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Effects of Spacing on Growth, Yield and Yield Components of Hot Pepper (*Capsicum Annum* L.) Under Irrigated Condition in South Omo Zone

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Abstract: In Ethiopia, Hot pepper is important vegetable crops. But, the productivity of this crop is reduced due to nonexistence appropriate spacing for specific location and variety. Hence, the field research was carried out to evaluate the effects of spacing on yield and yield components of Hot pepper through 2018 and 2019 growing period at Omorate and Weyito, respectively, in South Omo Zone, Southern Ethiopia. The three inter-row spacing (50, 60, and 70) cm with three intra-row spacing (30, 40 and 50) cm were arranged in 3x3 factorial companions in randomized complot block design with 3 replications. Growth, yield and yield components parameters were recorded and carried out statistical analysis. The result of current study showed that, there was significant influenced by intra-row spacing on branch number per plant at Omorate and Weyito locations while both spacing hade significant variation in height of plant at Weyito. There was also variation in interaction effect in pod number per plant, fresh pod and dried pod weight at both locations. The maximum dried pods yields (3.06 t/ha) were recorded in 55,555 plants/ha (60cm inter with 30cm intra) row spacing and 33.6% dried pod weight increment as compared to recommended spacing (70cmx30cm) at Omorate location. While at Weyito, the highest dried pod yield (2.57 t/ha) was recorded in 50,000 plants/ha (50cm inter with 40cm intra) 30.5% dried pod weight increment as compared to recommended spacing (70cmx30cm) among tested treatments. Therefore, use of '55,555 plants ha^{-1} (60cm inter with 30cm intra) row spacing at Omorate and 50,000 plants ha^{-1} (50cm inter with 40cm intra) at Weyito can be recommended for hot pepper producing farmers, agro-pastoral at these location and its vicinity.

Keywords: Hot Pepper, Inter-row Spacing, Intra-row Spacing, Fresh Pod Yield, Dried Pod Yield

1. Introduction

"Hot pepper (*Capsicum annum* L.) is one of the major vegetable and spice crop in tropical area of Ethiopia and the genus *Capsicum* is a high value crop used as vegetables and spice in Ethiopia. Since it is a high value crop, it can be used as both domestic and export market" [1]. It is closely related to potato, eggplant, tomato and tobacco. It is the second greatest vital vegetable plant after tomato in the world [2]. Hot pepper is a vital crop, not only its financial significance, but also due to the nutritional and pharmaceutical value of its fruit [3]. Its fruit is an exceptional source of natural colors and antioxidant compounds whose intake is an important health protecting factor by prevention of widespread human diseases [4]. Hot pepper grows on almost all soil types, but is most suited to well drain sandy or loamy soils, rich in lime, with a pH of 5.5-6.8 and high water retention capacity. However, pepper can also tolerate a wider soil pH range of 4.5 (acidic) to 8.0 (slightly alkaline). Light sands, clay sandy and sandy loams are also suitable for growing pepper [5]. Higher yields produced when the temperature ranges between 18 and 32°C [6].

Hot pepper was grown on about 1,819.86 ha in SNNP Region from which about 14,283.710 tons green hot pepper yield was produced in the year 2017 and the average regional yield of 7.85 t/ ha. In the same year 33.31 ha was covered

with hot pepper in South Omo Zone from which about 26.81 tones green hot pepper yield was produced, with the average zonal yields 6.81t ha^{-1} [7] (CSA, 2017). But, tis yield is great gap with compared to the achievable yield (25-32t/h) in well agronomic management environments [8]. Low yield of hot peppers in Ethiopia were attributed different constraint in which included lack of improved varieties, poor crop agronomic management (plant density, plating time etc), low soil fertility, pest incidence and severity.

In Ethiopia, hot pepper produces foremost raining period and in irrigation during shortage of rain fall usually uses seed rate of 0.75kg ha^{-1} as well as (70cm inter with 30 cm intra)-row spacing's [8]. The optimal plant population density for better yield differs conditional on plant physical appearance and accessibility of growing influences such as nutrients, light and water. Thus ideal plant population of the crops at a location cannot be valid in another location, since variation in: soil character, and nutrient availability, and other environmental conditions. Therefore, it is important to identify appropriate plant density for specific environment. Thus, the object of this study was carried to identify suitable plant population density for production of hot pepper through irrigation at lowland area in South Omo Zone.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted during 2019 cropping season at Omorate (lobet kebele) and 2020 at Weyito (Enchete kebele). Omorate which is located South Omo Zone in Southern Nations, Nationalities and People's Regional State. It is situated between 4°37′-4°58′ North latitude and 35°56′-36°20′ East longitude with altitude of 365 meter above sea level. It is characterized by hot temperature, erratic rainfall, vast area of plain low lands suitable for large scale and subsistence agriculture including crops and livestock. The rainfall distribution of the area is bimodal, with a primary rainy season between March to May and secondary small rain between Septembers to December. The monthly average minimum and maximum temperature is 24.4°C-37.8°C, respectively. The soil of the experimental site is with a sandy clay loam texture. It has total nitrogen content of 0.08%, available phosphorus content of 58.9 mg kg $soil^{-1}$ and soil pH of 6.03.

Weyito also located South Omo Zone in Southern Nations, Nationalities and People's Regional State. It is situated between 5°01'-5°73' North latitude and 36°38' - 37°07' East longitude with altitude of 588 meter above sea level. The rainfall distribution of the area is bimodal with main rainy season extends from January to May and the second cropping season, from July to October. Average annual rainfalls for the last previous 10 years was 683.05. It receives annual average rainfall of 876.3 mm and the monthly average minimum and maximum temperatures of 18.2 and 34.3°C, respectively. All the metrological data a given above for the two location are long term averages. The soil of the experimental site is with a sandy loam texture. It has total nitrogen content of 0.0.086%, available phosphorus content of 29.355 mg kg $soil^{-1}$ and soil pH of 6.1.

2.2. Experimental Design and Treatments

The experiment was factorial with three intra-spacing (30cm, 40cm and 50cm) and three inter-row spacing including 50cm, 60cm and 70 cm). Factorial combinations were used as nine treatments laid out in a randomized complete block design (RCBD) with three replications

2.3. Experimental Field Management

The high yielder of Melka awaze variety for study area was used for this research. The field of nursery bed was cultivated and break up to bring it to a fine tilts and 1meter width and 5 meter length of seed bed was prepared. Seeds were sowed in to the nursery bed by hand within 15 cm spacing. The seed bed after sowing were covered by dry grass mulch until emergence. Watering was done from 2 up to 4 day according to weather condition and weeding also was done as quickly weeds emerged. Seven days before transplanting to main field, water apply for seedbed was decreased in order to withstand the seedling and reduce transferring shock. Selected one month seedlings and similar, unaffected and strong seeding were transferred in to main research field. A gross plot size of 5m x 5m for 50cm, 5m x 4.8m for 60cm and 5m x 4.9m for 70cm inter row spacing. The distance between plots and replications were 2.0 meter. The number of rows per plot for the 50cm, 60 cm and 70 cm were 10, 8 and 7, respectively. 100 $kgsha^{-1}$ of NPSB and 150 $kgsha^{-1}$ of urea were applied similarly for all plots. The entire quantity of NPS fertilizers were applied during transplanting time. Urea was side dressed in two splits of equal amounts at transplanting and 45day after transplanting. The hot pepper crop were irrigated by using furrow at every five up to seven days from transplanting up to flowering and then after from eight up to ten 8-10 days until physiological maturity at Omorate location while at Weyito location, six to eight days from planting up to flowering and then after nine to eleven days up to physiological maturity according weather condition. No any agro-chemicals were applied during growing period. The first, second and third weeding and hoeing were performed 20, 40 and 60 days after transplanted, respectively.

2.4. Data Collected

2.4.1. Growing Parameters

Measured plant height during physiological maturity from central rows as the mean height of five randomly taken sample plants from the ground level to the apex of each plant. Determined branch numbers per plant by counting primary branches randomly sampled plants from central rows during the second harvest.

2.4.2. Yield Components and Yield

Pods number per plant: Physiologically matured pods were determined from taken five plants randomly at each successive harvest. At the final harvest, the overall recorded data was summed up and the average was taken.

Total fresh pods yield (t/ha): This refers to the cumulative fresh pod yields obtained from three times successive harvests were summed up.

Total dry pod yield (t/ha): This was measured by taking the total weight at each successive harvesting from two central rows sun drying to constant weight then after summed up to estimate yield per hectare.

2.5. Data Analysis

Measured data were analyzed by using SAS software program version 9.2 [9] with a generalized linear model (GLM) procedure. All significant treatment mean differences were separated using the Least Significant Difference (LSD) test at 5% probability Level.

3. Results and Discussion

3.1. Growth Parameters

3.1.1. Plant Height (m)

In this study, plant height was significantly influenced ($P<0.05$) by the effects of intra-row and inter-row spacing, while was not significantly affected by their interaction at Weyito location. Which however, did not significantly influenced ($P>0.05$) due to the main effects and their interaction at Omorate location (Table 1). At Weyito, significantly higher plant height (1.05m) and (1.08m) were obtained from (30 and 50) cm inter and intra-row spacing, respectively and the lowest plant height (0.83) and (0.82) were obtained from 50cm intra-row spacing and 70cm inter-row spacing, respectively. Although intra and inter-row spacing did not exert significantly effect on plant height in Omorate location, slightly higher plant height (1.34m) was recorded at narrowest (30cm) intra-row and 70cm inter-row spacing while lower (1.27m and 1.28m) value were obtained at wider inter and intra-row spacing, respectively (Table 2). In general at both locations, these results showed that, an increase in plant height with increasing plant density in all tested varieties at Weyito location (Table 2). The possible reason for the tallest plant height with increased plant density might be due to the fact that as the spacing among plants decreased, the interplant competition for light increases and enhance apical growth, while wider spacing tends to encourage lateral growth and suppressing apical growth. The current study result in line with studied by [10] reported that, increased significantly plant height of hot pepper with decreased plant population density.

Table 1. *Anova values for crop growth attributers of hot pepper planted with different plant densities at Omorate (lobet kebele) and Weyito (Enchete kebele), lowland area of South Omo Zone during 2019 and 2020 cropping season.*

		Omorate(2018)		Weyito (2019)	
Source	**Degree of freedom**	**Plant height**	**Primary branches per plant**	**Plant height**	**Primary branches per plant**
Replication	2	0.003 *	0.867 *	0.010 ^{ns}	1.086*
Inter S	2	0.010 ^{ns}	2.16 ^{ns}	0.124*	1.947^{ns}
Intra S	2	0.080 ^{ns}	4.517**	0.146*	4.236**
Inter S x Intra S	4	0.042 ^{ns}	0.939 ^{ns}	0.019 ^{ns}	0.69 ^{ns}
Error	16	0.011	0.762	0.007	0.896
CV (%)		9.13	16.11	8.66	15.06

CV= Coefficient variance, NS= Non-significant, *= Significant at $P<0.05$, **= Highly significant at $P<0.01$ and S=spacing.

Table 2. *Mean value for crop growth parameters of hot pepper variety planted with different plant densities at Omorate (lobet kebele) and Weyito (Enchete kebele), South Omo Zone during 2019 and 2020 cropping season.*

Treatments	**Omorate(2018)**		**Weyito (2019)**	
	Plant height(m)	**Primary branches per plant**	**Plant height(m)**	**Primary branches per plant**
Inter-row spacing				
50	1.34	5.83	1.05^{a}	5.79
60	1.30	5.54	1.03^{a}	6.35
70	1.27	4.88	0.83^{b}	6.71
LSD(0.05)	NS	NS	0.08	NS
Intra row spacing				
30	1.34	4.06^{b}	1.08^{a}	5.57^{b}
40	1.29	4.66^{ab}	0.94^{b}	6.36^{ab}
50	1.28	5.54^{a}	0.82^{c}	6.93^{a}
LSD(0.05)	Ns	1.0	0.09	0.95

Means with the same letters in the same column are not significant difference at $P<0.05$; LSD=; Least significance difference; PPP= pods per plant; FPY= fresh pods yield and DPY= dried pods yield.

3.1.2. Branches Number Per Plant

In this study, branch number per plant was significantly ($P<0.01$) influenced due to intra-row spacing effect and their interaction effects were not significant effect at both location (Table 1). The highest primary mean number of

branches (5.54) and (6.93) per plant were recorded from at the increased intra-row spacing (50cm) at Omorate and Weyito location, respectively. Generally this result showed that, numbers of primary branch was decreased in dense spacing related to far spacing of inter x intra row spacing combinations (Table 2). The probable cause for increase primary branches number with decreasing plant density could be due to the fact that, as plant spacing increased sufficient resources become accessible for to each plant that improves the lateral vegetative growing. The current study result conforms with finding of [11] "who indicated that, plant height significantly increased with an increase in plant density because of lower amount of light intercepted by a single plant resulting in increased inter node-length in crops".

Table 3. *Anova values for yield attributes and yield of hot pepper planted with different plant densities at Omorate (lobet kebele) and Weyito (Enchete kebele), South Omo Zone during 2018 and 2019 cropping season.*

Source	Degree of freedom	Omorate(2018)			Weyito (2019)		
		Number of pod	Fresh pods yield	Dry pods yield	Number of pod	Fresh pods yield	Dry pods yield
Replication	2	13.30 *	1.578 *	0.407 *	143.38 *	2.090 *	0.604*
Inter S	2	49.51 * *	5.019**	0.774*	311.02**	0.771**	0.237*
Intra S	2	597.47*	8.277**	0.359*	5764.49*	20.478**	0.872*
Inter S x Intra S	4	390.22*	1.707**	0.525*	270.20*	5.465 **	0.391*
Error	16	104.21	0.259	0.115	23.46	0.373	0.141
CV (%)		7.20	9.13	15.65	4.8	7.81	19.96

CV= Coefficient variance, NS= Non-significant, *= Significant at P<0.05, **= highly significant at P<0.01 and S=spacing.

Table 4. *Mean value for yield attribute and yield of hot pepper planted with different plant densities at Omorate (lobet kebele) and Weyito (Enchete kebele), South Omo Zone during 2018 and 2019 cropping season.*

Inter-row spacing	Intra-row spacing	Omorate (2018)			Weyito (2019)		
		PPP	FPY(tha^{-1})	DPY(tha^{-1})	PPP	FPY(tha^{-1})	DPY(tha^{-1})
50	30	113.50^{ef}	9.910^{bc}	1.77^{cd}	99.10^{f}	6.58^{de}	1.47^{c}
	40	133.40^{d}	9.787^{bc}	2.08^{bcd}	110.33^{e}	11.03^{a}	2.58^{a}
	50	141.83^{cd}	9.580^{c}	2.29^{bc}	131.43^{c}	6.60d^{e}	1.99^{abc}
60	30	103.40^{f}	12.177^{a}	3.06^{a}	100.00^{f}	9.17^{b}	1.93^{bc}
	40	139.53^{cd}	11.467^{a}	2.52^{ab}	129.13^{c}	8.47^{bc}	2.22^{ab}
	50	162.0^{b}	9.067^{Cd}	1.95^{bcd}	15.53^{b}	6.04^{e}	1.77^{bc}
70	30	129.80^{de}	10.567^{b}	2.29^{bc}	119.40^{d}	7.57^{cd}	1.97^{abc}
	40	155.03^{bc}	9.567^{c}	1.97^{bcd}	144.63^{b}	8.57^{bc}	1.77^{bc}
	50	197.33^{a}	8.367^{d}	1.67^{d}	186.93^{a}	6.37^{e}	1.37^{c}
LSD(0.05)		17.67	0.88	0.59	8.38	1.06	0.65

Means with the same letters in the same column are not significant difference at P<0.05; LSD=; Least significance difference; PPP= pods per plant; FPY= fresh pods yield and DPY= dried pods yield.

3.2. Yield and Yield Attributes

3.2.1. Pods Number Per Plant

The current study showed that, the existence significantly influenced (P≤0.05) of inter and intra row spacing as well as their interaction (P≤0.01) in number of pods (Table 3). The maximum mean pod number (197.33) and (86.93) were recorded from wider (70cm inter x 50cm intra) row spacing at Omorate and Weyito, respectively. Whereas, the lowest (113.50) was recorded from Omorate location and (99.10) was recorded from Weyito at the same wider (70cm inter x 50cm intra) row spacing (Table 4). "The decrease in the number of pods per plant with increased plant density might be due to increased plant density that might have induced competition between the former and later emerged flowers that could lead to flower abortion and also increase in the number of pods per branches as the result of higher net assimilation rates and reduction of competition in wider spacing" [12]. In addition to, "wider inter row spacing, growth factors (nutrient, moisture and light) for individual plants might be easily accessible that retained more pods and supported the development of lateral branches" [13]). The result was also in conformity with the works of [14] obtained that, an increased pods number of sweet pepper variety at the wider row spacing. Similarly, [15] reported that, higher number pods per plant of pepper variety at wider spacing and the lower fruits per plant at narrower inter row spacing.

3.2.2. Fresh Pods Yield (t/ha)

Fresh pods yield indicated significantly influenced (P≤0.05) due to main effects as well as their interaction at Omorate location; other than, it were significantly influenced (P< 0.01) at Weyito location (Table 3). The highest fresh pods yield (12.18 t/ha) were obtained due to (60x30) cm intra-row spacing, while the lowest (8.367 t/ha) fresh pod yields were recorded from wider (70x50) cm spacing at Omorate location. However at Weyito location, the highest (11.03 t/ha) fresh pod yields were recorded from (50x40) cm spacing, while the lowest (6.37 t/ha) pod fresh yields were also recorded from (70x50) cm spacing. Generally, the maximum fresh pod yield was recorded from narrowest spacing (Table 4). Less plant density produced more branches per plant than more plant density, however these should not little plants per unit area [16]. Similarly, [17] and

[18] "had observed that, the highest fruit yield of pepper was obtained when grown at the higher population densities".

3.2.3. Dried Pods Yield (t/ha)

The findings regarding dried pods weight were significantly influenced (P≤ 0.05) due to factors of intra and inter-row spacing and their interaction factors of inter and intra-row at both location (Table 3). The highest dried pod yields (3.06 t ha^{-1}) were recorded from (30x60) cm spacing or (55,555 plants/ha). However the smallest dry pod yields (1.67 t ha^{-1}) were obtained from (70 x 50) cm inter-row x intra-row spacing (26,666 plants/ ha) related to other inter-row with intra-row spacing combinations at Omorate location (Table 4). At Weyito location, the maximum dried pod yields (2.58 t/ha) were obtained in (50 x 40) cm spacing (50000 plants/ha) and minimum dried pod yields (1.37 t/ha) were recorded in 70 cm of inter-row x 50cm of intra row spacing (26,666 plants/ha) (Table 4). The study result showed that appropriate plant population densities were different for both locations. The possible reason for observed differences optimum plant population density among of might be variation in soil type, watering, nutrient availability, and other environmental conditions due to the fact that difference location has different environmental factors. The current result was similarly with the studying of [12] found that, the highest dried pod yield from (60 cm inter row with 20cm intra row spacing (83,333 plant/ ha) at Halaba special woreda during 2014 cropping season, however in 2015 cropping season they recorded greater yields due to wider 70 cm inter row spacing with 30 cm intra row spacing at the same location. The study of current finding was also slightly in agreement with the results of [10] obtained that, the maximum yields of hot pepper were recorded from 40cmx40cm plant spacing. So these above finding showed that appropriate plant density of hot pepper varied depended season and environmental factors.

4. Conclusion and Recommendation

The yield of hot pepper in Ethiopia including South Omo Zone is low mainly attributed to several production constraints among them, inappropriate plant population density along with other constraint factors. To increase the productivity of hot pepper at South Omo Zone use of appropriate population spacing is vital.

In this study, a factorial research experiment was carried out to evaluate the influence of three (30,40 and 50) cm intra row spacing and three (50cm, 60cm and 70 cm) inter row spacing during 2018 and 2019 cropping season at Omorate and Weyito location, respectively. Data of yield and yield components were collected and analyzed. The study result revealed that, pod number per plant, fresh and dried pod yield were significantly affected by the interaction effect of intra-row with inter-row spacing. The highest dried pod yields (3.06 t/ha) were obtained in 55,555 plants/ha (60cm inter with 30cm intra) row spacing and 33.6% dried pod weight increment as compared to recommended spacing (70cmx30cm) at Omorate location. At Weyito, the highest dried pod yields (2.57 t ha^{-1}) were recorded from 50,000 plants ha^{-1} (50cm inter with 40cm intra) 30.5% dried pod weight increment as compared to recommended spacing (70cmx30cm) among tested treatments.

From the results of this study it can be concluded that 60 cm inter and 30 intra-spacing is superior dried pods weight for Omorate location. Whereas, at Weyito location, 60 cm inter and 30 intra-row spacing was the highest yielder (2.58 tha^{-1}). Therefore, this finding should be demonstrated and popularized at Pastorals' field prior large-scale use in the study areas and its vicinity.

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Conflict of Interests

The authors have not declared any conflict of interests.

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