintaining organic mulch on the soil surface to promote infiltration and reduce evaporation from the soil surface. All such practices require extra resources (Handbook of Integrated Fertility Management, 2012)

Broadbent *et al.* (1988) found that a 10% reduction in applied water, expressed as a percentage of crop’s evapotranspiration requirement by sorghum, decreased dry matter production by 1.6 Mg ha^{-1}, grain yield by 1.9 Mg ha^{-1}, total N uptake by 22 kg ha^{-1} and grain N uptake by 9.3 kg ha^{-1}. Power *et al*. (1961) also reported that 53% of the variation in fertilizer response of spring wheat (*Triticum aestivum* L.) on medium P soils was because of variation in available soil moisture. Tisdale *et al*. (1985) similarly indicated that crop response to fertilizer nitrogen is very dependent on moisture supplies during the growing season. It was observed that increasing nitrogen rates up to 168 kg ha^{-1} under dry land conditions increased rape yield; however, high rates of nitrogen in combination with irrigation resulted in nearly fourfold increase in yield.

Excess moisture also adversely affects plant growth and development. Soils with poor drainage conditions have poor aeration and under such conditions most crops do not grow (Ignatieff and Page, 1968). Anaerobic soil condition has serious effect on the metabolism and growth of sensitive plants. Species intolerant of water logging experience an acceleration of endogenously produced ethanol and acetaldehyde, cell membranes become leaky and ion and water uptake is impaired which has the characteristic symptoms of wilting and yellowing of leaves (White, 1997). Tisdale *et al*. (1985) also reported that flooding of soil pores by excessive amounts of moisture is detrimental since the resultant lack of oxygen restricts root respiration and ion adsorption.

In anaerobic conditions NO_3^- reduction and evolution of N_2O and N_2 (denitrification) takes place that reduces the efficiency of fertilizers applied. Denitrification loss is serious in agricultural soils especially those exhibiting a mosaic of aerobic and anaerobic zones, because the aerobic condition supplies NO_3^- that will eventually denitrifies in the anaerobic layer (White, 1976). Excess gravitational water from heavy rainfall or irrigation will also move nitrate deeper in the soil profile, particularly in soils with rapid internal drainage like sands and loams, which minimize the efficiency of applied fertilizer (Strong and Mason, 1999).

3.2.1.4. Impermeable Soil Layer

A layer in the soil which is impermeable to plant roots (pan) restricts the soil volume which the plant roots may exploit. The soil declines more rapidly in fertility when the pan is close to the surface. This is because nutrients cannot be brought up from below the impermeable layer (Campbell *et al*., 1974; Ignatieff and Page, 1968).

Continuous management on soils that are prone to compaction can result in a sub-surface soil barrier to crop root growth. Breaking such hardpans by deep ploughing or chisel ploughing to a depth of up to 30 cm allows roots to penetrate the hardpan and access more nutrients and water, resulting in better crop growth (Handbook of Integrated Fertility Management, 2012).

3.2.1.5. Soil Texture and Bulk Density

On coarse textured soils, it is often necessary to apply nitrogen fertilizer in several doses during the season because of the potential leaching of applied fertilizers (Ignatieff and Page, 1968). The higher the bulk density, the more compact the soil is and this is quite frequently reflected in restricted plant growth (Tisdale *et al*., 1985). This is associated with poor water, nutrient and air supply which reduces nutrient use efficiency. Carter and Tevernetti (1998) showed that cotton (*Gossypium hirsutum* L.) yield decreased as soil bulk density increased from 1.5 to 1.6 Mg m^{-3} on a sandy loam soil.

3.2.1.6. Availability of other Nutrients in the Soil

The presence of one essential nutrient with the other gives a synergistic effect and increases yield. Russel (1961) reported that adequate supply of nitrogen in the absence of K increased potato yield by 0.4 ton, and adequate supply of K in the absence of N increased potato yield by 2.5 tons. When the two elements were given together in adequate amounts, yield increase was 4.3 tons, which was by far greater than the sum of the individual effects.

Presence of N was reported to improve P use efficiency. Adams (1980) indicated that nitrogen could increase P concentration in plants by increasing root growth, increasing ability of roots to absorb and translate P.

In a field experiment with mustard (*Brassica juncea* L.), grain yield response to N was greater when S was applied and the response to S was greater when N was applied. The combined effect of N and S was greater than the sum of the individual effects of N and S (Dubey and Khan, 1993). Similarly, Teng and Timmer (1994) also reported that white spruce seedlings receiving NH_4NO_3 alone increased in biomass by 34% while monocalcium phosphate addition stimulated growth by 107%.

It has been indicated that additions of large amount of P fertilizers to soils ameliorates not only the status of P in the soil but also diminishes the effects of Al toxicity due to the direct precipitation of Al-phosphates in the zone of P incorporation (Alva *et al*., 1986; McLauglin and James, 1991; White, 1976). This improves the capacity of plants to uptake other nutrients and enhances metabolism of crops. Wilson (1993) concluded that the response to one nutrient depends on the sufficiency level of other nutrients and yield depressions were found when high levels of one nutrient were combined with low levels of other nutrients.

3.2.2. Climatic Factors

3.2.2.1. Temperature

Chemical reactions generally double for each 10^{o}C increase in temperature until the optimum temperature for the reaction was reached (Wilkinson *et al*., 2000). The range of temperature for growth of most agricultural plants is between 15 and 40^{o}C (Tisdale *et al*., 1985). Temperature affects photosynthesis, respiration, absorption of water by roots, mineral element absorption and finally yield of crops (Tisdale *et al*., 1985). Wilkinson *et al*. (2000) also reported that temperature affects the growth of roots, which may limit nutrient uptake to shoots and growth of tops at low nutrient supply. It has been indicated that an increase in temperature from 5^{o}C to 29^{o}C increased root and shoot P, Mn and Fe contents (Tisdale *et al*., 1985).

Marschner (1995) also reported that P uptake is depressed more than other nutrients by low root zone temperatures. Under cool conditions, which are not conducive to rapid rates of decomposition and nitrification of organic matter, more nitrogen fertilizer is needed than under warmer conditions (Ignatieff and Page, 1968). Generally, temperature affects plant growth and consequently affects demand for nutrients (Wilkinson *et al*., 2000).

3.2.2.2. Light Intensity and Length of the Day

Tisdale *et al*. (1985) indicated that net photosynthesis rate in maize is almost linearly proportional to radiation interception, provided that soil moisture is adequate. Crops growing under long-day conditions in the higher latitudes would require more fertilizer nutrients than crops growing under short-day conditions (Ignatieff and Page, 1968).

3.2.3. Crop Factors

3.2.3.1. Crop Adaptability to Local Conditions

Crops like rice grow under widely different conditions. This affects the nutrient requirements of different varieties of the same crop. With low land paddy, almost all nutrients are supplied by the soil above the impermeable layer, whereas with upland rice the roots are able to forage deeply for nutrients. Hence, the latter may need relatively less fertilizer application (Ignatieff and Page, 1968).

Plants that have evolved in desert region have adapted to thrive on neutral and alkaline soils and many desert plants have great tolerance for soluble salts and soluble Na (halophytes). Plants that are native to the humid tropics have high tolerance for soluble Al (Foth and Ellis, 1997). Therefore, plants will respond to applied fertilizer if they are grown in areas where they have adapted.

3.2.3.2. Fertilizer Requirement of the Crop

The differences among crops in their nutrient requirements depend upon differences in actual uptake of mineral nutrients, differences in the ability to obtain nutrients from the soil, and symbiotic relationships that may exist between crops and microorganisms (Ignatieff and Page, 1968).

Those crops that accumulate high biomass remove more nutrients from the soil than otherwise. A good crop of oats may utilize only 80 kg N ha^{-1}, while maize would utilize 140 kg N ha^{-1} (Ignatieff and Page, 1968).

The difference among crops in ability to absorb nutrients from the same medium may depend upon the size of the root system and the inherent characteristics of the roots themselves (Ignatieff and Page, 1968). In a field experiment where equal amount of N was applied to maize (*Zea mays* L.) and bromegrass *(Bromus enermis* L.), N recovery was found to be greater with bromegrass than with maize due to better root system and greater biomass production (Power *et al*., 1973). Khasawneh and Copeland (1973) also found that root length had a linear relationship with cotton P uptake. It was reported that <1% of the soil volume is usually occupied by plant roots and, therefore, any factor influencing root system size or morphology will likely affect the quantity of soil P that is available to a plant (Fixen and Groove, 1990).

Cereals and legumes have different demands for external fertilizer inputs. Legumes can grow on soils too low in available N if correct strain of rhizobium bacteria in the soil exists for proper nodulation and fixation of nitrogen (Ignatieff and Page, 1968). Large increase in uptake of most elements from soil can also occur by fungal symbiosis with the root, both with ectomycorrhizal and endomycorrhizal infection of a wide range of species (Bown and Cartwright, 1977). Suwanarit *et al*. (1997) carried out a pot experiment to test effectiveness of some arbuscular mycorrhizal fungal species and found that maize plants inoculated with

Scutellospora sp. and *Acaulospora spinosa* gave significant increases in plant dry matter yield.

Variation in crop yield also occurs as a result of varietal differences within a single crop species. High crop yields produced with modern hybrids, varieties and lines require more plant nutrients than was necessary for the lower yields of the past, because under low-fertility condition a new high-yielding variety cannot develop its full yield potential (Tisdale *et al*., 1985). It is a well known fact that improved varieties usually have a larger harvest index. They also usually have higher agronomic efficiency compared with 'local' varieties. Foth and Ellis (1997) also indicated that there are varieties of a particular crop that are efficient in utilizing limited amount of nutrient supply in the soil. Other crop factors affecting response of crops to applied fertilizer are resistance to diseases, pests, drought and other stress factors (Prasad and Power, 1997).

3.2.4. Fertilizer Characteristics

The response of crops to similar rates of one nutrient element from different sources may be different because the availability of an element found in different fertilizers is not equal. Nitrate is the preferred form of N for uptake by most plants, and it is usually the most abundant form that can be taken up in well-aerated soils (Blackmer, 2000). Prasad and Power (1997) also indicated that in most well-drained soils suitable for crop production, oxidation of NH_4^+ to NO_3^- is fairly rapid and, therefore, most plants growing under well-drained conditions have developed to grow better with NO_3^--N. Debreczeni (2000) tested the response of two maize hybrids to different nitrogen forms (NH_4^+-N and NO_3^--N) and found that N uptake and grain yield of both varieties was considerably higher from NO_3^--N source than NH_4^+-N source.

However, the quantities of NH_4^+-N can exceed those of NO_3^--N in anaerobic soils (Blackmer, 2000). For crops growing under submerged conditions, like rice, NH_4^+-N is the ideal N source because NO_3^--N under such conditions could be lost by denitrification (Prasad and Power, 1997). Some reports also indicated that growth of plants is often improved when they are nourished with both NO_3^--N and NH_4^+-N rather than with either NO_3^--N or NH_4^+-N (Hageman, 1984; Tisdale *et al*., 1985).

Fertilizer sources affect the chemistry of the soil and indirectly determine the availability and uptake of nutrients. Some fertilizers change soil reaction to acidity, others to alkalinity, but the third group have little or no effect. Ammonium fertilizers, like NH_4Cl, acidify soil reaction whereas nitrate sources, like $NaNO_3$, do the opposite. It has been confirmed by reports of many authors that ammonia-based nitrogen fertilizers reduce soil pH during the oxidation process to NO_3^-. In this case, 1 mole of NH_4^+ produces 2 moles of H^+ (Schwab *et al.*, 1990). Abruna *et al.* (1958) applied very high rates of NH_4^+-N (up to 1200 kg ha^{-1} yr^{-1}) for three years and observed a change in pH from 7 to 3.9 in the surface soil (0 to 15 cm). Miller and Donahue (1990) also reported that about 1.8 kg of pure lime was required to neutralize the acidity of 1 kg of urea-nitrogen or ammonium-nitrogen. Fox and Hoffman (1981) observed the change in pH of surface 2.5 cm of a Typic Hapludult (pH = 6.7) receiving 202 kg N ha^{-1} yr^{-1} as NH_4NO_3, urea, UAN, $(NH_4)_2SO_4$ for 5 years. After five years, the soil pH in plots that received N as NH_4NO_3, urea or UAN decreased to 5.7, while in plots receiving the same rate of N as $(NH_4)_2SO_4$, the pH dropped to 4.7.

Fertilizer characteristics also influence availability of P to plants highly. The amount of total P contained in rock phosphate and triple super phosphate (TSP) does not have a big difference. Rock phosphate contains 13 - 17% total P and TSP contains 20 - 22% total P. Nevertheless, only 0.8 - 2.2% from rock phosphate is available while the whole P in TSP is in available form (Miller and Donahue, 1990).

The response to mineral fertilizer is greater when fertilizer is applied with added organic resources (Handbook of Integrated Fertility Management, 2012). It is apparent that organic inputs have a lot of benefits. They are useful by increasing the crop response to mineral fertilizer; improving the soil's capacity to store moisture; regulating soil chemical and physical properties that affect nutrient storage and availability as well as root growth; adding nutrients not contained in mineral fertilizers; creating a better rooting environment; improving the availability of phosphorus for plant uptake; ameliorating problems such as soil acidity; and replenishing soil organic matter. Hence, integrated nutrient management is useful to maximize crop yield. Crop based farm system will require more artificial fertilizer and is less efficient than crop-animal mixed farming system where organic matter is added to the soil in the form of manure.

3.2.5. Management practices

Farm management is a key for outstanding crop yield. Asnakew (1990), Lema *et al.* (1992), Yesuf and Duga (2000b) reported that improved wheat varities were responsive to management and input. Therefore, farmers should follow the following to achieve high crop yield.

3.2.5.1. Erosion control

Soil erosion can be a serious problem, especially on fields with steep slopes, and on slightly sloping fields with coarse textured topsoil that is prone to erosion. Soil organic matter and nutrients are lost in eroded soil, which may substantially reduce the agronomic efficiency of applied inputs. Several measures can assist in controlling erosion, including planting of live barriers (e.g., grass strips), construction of terraces, or surface mulch application.

3.2.5.2. Land preparation

Appropriate seedbed preparation is a prerequisite to achieve good crop establishment, particularly with crops that produce small seeds. Germination is improved (and seed requirements may be reduced) when the top soil is cultivated to produce a tilth comprising small particles.

3.2.5.3. Planting date and practice

A delay in planting date usually affects yields negatively, particularly where the growing season is short. Planting date should be selected based on knowledge of the onset of the rainy season. Early planting is generally a prerequisite for achieving high yields.

When crops are planted together, they compete with each other for nutrients, light, and water. Appropriate planting densities, expressed as number of plants per hectare need to be adjusted for different environments and these are often reduced when rainfall and soil fertility conditions are suboptimal. It is also important to consider the distance between planting rows, the distance between plants within a row, and the number of plants per planting hole.

Seed viability should be at least 80% to achieve a full crop stand. Seeds of cereals and grain legume crops should be planted at the correct depth. More seeds than required to reach the optimal planting density are planted to allow for thinning and incomplete germination.

3.2.5.4. Weed, pest and disease management

Weeds compete with crops for nutrients, water, and light, and their timely removal has a substantial impact on crop yield. It is also important to weed before applying top-dressed fertilizer so that the nutrients applied benefit the crop and not weed growth. Pests and diseases must be controlled at specific crop growth stages. Treated seed should be used where there is a risk of pest attack in the seed bed. In many crops, pest and disease control will be required, usually between flowering and pod or grain filling. Failing to do so will result in an unhealthy crop that will use nutrients and water inefficiently.

4. Conclusion

Crop yield can be improved by the combination of genotype, optimum environmental condition and appropriate management practices which can be generalized by the formula: Yield = G (genotype) x E (environment) x M (management). The genotype refers to healthy seeds of high yielding verities; environment refers to the soil’s physical and chemical properties and climate in the particular location; and management refers to the farmers' ability and skill in managing crops and the farming system.

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