PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 11(1): 397–404
https://doi.org/10.14719/pst.2445

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RESEARCH ARTICLE

Influence of farmyard manure and NPS fertilizer on Hot Pepper (*Capsicum annuum* L.) growth and yield variables at Western Ethiopia

Kitila Chala[1]* & Gemechisa Olana[2]

[1]Department of Plant Sciences, College of Agriculture and Natural Resource, Dambi Dollo University, Dambi Dollo P.O. Box: 206, Ethiopia
[2]Department of Plant Sciences, College of Natural Resource, Dambi Dollo University, Dambi Dollo P.O. Box: 260, Ethiopia

*Email: kit.chali2012@gmail.com

OPEN ACCESS

ARTICLE HISTORY

Received: 15 April 2023
Accepted: 16 July 202315 April 2023
Accepted: 16 July 2023

Available online
Version 1.0 : 27 December 2023
Version 2.0 : 14 January 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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Chala K, Olana G. Influence of farmyard manure and NPS fertilizer on Hot Pepper (*Capsicum annuum* L.) growth and yield variables at Western Ethiopia. Plant Science Today. 2024; 11(1): 397–404. https://doi.org/10.14719/pst.2445

Abstract

Hot peppers are important vegetable crops widely grown in Ethiopia. Investigation into the economic, nutritive and therapeutic purposes of the pepper plant is extremely limited. Thus, a field trial was piloted to assess the influence of NPS (compound fertilizer containing three important plant nutrients of nitrogen, phosphate, and sulphur with the ratio of 19% N, 38% P_2O_5, and 7% S) and farmyard manure (FYM) fertilizer on hot pepper at the Dambi Dollo University research field for two consecutive years (2020 and 2021) under rain fed. The finding was systematized in a Randomized Complete Block Design (RCBD) with three repetitions and variety of Marako Fana hot pepper was assessed. NPS fertilizer at four level (0, 100, 200, 300 kg N ha^{-1}) and four FYM levels (0, 2.5, 5, 7.5, 10 t ha^{-1}) were owed to the study area and a total of 20 treatments. The research results revealed that FYM and NPS mineral fertilizer interacts to affect positively (P<0.05) maximum parameters without unmarketable harvest, which was influenced through the single effect of NPS and FYM. The highest marketable pod yield (2.28 t ha^{-1}) and total pod harvest (2.72 t ha^{-1}) was recorded through NPS rates of 100 kg ha^{-1} applied with 5 t ha^{-1} of farmyard manure. Consequently, it is likely to determine that hot pepper farmers can use NPS mineral fertilizer rate of 100 kg ha^{-1} with 5 t ha^{-1} of FYM that would expand yield of the hot peppers in the study area with similar agro-ecological conditions.

Keywords

Hot pepper; Marako Fana; NPS; FYM; inorganic fertilizer; yield traits

Introduction

Hot pepper (*Capsicum annuum* L.) is the very important vegetable plant eaten as a raw fruit and dry spice in the world (1). It is a main spice crop in humid regions of the world and is categorized under the family of Solana-ceae genus *Capsicum*. It is the most important vegetable in the Solanaceae family after tomatoes worldwide.

It is one of the best spice plants grown worldwide due to its content of spicy taste and fragrance. Spicy pepper (berbere) plays a major role as an ingredient in the daily Ethiopian pulps (wot), and the raw fruit is used for herbal and nutritional purposes (2). In Ethiopia, hot peppers are usually planted at an elevation of 1400 to 1900 m above sea level (3) and the area receives a yearly precipitation range between 600–1200 mm, with a hotness series of 25 to 28°C (4).

Hot pepper is the most important vegetable crop globally because of its versatility. It is an important plant that is valued primarily for its redness and colour. Berbere is among the most valuable crops in the warm season for traditional sauces. It is vital for its colouring and raw materials in the market in the form of oleoresin in the processing industry (1).

Ethiopian climate and edaphic conditions favour *Capsicum* production under both rainy seasons and irrigated conditions. Many parts of Ethiopian regions (Oromia region, Amhara region, South region and Somali region) are suitable for hot pepper production. The planting of red peppers occupies 180,701.46 ha of land and the cover of 9832.3 ha green peppers produced 1.8 t ha^{-1} red pepper and 6.31 t ha^{-1} green pepper, respectively (5).

The yield status of hot peppers expanded to the intervals of 1.8 to 2.5 t ha^{-1} for dehydrated peppers and 15 to 20 t ha^{-1} for green peppers under investigation-field conditions. Conversely, the yield of hot peppers on average for small holder farmers is relatively low in relation to the global average of dry (2.57 t ha^{-1}) and raw (17.8 t ha^{-1}) manufacture, respectively. The oleoresin capacity of *capsicums* varies about 9.0% in 'PBC-776' and 21.8% in 'PBC-380', and Marako fana variety of Ethiopia contains 3.5% of oleoresin, which is very low in comparison at the international level (5-12%) (2).

Poor soil fertility is an additional factor that limits the yields of hot peppers. Most Ethiopian soils do not contain N, P, S and K, besides three other micronutrients, mainly Zn, B and Cu. Hot peppers need a sufficient amount of macro and micronutrients; nevertheless, N and P are widely used (1). N is an important element directly affecting several metabolic processes, especially photosynthesis.

A suitable quantity of N is essential for adequate development, harvestable yield, and quality of hot pepper. However, excessive use of N delays plant maturity as compared to other nutrients such as phosphorous, potassium, and sulphur.

Farmers produce peppers in the study area during rainy season and the use of fertilizer in the production of hot peppers is not well known. As a result, production is low due to N, P and other trace elements, as deficiency of S, B, and Zn is a main factor for productivity. Recent soil record data obtained from Ethio-SIS (Ethiopian Soil Information System) also reveals that nutrients like sulphur, boron, and zinc are scarce in Ethiopian soil in general and study area in particular, next to N and P (6).

NPS has recently introduced fertilizer containing 38% P_2O_5, 19% N, and 7% SO_4 S, but this situation is changing with the use of integrated fertilizers, being closely related to specific African soil needs, including Ethiopia. Nowadays, in addition to the deficiencies of nitrogen and phosphorous, sulphur, boron, and zinc are extensive in Ethiopian mostly and are poor in potassium, copper, manganese, and iron. Inorganic fertilizers comprising major nutrients N, P, K, and S not merely intensify yields; nevertheless, it also advances the nutritious quality of crop.

Organic fertilizer application improves soil water holding, contributing to alleviate the nutrient status, and compensates to the outstanding pool of organic N and P in the soil (7). Conversely, the use of farmyard only as an additional source of mineral nutrient is not enough to sustain the current status of crop production (8).

In general, the recommended use of rate of NPS fertilizer is one of the main factors that reduce the hot pepper yields and the poor use of organic fertilizers. There are no studies conducted in the study area to increase productivity of hot pepper and nutrient deficiency constraints are not addressed at study area. Hot pepper production for growth, high yield, quality, pest, and disease resistance in the existing agroecology needs to be closely monitored and the NPS and FYM recommendation is an important matter to reach the crop possible in the study location. In this study area, this crop is a main spicy-flavoured vegetable crop produced by most farmers (9). Conversely, the production of hot pepper is gradually depleting the soil nutrients in the study area, because of a lack of the ideal quantity of organic and inorganic nutrients by producers. The aims of this research were:

To evaluate the effect of FYM and NPS fertilizers on development and phenological features of Marako Fana pepper variety.

To evaluate the effect of FYM and NPS on yield and yield associated characters of Marako Fana pepper variety.

Materials and Methods

Trial was conducted at Dambi Dollo University investigation site in 2020 and 2021 cropping spell under irrigated conditions. The area is situated in Dambi Dollo zone of the west region of Ethiopia, situated 640 km from capital city, Addis Ababa at 1580 m above sea level. The area recieves a yearly rainfall of 1500 and 2000 mm. The extreme and least temperatures of the zone are 20°C and 28°C, respectively. The top soil of the area is typically a sandy loam type (10).

Explanation of Treatments and Experimental Design

Marako Fana variety of hot pepper was used in this experiment, which is the most popular and most recommended in Dambi Dollo area. The source of the experimental materials (Marako Fana) seeds was gained from the Malkassa Agricultural Research Centre and disseminated in rows 15 cm from the nursery built into a ready seed bed; an adequate number of plantlets were raised up, which were frequently inspected.

The recommended level of mineral fertilizer of 82 kg N ha^{-1} with 92 kg P_2O_5 ha^{-1} for the trial was applied, selecting the dose of 10 t ha^{-1} FYM as the optimal biological fertilizer proportion for hot peppers to arrange the experimental fertilizer treatments. By grouping the whole mineral and biological fertilizers amounts in blend as extreme, the treatments were organized as 100, 75, 50, and 25 % of these amounts.

Field test was organized as Randomized Complete Block Design (RCBD), with three repetitions. The space between plants and between the rows was 30 and 70 cm, respectively. Rows were established with 15 plants in each row, defining a plot with 6 rows. The total number of plants per plot was 90. The plot size was 4.5 m in length and 4.2 m in width. The border effects were considered to leave the plants found in the 2 rows at the end of equal edges of each design and the 2 plants at the end of each row. The plot size was 3.9 m × 2.8 m (10.92 m^2), considering 52 plants per net plot. The distance among plots and blocks was 1 m and 1.5 m, respectively.

Descriptions of Experimental Materials

In this field experiment, cow dung was used to produce FYM fertilizer and NPS fertilizer. Urea (46% N) and NPS (19% N, 38% P, and 7% S) were applied as the sources of mineral fertilizer. Soil samples were taken with a conventional auger.

The variety used in this study was Marako Fana, released in 1976 by Malkassa Agricultural Research Centre, characterized by highly spicy pods with dim-red colour. The cultivar isfavourite among resident customers owing to its pungency level, good-looking colour, and great powder yield.

Marako Fana's marketable yield varies from 1.5 to 2 t ha^{-1} (3). In this context, (11) reported about the pepper response to N and K fertilizers at Agarfa, South-Eastern Ethiopia, that the maximum saleable yield of this crop was about 2.72 t ha^{-1}, with the quantity of 100 kg N ha^{-1}+115 kg P_2O_5 ha^{-1} in soil with a clay textural class. The variety produced 2.83 t ha^{-1} of dry pod yield in Abergelle district (12). The study from adaptation trial of (13), showed that Marako Fana pepper variety gave around 2.1 t ha^{-1} of saleable yield in South Ethiopia.

The seed bed size of 1 × 5 m was prepared and the seeds were sown on November 6, 2019. Dry glass mulch was used to cover the seedbeds till appearance and irrigated using spraying cane as desirable. After full seedling emerge, the covering was detached, and the beds were enclosed by elevated shadows to guard the sprout from sturdy sunshine till 8 days persisted for resettling. Irrigation was done with a well spraying cane, in which the regularity varied according to the categories of seedlings and the seedbed was manually cleared.

Plantlets were established in the field one and a half months (48 days) after sowing or in the stage after the sprouts had reached 20 to 25 cm in height. Arrangement of test units was finished one month before the seedlings were relocated on November 20, 2019. Farmyard (FYM) fertilizer was applied on the site one month before seedlings were transplanted. The well decomposed cow dungs were variegated with soil manually. Transplanting took place on December 21, 2019. Replenishing of deceased plantlets in the experimental unit was ready in a single week after transplanting.

Properties of the Experimental Soil

The Physico-chemical properties of the experimental soil are explained in the following Table 1.

Table 1. Selected physicochemical properties of the soil at the experimental site before planting.

Properties	Result	Rating
Depth (cm)	0-30	Normal
Sand, silt, clay	40, 25, 35	Mostly common
Textural class	Clay loam	Low-medium drainage
pH (1:2.5 H_2O)	5	Slightly acidic
Organic matter /OM/ (%)	4.99	Medium
Organic carbon /OC/ (%)	2.9	Medium
CEC (meq/100g soil)	43	Very high
Total nitrogen/TN (%)	0.27	Medium

Data Collected

In an experiments trial, data were collected from five randomly selected points in the central rows of each treatment plot and tagged. Phenological parameters and growth variables like days to 50% flowering, days to 90% maturity, and plant height (cm) were recorded.

Yield and yield components such as number of pods per plant, marketable pod numbers per plant, marketable pod yield (t ha^{-1}), total pod yield (t ha^{-1}), and unmarketable pod yield were recorded.

Statistical Analysis of Data

The collected data were exposed to variance analysis (ANOVA) in overall rectilinear model of Genstat 16th edition statistical package. Duncan Multiple Range Test (DMRT) was used to separate means using at 5% significance level.

Results and discussion

Crop Phenology and Growth Traits

Days to 50% Flowering

The parameters like days to 50% flowering and plant heights are significantly affected by the main and interaction effects of FYM and NPS fertilizers. Early flowering (69 days) was recorded at NPS mineral fertilizer levels of 0 kg ha^{-1} and FYM rate of 0 t ha^{-1} (control treatment) and the late days to flowering (87 days) were observed at 300 kg ha^{-1} NPS stimulant rate and 10 t ha^{-1} FYM application in 2020 growing season (Table 2). This variation may be due to NPS fertilizer which has a positive effect on flowering initiation by accelerating the germination phase through the accumulating effect of nutrients absorbed in the process of photosynthesis, but the nitrogen contents slow down flowering time.

Delays in blossoming owing to high levels of nutrients application may be due to the rich absorption of nutrients by plants, which increases the growth of vegetative parts and delays the propagative stage.

Likewise, (14, 15) chemical fertilizer application lead to release the nutrient slowly and sustainably and to promote good vegetative growth and improve blossom in pepper. High nitrogen levels promote vegetative growth at the loss of flowering. Correspondingly, (16) suggested that blossoming is hindered due to increase N availability due

Table 2. Interaction effect of FYM and NPS fertilizer on days to 50% flowering.

Farmyard manure (t ha^{-1})	Days to 50% flowering							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2020				2021			
0	69.25^{i}	74.94^{fgh}	75.32^{efgh}	74.94^{fgh}	69.97^{i}	76.02^{efg}	76.16^{efg}	74.94^{fgh}
2.5	71.75^{hi}	74.95^{fgh}	79.25^{cde}	78.57^{def}	71.75^{hi}	74.95^{fgh}	79.25^{cde}	78.57^{def}
5	76.29^{efg}	83.05^{bc}	82.0^{bcd}	83.95^{ab}	76.3^{efg}	83.05^{bc}	82.0b^{cd}	83.95^{ab}
7.5	75.45^{efgh}	73.40^{gh}	81.73^{bcd}	81.58^{bcd}	75.5$^{e\text{-}h}$	73.4^{ghi}	81.7^{bcd}	81.6^{bcd}
10	75.7^{efgh}	76.56^{efg}	80.8^{bcd}	87.25^{a}	75.7^{efg}	76.56^{efg}	80.8^{bcd}	87.25^{a}
LSD (0.05)	4.06				3.81			
CV (%)	3.2				3.0			

to the alteration growth phase viz. more vegetative growth occurs.

The first flowering days (66.33 days) of the Marako Fana variety were noted from the design treated with 0 kg NPS ha^{-1} and 138 kg P_2O_5 ha^{-1} and the late blossoming (93.33 days) was obtained in plots that applied a mixture of 92 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1} (17). Moreover, (18) showed times to 50% blossoming phase overdue slowly with the increase level of FYM from 0 t ha^{-1} to 4 t ha^{-1}.

Days to 90% Physiological Maturity

The variables like days to 90% physiological maturity are suggestively influenced by the collaboration effect of FYM and NPS fertilizers. The early matured (124 days) hot pepper was recorded in 0 NPS kg ha^{-1}and 0 t ha^{-1} FYM application, while the late matured (148 days) hot pepper was recorded in 300 NPS kg ha^{-1}and 10 t ha^{-1} FYM (Table 3).

the low plant height (29.25 cm) was noted at control or unfertilized (0 NPS fertilizer and FYM) (Table 4). This may be due to enhanced nutrient supply. In agreement with (21), who stated that the use of biological manure and mineral fertilizer increased growth variables, including plant height. Likewise, (22) reported that increased in height of plant may be commenced owing to more accessibility of nutrients available in the soil at growing areas, particularly nitrogen and phosphorous, that contribute to plant development by cumulative cell division and elongation. Similarly, (23) noted that the application of 250 kg ha^{-1} mixed NPS fertilizer shows suggestively highest plants, whereas hot pepper plants grown without fertilizer application produced significantly shortest. Likewise, (24) also documented that NPK mineral fertilizer expressively improved growth factors of pepper.

Table 3. Interaction effect of FYM and NPS fertilizer on days to maturity.

Farmyard manure (t ha^{-1})	Days to maturity							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2020				2021			
0	124.7^{g}	127.0^{g}	126.7^{g}	127.0^{g}	125.7^{g}	128.0^{efg}	127.0^{g}	127.0^{fg}
2.5	127.0^{g}	130.4^{f}	142.5^{bc}	138.0^{e}	127.0^{fg}	130.4^{ef}	142.5^{b}	138.0^{d}
5	125.3^{g}	139.1^{de}	141.6^{cd}	142.8^{bc}	125.3^{g}	139.1^{cd}	141.6^{bc}	142.8^{b}
7.5	126.7^{g}	144.7^{b}	144.7^{b}	143.6^{bc}	126.7^{g}	144.7^{ab}	144.7^{b}	143.6^{b}
10	130.7^{f}	139.1^{de}	144.0^{bc}	148.0^{a}	130.7^{e}	139.1^{cd}	144.0^{b}	148.0^{a}
LSD (0.05)	2.98				3.167			
CV (%)	1.3				1.4			

The outcome of the study showed that increment rate of FYM at the time of maturity of the crop may be credited to the fact that manure plays an important role in stimulating vegetative growth, as N encourages vegetative and lush growth, so suspending plant maturity. Likewise, (18) noted that the days to maturity were delayed as the FYM application increased. Moreover, (19; 20) stated that fruit setting and fruit ripening were delayed by increasing levels of N.

Plant Height

The highest plant height (62.01 cm) was recorded in the NPS mineral fertilizer of 200 Kg ha^{-1} and 5 t ha^{-1} of FYM and

The reason why plant height increased as FYM and NPS rates could be attributed to nitrogen, which promotes plant elongation and produces indole acetic acids that are similar to those produced by zinc and protein synthesis. The application of this nutrient appears to increase plant height, because N is a component of amino acids and chlorophyll, which is the main light-harvesting pigment for photosynthesis (25). In addition to its other function, sulphur consumption may help the plant to have access to other nutrients.

In order to increase the availability of nutrients like P, K, Zn, Mn, and Cu, sulphur is often applied to the soil as

Table 4. Interaction effect of FYM and NPS fertilizer on plant height.

Farmyard manure (t ha^{-1})	Plant height							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2020				2021			
0	29.25^{f}	35.69^{ef}	35.39^{ef}	37.68^{e}	30.54^{e}	36.54^{e}	35.63^{e}	37.68^{e}
2.5	31.35^{ef}	36.08^{ef}	50.24^{cd}	50.91^{cd}	31.35^{e}	36.08^{e}	50.24^{bcd}	50.91^{bcd}
5	32.80^{ef}	54.63^{bc}	62.01^{a}	52.38^{bcd}	32.80^{e}	55.31^{abc}	62.01^{a}	52.38^{bcd}
7.5	32.95^{ef}	47.74^{cd}	54.84^{bc}	51.45^{bcd}	32.95^{e}	47.74^{cd}	54.84^{abc}	51.45^{bcd}
10	32.46^{ef}	45.61^{d}	58.29^{ab}	51.02^{cd}	32.46^{e}	45.61^{d}	58.29^{ab}	51.02^{bcd}
LSD (0.05)	**7.162**				**7.083**			
CV (%)	**9.8**				**9.70**			

a soil supplement. This element also lowers the pH of the soil and transforms unrefined phosphorus into a form that can be used by plant tissues. Additionally, (24) also observed that pepper growth factors were significantly enlarged by NPK fertilizer.

Yield and Yield Variables

Number of Fruits Per Plant

The quantity of pod per plant is suggestively affected by the interactive effect of NPS fertilizers with the manure. The highest number of fruits per plant (26.56) was noted in 200 NPS kg ha^{-1} and 5 t ha^{-1} of FYM, which is 48.08% more than the lowest number of pod per plant recorded in 0 NPS kg ha^{-1} and 0 t ha^{-1} of FYM (control) (Table 5). It may be due to combination of a high level of inorganic fertilizer with a low value compared to FYM, which may result in the release of nutrients more easily than a high level of FYM. The findings showed that the Marako Fana pepper variety's fruit number was significantly impacted by inorganic fertilizers. Unless FYM is united with mineral fertilizers, the practice of farmyard manure only might not entirely content the nutrient requirements of the crop, especially in the application year.

per plant in hot pepper (27). The amount of nutrients applied to different pepper varieties in Sierra Leone was also observed to be directly correlated with the number of fruits per plant produced. Moreover, (18) showed that the maximum number of pods were noted in treatment mixture of mixed inorganic fertilizer and FYM application at the rate of 100 kg ha^{-1} + 4 t ha^{-1}, respectively.

Through influencing photosynthetic activity and its proper partitioning, it was discovered that N rates revealed a positive association and highly significant variation on pod number per plant (11, 28). The plant is able to acquire a higher number of pods per plant and seeds per pod, resulting in an adequate supply of nutrients, due to the application of blended fertilizer and farmyard manure.

The rate at which pepper pods set is depressingly correlated with the number of fruits growing on plants, and pepper pods are affected when assimilation from leaves is restricted. When a plant produces more fruit, the level of flower production decreases in the next production cycle.

Table 5. Interaction effect of FYM and NPS fertilizer on fruit number per plant.

Farmyard manure (t ha^{-1})	Number of fruit per plant							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2021				2022			
0	13.79^{k}	15.81^{hij}	16.78^{ghi}	18.88^{ef}	15.27^{hij}	16.70^{fgh}	17.59^{ef}	18.88^{de}
2.5	14.25^{jk}	15.46^{ij}	23.85^{bc}	23.7^{bc}	14.25^{ij}	15.46^{ghi}	23.85^{b}	23.70^{bc}
5	14.31^{jk}	24.86^{b}	26.56^{a}	22.56^{cd}	14.31^{ij}	25.67^{a}	26.56^{a}	22.56^{bc}
7.5	13.69^{k}	17.33^{fgh}	21.8^{d}	22.69^{cd}	13.69^{ij}	17.33^{efg}	21.80^{c}	22.69^{bc}
10	13.33^{k}	16.89^{ghi}	19.62^{e}	18.35^{efg}	13.33j	16.89^{fgh}	19.62^{d}	18.35^{def}
LSD (0.05)	**1.58**				**1.783**			
CV (%)	**5.1**				**5.7**			

Likewise, (26) examined how different nitrogen sources affected the production of peppers in subtropical climates and discovered that the application of 50% FYM + 50% UREA resulted in the highest percentage of fruit set. (12; 27) noted that the combined use of nitrogen and phosphorous had a major impact on the amount of fruits

Marketable Pod Yield

The maximum marketable yield of hot pepper (2.28 t ha^{-1}) was recorded with 100 and 200 NPS kg ha^{-1} of inorganic fertilizer combined with 5 t ha^{-1} of farmyard manure application in 2021 growing season and 41.67% more than the lowest value recorded at unfertilized (control) treatment in

2020 growing season (Table 6). The lowest and noticeably different yield of marketable dry fruit was observed in an area without fertilizer.

Likewise, entire commercial pod load per plant was reduced by 0.5 kg per plant as N level enlarged from 112 to 448 kg ha^{-1} in pepper. Similarly, (11) found that as the nitrogen level increased from 100 kg ha^{-1} to 150 kg ha^{-1}, the marketable yield of Marako Fana decreased. The release of less phosphorus from FYM to the crop in comparison to other treatments may be a contributing factor in the production of lower marketable yield from lower rate combinations. The use of essential nutrients increases vegetative growth, and this has led to the formation of healthy, attractive, and acceptable pods in markets. Furthermore, marketable pod yield rises in relation to toting of nutrients in nutrient lacking soils.

Table 6. Interaction effect of FYM and NPS fertilizer on marketable pod yield.

Farmyard manure (t ha^{-1})	Marketable pod yield (t ha^{-1})							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2020				2021			
0	1.33^{i}	1.39^{i}	1.35^{i}	1.54^{fg}	1.357^{l}	1.4^{ijkl}	1.377^{kl}	1.54^{fghi}
2.5	1.56^{efg}	1.50^{gh}	2.18^{a}	2.18^{ab}	1.56^{efgh}	1.5^{hijk}	2.187^{ab}	2.18^{ab}
5	1.66^{de}	2.19^{a}	2.17^{ab}	2.10^{ab}	1.66^{def}	2.277^{a}	2.17^{ab}	2.103^{b}
7.5	1.52^{g}	1.60^{efg}	2.07^{b}	1.86^{c}	1.52^{ghij}	1.603^{efgh}	2.067^{b}	1.860^{c}
10	1.40^{hi}	1.64^{def}	1.67^{de}	1.74^{d}	1.4^{jkl}	1.64^{defg}	1.67^{de}	1.740^{d}
LSD (0.05)	0.11				0.12			
CV (%)	4.0				4.1			

In spite of this, many of the plots treated with a combination of organic and inorganic fertilizers at lower rates and combinations treated with the highest rate, FYM (10 t ha^{-1}), produced statistically the same amount of low marketable dry fruit yield. Its release of FYM elements may be lower compared to other treatments, or it may have a toxic effect on higher-rate combinations.

Likewise, (28) testified, indicating that pepper plants grown in plots without nitrogen fertilizer produced lower total and marketable yields. Similar studies showed that applying NP fertilizers at higher rates (150/50 kg/ha N/ P_2O_5) increased the Marako Fana pepper variety's plant height, canopy diameter, and total and marketable dry pod yield.

Moreover, (28) noted that the maximum dry commercial yield (2.05 t ha^{-1}) was perceived at 102/115 kg N/ P_2O_5 ha^{-1}. Different levels of treatment with organic and inorganic fertilizers could be the cause of the variation in marketable pod yield. Small seedlings can die if there is too much salt in the soil because it can compact small leaves in the ground and cause young, tender roots to become saline. Low yields may result from high nitrogen fertilizer that is unable to transport enough calcium to the pod.

Total Pod Yield

Total pod yields of hot pepper was significantly affected by the interaction effect of FYM and NPS fertilizers. The maximum total fruit yield of hot pepper (2.72 t ha^{-1}) was noted from 200 NPS kg ha^{-1} fertilizer mixed with 5 t ha^{-1} of FYM application in 2021 growing season, which is 41.91% more than the lowest value recorded at 0 level application of FYM combined with 100 NPS kg ha^{-1}fertilizer rates in both growing season (Table 7).

The inadequate accessibility and nutrient absorption in the plants may be the cause of the low production of fresh and dried fruit observed in plots with low amounts of inorganic and organic fertilizers combined.

In a while, the toxic effect of nutrients delivered at greatest rates may be the cause of the low fruit yields observed in places where combined inorganic and organic

Table 7. Interaction effect of FYM and NPS fertilizer on total pod yield.

Farmyard manure (kg ha^{-1})	Total pod yield (t ha^{-1})							
	NPS (kg ha^{-1})							
	0	100	200	300	0	100	200	300
	2020				2021			
0	1.58^{hi}	1.53^{i}	1.59^{hi}	1.72^{fgh}	1.177^{h}	1.58^{g}	1.65^{efg}	1.72^{defg}
2.5	1.77^{fg}	1.7^{fgh}	2.36^{b}	2.28^{b}	1.77^{defg}	1.59^{fg}	2.363^{b}	2.28^{bc}
5	1.81^{ef}	2.62^{a}	2.26^{b}	2.35^{b}	1.8^{defg}	2.72^{a}	2.263^{bc}	2.35^{b}
7.5	1.7^{fgh}	1.74^{fgh}	2.22^{b}	2.00^{cd}	1.7^{defg}	1.74^{defg}	2.217^{bc}	2.0^{cde}
10	1.63^{ghi}	1.84^{def}	1.94^{cde}	2.05^{c}	1.63^{fg}	1.84^{defg}	1.94^{cdef}	2.05^{bcd}
LSD (0.05)	0.16				0.3017			
CV (%)	5.1				9.5			

Means sharing the similar letters are not suggestively dissimilar at 5% level of implication, LSD (0.05) = Least Significant Difference at 5% level, CV= coefficient of variation fertilizer are at highest rates. High N content plants typically have many leaves, a dark green colour, and few roots, flowering and seed production are typically limited.

Therefore, the use of recommended levels of 100% NP and very high FYM levels (10 t ha^{-1}) may allow plants to absorb too much N and P and through the mixture of this, somewhat salinity delinquent of the investigational field results in less yield of fruit. According to the (7) report, adding a lot of biological compost to farming soils could cause salt, nutrient, or heavy metal build-up, which would negatively impact plant growth, soil life, and water quality. As per (27), excessive nitrate concentrations in ground water can make plants poisonous.

Nitrate can become harmful in underground at high concentrations. Consequently, excessive organic fertilizer may not release nutrients more quickly than at other levels to boost fruit yields, but rather, it may have the opposite impact due to increased salinity and poisonous ground water. Likewise, (12; 28) noted that the combined use of nitrogen and phosphorous had a major impact on the amount of fruits per plant in hot pepper. Furthermore, the use of inorganic fertilizers containing sulphur elements improves the yield of chili. Proper quantity of necessary nutrients is essential for strong vegetative growth, thus creating better pepper seeds; in contrast, the deficiency of macronutrients has led to poor seed growth thus having a small amount of seed obtained and reduce yields.

Unmarketable Pod Yield

Unmarketable pod yield of hot pepper was greatly influenced by NPS fertilizer and FYM. The maximum unmarketable yield of hot pepper (0.22 t ha^{-1}) was noted from 300 NPS kg ha^{-1} of fertilizer, while the minimum unmarketable yield (0.2 t ha^{-1}) was documented at 0 NPS kg ha^{-1} of fertilizer. On the other hand, the highest unmarketable yield (0.25 t ha^{-1}) was observed at 10 t ha^{-1}, while the minimum unmarketable yield (0.15 t ha^{-1}) was noted at 7.5 t ha^{-1} of FYM application (Table 8).

Table 8. Main Effect of FYM and NPS fertilizer on unmarketable tuber yield.

NPS (kg ha^{-1})	2020 Unmarketable Yield (t ha^{-1})	2021 Unmarketable Yield (t ha^{-1})
0	0.20^{a}	0.1940^{a}
100	0.14^{b}	0.1360^{b}
200	0.21^{a}	0.2133^{a}
300	0.22^{a}	0.2193^{a}
LSD (0.05)	**0.04**	**0.03357**
FYM (t ha^{-1})		
0	0.20^{b}	0.1850^{b}
2.5	0.17^{bc}	0.1758^{b}
5	0.19^{bc}	0.1900^{b}
7.5	0.15^{c}	0.1508^{b}
10	0.25^{a}	0.251^{a}
LSD (0.05)	0.043	0.03753
CV (%)	26.7	23.8

Means sharing similar letters are not suggestively dissimilar at 5% level of implication, LSD (0.05) = Least Significant Difference at 5% level, CV= coefficient of variation

The maximum farmyard manure (10 t ha^{-1}) claim merely also formed a very dissimilar unmarketable fruit yield. Most other collective mineral and biological fertilizers have formed approximately the same quantity of unmarketable dry fruit yields. Treatment with an adequate level of phosphorus may initiate the development of fruit set and thus produce acceptable pods in the market.

Economic Analysis

From the final experimental data, the gross yield for all treatments was obtained. Then the recommended level of 10% was adjusted to obtain net yield. Net yield was multiplied by the market price to obtain gross field benefit. Costs and benefits were calculated for each treatment. All variable costs were calculated based on the current market price especially for fertilizers. Purchasing costs for Urea and NPS were taken as Birr 1,500/Qt and 1,600/Qt, respectively.

The selling price of hot pepper at the local market at harvest time was taken as Birr 200.00/kg. Variable costs were summed up and subtracted from gross benefits. This was taken as the net benefit. The total cost applied for control treatment was assumed to be 50 ETB for one plot and for one hectare, a total of 45,787.56 ETB were obtained. The plot receives fertilizer was calculated as the expense of urea is about 16.4 ETB and the variable cost of NPS is 17.47 ETB. The total cost of this treatment 33.87 ETB. Thus, the total cost of one hectare of hot pepper field receives was NPS and Urea was estimated to be 31,016.48 ETB (10.92 m^2 = 33.87 ETB). The gross margin of this hot pepper field is estimated to be 76,804.043516 ETB (10.92 m^2 = 33.87 ETB).

Therefore, the net benefit of this experiment was assumed to be total sell minus total cost, which is 76,804.043516 minus 31,016.48 equals to 45,787.563516 ETB. Based on this cost benefit analysis, use of NPS and Urea fertilizer for hot pepper in the study area is recommended.

Conclusion

In conclusion, hot pepper growth and yield variations respond differently to the flexible doses of NPS and FYM fertilizers. According to the current study, the maximum marketable yield was recorded from 100 kg NPS ha^{-1} in combination with 5 t ha^{-1} of FYM. Thus, 100 kg ha^{-1} of NPS with 5 t ha^{-1} was recommended to be an optimal and effective fertilizer for farmers planting hot peppers for the experimental area grounded on the research investigated in 2020 and 2021 growing season. Thus, it may be suggested that different types of hot pepper produce better yields.

Acknowledgements

The authors inspired to express heartfelt thanks to Dambi Dollo University for providing plot of land for field experiment and great thanks to technical assistances of Department of Plant Sciences for their collaboration in success of this work from the start to end.

Authors contributions

The corresponding author CK draft the research and data collection, GO have analysed the data and organize the paper.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest, financial or otherwise.

Ethical issues: None.

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