International Journal of Food Engineering and Technology
2024, Vol. 8, No. 2, pp. 34-41
https://doi.org/10.11648/j.ijfet.20240802.13

Review Article

Review on Integrated Nutrient Management on Yield and Yield Components of Okra in Ethiopia

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Abstract

Maintaining soil fertility necessitates applying inorganic and organic fertilizer sources in balance. Vegetable crops cannot be successfully produced without proper plant nutrition. Though little is known about it, okra is a crop that is commonly farmed in western Ethiopia and is rather adaptable. Grown across Ethiopia, okra is a vegetable crop with significant economic value, especially in the southwest region. For okra's output to increase integrated use of chemical and organic fertilizer on yield and yield components is essential. By optimizing the benefits from all available plant nutrient sources in an integrated manner, integrated nutrient supply/management, or INS, aims to maintain or improve soil fertility and plant nutrient supply to an optimal level for sustaining the desired crop productivity. This includes enhancing or maintaining soil productivity through a balanced use of fertilizers that are organic and biological sources of plant nutrients. Increase the amount and effectiveness of plant nutrients in the soils to reduce losses to the environment. However, the integrated nutrient management system (INMS) continues to be the means of preserving and perhaps enhancing soil fertility for long-term crop yield and lowering the cost of inorganic (fertilizer) inputs for all agricultural production.

Keywords

Integrated Nutrient, Okra, Plant, Organic Fertilizer, Chemical Fertilizer

1. Introduction

Okra (*Abelmoschus esculentus* (L.) *Moench)* is a leafy vegetable grown both in tropical and subtropical regions of the world [4]. It is commonly grown from Africa to Asia, southern Europe, and America. It is a popular vegetable in Sri Lanka, ranked fourth in cultivated extent among the low country vegetables [1]. Originally from Africa, the crop can still be found growing wild in Ethiopia, around Nile River [60]. Its native Ethiopian Highlands and Sudan, two north-eastern African countries, are where it originated, despite being the most consumed in India [37]. Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, India, Brazil, Ethiopia, Cyprus and in the Southern United States [9, 28].

The West African okra, or Abelmoschus caillei (A. Chev) Stevels, is a multipurpose woody crop plant that grows abundantly in the humid West African sub-continent and can be farmed as an annual, biennial, or occasionally perennial crop [49]. Around 10% of the world's okra is produced from Common (Abelmoschus esculentus) and West African okra (Abelmoschus caillei (A. Chev) Stevels), which are both

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Received: 21 November 2024; **Accepted:** 6 December 2024; **Published:** 25 December 2024

utilized in West and Central Africa [37]. However, both varieties together provide food, feed and fibre for many poor inhabitants of the region who rely on agriculture for livelihood.

Okra (Abelmoschus esculentus), previously named Hibiscus esculentus (L.) is the only vegetable crop of importance and significance in the Malvaceae family [37, 27]. It is a tropical and subtropical vegetable mainly grown in warm weathers. Despite detailed classification and scientific name, okra is named differently in different parts of the world. These include locally given names such as, Kacang Bendi, Qiu Kui, Okra, Okura, Okro, Quiabos, Ochro, Quiabo, Gumbo, Quimgombo, Bamieh, Bamya, Quingumbo, Bamia, Ladies Fingers, Bendi, Bhindi, and Kopi Arab [37].

Okra is a multipurpose crop due to its various uses of the fresh leaves, bud, flowers, pods, stems, and seeds [43]. Okra immature fruits, which are consumed as vegetables can be used in salads, soups, and stews, fresh or dried, fried or boiled [46]. According to [12], okra fruit contains 86% water, 2.2% protein, 10% carbohydrate, 0.2% fat, and vitamins A, B, and C. Okra seeds are a source of oil and protein [25]. Despite the numerous potentials of okra fruit production, its level of production and yield per hectare has been very low in most of growing areas due to the low fertility status of most soils. In Nigeria (about 2.7 M t ha-1) compared with India (10.5 M t ha-1), Sudan (10.2 M t ha-1), Egypt (15.7 M t ha-1), and Saudi Arabia (11.5 M t ha-1) [62].

According to [28], nutrients like nitrogen, phosphorus, potassium, calcium, salt, and sulfur are necessary for okra production and reproductive maintenance. When these nutrients are not present in sufficient amounts, okra performs poorly and produces less than desired. In conjunction with manures like compost, farm yard manure, vermicomposting, and green manures, as well as fertilizers fortified with micronutrients and bio-fertilizers (such as phosphate-solubilizing bacteria, Azospirillum, Azotobacter, Rhizobium, and potash-mobilizing bio-fertilizers) that can supplement some NPK fertilizers, Integrated Nutrient Management (INM) encourages the balanced and sound use of chemical fertilizers [30].

It is well known that the combined application of organic matter and chemical fertilizers can effectively stop the reduction in production by addressing minor nutrient deficiencies and improving the physical and biological properties of the soil. According to [64], this system has the ability to balance restorative and degenerative activities in the soil environment. Numerous studies have demonstrated the potential impact of micronutrients on agricultural plant growth and development. Utilizing micronutrients enhances both the amount and quality of agricultural output.

2. Response of Okra (*Abelmoschus esculentus* L.) to Organic and Inorganic Fertilizers

2.1. Importance of Integrated Nutrient Management (INM) in Crop Production

The control of soil organic matter and the sensible application of organic inputs such as crop residues, green manures, animal manures, sewage sludge, and wastes from the food industry will be crucial concerns in the design of sustainable agricultural systems in the ensuing decades. Organic manure is used alongside with chemical fertilizers which is significant from the standpoint of crop productivity and quality [55]. The fundamental idea of integrated nutrient management is still to reduce chemical fertilizer inputs while simultaneously maintaining potentially enhancing soil fertility for long-term crop production.

When the actual nutrient demand of the plants is met by organic inputs in addition to inorganic fertilizers that reduce the amount of chemicals fed to the soil, integrated nutrition management (INM) helps to provide balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance. By maximizing the benefits from all potential sources of organic, inorganic, and biological components in an integrated way, integrated nutrient management (INM) refers to the maintenance of soil fertility and plant nutrient delivery at an optimal level for maintaining the target productivity. It balances the supply of nutrients from applied and native sources with the demand for nutrients in crops. Fertilizer needs are crucial for the early growth and overall yield of okra. Crop productivity can be raised by using organic and inorganic fertilizers in together [41].

2.2. Farmyard Manure (FYM)

FYM is the most commonly used organic manure in okra production in India. According to [59], the effect of organic and inorganic source of nutrients NPK, FYM and Azospirillum on number of fruits per plant was found significant. The maximum number of fruits per plant 18.69 was recorded in T9 (NPK 100% + FYM 100% + Azospirillum 50%) and minimum number of branches 13.09 was recorded in absolute Control after harvesting respectively. Similarly, [33], suggested that application of 12 t /ha farmyard manure significantly produced higher mean values on plant height, number of leaves/ plant/ha, number of branches /plant/ha and leaf area /plant/ha at P = 0.05. However, the control treatment significantly produced lower mean values of all growth parameters of okra at P = 0.05. According to [11], application of 75% of recommended dose of NPK + FYM 2.5 t/ ha + VC 1.25 t /ha + NC 0.5 t/ ha was highly favourable for dry matter production, nutrient uptake and yield of okra. Similarly [2], recorded the maximum okra yield optained in poultry manure (14.91 tn/ha) which was statistically at par with chemical (12.78 t/ha) and goat manure (12.74 /ha) whereas the significantly minimum yield was recorded in control (7.03 tn/ha).

2.3. Poultry /Chicken/ Manure

Sustainable agriculture has effectively employed animal manures [45]. According to [45, 26], chicken manure is the most significant manure among organic leftovers due to its high content of nitrogen and other important nutrients. In dry and semi-arid climates, adding chicken manure as an organic amendment to the soil replenishes it with additional nutrients and enhances its physical and chemical properties. Additionally, according to [6, 15], Poultry manure (PM) is an excellent source of organic manure. It supplies both macro and micro-nutrients during mineralization, increases the organic matter content of the soil, and consequently enhances the texture, structure, aeration, moisture holding capacity, nutrient retention and water infiltration in the soil.

Furthermore, [47] reported that the plot improved by applying chicken manure along with pawpaw leaves had the highest mean pod length and pod girth of okra. This was comparable to applying neem leaves along with chicken manure. The plot without soil augmentation (0 g application) had the lowest mean pod length and pod girth (control). When chicken dung was used as the only fertilizer, the same pattern persisted. Numerous academics concurred that using organic manure, particularly chicken droppings, for crop development had improved agricultural practices in West African nations. In addition to providing an adequate supply of the nutrients required for soil production, organic manure improves the physical characteristics of soil, including structure, water-holding capacity, aeration, and drainage. One important source of plant nutrients is organic fertilizer or poultry waste. In this regard, [32] advocate that organic manure, or poultry manure, be utilized in the cultivation of vegetables, such as okra, because it contains nutrients that nourish the soil and the plant itself.

2.4. VermiComposting

The term "vermicompost" refers to earthworm droppings that are left over after organic materials have been digested in the intestinal tract. Vermicompost is an inexpensive organic material that is created by the bio-oxidation of organic substrates, combining the beneficial effects of earthworms and microorganisms [40, 8]. Due to its high organic content and lack of chemicals, vermicompost is environmentally beneficial. It is more abundant in nutrients and releases nutrients gradually, which plants absorb rapidly. As indicated by [36], plants are safer and less susceptible to pests and illnesses, which lowers the need for pesticides.

Vermicompost increases the production of okra as it improves soil bulk density, water retention capacity, pH, and electrical conductivity more than conventional compost or raw material. It is crucial to the long-term fertility and productivity of the soil. Additionally, it promotes crop development and growth while raising yield. Numerous biotic and abiotic factors have a substantial impact on okra production. Soil salinity is one of the elements impacting okra yield and cultivation in various locations of the world. Salinity in the soil negatively affects the growth, yield, and quality of crops [7, 18].

Unlikely, [34], suggested that, the presence of heavy metals in vermicompost made from urban and industrial wastes is a severe issue that restricts plant use, especially in vegetables, despite the positive impacts on soil physio-biochemical characteristics, plant growth, yield, and quality. Thus, the primary goal of the recent research would be the integration effects of vermicompost and chemical fertilizer levels determination for plant well growth and development, as well as the quantity and quality of fruit produced. Furthermore [14] hypothesized that the high nutrient contents of the inorganic fertilizer and vermicompost, as compared to the control treatment, might account for the greatest agronomic parameters reported with them. In a similar vein, a number of researchers found that adding NPK and vermicompost to the soil increased the okra's agronomic parameters.

2.5. Biofertilizer

Biofertilizers are substances that are enriched with bacteria that aid in the growth of trees and plants by providing them with more vital nutrients. It is made up of living things, such as bacteria, blue-green algae, and mycorrhizal fungus. For the benefit of the plant, mycorrhizal fungi selectively remove minerals from organic materials, whereas cyanobacteria are known for their ability to fix nitrogen. The process of turning di-nitrogen molecules into ammonia is known as nitrogen fixation. Certain bacteria, for example, change nitrogen into ammonia. Nitrogen is therefore made accessible to plants.

Biofertilizers release substances that promote growth and vitamins that support soil fertility. By acting as an antagonist and reducing the prevalence of soil-borne plant pathogens, they contribute to the management of illnesses. The microorganisms in biofertilizer that fix nitrogen, break down plant materials into smaller pieces, and mobilize phosphate improve the amount of plant nutrients available in the soil, which benefits farming practices and agricultural output. When biofertilizer is applied, it promotes root development, nitrogen fixation, mineral and water intake, and vegetative growth [16].

According to [10], the highest yields observed with the biofertilizer Retone would the result from its ability to induce good chlorophyll content in okra plants, coupled with its capacity to increase resilience to abiotic stresses. The lowest averages recorded for the various parameters assessed were obtained using Spaawet and Super Gro biofertilizers, as well as the no-fertilizer control. These results may be explained by the fact that Spaawet biofertilizer is a polyether trisiloxane-modified agricultural adjuvant that possesses surface-active properties and significantly reduces water surface tension. The Retone biofertilizer produced the best results in terms of growth and yield parameters of okra. In a similar vein [61], suggested that the application of Eco-Agra as a liquid biofertilizer may have a substantial impact on the development and yield of okra. In addition, compared to the control treatment, the higher dosages (6 ml/L) of liquid bio-fertilizer (Eco-agra) enhanced yield by almost 60%. Thus, using liquid biofertilizer at a rate of 6 milliliters per liter may be the optimal dosage for okra cultivation.

2.6. Chemical Fertilizer

Inorganic fertilizers are either produced chemically in an industrial setting or extracted from mineral reserves that require minimal processing, such as phosphate rock, potash, or lime. Based on the manufacturing method, inorganic fertilizers have different looks. Fertilizer grades include compound fertilizers (containing two or more nutrients typically combined in a homogeneous mixture by chemical interaction), blends of fertilizers (formed by physically blending mineral fertilizers to obtain desired nutrient ratios), and crystals, pellets, granules, or dust are examples of the many different sizes and shapes of the particles. Fertilizers are now necessary for contemporary agriculture in order to feed the world's expanding population. Humanity has benefited from the use of fertilizers, particularly chemical fertilizers, which have helped to reduce global hunger and mortality.

Chemical fertilizers boost agricultural yields, but when used excessively, they weaken soil fertility, intensify pesticides, contaminate air and water, and emit greenhouse gases, all of which pose risks to human health and the environment. Chemical fertilizers have been demonstrated to provide significant obstacles to sustained and balanced growth. Therefore, it is evident that scientists and experts are praising organic fertilizers as the ideal way to prevent soil degradation as well as several other environmental and biological hazards brought on by the excessive use of chemical fertilizers [57]. In comparison to other nutrients, nitrogen, phosphorus, and potassium are the most crucial elements that plants require in relatively significant amounts. Okra plants benefit more from the combined use of organic and mineral fertilizers than they would from the use of either organic manure or mineral fertilizers by themselves [5].

2.6.1. Nitrogen (N)

N is a fundamental constituent of organic substances, including nucleic acids, proteins, and amino acids. A lack of it causes phenological development in the vegetative and reproductive phases to be delayed [22]. Whereas ammonium is the least leaching-prone type of N, urea is somewhat vulnerable, and nitrate is the most susceptible. Fertilizer compounds containing nitrate are less vulnerable to ammonia-induced volatilization loss of nitrogen than ammonium and urea. Ethiopian horticulture and grain crops mostly obtain their nitrogen fertilizer from urea.

High biomass is only achievable under N fertilization circumstances, and applying the proper quantity of N fertilizer may greatly boost biomass [23]. Nitrogen seems to keep leaves viable on the surface; as leaves become more durable, so do the length and rate of photosynthesis, which enables the plant to create more dry matter. Lack of N increases competition for the element's transfer within the plant, hinders the timely and full development of reproductive organs by lowering the crop growth rate (CGR), delays plant phenology, lowers the harvest index, and ultimately lowers plant grain yield [22], and slows down the rate of pure assimilation [19] and speeds up leaf senescence [17].

According to [21] suggested that, Plant development is inhibited by N deficit, which eventually lowers yield. On the other hand, issues arise when N fertilizer is not used properly. Plant production is decreased by overusing necessary nitrogen. Thus, it's essential to assess the N content of the field soil before adding N fertilizer. Plants need the ideal amount of nitrogen to grow and develop. Leaching is one of the main issues with nitrogen-limiting variables. When applied to a crop, nitrogen dissolves in irrigation water and percolates from the upper soil surface to the lower soil layer. N deficit is the result of this process, and as the saying goes, "limited nitrogen means limited its use efficiency." It is evident that less nitrogen available limits plant growth and development [39]. Furthermore, [63] research indicated that okra plant height, stem diameter, maximum leaf length, maximum leaf breadth, and number of leaves all significantly increased with proper N treatment and were directly connected with high yield while zero nitrogen or control resulted lower yield.

2.6.2. Phosphorus (P)

Plant development requires 17 nutrients, among which is phosphorus. P is an essential component for optimal development and reproduction, and no other nutrient can fulfill its roles. Because it is a significant nutrient and is needed by crops in relatively high quantities, phosphorus is often lacking for crop production. Crops used for agriculture typically have a total P content that ranges from 0.1 to 0.5%. By 2050, there are expected to be 9.9 billion people on the planet, which means that food production must rise by more than 70% [58]. Thus, it is vitally important to use resources efficiently in order to increase agricultural productivity. A major section of soils globally lacks phosphorus (P), resulting in a severe restriction of crop production and posing a substantial danger to global food security [31]. Although phosphorus is abundant in the lithosphere, plants require inorganic orthophosphate (Pi), a type of phosphorus that diffuses slowly in soils due to its intractable nature [51]. This causes ecosystems and agricultural fields to become P deficient. Soil microbiota also influences phosphorus availability; it may either out compete plants for phosphorus or form advantageous partnerships, like mycorrhizae, to improve phosphorus acquisition efficiency. P fertilizers are ineffective because of their characteristics; only 15-20% of the P is absorbed by plants; the rest is leached, degrading the soil and eutrophicating the water [13].

Unlike nitrogen, which is found in large quantities in the atmosphere, rock phosphate, or rock P, is scarce. In conclusion, according to [35], a lack of phosphorus significantly affects the density and stomatal conductance of a variety of plant species, which in turn affects photosynthetic efficiency, growth, and water relations. Plants that receive enough P nutrients are more resilient to abiotic stressors. Restoring P to P-starved plants can help them recover from abiotic stress situations by preventing photosynthesis inhibition and enhancing stomata conductance and photosynthesis.

In a similar vein [29], found that applying phosphorus up to 100 kg/ha increased okra plants' fresh and dry weight pod (160 and 92 g/plant, respectively), leaves (24.3/plant), plant girth (5.6 cm), plant spread (45.8 cm), and height (3. 5 m). This might be because there is more phosphorus available, which creates a better nutritional environment for growth and development in the root zone. [44], also demonstrated that when phosphorus levels rose, so did the number of branches per plant. At all development stages on the rooftop, P2 (120 kg P_2O_5 ha^{-1}) had the most branches per plant (4.2), followed by P1 (80 kg P_2O_5 ha^{-1}). In field plants, P0 generated the fewest branches per plant (3.07) during all growth phases, with P1 and P2 showing no discernible variation. The administration of less phosphorus may not have been able to be absorbed by the okra plants in the control plots, and it was likely insufficient for normal plant growth and development, which led to a decrease in the number of branches per plant.

2.6.3. Potassium (K)

One of the three macroprimary nutrients required for plant development is potassium. Potassium (K) is essential for the physiological processes of protein synthesis, water, nutrient, and carbohydrate transfer, photosynthesis, nitrogen use, early growth stimulation, and pest and disease resistance, according to [54, 38]. In addition, it facilitates assimilate transportation, regulates stomata opening, activates plant enzymes, particularly those involved in energy transfer and the synthesis of sugars, starches, and proteins, and supports microbial activity in addition to enhancing human and animal nutrition and health.

Potassium is present in the soil as the water-soluble, exchangeable, fixed mineral K. Plants absorb soil-exchangeable K, or accessible K, from the soil solution. When plant removal, leaching, or exchange reactions with other cations reduce solution and exchangeable K, some non-exchangeable K may become exchangeable. However, long-term soil weathering may only very slowly make mineral K, which makes up the majority of total K in soils, accessible. As K is introduced to the soil through agricultural waste, manure, or fertilizer, it is also distributed among different forms [24].

According to [44], potassium showed a significant variation for different levels on yield per plot on rooftop and field. The rooftop K2 (80 kg K_2O/ha) produced the highest yield (15.69 kg/plot), whereas the control circumstances produced the lowest yield (13.05 kg/plot). In the field, K2 and K_o (zero) yielded the highest yield/plot (14.72 kg) and lowest yield/plot (12.04 kg), respectively. According to [56], an increase in potassium levels had an impact on vegetative development as well as an increase in production. 30% more K-based fertilizer treated the plot with the highest output (6.98 t ha-1), closely followed by 30% more P-based fertilizer (6.38 t ha-1).

More likely, K has a well-established role in reducing insect-caused agricultural damage. According to reports, a high level of K combined with the required amount of nitrogen can improve the metabolism of secondary compounds, decrease the buildup of carbohydrates, facilitate the removal of amino acids, and raise the silica content of leaves. Furthermore, a high potassium supply tends to harden the structure of plants, making the cuticle, cell walls, and outer layer of the epidermis stronger, increasing the amount of sclerenchymatous tissues and silicification, and ultimately making the stem thicker and harder [20]. It is commonly believed that this hardening of the plant structure increases the mechanical resistance to insect feeding, particularly that of sucking insects [52].

2.6.4. Micronutrients

Although they are required in extremely minute amounts within the plant system, micronutrients, also known as trace elements, are crucial for the growth and development of plants. It comprises Fe, Cu, Cl, Mn, B, Ni, Zn and Mo. Plants often accumulate these micronutrients in the following order: Mn>Fe>Zn>B>Cu>Mo [3]. This order may fluctuate among plant species and growing situations (e.g.; flooded rice). They are typically found in conjunction with bigger molecules like enzymes, cytochromes, and chlorophyll [53].

Micronutrients can have a significant influence on crop development even if their levels relative to the crop's needs may be small. Whenever the availability of one or more of these elements is inadequate, yields will be lowered and the quality of crop products compromised, although crop species and cultivars vary widely in their sensitivity to shortages. Micronutrients are essential for soil fertility, agricultural yield, growth, and human nutrition.

However, when these micronutrients are present at high amounts, they can also be shown to have a toxic impact, which puts plant growth at risk. To prevent needless expenses, potential harmful effects, and harmful interactions with other nutrients, growers should closely adhere to recommendations for micronutrients [42]. Micronutrients must be absorbed by plants from the soil or added through foliar treatment to enhance vegetative growth and crop output. Micronutrients applied foliarly are more efficient than those applied in soil since the latter technique takes longer for micronutrients to be absorbed and assimilated [50].

3. Conclusion

Vegetable crops depend on integrated nutrition management for their growth and development. The nutritional value of crops is becoming a serious concern, thus, application of balanced agricultural nutrients are vital to support soil health and crop production moreover sustaining the quality of vegetables like okra is of profound importance. Improved yield, quality, earliness, fruit setting, increased post-harvest life, and development of tolerance to biotic and abiotic stressors of okra cultivation are all benefits of integrated nutrition management.

Abbreviations

INMS	Integrated Nutrient Management System
N	Nitrogen
k	Potassium
p	Phosphorus
PM	Poultry Manure
FYM	Farm Yard Manure

Author Contributions

Mathewos Misgana Gaddisa is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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