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The Use of Nitrogen and Potassium Fertilizer for Cotton in the Tropics

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Abstract

Fertilizers are used to increase crop yields and also to improve crop quality. Nutrients removed from the soil by crops, lost by leaching, erosion, fixed or immobilized by micro-organisms or volatilized due to high temperature should be replaced to ensure optimum crop performance. One of the most important pre-requisites for formulating a sound fertilizer recommendation for a given crop in a given area, therefore, is the knowledge of the nutrient status of the soil, which is realizable only through a rational and systematic soil fertility evaluation. The requirement for organic and synthetic amendments to increase yield and facilitate crop growth has long been recognized by farmers. Synthetic N fertilizer produced via the Haber-Bosch process was a key component of the green revolution that increased agricultural productivity and alleviated hunger for many across the globe. Inadequate N reduces the number of fruiting sites and potential yield, whereas excessive N can create rank growth, actually lower yields and quality, delay maturity, increase problems with disease, insects, and defoliation, and pollute ground and surface water resources. When soil analysis calls for additional K, the cotton crop is usually fertilized with a single preplant broadcast application of K fertilizer. Mid-season applications are infrequently applied, and foliar applications are used occasionally to correct K deficiencies during fruiting. However, despite soil analyses and subsequent soil applications of fertilizer prior to planting, K deficiencies have occurred sporadically and somewhat unpredictably across the US Cotton Belt. This has prompted a renewed focus on K management in cotton with some emphasis on understanding K fertilizer requirements and use by the cotton plant. Hence this paper tends to address the use of Nitrogen and Potassium fertilizer for cotton production in the tropics.

Keywords: Cotton, Nitrogen, Potassium, Fertilizer

Introduction

Fertilizers play a critical role in enhancing crop productivity, farmer's income and sustainability of production systems. Consumption of fertilizers has been increasing over time and demand projections showed that, at the current rates, we would need an additional 2.57 to 2.97 million tonnes of fertilizer by 2023-24 [1]. However, the major concern has been imbalanced use of N, P and K fertilizers, which has been arising mainly because of limited purchasing power of farmers, and using more of urea because of its comparatively low prices [1].

In the past decades, intensive use of chemical fertilizers at recommended rate (NPK 15:15:15) was advocated for crop production in the tropics in order to alleviate these nutrient deficiencies [2]. Over the last 37 years, the average cotton lint yield has increased by 57% to 2 360 kg•hm^{-2} (Cotton Australia 2017) due to improved crop genetics, irrigation practice and farm management which includes increased N fertilizer use and improved pest controls.

Cotton in the Southeast is grown on soils ranging in texture from sands to heavy clays and under rainfall of 40 inches to more than 80 inches annually. Because of the low water holding capacity of many of the soils and erratic rainfall during the growing season, moisture deficiency is responsible for reduced yields almost every year [3].

The challenges facing today's cotton industry are many. For instance, among the major price-supported crops, only growers of cotton and tobacco still find themselves plagued with surpluses. And only cotton growers face the loss of their market to substitutes. Such pressure against the industry calls for action. For centuries, cotton was grown without any external input. However, this average yield is well below the yield that would be expected from the amount of N fertilizer used. It is clear from the recent studies that across all growing regions, conversion of fertilizer N into lint is not uniformly occurring at application rates greater than 200–240 kg•hm^{-2} of N. This indicates that factors other than N availability are limiting yield, and that the observed nitrogen fertilizer use efficiency (NFUE) values may be caused by subsoil constraints such as sodicity and compaction [4].

Mid-season applications are infrequently applied, and foliar applications are used occasionally to correct K deficiencies during fruiting. However, despite soil analyses and subsequent soil applications of fertilizer prior to planting, K deficiencies have occurred sporadically and somewhat unpredictably across the US Cotton Belt. This has prompted a renewed focus on K management in cotton with some emphasis on understanding K fertilizer requirements and use by the cotton plant. Hence this paper tends to address the use of Nitrogen and Potassium fertilizer for cotton production in the tropics.

Nitrogen Fertilizer in Cotton Production

The key fertilizers used in cotton production at nitrogen (N), phosphorous (P), and potassium (K). Deficiencies are rare in other essential nutrients such as copper, boron, calcium, magnesium, sulphur, manganese, iron, zinc, cobalt and molybdenum.

Nitrogen (N) is the most heavily applied and one of the most expensive nutrients used for cotton production, and is also the most difficult to properly manage because of its reactivity and mobility in the soil environment. Nitrogen (N) is the main nutrient by mass that limits plant growth if the soil supply is inadequate [5,6]. The total uptake of nitrogen by cotton varies with such factors as nitrogen and moisture available [7].

Delaying soil nutrient applications until the root system has sufficiently developed for nutrient uptake reduces potential erosion and leaching nutrient losses [8]. However, delayed nutrient application may require changes in management practices and require specialized application equipment as opposed to broadcasting equipment. Nitrogen fertilization materials in particular may require specialized injection equipment. Furthermore, because of possible loss mechanisms, N is the primary nutrient that the crop has the greatest need for after crop establishment [9]. Among the major nutrients, nitrogen is required in the largest amount by plants and has an essential role for plant productivity because it is main part of essential active compounds, i.e., chlorophylls, proteins, nucleic acids and enzymes [10]. N has important role in many active processes such as cell division and photosynthesis and accumulation of organic matter in plant tissues [11]. Next to N, potassium is required in the largest nutrient amount by all cultivated plants.

Nitrogen, applied in commercial crops, results in a decrease in the productive cycle and improvement of the physical and chemical fruit qualities [12,13]. The major reasons are the lack of knowledge and skill in land preparation and agronomic practices, weather uncertainties, pest outbreak and above all the use of fertilizer [14]. Fertilizer application began only in the 1950s, initially with the application of N alone. The concept of balanced fertilizer (N, P and K) began with the adoption of high yielding varieties and hybrid cotton. Several intensive nutrient exhaustive cropping systems became popular and consequently, secondary and micronutrient deficiencies started emerging in pockets [15]. Fertilizer is but one of many inputs which growers must use to obtain profitable yields. Fertilizer is unique, however, in two ways: First, it has considerable benefit in producing profit, and secondly, its cost has remained steady without inflation. Since fertilizer is so important to the profitability of growing cotton it is astounding that so lithe science is used in guiding fertilization practices [16].

Nutrient efficiency can be improved by production practices that include delaying nutrient applications until sufficient plant root development, or utilizing slow-release fertilizers, and foliar feeding [5]. Abdulraheem, et al. [14] opined that one of the solutions to food insecurity and malnutrition in Sub-Saharan Africa is to promote local crops, encourage the use of locally source materials as amendment, improve their traditional system of production, and so diversify subsistence crop. Plant nutrition has a direct effect on cotton (Gossypium hirsutum L.) health, so proper nutrition can have a positive impact on cotton yield and quality.

There are concerns about N fertilizer use efficiency in the cotton industry and the potential for off-site impacts [17]. Over application of fertilizers contributes to global warming due to the emission of nitrous oxide (N2O-N) and nitrogen oxides (NOx-N), and the volatilization of ammonia (NH3-N), as well as pollution of surface and ground waters, due to run-off and leaching of dissolved organic N (DON-N), urea (CON2H4-N), and nitrate (NO3 −N) [18]. Nitrogen in the aboveground crop increased when nitrogen was in-creased with and without irrigation. However, with irrigation, nitrogen uptake was much greater at the 120-and 240-lb N rates. Where recommended rates of nitrogen are used, nitrogen uptake under natural rainfall would range from 100 to 125 lb N/acre.

Potassium Fertilizer in Cotton Production

Potassium is an especially important nutrient in cotton production. It reduces the incidence and severity of wilt diseases, increases water use efficiency, and affects fiber properties like micronaire, length and strength. It is important in maintaining sufficient water pressure within the boll for fiber elongation, and for this reason bolls are a major sink for K. Cotton takes up about 60 lb of K2O per bale. Some of the early work showed that cotton rust could be controlled by adding potassium fertilizer. Most upland soils in the Southeast are low in total potassium and are usually low in available potassium if they have not received rather large applications. Since phosphorus accumulates to a greater extent than potassium, the latter is becoming more limiting in cotton production than phosphorus.

Potassium deficiency may be expressed as a full season deficiency, or it may not appear until late season since this is the period of greatest demand. A shortage of K compromises fiber quality and results in plants that are more susceptible to drought stress and diseases. Preplant applications of K fertilizer, and in some cases mid-season foliar applications, are effective in correcting deficiencies. The onset of potassium deficiency is generally characterized by a marginal chlorosis progressing into a dry leathery tan scorch on recently matured leaves. This is followed by increasing interveinal scorching and/or necrosis progressing from the leaf edge to the midrib as the stress increases. As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green and the leaves tend to curl and crinkle. Potassium deficiency can be greatly alleviated in the presence of sodium but the resulting sodium-rich plants are much more succulent than a high potassium plant. In some plants over 90% of the required potassium can be replaced with sodium without any reduction in growth.

Recommendations in the Southeast usually range from 30 to 120 lb K20/ acre. Recommendations should be based on soil test values. Results by Rouse (1967) show that soils testing high responded to about 20 lb K20, soils testing medium responded to 50 lb, and soils testing low responded to 100 lb. Moisture is often limiting and likely prevents response to more than about 100 lb K20 for soils testing low. The role of K is maintenance of electrochemical equilibrium in plant cells and cell compartments and enzyme activities regulation [19]. K has important role for translocation and storage of assimilates and maintenance of tissue water relation. K is the key for quantity and quality of the product due to its role in stimulating root growth and improving the size of fruits. The formations of carbohydrates and sugars translocation in plant depend on potassium [20].

Inadequate N reduces the number of fruiting sites and potential yield, whereas excessive N can create rank growth, actually lower yields and quality, delay maturity, increase problems with disease, insects, and defoliation, and pollute ground and surface water resources. In addition to potassium, nitrogen has a physiological function, acting effectively on photosynthesis processes and on the distribution of photoassimilates to the various plants organs, resulting in the accumulation of dry matter, plant and fruit development [21].

The risk of N run-off and leaching loss is greater early in the irrigation season when the crop is small [22-24]. Another timing option increasingly practiced by cotton growers is to split N applications between pre-plant and in-crop applications in conjunction with early season irrigation events.

The easiest and fastest methods of correcting nutrient deficiencies are through the use of fertilizers which are mostly applied directly to the soil or directly to the crop foliage in liquid form. The amount of fertilizer applied in any given season may depend on both method of application (e.g. banded or broadcast) and the expected maximum net return on the immediate crop and thus neglecting residual effects, or calculating the total requirement for a number of years and then applying it at the most appropriate time in order to realize the greatest net returns.

Growers often apply fertilizer N as early pre-plant applications up to eight months prior to sowing. It has been shown that losses from these pre-plant applications can be significant, with only 20% of the applied fertilizer N being available to the cotton plant at sowing. The potential for losses is minimized when the N fertilizer is applied closer to sowing (August–September) rather than earlier in the year [16]. The only way to lower the risk of denitrification caused by rainfall is to delay the formation of nitrate-N from the applied fertilizer, either chemically through nitrification inhibitors, or physically, through slow-release coatings of polymers etc. If irrigation techniques are the cause of the denitrification, then methods that reduce waterlogging should be investigated.

Use of Nitrogen and Potassium Fertilizer for Cotton

The appropriate supply of nutrient fertilizers is very necessary to obtain optimum growth and head yield of cotton and to improve quality of the edible product [25]. An integrated approach should be used to achieve optimal cotton yields more economically and friendly to the environment. Thus, improving nutrient use efficiency through balanced nutrient management including macro and micronutrients, organic and inorganic sources, and soil and foliar applications and adopting integrated nutrition management according to cultivar genotype, local tillage system, and water management should be addressed in future cotton nutrient management [26]. Cotton takes up great amounts of K, which plays an important role in plant development and fiber quality [27].

In cotton, over-application of fertilizer N can negatively affect yields by encouraging "rank growth" and fruit shedding, reducing lint production, hampering defoliation, encouraging insects and disease, and delaying plant maturity [28]. Over-fertilisation also affects secondary income from cotton crops by reducing cotton seed oil content [7]. Good nutrient management can result in higher cotton yields, improved fiber quality, greater water and nutrient use efficiency, and more profit [2]. Soil and plant analyses, field history, and experience should all be considered when planning fertility programs. Utilization of MPRN fertilizer would allow cotton production in areas improve nutrient efficiency and restrict potential environmental concerns [29].

Conclusions

Fertilizer applications are generally considered in relation to their immediate effects on crop yields and all too often their residual effects are ignored. Yet when farming is continued on the same site for several years residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently the yield of crops grown in later years. One of these residual effects is on the relative abundance of the cations in the soil subsequent to fertilizer application. There have been significant researches on fertilizer N in the cotton industry over the last 40 years. Despite this investment, N fertilizer usage is currently below optimum and there is significant potential for its improvement in the cotton industry. It is apparent that improvements can be made in the time of N fertilizer application strategies, but these cannot improve N fertilizer usage until N fertilizer rates are reduced from luxury to optimum levels.

The use of high N rates for cotton grown in narrow row with higher plant population, as compared to conventional systems, is not a requirement for higher yields, although it can reduce fiber quality. More plants in the field will compete for light, water, and nutrients, which will compensate plant height and yield.

Research in Texas has shown that deep soil sampling for N management in cotton production systems is effective. Crediting residual soil N to a depths as great as 24 inches can substantially reduce fertilizer N requirements, and may reduce other related input costs (growth regulators, defoliants). Together, soil and irrigation water testing for nitrogen are important management practices that can enhance both production economics and environmental stewardship.

Potassium application is a key practice for cotton grown in narrow row systems. Cotton uptakes high amounts of K, that can be affect by low soil K availability due to no application or low water content in the soil. High K rates applied to cotton in narrow row systems, grown as a second crop after soybeans, sustains higher yields and fiber quality [16].

Good nutrient management can result in higher cotton yields, improved fiber quality, greater water and nutrient use efficiency, and more profit [2]. Soil and plant analyses, field history, and experience should all be considered when planning fertility programs.

Though, integrated application of organic and inorganic nutrients sources rather than total dependence on any of the sources is expected to ensure reduction in expenditure on chemical fertilizers, a more balanced plant nutrition and control of soil acidity [30,31].

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