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Effect of Intra Row Spacing and Nitrogen Fertilizer Rates on Growth Performance of Hot Pepper (*Capsicum annuum* L.) at Wolkite University, Central Ethiopia

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Abstract: Hot pepper (*Capsicum annuum* L.) is one of the most important and economical vegetable crop produced in Ethiopia including Gurage zone. Use of appropriate plant spacing's and optimum nitrogen application are the major agronomic practice to improve the productivity of hot pepper. However, the productivity of hot pepper is low its potential due to many factors such as poor soil fertility, under or above optimum plant population, inappropriate fertilizer application with blanket application in all soil type and crop varieties. Therefore, this experiment was conducted at Wolkite University, College of Agriculture and Natural Resource Demonstration site with the objectives of determining the optimum level of N fertilizer and intra-row spacing for better growth of hot pepper. The experiment consisted of three levels of nitrogen (N1 (75 kg/ha), N2 (100 kg/ha), N3 (125 kg/ha)) and two levels of intra-row spacing (S1 (70×25cm) and S2 (70×30cm)). The inter row spacing was maintained as 70cm. The experiment was laid out in 3×2 factorial arrangement in a randomized complete block design (RCBD) and replicated three times. The analysis of variance revealed that the main effects of intra row spacing and nitrogen rates as well as the interaction of the two factors had a significant effect in all tested growth parameters of hot pepper. The main effect of nitrogen resulted maximum plant height (49.92cm), leaf number per plant (35.45), and number of branch per plant (10.92) which were recorded by the application of 125kg/ha nitrogen. Likewise, the main effect of intra row spacing gave maximum plant height (49.52cm) at 25cm plant spacing, and leaf number per plant (35.30), and number of branch per plant (11.21) from 30cm plant spacing. For interaction effect, the highest plant height (52.00cm) were recorded from S1N3 (25cm plant spacing and 125kg/ha N), whereas the maximum leaf number per plant (38.83) and number of branch per plant (12.67) were obtained from S2N2 (30cm plant spacing and 100kg/ha N fertilizer). Mostly, leaf number and number of branch positively correlated with yield of the crops where the branch increased fruit setting become increased as a result yield increased. Therefore, applying 100 kg/ha N with 70×30 cm plant spacing can be advisable for hot pepper production.

Keywords: Intra Row Spacing, N Fertilizer, Growth Performance and Hot Pepper

1. Introduction

Hot pepper (*Capsicum annuum* L.) is the world's most important vegetable crop and that belongs to *Solonaceae* family [11]. There are five domesticated species and uncertain number of wild species; these are *C. annuum* L.*, C. frutescence, C. Chinese* jacq, *C. baccatum* var. Pendulum L., and *C. pubescens* R., *P. capsicum.* Plants are dicotyledonous woody shrub with erect, sometimes prostrate growth habit, perennial in nature but cultivated as annual. All cultivated capsicum species are diploid and have the same chromosome number of 2n=22 [5]. Capsicum fruits are consumed as fresh, dried or processed, as table vegetable and as spice or condiments [4]. The nutritional value of hot pepper merits special attention because it is rich source of vitamin A, C and E. Both hot and sweet pepper contains more vitamins C than any other vegetable crops [11].

Hot pepper is one of the major vegetable crops produced in Ethiopia. Ethiopia is one of a few developing countries that have been producing paprika and capsicum oleoresins for

export market [4]. Because of it's widely used in Ethiopia diet, hot pepper is an important traditional crop mainly valued for its pungency and color. It is extensively grown in most parts of the country, with the major production area concentrated at altitude of 1400 to 1900 m.a.s.l [4]. The central (Eastern and Western Shewa), western and north western (Wollega and Gojam) and northern parts of the country are the potential pepper producing areas. About 232,000ha of land is cultivated for hot pepper in Ethiopia. The total yield gained from hot pepper is still remains low as compared to the yield potential of the crop. This is due to a number of constraints that hinder the production and productivity of the crop.

Densely populated planting, affect the growth and yield component of hot pepper by computing nutrients, moisture, light and all available materials in the soil. These all factor known to affect the number of branches, leaf numbers, flower setting, fruit setting, stem biomass and size of fruit. Plants grown densely produce the smallest plant leaves and stem biomass but resulted in more upright plants and produce the highest fruit yields and counts per hectare and lowest fruit yield per plant. The higher plant population at the narrower intra row spacing responsible for lower yield per plant but result increase yield per area. It is obvious that to get better growth, optimum plant density (spacing) is needs for the crop to access soil nutrient, moistures, light, and space. Unless optimum spacing is determined the wise use of limited land for production of hot pepper and optimizing soil nutrient, moisture, light and space use is impossible. There is knowledge gap in the optimum intra row spacing of the crop and factors of densely populated. Crop (cultivars) with vigorous growth habit are usually planted at a wider row spacing to avoid competition among neighboring plants and also to prevent mutual shading in plant canopies. Disease prevalence and severity are also important considerations for a wider row planting option [1]. Plant densities beyond certain thresholds can adversely affect fruit quality and encourage disease development in pepper plants. Inadequate fruit color development was also observed in over densely planted hot pepper [9]. This may be due to the inability of some of the fruit to be in direct sunlight, which is important for the development of carotenoid pigments.

Nitrogen is an important mineral element that is used by almost all crops. Nitrogen, as a key component of plant proteins, plays an important role in plant growth and development. Because of nitrogen's involvement in protein synthesis, soil nitrogen deficiencies may lead to lower protein concentrations in vegetables, thereby affecting the nutritional composition of the crop. Adequate soil nitrogen supplies allow for the optimal development of vegetable color, flavor, texture, and nutritional quality. However, plants receiving excess nitrogen produced excess foliage and decreased yield [10]. Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development. Because of nitrogen constituent of amino acids, which are required to synthesize proteins and other related compounds, it plays a role in almost all plant metabolic processes. Nitrogen is also an integral part of chlorophyll manufacture through photosynthesis. Excess N causes increased susceptibility of vegetable crops to fungal diseases and deterioration of post-harvest quality [2].

Hot pepper is one of the major vegetable crops grown in Ethiopia. Their growth, yield and yield component is influenced by the following factors: lack of improved varieties for different agro ecology, adverse environmental factors and agronomic practices such as fertilization, irrigation, cultivation, weeding, disease and insect pest and plant density. From those factors intra row spacing and nitrogen level is the major influence. Many researchers have been revealed that lack of appropriate agronomic practices has been influence the growth and yield components. Farmers are complaining of difficulty in management activities for different varieties to obtain the potential yield. Therefore, knowing of optimum intra row and nitrogen level improve production and productivity of the crop, which has great contribution for increment of the national average yield by using optimum plant population per hectare. Therefore our research focuses on this problem to inform farmers with optimum spacing between plant and nitrogen level to increase the growth performance of hot pepper.

Objectives:

1. To determine the effect of nitrogen level on growth performance of hot pepper
2. To determine the effect of intra row spacing on growth performance of hot pepper
3. To determine the interaction between nitrogen level and intra row spacing on growth performance of hot pepper

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Gurage Zone at Wolkite University, College of Agriculture and Natural Resources demonstration site during the off season of 2019 under irrigation condition. Wolkite University is geographically located 170 km from Addis Ababa to South West direction. The latitude is about 8011'60.0''N (8.200) and 370-47'60.0" (37.80) E longitude. Its elevation is ranging from 1300 meters above sea level. The annual rain fall of the area is 1294mm and the annual average temperature is 20.5°C. While the maximum and minimum recorded temperature being 24°C and 14°C, respectively. The soil type of the area heavy vertisol is around 80%, which is rich in organic matter, while there is less capability to drain water. The rain fall of Wolkite is bimodal in which 80% of rain falls in the winter period of June to August whereas 20% in the *belg* period of February to May.

2.2. The Experimental Materials

The experimental materials were used for the study; seeds of hot pepper (Mareko Fana)) and urea fertilizer as a source

of nitrogen.

2.3. Experimental Design and Treatments

The experiment consisted of three rates of N fertilizer (75, 100 and 125 kg ha^{-1}) and two intra row spacing (25cm and 30cm) arranged in 3×2 factorial combinations having six treatments in randomized complete block design (RCBD) with three replications. Experiment treatment combination S1N1 (70cm×25cm and 75kg/ha), S1N2 (70cm×25cm and 100 kg/ha), S1N3 (70cm×25cm and 125 kg/ha), S2N1 (70cm×30cm and 75 kg/ha), S2N2 (70cm×30cm and 100kg/ha), and S2N3 (70cm×30 cm and 125kg/ha).

The gross size of each plot was 6.72m^2 (2.4m length × 2.8m width) accommodated four rows with 10 and 8 plants per row for the intra-row spacing of 25cm and 30cm, respectively. There were 40 and 24 plants per each plot with the spacing of 25cm and 30cm between the plants, respectively. The recommended inter-row spacing of 70cm was maintained for all plots. The distances of adjacent plots and between blocks were 0.5m and 1m, respectively. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants.

2.4. Land Preparation and Seedling Transplanting on Experimental Plots

The experimental field was ploughed and harrowed by tractor. Large clods were broken down in order to make the land fine tilth and plots were leveled and drip lines on ridges were prepared at a spacing of 70cm. Experimental plots were prepared based on the design of the experiment as indicated above. During transplanting only well established, uniform, healthy and vigorous seedlings (standard seedlings) grown at the center of seed beds and having a height of 20-25cm were selected and transplanted after 50 days from sowing to the experimental field on ridge planting system at the specified spacing [3]. Seedling gap filling was done within a week after transplanting.

According to the treatment combination, nitrogen was applied in two splits were half rate of nitrogen in the respective treatments in the form of urea (46% N) was applied in bands at the time of transplanting. The remaining half rate of nitrogen fertilizer was applied during active vegetative growth (four weeks after transplant). All agronomic practices were applied according to the standard practices recommended for the hot pepper crop.

2.5. Data Collected

The important growth performance parameters were measured from effect of intra row spacing and level of nitrogen fertilizer on hot pepper includes; plant height (cm), leaf numbers and number of branch per plant. Selected sample plants at middle which is represented the total number of population.

The growth performance parameters were measured from five plants randomly sampled from the two middle rows of each plot were recorded at maximum vegetative growth stage of the plant. The data which would have been recorded on the growth response were as follows:

Plant Height (cm): The average plant height of the five randomly selected sample plants from each plot measured by using a ruler from the ground level to the terminal end.

Number of leaves per plant: The number of leaves per plant was counted and then means value of five plants per plot was recorded.

Number of branches: The number of branch per plant was counted and then means value of five plants per plot was recorded.

2.6. Data Analysis

All the collected data were subjected to analysis of variance (ANOVA) by statistical procedures as described by Gomez (1984) and means were compared using least significance difference (LSD) at 5% probability level.

3. Results and Discussion

The effect of intra row spacing and nitrogen level were evaluated on the growth performance of hot pepper, was found on growth parameters of plant height, numbers of branches and leaf numbers.

3.1. Plant Height

Nitrogen had significance effect on plant height of hot pepper with the highest value 49.92cm obtained from application of 125kgha^{-1} but statistically as par with 100kgha^{-1} N application, whereas the least leaf number recorded at 75kgha^{-1} N (Table 1), this clearly showed that nitrogen is mainly concerned with the vegetative growth of the plants.

Significantly highest plant height 49.52cm was obtained from intra row spacing of 25cm followed by 44.12cm obtained when the spacing of 30cm was used (Table 1). Closer spacing resulted in competition for nutrient and light thus resulting in plants that were grow upright while the wider spaced plants had adequate spaced for their growth and development.

The interaction effects of nitrogen fertilizer and intra-row spacing on the height of the hot pepper was significant at 5% level of probability. The best result regarding the plant height (52.00cm) were recorded under the treatment combination S1N3, whereas adopted spacing 25cm and 125kgha^{-1} N in comparison to individual treatments and control, and the shortest plants were observed in the S2N1 with the mean height of 44.56cm. The plant height significantly with the adopted spacing and application of nitrogen may be due to the fact of nitrogen in promoting height of plant might be due to the fact that, the net assimilation rate of the nitrogen fed plant was accelerated by their increased chlorophyll content, and the absorbed nitrogen helped the formation of food reserves due to higher photosynthetic activity. The favorable effect of greater spacing in promoting height of plant might be due to the greater spacing of the hot pepper plants seem to have helped the individual plants to utilize more soil water,

nutrition, air and light to help it to put up better than those having lesser spacing where the plant population per unit are had increased. The above results were in close agreement with the findings where the highest plant height recorded from the densely populated plant and maximum fertilizer rate applications [8].

Table 1. *Effect of intra row spacing and nitrogen level on plant height, number of leaf and number of branch per plant.*

Treatments	Plant height (cm)	Leaf number per plant	Number of branch per plant
Spacing			
S1 (70*25cm)	49.52[a]	27.07[b]	9.17[b]
S2 (70*30cm)	44.12[b]	35.30[a]	11.21[a]
LSD (5%)	1.73	2.32	0.43
Nitrogen			
N1 (75kgha^{-1})	46.15[b]	30.68[b]	9.58[b]
N2 (100kgha^{-1})	49.70[a]	34.42[a]	10.92[a]
N3 (125kgha^{-1})	49.92[a]	35.45[a]	10.97[a]
LSD (5%)	2.11	2.84	0.53
Interaction			
S1N1	48.70[b]	27.63[c]	8.76[d]
S1N2	50.83[a]	30.00[c]	9.17[cd]
S1N3	52.00[a]	23.56[d]	9.57[c]
S2N1	44.56[c]	33.73[b]	10.40[b]
S2N2	47.56[b]	38.83[a]	12.67[a]
S2N3	48.23[b]	33.33[b]	10.56[b]
LSD (5%)	2.10	4.01	0.75

Where: LSD= Least Significance Difference; means with the same letter in the columns are not significantly different at 5% level of significance.

3.2. Number of Leaves Per Plant

Nitrogen level significantly ($P<0.05$) affected the number of leaves per plant of hot pepper with the highest value (35.45) obtained from 125kgha^{-1} but statistically similar with 100kg/ha N application and the least number of leaves (30.68) was observed at the level of 75kgha^{-1}. This results show that nitrogen played important role in leaf production via its role in vegetative growth. Number of leaves per plant increased with increasing nitrogen levels up to the recommended rates [7].

There was significant effect on intra row spacing on number of leaves per plant; significantly higher number of leaves (35.30) was recorded with 30cm and least number of leaves (27.07) with 25cm. When the population of hot pepper increase can be alter the growth of hot pepper by high computation of nutrients and water. Low plant density have less computations of nutrient and water but the growth of weed can be increase to affect the growth of hot pepper by computing of nutrient and waters. Narrow row spacing (higher population density) resulted in plants that were smaller less leaf.

Significance effect of interaction between nitrogen and intra row spacing with the maximum number of leaves (38.83) was related to30cm planting distance and when N fertilizer rates applied was 100kgha^{-1} and the least numbers of leaves (23.56) was observed in S1N3 treatment combination (Table 1). The additive effect of nitrogen levels on the hot pepper leaves was associated to the plant metabolism that resulted in increasing of the photosynthetic products. The favorable effect of wider spacing in promoting number of leaves of the plant might be due to the fact that the greater spacing of the hot pepper plant seem to have helped the individual plants to utilized more soil water, nutrition, air and light to help it to put up better growth then having lesser spacing where the plant population per unit area had increased. The above results were in close agreement with the findings where the wider spacing with maximum nitrogen rate obtained maximum numbers of leaf per plant [7].

3.3. Number of Branches

Nitrogen level significantly affected the number of branche per plant of hot pepper with the highest value (10.97) obtained from 125kgha^{-1} N and the least number of branch (9.58) was observed at the level of 75kgha^{-1}. There was no significant difference between N2 and N3 on the numbers of branch with the mean value of 10.97 and 10.92, respectively. This results show that nitrogen played important role in branch production via its role in vegetative growth [7].

The significant effect of intra row spacing on number of branch per plant, significantly higher number of branches (11.21) was recorded with 30cm and least number of branches (9.17) with 25cm, densely populated planting affect the growth of hot pepper by computing nutrients, moisture, light and all available materials in the soil. These all factor known to affect the number of branches.

The interaction effects of nitrogen fertilizer and intra-row spacing on the number of branches of the hot pepper was highly significant at 5% level of probability. The highest number of branches (12.67) was obtained with the adopted rate of 100kgha^{-1} and with the spacing of 30cm between the plants, while the least number of branches (8.76) recorded in S1N1 treatment combination (at 25cm plant spacing and 75kgha^{-1}). This might be attributed to the reduction of the possible competition for soil moisture and nutrients at wider spacing. Nitrogen promotes rapid growth and increases leaf size. This is because of the fact that N is mainly concerned with the vegetative growth of plants through cell division and

elongation, and promotes rapid growth and increases branches [6].

4. Conclusion and Recommendation

Based on the results of the study, determine the optimum plant density and nitrogen rate are necessary for economic production of hot pepper. Accordingly, application of 100kg ha^{-1} nitrogen fertilizer for hot pepper plants which were planted at 30cm intra row spacing, obtained maximum number of leaf and branches per plant, which is recommended for economically and agronomical production of hot pepper in the study area and similar agro-ecologies. However, this experiment only tested some growth parameters of hot pepper hence similar experiments involving yield and yield components parameters of hot pepper and additional combinations under different locations and seasons should be conducted to come up with a conclusive recommendation.

Data Availability

The data of this study are available with the corresponding author.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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