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Optimizing nitrogen fertilizer rates for selected hot pepper varieties (Capsicum annuum L.) under dryland conditions in Asaita, Afar Region, Ethiopia

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Abstract

The northeastern Ethiopian (Afar Awash basin, including the Asiata district) soils are deficient in macronutrients like Nitrogen and affected by ongoing alkaline problems. At the same time, it is characterized by high salinity and low nitrogen tolerance. These have effect on growth, yield, and NUE of Solanaceae in general, and hot pepper in particular. However, studies on the effects of variety and inorganic nitrogen fertilizer rates on the growth, yield, and NUE of green pods of hot Pepper are scant in the study area. Therefore, a field experiment was conducted to determine the optimal nitrogen fertilizer rate that maximizes fruit yield and nitrogen use efficiency of selected hot Pepper (*Capsicum annuum* L.) varieties under irrigated dryland conditions in Asaita district during the 2021/22 cropping season. The treatments consisted of four hot pepper varieties (Marko Fana, Melka Awaze, Melka Shola, and Irta Ale F1) and four nitrogen fertilizer rates (0, 23, 46, and 69 kg ha^{-1}). They were laid out in a 4x4 factorial arrangement in a randomized complete block design with three replications. The ANOVA result show that Pod length, pod diameter and 50% days of flowering were highly significantly ($P < 0.001$) affected by interaction effect variety and nitrogenous fertilizer rate; plant height, number of pod per plant and total pod yield were highly significantly ($P < 0.001$) affected by main effect of nitrogen fertilizer rates whereas marketable pod yield per plot and nitrogen use efficiency were highly significantly ($P < 0.001$) affected by main effect of variety. On the other hand, the number of branches per plant and the unmarketable green pod yield per plot are considered. Above-ground biomass and harvesting index were found to be statistically non-significant due to the main and interaction effects of variety and nitrogen fertilizer rates. The Maximum total green pod yield (8.30 kg/plot) and NUE (9.40 g g^{-1}) were obtained with the height application rate of nitrogenous fertilizer ha^{-1} and the Irta Ale F1 variety, respectively. Therefore, the improved green pod yield and nitrogen use efficiency achieved through the application of nitrogenous fertilizer and the use of the Irta Ale F1 variety are important for ensuring sustainable hot pepper production and productivity.

1. INTRODUCTION

1.1. Background and Justification of The Study

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. The genus Capsicum is the second most important vegetable crop, ranking directly behind the tomato in global economic significance and production (Rubatzky & Yamaguchi, 1997; Berhanu *et al.,* 2011). It is an economically, nutritionally and medicinally important vegetable crop. The fruit is an excellent source of natural colours and antioxidant compounds whose intake is an important health-protecting factor by preventing widespread human diseases (Howard *et al*., 2000). The antioxidants vitamins A, C, and E are present at high concentrations in Pepper (Robi & Sreelathakumary, 2004).

Hot Pepper is one of the most important spice crops, widely cultivated worldwide for its pungent flavour and aroma, including in Ethiopia (Ikeh *et al.,* 2012). Fine, pungent powder of hot Pepper ('berbere') is an

indispensable flavouring and colouring ingredient in the daily preparation of various Ethiopian sauces ('wot'). In contrast, the green pod is consumed as a vegetable with other foods. In Ethiopia, hot Pepper is commonly cultivated at altitudes of 300 to 1200 meters above sea level (EIAR, 2017), which receive mean annual rainfall of 500 to 1200 mm and have mean annual temperatures of 35 to 8°C (EIAR, 2017).

In terms of total production, the share of Pepper is high compared with other vegetables such as lettuce, tomatoes, head cabbage, onion and others (CSA, 2016). In Ethiopia, the total area under hot Pepper for dry pod (Berbere) and for green Pepper (Karia) in 2017 was estimated to be 142,795.16 ha, and 7,449.59 ha respectively, While in Afar Regional State the total area covered with hot Pepper in years 2016/17 cropping season were very low (below 70ha with estimated total production of 125.6tone/ha (CSA, 2016). The possible reason for this very low productivity is related to a lack of proper nursery, field agronomic management practices (adequate nutrient supply, diseases, poor aeration, soil salinity, inappropriate fertiliser utilisation, due to an increase in the price of fertilizers) and lack of high-yielding and adaptive cultivars (EIAR, 2017).

Among the above factors, nutrient deficiencies, particularly Nitrogen, and adaptive varieties are the most yield-limiting factors in vegetable production in Ethiopia (Alemu & Ermias, 2000). The application of fertilizers increases crop output from existing land under cultivation, and nutrient requirements are determined by a crop's physiological requirements and expected yields (Ryan, 2008). Previous fertilizer research in Ethiopia has focused on N and P across different soil types and climatic conditions. In contrast, very little work has been reported in the Afar Regional State, particularly in the Farah region, on vegetable production, unless growers used their own knowledge to determine fertiliser rates and select fertiliser-responsive varieties, including hot Pepper. Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) also revealed that N nutrients are deficient in Ethiopian soils, including in the Afar area to some extent (ATA, 2013).

In smallholder farming systems, the causes of nutrient deficiency include high plant nutrient uptake, removal of entire crop residues, and use of cattle dung as a source of fuel energy for cooking, high rainfall, which leads to nutrient loss through leaching and gaseous loss of N (Eyasu *et al.,* 1998; Aticho, 2011). Fertilisers are an efficient exogenous source of plant nutrients (Akram *et al.,* 2007), as plant growth and crop production require an adequate and balanced supply of nutrients to maximise productivity by optimising nutrient uptake (Mengel & Kirkby, 2001). For instance, the application of mineral N fertilizers improved dry marketable pod yield and yield components by enhancing nutrient uptake, growth, and development (Obidiebube *et al.,* 2012). Determining nutrient use efficiency for crop sustainability, profitability, and productivity through agronomic, physiological, and apparent nutrient recovery is the most important tool for soil fertility management, particularly in fertilizer experiments.

In Ethiopia, farmers produce vegetable crops, including hot peppers, using blanket fertilizer recommendations such as 100 kg Urea + 100 kg DAP ha^{-1} (EIAR, 2017). However, such recommended fertilizer is not suitable for all agro-climatic conditions and is not adopted by farmers. In addition, unbalanced application of plant nutrients may exacerbate the depletion of other important soil nutrients,

such as K, Mg, Ca, S, and micronutrients (Wassie *et al.,* 2011). As a result, the current productivity of hot Pepper is very low compared to the crop's potential yield nationwide.

The average national productivity of hot Pepper was 2.18 t ha^{-1} for green peppers and 1.15 t ha^{-1} for red peppers (CSA, 2016). Whereas under research conditions in Ethiopia, 1.8-2.5 t ha^{-1} of dried Pepper and 15-20 t ha^{-1} of green Pepper were recorded (Fekadu *et al.,* 2008). Similarly, the average pod yield in the research condition in the Afar area was 1-2.0 t ha^{-1} (Progress Report of MWARC, 2016). These findings showed significant differences in hot pepper yield between the research station and farmers' plots. In view of these, different fertilizer rates were recommended for different parts of the hot pepper production areas of Ethiopia. For instance, Girma *et al.* (2001) reported that applying 200 kg ha^{-1} of DAP and 100 kg ha^{-1} of urea was optimal for higher yields in the Afanbo area. Whereas, application of 207 kg of DAP and 137 kg of urea per hectare resulted in the highest pod yield in the hot pepper variety Oda Haro at Bako (MoARD, 2009). These indicate that the actual amount of fertiliser to apply depends on soil fertility, crop variety, and the fertiliser-use efficiency of that variety. Understanding plant nutrient requirements and the availability of high-yielding, adaptive varieties for a given area is vital to sustainably enhancing crop production and productivity.

Recent studies indicate that elements such as N are becoming depleted in most Ethiopian soils, and deficiency symptoms are being observed on major crops across different areas of the country (ATA, 2013). Improved varieties grown with high levels of macronutrients are, in many cases, depleting micronutrients at a rate that the soil cannot replenish (Wassie *et al.,* 2011). Nevertheless, no information was available on the N fertilizer requirements of hot pepper, including macro- and micro-nutrients, in the study area, except for a few ongoing studies on other crops (EIAR, 2017).

In addition, in arid regions, hot Pepper is a major spice and vegetable crop produced by the majority of agropastoralists in their home gardens and used day to day in their diet. Therefore, strong support is needed for agropastoralists and private producers to achieve sustainable production, increase their income, and secure their livelihoods by providing the best-adapted, high-yielding varieties. The present situation indicates that in faraway areas, there is a shortage of well-adapted hot pepper varieties, including improved local varieties. As a result, varietal information to improve crop yield in the existing agroecology was inadequate, and no research was conducted to evaluate hot pepper varieties, thereby preventing agropastoralists and private growers from selecting the best-performing varieties in the study area (Asaita district). Therefore, evaluation of selected varieties and N fertilizer rates for their agronomic performance was one of the considerations to alleviate the existing problems of attaining good adaptable and high-yielding hot pepper varieties and their optimum N fertilizer rates, for which the output of this study was likely to help and raise awareness among hot pepper growers, agropastoralists, and processors.

1.2. Objectives of The Study

General objective

· To determine the optimum nitrogen fertilizer rate and best variety that maximizes green pod yield and nitrogen use efficiency of selected hot Pepper (*Capsicum annuum* L.) varieties under irrigated dry land conditions in Asaita, Afar Region, Ethiopia.

Specific objectives

- To evaluate the effects of N fertilizer rates and varieties on hot pepper growth parameters.
- To evaluate the effects of N fertilizer rates and varieties on green pod yield of hot Pepper.
- To determine the best nutrient uptake and use efficiency of the hot pepper variety

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The experiment was conducted in Asaita district, Afar Regional State, in the year 2021/22 E.C., where irrigation practices are suitable for Vegetable Crop production. Asaita is one of the districts in the Afar Regional State of Ethiopia, part of Administrative Zone 1, and it is bordered on the south by Afambo, on the west by Dubti, on the north by the Awash River, which separates it from Elidar, and on the east by Djibouti. According to the Central Statistical Agency of Ethiopia, Asaita district has a total population of 50,803, an area of 1,678.28 square kilometres, and a population density of 30.27. While 16,052, or 31.60%, are urban inhabitants, another 9,358, or 18.42%, are pastoralists. Of the total land under cultivation in this district, about 66.21% is planted with cereals, such as maize, and around 1 hectare is planted with pulses and vegetables.

In contrast, 9 hectares are planted with fruit trees, including 0.81 hectares of bananas and 0.41 hectares of guavas. Around 9.95% of farmers produce both crops and livestock, while 25.79% grow only crops and 64.26% raise only livestock (CSA, 2012). The soil in the area is clay loam, with a pH of 7.8. The total rainfall ranges from 100mm to 5mm, and the monthly mean maximum and minimum air temperature usually range from 42°C to 30°C, respectively (CSA, 2016).

2.2. Experimental Materials and Nursery Management

Four varieties of hot pepper, namely, Mareko Fana, Melka Awaze, Melka Shote and Irtali F1, which are high-yielding and adapted to the low-land agroecology of the area, were used as a treatment. It has greater adaptability and grows well at altitudes of 300–800 meters above sea level, with annual precipitation of 300-850mm and annual temperatures of 20–35°C, as reported by the Melkassa Agricultural Research Centre.

The nursery bed was ploughed and harrowed to bring it to a fine tilth, and a seedbed 5m long and 1m wide was prepared. Seeds will be drilled by hand into the nursery bed at the inter-row spacing of 15 cm on 15 February, 2021. After sowing, the beds were covered with dry grass mulch and kept on until the seedlings emerged. Afterwards, based on the environmental conditions, watering was done three times a week. Hand weeding was done as frequently as weeds emerged. A week before transplanting, the water supply to the nursery seed bed will be reduced to harden the seedlings and reduce transplanting shock. Uniform, healthy, and vigorous seedlings were transplanted into experimental plots after 4 weeks of sowing in the seedbed, or when they were about 20 cm tall (Fekadu et al., 2008).

In contrast, field transplanting was done on 10 March, 2021. The seedlings were planted at 30 cm between plants and 70 cm between rows. Refilling of dead seedlings in the field was done after transplanting to the place where the first seedlings were planted. The other crop management practices were applied uniformly across all plots as recommended for hot Pepper.

2.3. Treatments and Experimental Design

UREA fertilizers type was selected for a specific area of Afar based on the Ethio SIS soil fertility map (ATA, 2013), and four varieties (Mareko Fana, Melka Awaze, Melka Shote and Irtai Ali F1) and four rates of urea (0, 50,100 and 150kg/ha) were used as a treatment. Half of the nitrogenous fertilisers were applied at planting, and the other half of the nitrogenous fertilisers were applied after 30 days of transplanting.

The experiment was arranged in a 4x4 factorial design with a randomized complete block design (RCBD) and three replications, yielding 16 treatments. Each plot was 3m wide and 4.2m long (12.6 m2), with 1 m between plots and 1.5 m between blocks. There were six rows per plot, with 10 plants per row, for a total of 60 plants per plot. The other crop management practices were uniformly applied across all plots as recommended.

Table 1
Factorial Combination of Treatments

NO.	Fertilizer	Variety			
	N rates kg/ha	V1	V2	V3	V4
1	N0 (control)	N0V1	N0V2	N0V3	N0V4
2	N1(23)	N1V1	N1V2	N1V3	N1V4
3	N2(46)	N2V1	N2V2	N2V3	N2V4
4	N3 (69)	N3V1	N3V2	N3V3	N3V4

NO= control, N1 = 23kg nitrogen, N2 = 46 kg nitrogen, N3 = 69 kg nitrogen; V1 = Marko fan, V2 = Melka awaze, V3, Melka shola and V4 = Irta Ale F1 Varieties.

2.4. Soil Sampling and Analysis

Before planting, 12 representative soil samples (0 to 30 cm) were randomly collected from the entire experimental area in a W-shaped pattern using an auger for all physio-chemical properties, except soil bulk density (own sample). The soil samples were taken from public land sites. The samples were bulked into a single composite sample, air-dried, ground in a mortar and pestle, and passed through a 2mm sieve. Soils were analyzed for soil texture, pH, OC, total N, CEC, available K, P, S, B, and Zn using standard laboratory procedures at the Adet Agricultural Research Centre.

2.4.1 Soil Physical Properties

Composed core-sampled soil was used for the bulk density analysis. The particle-size distribution was determined using the hydrometer procedure of Sahlemedhin and Taye (2000). The contents of sand, silt, and clay were computed, and the soil textural class was identified from the textural triangle (Motsara & Roy, 2008).

2.4.2. Soil Chemical Properties

Organic carbon (OC) content was determined using the Walkey and Black wet oxidation method, as outlined by Sahlemedhin and Taye (2000). Total nitrogen content was analyzed by the Micro-Kjeldahl method (Horneck et al., 2011). The soil pH was determined using a 1:2.5 soil-to-water ratio and a digital pH meter (FAO, 2009). Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4OAc) and displacing it with 1N NaOAc (Chapman, 1965). Available phosphorus was determined by Olsen's method (Olsen et al., 1954)

Table 2
Initial physicochemical properties of soil

S.n	Soil Parameters	Value	Rating	Reference
1	pH	7.8	Alkaline	Landon (1991)
2	Total N%	0.074	Very low	EthioSIS (2014)
3	Av. P (ppm)	9.85	low	EthioSIS (2014)
4	CEC	46.46	Very high	Hazelton and Murphy (2007)
5	OC (%)	1.115	Moderate	Hazelton and Murphy (2007)
6	Soil Texture			
	Sand%	25		
	Clay%	52		
	Silt %	24		
	Texture class	Sandy clay		

Where cmol =Cent mole, pH = hydrogen power, % OC = percent of organic carbon %TN = Percent of total nitrogen, Av.p (ppm) = available phosphorus in parts per million, CEC = Cation exchange capacity

2.5. Data Collection Method

Data on quantitative and qualitative parameters were collected from the middle rows, excluding plants in the border rows to avoid edge effects. Data on a plant basis: Data were recorded for the following characters on five hot pepper plant stands from randomly selected middle rows of each treatment plot, and the plants were tagged for sampling at their respective stages. Harvesting and Drying Procedure: Pods were harvested two or three times, depending on the uniformity of maturity, when they fully turned red on the plant. After harvesting, the pods will be further dried in partial shade.

2.5.1. Crop Phenology and Growth Characters

Days to 50% flowering

The number of days when 50% of the plants started blooming from the days of transplanting.

Days to 50% maturity

This refers to the number of days from the day of transplanting until 50% of the pods in the net plot area show colour change, as indicated by reddish colour. It was recorded by counting days from the day of transplantation.

Plant height (cm)

Plant height was measured from the soil surface to the top-most growth points of the above-ground plant parts. The measurement was taken as the length from ten plants of the central rows of each plot at the last harvesting time.

Days to first harvest

The number of days from transplanting to first harvest was recorded for 10 sample plants selected from the central rows.

Number of branches

The number of primary and secondary branches will be counted from the harvestable rows at the second harvest and reported as a number.

2.5.2. Yield and Yield Components

Number of pods per plant

The number of physiologically mature pods was counted from randomly selected five plants at each successive harvest and recorded from the central rows for each plot. At each harvest, the recorded data were summed, and the average was calculated.

Total fresh pod yield (t ha^{-1})

This refers to the cumulative fresh pod yields obtained at several harvests. The marketable and unmarketable pods were harvested from the middle three rows. The sum of marketable and unmarketable pod yield of two/three successive harvests was summed up, and the weight was determined using a scale balance.

Marketable yield (t ha-^{1})

The marketable yield was determined at each harvest by sorting dried fruits according to colour, shape, presence of surface defects due to insect or disease damage, shininess, firmness, and size, which were used as visual parameters for marketable rating. Those pods that met the above criteria were considered marketable, and those that did not were discarded as unmarketable. After drying, the marketable fruits were separated; the weight of each category was recorded and converted to t ha-1.

Unmarketable yield (t ha^{-1})

The yield obtained by sorting diseased, discoloured, shrunken, and undersized (< 1cm) pods, as well as totally unwanted pods by consumers, from marketable dried pods was recorded at each harvest and converted to t ha^{-1}.

Total dry pod yield (t ha^{-1}): The weight of total (marketable and unmarketable) fruits at each successive harvesting from the net plot area was recorded and summed up to estimate yield ha^{-1}.

Above-ground total dry biomass yield (t ha^{-1})

Dry total biomass yield was assessed by chopping all the plant parts, including pods, leaves, and stems and drying the samples of ten plants per plot in an oven at 70°C until constant weight was attained. This was done at fruit maturity, before drying the vegetative parts, and the mean weight was used for analysis.

Average number of seeds per pod

Seeds from randomly selected 10selected 10 marketable pods from sample plants were counted and recorded.

Seed weight (g): Seeds were extracted from randomly selected 10 marketable pods, weighed using a sensitive balance, and mean values were calculated.

2.5.3. Physical quality parameters

Pod length (cm)

The length of 10 randomly selected pods from each plot at each harvest was measured with a centimetre ruler, and mean values were taken.

Pod diameter (cm)

The body widths of the pods at the middle of each fruit were measured from ten marketable pods of the sample from each plot using centimetres, and the mean values were recorded. This procedure continued until the end of harvest to assess possible size variation throughout the harvest period.

Pod dry weight (g)

The weight of ten individual pods from each plot was taken. The samples were dried in an oven at 65°C until a constant weight was reached.

2.5.5. Plant Tissue Sampling Analysis

The vegetative above-ground parts and pods will be sampled from one central row of each treatment at the early flowering stage and at maturity, respectively. The samples will be dried at 65 ^{O}C for 72 hours in an oven, finely ground to less than 1mm, and wet-digested for the determination of nutrient content in tissues and pods using standard procedures. The total N will be analyzed by the Kjeldahl method (Bremner & Mulvaney, 1982).

2.5.6. Plant Nutrient Use Efficiencies

Nitrogen use efficiency (NUE) is the efficiency with which soil nitrate-N is converted into grain/ green pod N. Nitrate-N comes from fertilizer, crop residues, manure, and soil organic matter. However, the efficiency of converting fertilizer into grain/pod is generally of greatest concern to growers. However, efficiency is reduced by seasonal conditions, crop diseases, and losses of N from the soil as gases, N leaching, or N immobilization into organic forms.

The NUE in plants was calculated as the nutrient efficiency ratio (NER), as reported by Baligar *et al.* (2007), and expressed as total nitrogen use efficiency gramsper gram.

$$\text{Nutrient Efficiency Ratio (NER)} = \frac{Units\ of\ yield\ (g)}{Units\ of\ nutrients\ in\ plant\ tissue\ ()due\ to\ applied}\ \text{gg}^{-1}$$

In this experiment, the harvest time was set at 12 weeks in the field. Harvested plant parts were washed with tap water and again washed with distilled water. Plant samples in each treatment were combined as above-ground straw (stems, leaves, and green pods) and weighted using a sensitive balance (CTG-6H+) then oven dried (70^{0} C for 48 hours) to constant weight (dry weight) and crushed into powder form for preparation of laboratory analysis (Shashidhar *et al.*, 2012), and nitrogen use efficiency was determined.

2.6. Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate for a factorial experiment in RCBD, according to the General Linear Model (GLM). Then the data were subjected to Analysis of Variance (ANOVA) and correlation analyses using SAS version 9.3, and the interpretations were made following the procedure described by Gomez and Gomez (1984). When ANOVA showed significant differences, mean separations were carried out using the LSD (Least Significant Difference) test at 5% level of significance. All figures and tables were generated in Excel.

3. RESULT AND DISCUSSION

3.1. Effects of Nitrogen Fertiliser Rate and Varieties on Hot Pepper Growth Parameter

The growth parameters of hot pepper, including 50% date of flowering, plant height, and number of pods per plant, were highly significantly influenced by the main effect of nitrogen fertilizer rate ($p < 0.01$). However, the main effect of variety and the interaction of variety and rates of nitrogen fertilizer did not affect the growth parameters of the crop (appendix table 1). The shortest 50% days of flowering were observed from the control plot, while the late 50% days of flowering were recorded from the plot that received 69 kg per hectare; the tallest plant height was recorded from the pot that received 69 kg per hectare, while the shortest plant height was from a control pot. The highest number of primary branches per plant was observed from a plot that received 69 kg per hectare, while the lowest number of primary branches per plant was recorded from the control plot (Table 3). The difference in growth parameters showed that Nitrogen has the greatest effect on average nutrient requirements for optimum yield of Capsicum. This crop is particularly responsive to Nitrogen for plant growth and yield (Bosland & Votava, 2000). Nitrogen is a component of protoplasm, proteins, nucleic acids, and chlorophyll, and it plays a vital role in both the vegetative and reproductive phases of crop growth.

This result was consistent with Bosland et al. (1994) during growth; further Nitrogen may be applied to achieve higher 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.

Table 3
Main effect of nitrogen fertilizer rates on 50% DF, pH, and NPPP of hot pepper varieties

Treatment	Growth parameters		
Nitrogen rate (kg/ha)	**50% Days of flowering**	**Plant height**	**Number of pods per plant**
N0	30.00c	0.92c	56.45c
N1	32.00c	1.07cb	61.35cb
N2	36.42b	1.17b	63.31b
N3	41.92a	1.44a	77.01a
LSD (5%)	2.76	0.15	6.80
CV. (%)	9.44	15.83	12.65

Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

The growth parameters of hot pepper, such as pod length and pod diameter, were highly significantly influenced by the interaction between varieties and nitrogen fertilizer rates ($p < 0.01$). However, the main effect of variety and rates of nitrogen fertilizer did not affect the pod length and pod diameter of the hot pepper crop (appendix table 1). The shortest pod length (5.93cm) had observed from control plot, while the longest pod length (10.26 cm) was recorded from the plot receive (V4) Irtalia FI variety and 23 kg per hector; the shortest pod diameter (4.33cm) was recorded from the pot received (V3) Melka shote and control (N0) while the longest pod diameter (8.93 cm) was recorded from a pots received (V4) Irtalia and 69 kg nitrogen per hector (Table 4). The differences in growth parameters showed that Nitrogen is important for the growth parameters and genetic potential of the varieties, with Nitrogen having the greatest effect on the average nutrient requirements for optimal yield of Capsicum. This crop is particularly responsive to Nitrogen for plant growth and yield (Bosland & Votava, 2000). Nitrogen is the main plant nutrient which limits plant growth (Suganiya, S., Kumuthini and Harris, D., 2015). More Nitrogen is required for production than P and K, since it serves both structural and enzymatic functions (Uchid R., 2000). Nitrogen is a component of protoplasm, proteins, nucleic acids, and chlorophyll, and it plays a vital role in both the vegetative and reproductive phases of crop growth.

This result agrees with Roy et al. (2011), who found that the pod length and diameter of Pepper significantly increased with increasing nitrogen level. They reported the highest Pepper length (7.63 cm) with 150 kg N ha-1, which was statistically similar to that of the 100 kg N ha^{-1} treatment (7.41 cm), while the lowest length (5.83 cm) was observed in the control treatment.

Table 4
Interaction effect of nitrogen fertilizer rates and varieties on pod length and pod diameter of hot pepper varieties

Treatment		Growth Parameters	
Nitrogen rate (kg/ha)	**Variety**	**Pod Length (cm)**	**Pod Diameter (cm)**
N0	V1	5.93e	4.86h
N0	V2	6.63d	5.66g
N0	V3	7.10c	4.33h
N0	V4	8.80b	7.20d
N1	V1	7.15c	5.86f
N1	V2	7.03c	6.26f
N1	V3	7.60c	6.16f
N1	V4	10.26a	8.36b
N2	V1	8.43b	6.93e
N2	V2	8.50b	7.23d
N2	V3	8.59b	6.50e
N2	V4	9.73a	7.96c
N3	V1	8.50b	7.83c
N3	V2	8.97b	7.40c
N3	V3	8.87b	7.10d
N3	V4	9.87a	8.93a
LSD (5%)		**0.55**	**0.57**
CV. (%)		**7.87**	**9.89**

Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

3.2. Effects of Nitrogen Fertiliser Rates and Varieties on Hot Pepper Green Pod Yield Parameters

The yield components of hot pepper, such as total pod yield, were highly significantly ($P < 0.01$) influenced by nitrogen fertilizer rate. Marketable pod yield and nitrogen use efficiency (NUE) were also highly significantly ($P < 0.01$) influenced by the main effects of varieties (appendix table 2). The maximum total pod yield per plot (8.30 kg) was recorded at the highest nitrogen application rate

(69kg/ha), which was not significantly different from the 0 kg/ha rate; a plot received 0, 23, and 46 kg of Nitrogen per hectare.

While the minimum total pod yields per plant (5.38 kg) was found from control plot (Table. 5). This yield increasing from control to highest rate of is due importance of Nitrogen which 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 & Votava, 2000).

This result was supported by Roy et al. (2011), who reported that the optimal fertiliser dose promotes proper growth and development and maximises yield in hot Pepper. In addition, an adequate amount of Nitrogen has been shown to increase the number and size of pepper marketable fruits, fruit pungency, and overall yield (Charles & Decoteau, 1996).

Similarly, marketable pod yield and nitrogen use efficiency NUE) were also highly significantly ($P < 0.01$) influenced by the main effects of varieties. The maximum marketable pod yield per plot (1.75 kg) was recorded for Marko fana (V2), but this difference was not statistically significant, whereas the marketable yield for Itrat alie F1 (V4) was 0.75 kg. While the minimum marketable pod yields per plant (0.92 kg) was found from melka Awaza(V3) which is statically non-significant marketable pod yield per plot recorded from Melka Shote variety (V4) (Table. 5). It was observed that as the rates of N fertilizer increased up to 69 kg ha-1 across each variety so did the yield components of hot Pepper though the relationship had consistencies and linear in some other parameters (Table. 5). These revealed that the varieties are highly responsive to the applied N fertilizer rates.

These indicate that applying N fertilizer in nutrient-deficient soil is essential to promote the development of yield-contributing traits in hot pepper varieties. This is likely due to sufficient availability of N macronutrients through UREA fertilizer application, coupled with varietal genetic potential, which enables the plants to achieve better yield components. Therefore, an adequate supply of essential nutrients, achieved through optimal N fertilizer application, plays a significant role in improving yield components **in hot pepper varieties.**

This result was consistent with Maya et al. (1997), who reported the highest dry matter production in sweet Pepper at 150 kg N ha-1. Prabhakar and Naik (1997) also observed the highest dry matter production of pepper at 98.4 and 98.8 g per plant with the highest level of Nitrogen (180 kg N ha^{-1}) in two-year studies. At the same time, the control plots produced 43.8 and 32.0g per plant, respectively. Fertiliser trials conducted in different sites of Ethiopia showed differences in yield performance of pepper (Sam–Aggrey and Bereke-Tsehai, 1985). In the fertilizer trial conducted at Bako, 100 kg ha-1 N and 100 kg ha-1 P_2O_5 resulted in higher marketable and total dry pod yields. However, Jackson et al. (1985) recommended inorganic fertilizers for better Pepper performance, with 140 kg ha^{-1} of P_2O_5 and 130 kg ha-1 of N as the optimum levels. Application of 95.22 kg ha^{-1} P_2O_5 and 97.06 kg ha-1 N provided an optimum yield of the pepper variety Oda Haro at Bako (MoARD, 2009). This indicated that the nitrogen requirements of hot Pepper differ across different parts of Ethiopia, due to differences in environmental

conditions, varieties, and soil types. In Ethiopia, the recommended fertilizer rate for hot Pepper is 100 kg ha-1 of UREA (EIAR, 2017).

Table 5
Main effect of nitrogen fertilizer rates on Total pod yield per plot, marketable pod yield per plot, and varieties on NUE of hot pepper varieties

Treatment	**Growth parameters**		
Nitrogen rate (kg/ha)	**TPY/P(kg)**	**MPY/P(kg)**	**NUE(g/g)**
N0	5.38c		
N1	6.49b		
N2	6.69b		
N3	8.30a		
V1		0.92b	
V2		1.75a	
V3		0.98b	
V4		1.60a	
V1			5.34c
V2			7.11b
V3			4.59c
V4			9.40a
LSD (5%)	0.80	0.22	1.68
CV. (%)	14.28	19.82	**30.52**

3.3. Determine Best Nutrient Uptake and Use Efficiency of Hot Pepper Variety

According to Table 5, in addition to yield, the maximum nitrogen use efficiency (NUE) was recorded for the Irtai ali variety (9.40 g/g), which is statistically different from Marko fana, Melka shola, and Melka awaze. While the minimum nitrogen use efficiency (NUE) (4.59 g/g) was observed from Melka awaze (V3 which is statistically similar to the NUE recorded from Marko fana (V1) (table.5) the height of the NUE resulted from 4 May due to the genetic potential of the variety, in which F1 varieties have higher nutrient use potential and changed it to yield. Improving agronomic efficiency provides both direct and indirect economic benefits: larger yield increases can be achieved for a given amount of fertiliser applied, or less fertiliser is required to achieve a given yield target (Bationo et al., 2012). 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.

This result agrees with Mengel and Kirkby (2011), who found that the nutrient content of plant tissue reflects soil availability. The amounts of nutrients exploited in the harvested portion of the crop will depend on yield, nutrient concentration, time and space, variety, soil, and environmental factors (Fageria et al., 2015). In crop production to attain higher yields, plants require adequate nutrient fertilization (Fageria *et al.*, 2012).

4. CONCLUSION AND RECOMMENDATION

This study was conducted to determine the effect of varieties and nitrogenous fertiliser rates on yield and NUE of hot Pepper (*Capsicum annum* L.) to determine the optimum rate of N fertiliser and a high-yielding variety for higher yield and NUE of hot Pepper at Asaita under an irrigation farm. The findings of this study showed that growth, yield and NUE parameters in which hot Pepper was grown, such as 50% days of flowering, pod length, pod diameter, plant height, total green pod yield, marketable pod yield and NUE of hot pepper, increased along with increased application rates of nitrogen fertilizer. Accordingly, the main effect of variety was highly significantly influenced plant height, number of pods per plant and total pod yield; the main effect nitrogenous fertilizer rates was highly significantly influenced marketable pod yield and NUE, as well as the main and interaction effects of variety and nitrogenous fertilizer rates, which highly significantly influenced pod length, pod diameter and 50% days of flowering. The highest total pod yield (8.30kg/plot) and NUE (9.40 g g^{-1}) were recorded with the application of 69 kg ha^{-1} N fertilizer and the Irta Ale variety, respectively. In conclusion, the results of the present study indicated that applying nitrogen fertilizer with an adaptable, high-yielding variety substantially improved growth, yield, and NUE in hot Pepper. Variety and N fertilizer levels resulted in higher marketable pod yields and related yield and NUE parameters than the control treatment. For instance, the maximum total pod yield per plot and NUE were obtained with 69 kg ha^{-1} N fertilizer and the Irta Aili variety, respectively. Therefore, based on this finding, it is evident that hot Pepper can grow well in the study area, and farmers can benefit more by applying 69 kg ha^{-1} of nitrogenous fertilizer with the Irta Ale variety, which resulted in higher total green pod yield and NUE.

However, since the data are obtained from a field experiment, only one season (off-season) and 3 open-pollinated and 1 F1 variety, it may be worth repeating the experiment under field conditions across different seasons and locations, including various varieties and both organic and inorganic fertilizers, to draw the best conclusions and recommendations. A similar experiment is suggested for future researchers, especially during the main production season, under field conditions, including different types of inorganic fertiliser, different organic fertilisers, varieties, and different soil types and agroecologies. Further studies on different types of organic and inorganic fertilizers, and varieties are suggested to increase marketable green pod yield and NUE.

Declarations

Competing interests

The authors declare no competing of interests.

Ethics approval

not applicable

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Author Contribution

OA: Conceptualization, designed the experiments, carried out the experiments, collected the data, analyzed the dataSAS: Reviewed the final manuscript, drafing and eidtingSE: Conceptualization and designed the experimentsMS:Proofreading/editing ZE: Collected the dataAHS: Designed the experiments

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Data Availability

The datasets analyzed during this study can be available by requesting the corresponding author or the first author.

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