E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2020; 3(1): 25-32
Received: 12-11-2019
Accepted: 15-12-2019

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Yield response and nutrient use efficiencies of hot pepper (*Capsicum annuum* L.) to inorganic fertilizers in Ethiopia: A review article

Nimona Fufa Hunde

Abstract
Hot pepper is an important spice and vegetable crop in Ethiopia. Its production is constrained by a number of problems among which declining soil fertility is the primary. The amount of fertilizer to be applied depends on soil fertility, fertilizer recovery rate, and organic matter, soil mineralization, and soil leaching. The solanaceous groups of vegetables including hot pepper generally take up large amounts of nutrients. The amount of nutrients it take up depends on the quantity of fruit and dry matter produce, which in turn is influenced by a number of genetic and environmental variables. In the absence of any other production constraints, nutrient uptake and yield are very closely related. Pepper, like other crop produces well when it is adequately supplied with the essential nutrients through fertilization. Farmers produce hot pepper using fertilizer which is essentially required for growth and productivity but, unbalanced application of plant nutrients magnifies the reduction of other important nutrient elements in soils. Previous fertilizer research work in Ethiopia has focused with macro nutrients under different soil types and various climatic conditions, while very limited work has been reported with other essential macro and micro nutrients. Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) revealed that in addition to N and P, nutrients such as S, B, Zn and Fe are deficient in Ethiopian soils. The yield of hot pepper varies year to year; this indicates that pepper crop need intensive care and management for high return per unit area and also fertilizer use efficiency depends to large extent on soil fertility conditions. Improving agronomic efficiency provides yield increases which can be achieved for a given quantity of fertilizer applied.

Keywords: EthioSIS, fertilizer, soil fertility, unbalanced application

Introduction
Hot Pepper (*Capsicum annum* L.) is an important spice and vegetable crop in tropical areas of the world and it belongs to the *Solanaceae* family, and the genus *Capsicum.* It is closely related to tomato, eggplant, potato and tobacco. The genus *Capsicum* is the second most important vegetable crop of the family after tomato in the world (Berhanu *et al.*, 2011) [10]. It's an important crop, not only because of its economic importance, but also due to the nutritional and medicinal value of its fruit. The fruit is an excellent source of natural colours and antioxidant compounds whose intake is an important health protecting factor by prevention of widespread human diseases (Howard *et al*., 2000) [45]. The antioxidant, vitamin A, C and E are present in high concentrations in pepper (Robi and Sreelathakumary, 2004) [69].
It is one of the most important spice crops widely cultivated around the world for its pungent flavor and aroma (Obidiebub *et al.,* 2012) [59]. Fine pungent powder of hot pepper ('berbere') is an indispensable flavoring and coloring ingredient in the daily preparation of different types of Ethiopian sauces ('wot'), whereas the green pod is consumed as a vegetable with other food items. In Ethiopia, hot pepper is commonly cultivated within an altitude ranges of 1400 to 1900 meter above sea level (MoARD, 2009; EIAR, 2007) [25], which receives mean annual rainfall of 600 to 1200 mm, and has mean annual temperature of 25 to 28°C (EIAR, 2007) [25].
In terms of total production, the share of pepper is high as compared with other vegetables such as lettuce, tomatoes, head cabbage, onion and others (CSA, 2018) [17]. In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2017 was estimated to be 152,752.94 ha, and 10,207.26 ha respectively, (CSA, 2018) [17].

However, the productivity is still low attributed to lack of proper nursery and field agronomic management practices, (adequate nutrient supply, diseases, poor aeration, unbalanced nutrient supply and lack of high yielding cultivars).

Among these, nutrient deficiency is the most yield limiting factor in vegetable production in Ethiopia, nitrogen, phosphorus and other micronutrient as S, B, Zn deficiencies are the main constraint for vegetable and other crop production (Alemu and Ermias, 2000) [3]. Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields (Ryan, 2008) [72]. Previous fertilizer research work in Ethiopia has focused with N and P under different soil types and various climatic conditions, while very limited work has been reported with other essential macro and micro nutrients. Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) also revealed that in addition to N and P, nutrients such as S, B, Zn are deficient in Ethiopian soils (ATA, 2014) [6].

In smallholder farming system, the causes of nutrient deficiency includes high plant nutrient uptake, removal of entire crop residues, use of cattle dung as source of fuel energy for cooking, high rainfall, nutrient loss through leaching, P-fixation in acid soil and gaseous loss of N (Aticho, 2011) [7]. Fertilizers are efficient exogenous source of plant nutrients (Akram *et al*., 2007) [2], since, plant growth and crop production require adequate and balanced supply of nutrients in order to maximize productivity by optimizing the plant nutrient uptake (Mengel and Kirkby, 2001). For instance application of mineral N, P and K fertilizers improved dry marketable pod yield and yield contributors through better nutrient uptake, growth and development (Obidiebube *et al.*, 2012) [59]. In addition, some reports also indicated that supply of micronutrients along with NPK fertilizer can increase nutrient use efficiency of crops (Malakouti, 2008) [50]. The nutrient use efficiency determination for crop sustainability, profitability and productivity by agronomic use efficiency, physiological nutrient use efficiency and apparent recovery of the nutrients were the most important tools for soil fertility management practices particularly for fertilizers experiment.

In Ethiopia, farmers produce vegetable crops including hot pepper using blanket fertilizer recommendation such 100 kg Urea + 100 kg DAP ha^{-1} (EIAR, 2007) [25]. Nevertheless, essential micronutrients required for successful plant growth and productivity have never been included in the fertilizer program of Ethiopia. Such unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, Mg, Ca, S and micronutrients (Wassie *et al.*, 2011) [79]. As a result the current productivity of hot pepper is very low compared to the potential yield of the crop, in all parts of the country.

In Ethiopia the average national productivity of hot pepper was 6.2 t ha^{-1} for green peppers and 1.7 t ha^{-1} for red peppers (CSA, 2018) [17]. Whereas under research condition of Ethiopia 2.5 t ha^{-1} dried pepper and 20 t ha^{-1} green pepper were recorded (Lema *et al.*, 2008). In view of these different fertilizer rates were recommended for different parts of hot pepper production areas of Ethiopia. For instance Girma *et al.* (2001) [38] reported that application of 200 kg ha^{-1} of DAP and 100 kg ha^{-1} of urea was found optimum for better yield at Abobo area. Whereas, application of 207 kg of DAP and 137 kg of urea per hectare gave optimum yield of pods in hot pepper variety Oda Haro at Bako (MoARD, 2005) [55]. These indicate that actual amount of fertilizer to apply depends on soil fertility, crop variety and fertilizer use efficiency of the variety. Understanding plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, increasing crop yields through the application of nitrogen and phosphorus alone can deplete other nutrients (FAO, 2000) [31].

Recent studies have indicated that elements like N, P, K, S and Zn levels as well as B and Cu are becoming depleted in most Ethiopian soils and deficiency symptoms are being observed on major crops in different areas of the country (ATA, 2014) [6].

In Ethiopia, soil fertility depletion (nutrient deficiency) is one of the vital yield limiting factors in vegetable producing areas of the country owing to intensive cultivation, very low and unbalanced nutrient supply. In Ethiopia, utilization of chemical fertilizers in the country increased significantly since the 1980's but it still remains very low (Zeleke *et al*., 2010). Farmers produce hot pepper either by using the recommended blanket fertilizer (100 kg Urea ha^{-1} + 100 kg DAP ha^{-1}) or smaller amounts based on their economic capacity. The essential micronutrients needed for plant growth and productivity were not applied and this may be a cause for low hot pepper crops productivity. Therefore, the information generated though this review were bases for understanding on the nutrient requirements of pepper and to assess the effects of inorganic fertilizers on yield of hot pepper

2. Literature Review

2.1 Origin and Distribution of Hot pepper

The origin of *Capsicum* species is extended from Mexico in the North to Bolivia in the South of Latin America, where it has been part of human diet since about 7500BC (Purseglove *et al*., 1981) [65]. Spanish and Portuguese explorers spread pepper around the world. Pepper was introduced to Spain in 1493, England in 1548 and Central Europe in 1585. Then, from Europe it spread to Asia. Currently the crop is produced in various countries around the world including India, China, Pakistan, Indonesia, Sri Lanka, Thailand and Japan in Asia and Nigeria, Uganda and Ethiopia in Africa. India and Indonesia have been the largest producers. Currently China is the main producer and exporter in the world. Hot pepper (*Capsicum annuum* L.) belongs to the genus *Capsicum* and family Solanaceae. The genus consists of approximately 22 wild species and five domesticated species.

Among the cultivated species the cultivation of *Capsicum annuum* is the most widely spread all over the world (Berke *et al*., 2005) [11]. It is believed to have originated in Central and South America. Peru and Mexico might have been the second centers of origin, after which it spread into the New World Tropics before its subsequent introduction into Asia and Africa in 1493. Columbus has been given credit for introducing hot pepper to Europe, and subsequently to Africa and Asia. Tropical Asia, tropical Africa and South America (Mexico) and the Caribbean are the main producers. It is a national spice of Ethiopia and believed to be introduced to Ethiopia probably by the Portuguese in the 17th century.

2.2. Economic Importance of Hot Pepper

2.2.1. Global importance of hot pepper

Both hot and sweet peppers are processed into many types of sauces, pickles, relishes and canned products. According to Bosland and Votava (2000), sweet pepper and hot pepper, like tomato and eggplant are rich in vitamins A and C and a good source of B_2, potassium, phosphorus and calcium and both hot and sweet peppers contain more vitamin C than any other vegetable crops. Hot pepper is an important vegetable crop both economically and nutritionally because these are excellent sources of natural colours and antioxidant compounds (Ou *et al*., 2002). A wide spectrum of antioxidant vitamins, carotenoids, ascorbic acids, capsaicinoids and phenolic compounds are present in hot pepper fruits (Nwose, 2009) [58]. The capsaicinoids are being studied as an effective treatment for a variety of sensory nerve disorders, cystitis and human immunodeficiency virus (Perucka and Materska, 2001) [62].

According to Bosland and Votava (2000), pepper is the most recommended tropical medication for arthritis and extracts are used in wide range of medicines against tonsillitis, loss of appetite, flatulence, intermittent fever, sore throat, swellings and hardened tumours. The pharmaceutical industry uses capsaicin as a counter-irritant balm (cream), for external application of sore muscles. Creams containing capsaicin ($C_{18}H_{27}O_3N$) have reduced pain associated with postoperative pain for mastectomy patients and for amputees suffering from phantom limb pain. Peppers also stimulate the flow of saliva and gastric juices that serve in digestion (Alicon, 1984). Hot pepper pungency is a desirable attribute in many foods. Pungency is produced by the capsaicinoids, alkaloid compounds ($C_{18}H_{27}NO_3$) that are found only in the plant genus, *Capsicum*. The capsaicinoids are produced in glands on the placenta of the fruit. While seeds are not the source of pungency, they occasionally absorb capsaicin because of their proximity to the placenta. No other plant part produces capsaicinoids (Hoffman *et al*., 1983) [44].

2.2.2. Importance of hot pepper in Ethiopia

Pepper (*Capsicum annuum* L.) is an important spice and vegetable crop in Ethiopia. The history of pepper in Ethiopia is perhaps the most ancient than the history of any other vegetable product (EEPA, 2003) [24]. Capsicums are the most popular salad vegetables (Esayas, 2009) [26]. Dried ripe pods of many different varieties of capsicum are utilized to prepare cayenne pepper, ground pepper and crushed red pepper (EEPA, 2003) [24]. This is because it increases the acceptance of the insipid basic nutrient foods. People consume hot pepper for intake enhancement as well as to supplement the dietary needs. It is also one of the major income-generating crops for most households of the pepper producing areas and it plays a vital role in food security in Ethiopia (Roukens, 2005) [70].

Ethiopians have strong attachment to dark red pepper, which has high value principally for its high pungency. The fine powdered pungent product is an indispensable flavouring and colouring ingredient in the common traditional sauce 'wot' whereas the green pod is consumed as a vegetable with other food items. Hot pepper spice is used to impart the desired colour, flavour and pungency in various dishes made from cereals. There is a general belief among Ethiopians that a person who frequently consumes hot pepper has resistance to various diseases. It is in the daily diet of most Ethiopians. The average daily consumption of hot pepper by an Ethiopian adult is estimated at 15 gram, which is higher than the consumption of tomatoes and most other vegetables.

In addition to having major role in Ethiopians daily dish, pepper also plays an important role in the national economy. It is a crop of high value in both domestic and export markets. Since it is a commercial and industrial crop, it generates employment to urban and rural workers. Oleoresin (colouring) and capsaicin (hot) are extracted from red pepper (capsicum) for export purpose. The deep red coloured and large pod cultivars have a very high processing demand in the country. The main processed product, oleoresin, is exported to different countries and the spiced ground is supplied to local market. From 1992/93 to 2003/04, a total of 616.16 tons of oleoresin, which worth 106.6 million Birr, was exported to different countries by Ethiopian Spices Extracting Factory (ESEF, 2005) [27].

2.3. Production of Hot Pepper Globally and in Ethiopia

The production of *Capsicum* species for spice, vegetable and other uses increases every year. The total area devoted to pepper worldwide is estimated at 4 million hectare with an average annual increase of 5% (Weiss, 2002) [80]. While, according to FAO (2007) [32] report world production of pepper was 28.4 million tons in both dry and green fruits from 3.3 million hectares of land with annual growth rate of 0.5 per cent. Forty-six percent of production of pepper is in Asia. Southern Europe is the second most important producing part with 24% of world production. Global production grew by 2.6% per year on average between 1992 and 2012. India is the largest producer (38%) followed by China (8.7%) and Peru (5.2%). India and China together account for about 75% of global exports of dry chilies (Crem and Freek, 2015) [16].

Hot pepper is the leading vegetable and spice crop grown in Ethiopia (Esayas, 2009) [26]. Pepper production accounts for 34% of the total spice production in the three regions of the country namely Amhara, Oromiya and Southern Nations Nationalities and Peoples Regional States (Roukens, 2005) [70]. In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2017 was estimated to be 152,752.94 ha, and 10,207.26 ha respectively. The central (eastern and southern Showa), western, north western (Wollega and Gojjam) and the southern part of the country are the potential pepper producing areas. Chilli is well adapted in Gambella, Mizan Teferi and Tepi as a rain fed crop and in Gode as an irrigated crop

FAO (2009) [33] report indicated that the estimated productions of peppers in Ethiopia were 220,791 t from 97,712 ha in green form and 118,514 t of dry pepper from an area of 300,000 ha. The productions of peppers in Ethiopia were 45,853.69 tons from 7,449.59 hectares in green form and 262,790.83 tons of dry pepper from an area of 142,795.16 hectares. Even though the average productivity of pepper at national level in 2016 was 6.16 and 1.84 t ha^{-1}, yield reduction by 0.18 and 0.05 t ha^{-1} was observed for green and dry pepper from 2014-2017 cropping season, respectively (CSA, 2016/17). This indicates that hot pepper and other vegetable crops need intensive care and management for high return per unit area. Yield is dependent on varieties and fertilizers themselves are considerably depending on a number of factors. In Ethiopia hot pepper production for dry pod has been low with a national average yield of 0.4 t dry fruit yield per hectare (Fekadu and Dandena, 2006) [36].

2.4. Agro-Ecological Requirements of Hot Pepper

Capsicums flourish in warm, sunny conditions and require 3-5 months growth period with a temperature range of 18-30 ºC; below 5 ºC growth is retarded and frost kills plants at any growth stage. A seedbed temperature of 20-28 ºC is the optimum for germination, which is slowed at 15 ºC and cease at 35 ºC (Weiss, 2002) [80]. If seeds are planted when soil temperatures are too cool, germination rate is retarded, affecting emergence and growth of the seedlings. Higher yields result when daily air temperature ranges between 18 and 32 ºC during fruit set (Bosland and Votava, 2000).

Pepper is adapted to high temperature but in excessively hot and dry weather may produce infertile pollen thereby reducing fruit set. Temperature above 32 ºC with a fairly low relative humidity may also cause excessive transpiration, resulting in dropping of buds, flowers, and fruits. A drop in temperature below 16 ºC at flowering may result in poor fruit set and seedless fruits (Rice *et al.*, 1990) [67]. Pepper (*Capsicum annuum* L.) grows on almost all soil types, but is most suited to well drain sandy or loamy soils, rich in lime, with a pH of 5.5- 6.8 and high water retention capacity. However, pepper can also tolerate a wider soil pH range of 4.5 (acidic) to 8.0 (slightly alkaline). Light sands, clay sandy and sandy loams are also suitable for growing pepper (Dennis, 2013) [21].

Similarly, Anonymous (2014) [5] reported that the quality and quantity of pepper fruits are of crucial importance and are greatly influenced by the fertility and nutrient levels of the soil. Pepper prefers sandy to loam soils. *Capsicum* is moderately sensitive to soil salinity (Berke *et al*., 2005) [11]. In addition to crop nutrient requirements and general soil types, fertilizer recommendations should take into consideration soil pH, residual nutrients, and inherent soil fertility (Decoteau, 2000) [20]. Therefore, fertilizer recommendations based on soil analyses have the greatest potential for providing peppers with adequate but not excessive fertility (Weiss, 2002) [80].

Capsicum can be grown as a rain-fed or irrigated crop and different soil types. In areas with regular and ample rain, irrigation is not needed. An annual rainfall of 600-1250 mm is suitable; above 1500 mm, soils must be free-draining since plants cannot tolerate water logging, even for short periods, especially at seedling stage (Weiss, 2002) [80]. Heavy rain at fruit bloom adversely affects pollination and reduces fruit yield, and promotes fungal damage of nearly ripe or ripe fruits (Weiss, 2002) [80]. Irrigation is essential in arid and semi-arid regions to provide adequate moisture for production of peppers. Studies show that irrigation increases pepper yields by an average of at least 60 percent over dry land production and that quality of irrigated peppers is also much better (Rice *et al.*, 1990) [67].

The most critical stages for watering of pepper crop are at transplanting, flowering and fruit development stages. According to Bosland and Votava (2000), moisture stress during blooming causes dropping of blossoms, immature pods and flowers. If plant growth is slowed by moisture stress, sun scald and dry rot of fruit may become severe though fruits may become more pungent. Moreover, moisture stress during the period of rapid vegetative growth and at flowering reduces yield by up to 50% depending on cultivar. Decoteau (2000) [20] also reported that water stress during flowering and fruit development can cause poorly developed, small, misshapen fruit or blossom-end rot while over watering can promote disease such as *phytophtora* and other root-rotting organisms.

2.5. Nutrients Requirement of Pepper

The amount of fertilizer to be applied depends on soil fertility, fertilizer recovery rate, and organic matter, soil mineralization of nitrogen (N), and soil leaching of N (Berke *et al.*, 2005) [11]. The solanaceous groups of vegetables (tomato, eggplant and pepper) generally take up large amounts of nutrients. The amount of nutrients they take up depends on the quantity of fruit and dry matter they produce, which in turn is influenced by a number of genetic and environmental variables. In the absence of any other production constraints, nutrient uptake and yield are very closely related (Hegde, 1997). Pepper, like other crop produces well when it is adequately supplied with the essential nutrients through fertilization (Fagbayide, 1997) [28].

Optimum dose of fertilizers improve the proper growth and development and maximize the yield of pepper (Roy *et al*., 2011) [71]. Pepper needs to absorb more nutrients than tomato to produce a unit of dry matter or fruit yield; concentrations of NPK are highest in the leaf, followed by the fruit and the stem. The author also reported, in pepper, dry matter production continues to the end of the life cycle. According to Decoteau (2000) [20], over fertilizing peppers can have negative effects on fruit earliness, yield and quality. *Capsicum annuum* species require adequate amount of macro and micro nutrients since nutrient uptake and dry matter production (fruit yield) of pepper are closely related (Hedge, 1997) [43]. According to Siddesh (2006) [75] major nutrients like nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) play an important role in vegetative and reproductive phase of crop growth.

2.5.1. Nitrogen fertilizer requirement of hot pepper

Nitrogen is the main plant nutrient which limits plant growth (Sabri *et al*., 2001) [73]. More nitrogen is required for production than P and K since it has both structural and enzymatic activity function. Nitrogen has the greatest effect on the average nutrients needed for optimum yield of *Capsicum* in which the crop is particularly responsive to nitrogen for plant growth and yield (Bosland and Votava, 2000). Nitrogen is a component of protoplasm, protein, nucleic acid, chlorophyll and plays a vital role in both vegetative and reproductive phase of crop growth. During growth, further nitrogen may be applied to achieve more yields. A side dressing of 22-34 kg ha^{-1} of nitrogen is applied when the first flower buds appear and when the first fruits are set (Bosland *et al*., 1994) [12].

Too much nitrogen on the other hand can over stimulate growth, resulting in large plants with few early fruits, or delaying maturity, reduces firmness by reducing wall thickness and causes flowers and small fruits to abscise and increasing risk of blossom-end rot or pod rots. But on adequate amount Nitrogen has been shown to increase the number and size of pepper marketable fruits, fruit pungency and overall yield. Roy *et al.* (2011) [71] also found that the length of pepper significantly increased with the increase of nitrogen level. They reported, the highest length of pepper (7.63 cm) found with 150 kg N ha^{-1}, which was statistically similar (7.41 cm) with 100 kg N ha^{-1} while the lowest length (5.83 cm) was found in the control treatment. Likewise, Prabhakar and Naik (1997) [64] also observed highest dry matter production of pepper 98.4 and 98.8 g per plant with highest level of nitrogen (180 kg N ha^{-1}) in two years studies. Whereas, the control plots produced 43.8 and 32.0 g per plant respectively.

Fertilizer trials conducted in different sites of Ethiopia showed difference in yield performance pepper (Sam–Aggrey and Bereke-Tsehai, 1985) [74]. In the fertilizer trail conducted at Bako, 100 kg ha^{-1} N and 100 kg P_2O_5 ha^{-1} gave higher marketable and total dry pod yield. However, Jackson *et al.*, (1985) [47] recommendation of inorganic fertilizers for better performance of pepper was that application of 140 kg ha^{-1} of P_2O_5 and 130 kg ha^{-1} of N as optimum level. Application of 95.22 kg ha^{-1} P_2O_5 and 97.06 kg ha^{-1} of N provided optimum yield of pepper variety Oda Haro at Bako (MoARD, 2005) [55]. This indicated that the nitrogen and P_2O_5 requirement of hot pepper in different parts of Ethiopia is different as the result of difference in environmental conditions, varieties and soil types.

2.5.2. Phosphorus fertilizer requirement of hot pepper

Phosphorus is a constituent of nucleoproteins, and it is involved in energy transfer of compounds like ADP, ATP. It also plays an important role in the transfer of energy in the metabolic processes (Siddesh, 2006) [75]. Phosphorous is absorbed by plants in different forms. Gupta (2011) [39] reported that Plants absorb most of their P as the primary orthophosphate ion (HPO_4^{2-} and

$H_2PO_4^-$) soil pH greatly influences the availability and uptake of P by plants. It is believed that phosphorus results in a better yield and more red colored fruit. Fertilizer requirements vary with soil type and previous crop history. And thus a balanced nutrient level is required for maximum production.

In Ethiopia, the recommended fertilizer rate for the hot pepper is, 100 kg ha^{-1} DAP and 100 kg ha^{-1} for UREA (EARO, 2004) [23]. There were no differences on plant height, foliage dry weight, and number of fruits per plant. In a study of the effect of nitrogen and phosphorus application rates on seed yield of sweet pepper, phosphorus rates decreased the days to flower. Phosphorus rates alone increased the number of branches per plant from 4.1 to 5.8. Increased P rates resulted in significant yield increases; higher P rates increased considerably the number of fruits per plant as well as seed yield. The effect of phosphate and plant densities on growth and yield of field grown capsicum were studied (Wanknade and Morey, 1982). Higher P rates increased plant height, dry matter, and yield. Bajaj *et al*. (1979) [8] reported an increase in capsaicin content of pepper pods with increasing P rates. The combination of the highest N and highest P rate reduced capsaicin content 0.40 g/100 g compared to 0.52 g/100 g obtained with the combination of lower P and highest N rate.

2.5.3. Potassium fertilizer requirement of hot pepper

Potassium is responsible for regulation and maintenance of electrochemical equilibrium in cells and other parts involved in enzyme activities. In addition, it takes part in protein synthesis, carbohydrate metabolism, regulation of activities of the essential elements, and control in plants (Siddesh, 2006) [75]. Peppers have a high K demand and the harvested fruit removes a large amount of K from the soil. Pepper has the greatest requirement for potassium (40%) and nitrogen (31 %) in relation to the total amount of absorbed nutrients. Soil K status influences K uptake by plant roots (Gupta, 2012).

Potassium also involves in facilitate the uptake of nitrogen by plants (Akram *et al*., 2007) [2]. High potassium could increase shriveling of harvested pepper and reduce shelf life. In general the amount of K removed by plants depends on the production level, soil type, and the retention or removal of crop residues (Yadvinder *et al*., 2005) [81]. Fawzy *et al*. (2005) [34] found that potassium fertilizer had a significant effect on the fresh weights of leaves and stems as well as early and total yield of sweet pepper plants. In another study, potassium is shown to affect pod pigment biosynthesis and pungency because of its effect on enzymes. Potassium fertility affects pepper plant growth, pod yield and pungency in which biomass, fruit count and fruit weight per plant increased linearly with increasing K rate Charles and Decoteau (2000) [20]. In contrary, field experiment conducted by Chattopadhyay *et al.* (2000) [15] on potassium fertilization revealed that different rates of potassium fertilizers did not register any significant variation with respect to growth and fruit characters in pepper where soil potassium test was high. Various studies have revealed that the kinds of potassium fertilizers used influence yield, size and quality, (Michalojc and Buczkowska, 2007) [53]. The authors added that supplying the plants with potassium greatly determines fruit quality in egg plant. Therefore, selecting an appropriate potassium fertilizer kind and dose appears to be very important

2.5.4. Sulfur fertilizer requirement of hot pepper

Sulfur (S) is one of the essential macro elements of plant and is regarded as the fourth key element after N, P and K (Lewandowska and Sirko, 2008). Most often S deficiencies are observed in low OM soils and coarse-textured soils where S can be easily leached out. It is used as a soil amendment to improve the availability of nutrients such as P, K, Zn, Mn and Cu (Hassaneen, 1992) [41]; where they found that sulfur element reduced pH and conversed the unavailable phosphorus to available form for plant tissues. Sulfur is required for the synthesis of important essential amino acids by increasing allylpropyl disulphide alkaloid (43% S) and the capsaicin which is the principle alkaloids responsible for pungency in onion and sweet pepper respectively and also it makes a key role in the defense of plants against nutrients stress, attacks of pests and increases the synthesis of chlorophyll and vitamins in the cell. (Hasseneen, 1992)

Nitrogen application in higher rates increases the intensity of sulfur deficiency. Without nitrogen fertilizer application, plants show no visible sulfur stress, whereas nitrogen fertilizer application to plants especially at higher levels without applying sulfur shows severe physiological disorders (Kopriva and Rennenberg, 2004) [48]. Moreover, Randle and Bussard (1993) [66] reported that sulfur often ranked immediately after nitrogen, phosphorus and potassium in terms of importance to crop productivity. Complete yield potential of a crop cannot be obtained where soil is suffering from sulfur deficiency, even irrespective of all the other nutrients application and under excellent management practices. Carrying out a systematic research is needed to find out the knowledge of these nutrient elements (Sulfur) in order to develop comprehensive information about the response of hot pepper to these elements.

Sulfur deficiency symptoms first appear in the younger leaves because S is not easily translocated in the plant. Root development is restricted, and shoot–root ratios usually decrease for plants grown under S deficiency. The total dry matter yields of crops increase as the sulfur fertilization increased and enhance the yield of barley, cabbage and onion yields compared to the NPK fertilized thus; highest yield was obtained after the application of 40 kg S and 80 kg S (Skwierawska *et al*., 2008) [76].

12.5.5. Micronutrient requirement of hot pepper

Micronutrients are usually required in small quantities, nevertheless are vital to the growth of plant. Improvement in growth characters as a result of application of micronutrients might be due to the enhanced photosynthetic and other metabolic activity which leads to an increase in various plant metabolites responsible for cell division and elongation as opined by Hatwar *et al.* (2003) [42].

2.5.5.1. Boron

Boron is absorbed by plants as boric acid, which is easily leached in soils. Globally, B deficiency has been recognized as the second most important micronutrient constraint in crops after zinc (Zn) (Ahmad, *et al*., 2014) [1]. Boron helps in the absorption of water and carbohydrate metabolism (Haque *et al*., 2011) [40], translocation of carbohydrates in plants, DNA synthesis in meristems, cell division and elongation, active salt absorption, water relation and photosynthesis and involves indirectly in metabolism of nitrogen, phosphorous, fat and hormones. Due to the lack of boron, there is hypertrophy, degeneration and disintegration of cambium cells in the meristematic tissues. Its deficiency may cause sterility, small fruit size, and poor yield (Davis *et al*., 2003) [19] and deficiency retards apical growth and development because of its impacts on cell development and on sugar formation and translocation.

Boron also plays an important part in flowering and fruiting processes, N metabolism, hormonal action and cell division (Nonnecke, 1989) [57]. Boron deficiency can be caused by high pH in the soil, the availability of B decreases when the pH is higher than 6.5-7.0. Boron has also helped to reduce disease severity in some crops because of the effect that B has on plant metabolism, cell membranes and cell wall structure (Dordas, 2009) [22].

2.5.5.2. Zinc

Zinc exerts a great influence on basic plant life process such as nitrogen metabolism, photosynthesis, protein quality and resistance to a biotic and biotic resistance in plants (Potarzycki, and Grzebisz, 2009) [63]. Zn involved in auxin (IAA) metabolism like, tryptophane synthesis, tryptamine metabolism, protein synthesis, formation of nucleic acid and helps in utilization of nitrogen as well as phosphorus by plants (Ram and Katiyar, 2013). In plant deficiency of $ZnSO_4$ affects various plant metabolic processes such as nitrogen uptake, photosynthetic activity, nitrogen metabolism chlorophyll synthesis and protein quality (Cakmak, 2008) [14].

According to Alloway (2008) [4], Zinc is essential for the normal healthy growth and reproduction of plants, animals and humans. Micronutrient deficiencies are often induced because of interactions with other nutrients. Zinc uptake was decreased with increasing P application (Oseni, 2009) [60]. Plant height, total chlorophyll and biomass were decreased as the amount of Zn concentration in the soil becomes above sufficient level of crops (Mirshekal *et al.*, 2012) [54]. In this country, blended fertilizer (Zn and B) micronutrients combined with (NPK) macronutrients improve nutrient concentration, and uptake and enhancing yield of teff (Feyera *et al.*, 2012). Fisseha (1996) [37] observed that the total Zn, Mn and Fe contents of the Vertisols at Shoa Robit areas were comparable and on most cases higher than values reported for most Vertisols elsewhere. As he, suggested that hidden micronutrient deficiencies are far more widespread than is generally estimated and the problems which today may be considered local may well become more serious in the relatively near future, occurring extensively over new areas and creating widespread and complicated production restrictions if they are not properly studied and diagnosed in time.

2.6. Nutrient Uptake and Use Efficiency of Hot pepper

Actual nutrient uptake will vary with crop yield and variety. The nutrient requirement of the crop can be met by nutrients available in the soil and by nutrient additions. When fertilizer prices represent a large portion of a producer's costs, it is very important to maximize fertilizer nutrient use efficiency (Warncke *et al.*, 2004) [78]. According to Mengel and Kirkby (1987) [52] the nutrient content of plant tissue reflects soil availability. The amounts of nutrients exploited in the harvested portion of the crop will depend on the yield and the concentration of the nutrients in time and space, variety, soil and environmental factors (Fageria *et al.*, 2011) [29]. In crop production to attain higher yields, the plants need nutrient fertilization in adequate quantity (Fageria *et al.*, 2011) [29]. The relationship of the uptake of N, P and S were very strongly correlated with total dry pod yield, this indicates the improvement of total dry pod yield was through nutrient uptake (Nimona and Girma, 2019) [56].

Balanced and adequate supply of plant nutrients is important in order to achieve a high degree of nutrient utilization by crops, which also results in lower losses (FAO, 2006). Fertilizer use efficiency depends to large extent on soil fertility conditions. To use fertilizer in a sustainable manner, management practices must aim at maximizing the amount of nutrients that are taken up by the crop and minimizing the amount of nutrients that are lost from the soil (Bationo *et al.*, 2012) [9]. Improving agronomic efficiency provides both direct and indirect economic benefits, larger yield increases can be achieved for a given quantity of fertilizer applied; or less fertilizer is required to achieve a particular yield target (Bationo *et al.*, 2012) [9]. Integrated plant nutrition systems (IPNS) are the maintenance or adjustment of soil fertility and of plant nutrient supply to sustain a desired level of crop production. It is achieved by optimizing the benefits from all possible sources of plant nutrients and by improving the overall management of the farm (FAO, 2000).

3. Conclusions

Hot pepper is one of the most important vegetable crops produced in Ethiopia, that serve as spice, coloration, appetizer and source of income for smallholders farmers in the study area. The production of hot pepper depends on either on the national recommendation of fertilizer rates or by farmer's decision. However, the application of fertilizer is necessary depending on the study results in the specific area and crop. Hot pepper quality and quantity of pepper fruits are of crucial importance and are greatly influenced by the fertility and nutrient levels of the soil. The nutrient content of plant tissue reflects soil availability. Thus, the amounts of nutrients exploited in the harvested portion of the crop will depend on the yield and the concentration of the nutrients in time and space, variety, soil and environmental factors. The nutrient concentrations and uptakes were linearly increased in response to the application of fertilizers rates increased. The fact that all the crop yield parameters being linearly increased with rising fertilizer rates up to optimum and declined when beyond. Finally, by virtue of its greater solubility in the soil, total nutrient uptake and fertilizer use efficiency, and apparent recovery were the inclusion of micronutrients as blended fertilizer brought higher pod yield compared to recommend NP fertilizer has been practiced in most area of the country.

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