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Inter and Intra Row Spacing Effects on Growth, Yield and Yield Components of Small Pod Hot Pepper (*Capsicum frutenscens* L.) Production in Kellem Wollega Zone

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Abstract

Small pod hot Pepper is a seasonal plant of the family Solanaceae. It is grown as an annual crop and produced for its fruits. It is one of the most important vegetable crops for fresh consumption, for processing and as a spice (for making stew). A field experiment was conducted at Haro Sabu Agricultural Research Center research of main station for two consecutive years in Kellem Wollega zone, Western Ethiopia, during the 2021 and 2022/3 main cropping season with objective of evaluating effects of different inter and intra row spacing on yield and yield components of small pod hot pepper production in Kellem Wollega zone. The combination Four inter row spacing (50cm, 60cm, 70cm and 80cm) and three intra row spacing (20cm, 30cm and 40cm) were used as experimental materials with Malka Dera small pod hot pepper. Analysis of variance (ANOVA) for total yield and other agronomic traits revealed that the main effect of intra row spacing showed highly significant effect on days to maturity, plant height, and total yield and the main effect of inter row spacing showed significant effect only on total yield. Similarly the main effect of year showed highly significance effect on, days to maturity, plant canopy, number of primary branches per plant, number of pods per plant, pod length, pod diameter and pod weight.. However the interaction effect was revealed highly significant effect on stand count. In this experiment 50cm inter row spacing and 20 intra row spacing found higher dry pod yield and yield component parameters. hence 50cm inter row spacing and 20 cm intra row spacing is recommended for the yield increment of small pod hot pepper in the studied areas of Western Oromia.

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Keywords

hot pepper, inter row, intra row, spacing.

Introduction

Hot peppers are under heavy demand in international and national markets, are eaten fresh or dried, or processed into a variety of products. They are popular food additives, valued for their color, pungency, and aroma Bassett (1986) Hot Pepper (*Capsicum annum* L.) is an important spice and vegetable crop in tropical areas of the world and it belongs to the *Solanaceae* family, and the genus *Capsicum.* It is closely related to tomato, eggplant, potato and tobacco. The genus *Capsicum* is the second most important vegetable crop of the family after tomato in the world (Berhanu *et al.*, 2011).

Hot Pepper an important crop, not only because of its economic importance, but also due to the nutritional and medicinal value of its fruit (Nimona and Girma, 2019). The fruit is an excellent source of natural colours and

antioxidant compounds whose intake is an important health protecting factor by prevention of widespread human diseases (Howard *et al.,* 2000). It is one of the most important spice crops widely cultivated around the world for its pungent flavor and aroma (Obidiebube *et al.,* 2012). The hot pepper requires a hot and dry climate free of frost and suitable agro ecological areas. Suitable altitude ranges for optimum production of pepper is between 1000 and 1800 m.a.s.l. During 2019/20 Meher cropping season, the total area cultivated of pepper (Green and Red peppers) was 185,872.63 hectares and the total production was estimated 3,803,188.67 quintals (MoA, 2020) in Ethiopia. However its production and productivity is below the estimated yield (FOA, 2021).

It is important to consider spacing because of its effects on crop growth, development and yield. Spacing of crops varies with the plant, environment and cultural factors. Plants are spaced to achieve optimum desired population per unit area. The optimum plant population produces the greatest net return to the grower and inter-intra row spacing has direct effects on the quantity, varietal purity and the quality of seed Akililu *et al.,* (2016). Studies on plant density on different types of pepper cultivars showed that plant density and plant arrangement could influence plant development, growth and marketable yield Aklilu *et al.,* (2016). Daniel and Shiferaw (2017) reported that increasing plant density resulted in greater yield/ha of hot peeper for Halaba variety. Wider spacing on the other hand led to increase in fruit yield/plant with bigger fruits and more cracked fruits/plant (Boateng, 2021). Increasing plant density decreased pepper root dry weight and had positive relationship with fruit weight and root weight. Increase in yield with higher plant density was a result of increased number of fruits/ha in direct seeded paprika pepper (Boateng, 2021).

In Oromia region, the total area under hot pepper for green pepper (*Karia*) and for dry pod (*Berbere*) in 2020 were estimated to be 6429 ha and 75691.85ha, respectively, while in West Wollega Zones the total area covered with hot pepper for green pepper (karia) and dry pod was 599.52 ha and 4009 ha, respectively (CSA, 2022) which accounts 9.32% and 52.947% for green pod and dry pod respectively of the total area coverage of the region. Despite the area coverage; hot pepper the productivity is still low attributed to lack of proper nursery and field agronomic management practices (in adequate and/or unbalanced nutrient supply, diseases, poor aeration and lack of high yielding cultivars). However, the productivity of small pod hot pepper in Kelem Wolega and West Wolega is below the average yield estimation at national level (CSA, 2017). This yield loss might be due sowing methods, lack of appropriate plant spacing and environmental conditions and different agronomic practices (Mavengahama *et al.,* 2009). According to Fekadu and Dandena (2006) the decline of hot pepper production is also attributed to poor varieties, poor cultural practices, the prevalence of fungal (blights) and bacterial as well as viral diseases

This yield loss may be due to inappropriate plant population and age seedling at transplanting. Plant spacing can influence morphological development of pepper including reproduction characteristics. Competition for available water and mineral nutrients from the soil and light is greater at high plant population densities. Environmental factors, especially light intensity, stimulate the process of photosynthesis which, in turn, affects biomass production and is closely associated with plant growth rate (Alabi *et al.,* 2014). In plant densities studies, inter-plant competition is one of the most important stress affecting biomass production, crop yield and economic profitability (Nase *et al.,* 2013).

Despite the fact that recommended varieties were in good performance and higher yield than the local variety, the production per unit area is still low as compared to the potential productivity of the area. Since farmers follow broadcasting sowing method and they never use inter row spacing and plant spacing for hot pepper, it is significant to evaluate effect of inter row and intra row spacing to recommend appropriate row and plant spacing so as to increase the productivity of small pod hot pepper with objective of evaluating effects of different inter and intra row spacing on yield and yield components of small pod hot pepper production in Kellem Wollega zone.

Materials and Methods

Experimental materials and design

The experiment was conducted at Haro Sabu Agricultural Research Center of Haro Sabu main station, for two consecutive years during 2021 and 2022/23 main cropping season. Four inter row and three intra row spacing were evaluated on small pod hot pepper Malka Dera variety.

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each treatment was applied in the main field in a gross plot size of 2.8m*4.2m with four inter row spacing (50 cm, 60 cm, 70 cm and 80 cm) and three intra row spacing (20

cm, 30 cm, and 40 cm). All middle rows on each plots were used for data collection leaving the two rows as borders. 100 Kg/ha NPS and 100 Kg/ha Urea fertilizers were used. Others agronomic practices (fertilizer rates, transplanting time, cultivation, weeding and hoeing frequencies) were applied uniformly for all plots according to the recommendation for the crop.

Data collection and Data analyses

Ten plants were randomly sampled from middle three rows. Data on plant height, plant canopy, number of primary branches per plant, number of pods per plant, pod yield per plant (g), average pod weight (g), pod length (cm), pod diameter (cm) were recorded per plant and fruit basis. While measurements such as days to flowering, days to maturity, marketable dry pod yield hectare^{-1}(kilogram) were taken on plot basis.

The collected data were subjected to analysis of variance using GenStat (2016) computer software and Least Significant Differences (LSD) was used to compare the treatment mean using the procedures of Fishers protected at the 5% level of significance.

Results and Discussion

ANOVA

The analysis of variance (ANOVA) for phenological, growth parameters, yield and yield related data of treatments in 2021/2022 and 2022/23 revealed significant on stand count, days to maturity and plant height for main effect of intra row spacing; whereas stand count and dry pod yield were significantly affected by the main effect of inter row and intra row spacing.

However the interaction effect of inter row and intra row spacing were relieved highly significant effect on stand count of small pod hot pepper; Malka Dera variety ; whereas others growth parameters and yield related parameters were non-significant (Table 1 and 2).

Stand count at harvest

The analysis variance showed the main effect of inter row spacing, intra row spacing, year and all the interaction except the three way interaction were highly significant ($P<0.05$) (Table 1). The maximum (75) and the minimum (19.5) stand count were recorded from 50cm x 20cm and 80cm x 40cm inter and intra row spacing, respectively (Table 3). The maximum crop stand count might be due to the higher number of seedling at established and there might be no higher mortality rate due crowdedness plants which may indicate the narrower inter(50cm) and intra (20 cm) row spacing might be the optimum spacing to increase economic yield (dry pod). This result was similar with the work of Mavengahama *et al.,* (2009) who stated increasing plant population from 35000 to 65000 plants per hectare increases yield of hot pepper without increasing the mortality rate of plant stand count.

Days to Flowering and Maturity

The main effect of inter row, intra row spacing and all the interaction effects were revealed not significant effect on days to 50% flowering except the main effect of year.(Table 1, Table 3). The main effect of intra row spacing and year showed highly significant effect ($p<0.01$) on days to maturity, while the main effect of inter row spacing and all the interaction were not significant. The significant effect of year and intra row spacing on days to flowering and days to maturity might be due fluctuation of climatic and biotic condition (rainfall, soil fertility) and due to competition for nutrient(sunlight) since competition for sunlight is higher at large population.

Plant height

The main effect of intra row spacing showed that there was a significant ($P \leq 0.05$) effect on plant height and while the main effect of inter row spacing and year and all the interaction were not significant(Table 1). The longest (55.17 cm) and the shortest (49.17 cm) were recorded from the 20cm and 40cm intra row spacing, respectively (Table 4).

This differences of inter row spacing on plant height might be due to competition for sunlight radiation for which dense population are more competent for sunlight than sparse populated plants). This work is in line with Awoke and Yimegnushal (2021) who reported increasing in plant height with decreasing intra and inter spacing at southern parts Omo Zone. Similarly, Essilfie *et al.,* (2017) reported that that the longest plant height at lower inter row spacing which might be due to maximum competition for light and air and probably in relation to lower competition for physical production resources (soil moisture and nutrients) which would enhance nutrient availability and efficient utilization of assimilates.

Table.1 ANOVA for small pod hot pepper inter and intra row spacing of phenological and growth parameters at HSARC

Source of variation	d.f.	SC	DF	DM	CL	PH	NBPP
Rep	2	0.292	71.93	23.292	204.73	138.87	0.0717
Intra row spacing	2	2608.759**	72.76	86.292**	13.83	220.8*	2.265
Inter row spacing	3	4411.167**	6.01	1	62.08	27.64	0.6348
Year	1	200**	4785.68**	8064.5**	1383.38**	0.76	4.9089*
Intra row*Inter row	6	88.981**	5.26	4.792	21.69	10.67	0.3798
Intra row*Year	2	34.556*	100.6	6.292	30.05	108.64	1.3072
Inter row*Year	3	36.167*	47.61	8.907	76.79	47.16	0.8363
Intra row*Inter row* Year	6	3.5	29.13	7.088	36.24	22.84	0.4457
Residual	46	9.944	36.39	9.234	52.9	46.54	0.9708
CV(%)		7.7	7.4	1.9	13.9	13.1	20.6

Table.2 ANOVA for small pod hot pepper inter an intra row spacing of yield and yield components parameters at HSARC

Source of variation	d.f.	NPPP	PL	PD	PW	TY
Rep	2	388.8	0.2539	0.12722	0.019117	234894
Intra row spacing	2	460.1	0.5272	0.00722	0.01865	1096777**
Inter row spacing	3	154	0.3606	0.03704	0.017265	257363*
Year	1	3522.4**	12.3339**	1.62**	0.814939**	145875
Intra row*Inter row	6	219.9	0.505	0.03315	0.006754	34624
Intra row*Year	2	499.1	0.0772	0.045	0.004106	76409
Inter row*Year	3	263	0.4583	0.02741	0.012791	162013
Intra row*Inter row* Year	6	187.9	0.5972	0.0413	0.008135	41488
Residual	46	238	0.3095	0.04548	0.007743	76304
CV(%)		32.1	9.5	6.1	14.6	27.7

Table.3 Interaction effect of inter and intra row spacing on stand count of small pod hot pepper

Intra row spacing(cm)	Inter row spacing(cm)			
	50	60	70	80
20	75 a	60.33 b	51 c	36.67 ef
30	50.67 c	42.5 d	34.17 fg	24 h
40	39.83 de	31.5 g	25.83 h	19.5 i
LSD(0.05)	3.67			
CV(%)	7.7			
Mean	40.92			

Table.4 Combined mean of inter and intra row spacing on phenological and growth parameters of small pod hot pepper production at HSARC

Inter row spacing (cm)	DF	DM	PH	CL	NPrB
50	81.78	160.1	52.66	50.96	4.76
60	81.39	160.2	51.71	50.97	4.53
70	82.44	160.6	53.02	54.90	4.97
80	81.11	160.4	50.54	52.20	4.88
LSD(0.05)	NS	NS	NS	NS	NS
Intra row spacing (cm)					
20	80.42	158.5c	55.17a	53.08	4.43
30	80.96	160.3b	51.39ab	52.09	5.01
40	83.67	162.2a	49.17b	51.59	4.91
LSD(0.05)	NS	1.77	3.96	NS	NS
Year					
2021	89.83a	170.9a	52.01	47.87b	5.04a
2022	73.53b	149.8b	51.81	56.64a	4.52b
LSD(0.05)	2.86	1.44	NS	3.45	0.47
CV(%)	7.4	1.9	13.1	13.9	20.6
Mean	81.68	160.3	51.91	52.26	4.78

Where DF, DM, PH, CL, NPrB, NPPP, PL, PD, PW, TY, LSD(.05) and CV(%) are days to 50% flowering, days to 50% maturity, plant height(cm), canopy length(cm), number primary branches per plant, number of pod per plant, pod length, pod diameter, pod weight, Total yield(Kg/ha), Least significance difference and coefficient of variation respectively.

Table.5 Combined mean of inter and intra row spacing on yield and yield components of small pod hot pepper production at HSARC

Inter row spacing (cm)	NPPP	PLcm	PDcm	PWg	TYKgpha)
50	44.7	6.0	3.58	0.62	1134.2a
60	47.7	5.8	3.50	0.58	1009.2ab
70	51.9	6.0	3.48	0.64	1006.2ab
80	48.0	5.7	3.49	0.57	842.6b
LSD(0.05)	NS	NS	NS	NS	185.342
Intra row spacing (cm)					
20	43.2	5.68	3.52	0.57	1222.1a
30	49.6	5.92	3.53	0.62	975.6b
40	51.5	5.96	3.49	0.61	796.3c
LSD(0.05)	NS	NS	NS	NS	160.51
Year					
2021	41.1b	5.4b	3.36b	0.50b	953.02
2022	55.1a	6.3a	3.66a	0.71a	1043.05
LSD(0.05)	7.32	0.26	0.10	0.04	NS
CV(%)	32.1	9.5	6.1	14.6	27.7
Mean	48.10	5.90	3.51	0.60	998.04

Where DF, DM, PH, CL, NPrB, NPPP, PL, PD, PW, TY, LSD(.05) and CV(%) are days to 50% flowering, days to 50% maturity, plant height(cm), canopy length(cm), number primary branches per plant, number of pod per plant, pod length, pod diameter, pod weight, Total yield(Kg/ha), Least significance difference and coefficient of variation respectively.

This agrees with the work of Alabi *et al.,* (2014) indicating that plants grow taller at narrower row spacing, and that taller plants were observed as plant population reduced. On the contrary, Daniel and Shiferaw (2017) reported a non significant effect of intra row spacing on hot pepper of Halaba variety.

Number of primary branches per plant and Plant Canopy

Analysis of variance showed that the main effect of inter and intra row spacing and all the interaction effects were not significant effect on number of primary branches per plant; while the main effect of year was significant($P \leq 0.05$) (Table 1); whereas only the main effect of year was highly significant plant canopy diameter ($P \leq 0.01$) (Table 1). The maximum (5.04) and the minimum (4.52) branches per plant was record from year one (2021) and year two (2022), respectively (Table 4). The wider (56.64) and the narrower (47.87) plant canopy diameter was recorded in 2022 and 2021, respectively (Table 4). A significant effect of year on branch number per plant and plant canopy diameter might be due to environmental factors such as rain fall, temperature which are fluctuated every year and the play a great role affecting plant growth parameters. Correspondingly, Daniel and Shiferaw (2017) reported that more branches per plant in 2014 than 2015. Similarly significant effect of year on plant canopy length might be due to positive associations of plant canopy width with number plants per plant (Daniel and Shiferaw, 2017).

Number of pod per plant, pod length, pod diameter and average pod weight

The main effect of inter and intra row spacing and all the interaction were not revealed significant effect on number of pod per plant, pod length, pod diameter and pod weight. Only the main effect of year showed highly significant ($P \leq 0.01$) (Table 1). The highest pod per plant (55.1), longest pod length(6.3 cm), the widest pod diameter (3.66 cm) and the weightiest pod weight (0.71 gram) recorded in 2022, respectively (Table 5).

The lowest pod per plant (41.1), shortest pod length (5.4 cm), the narrower pod diameter (3.36 cm) and the lowest pod weight (0.50 gram) recorded in 2021, respectively (Table 5). The significant effect of year on number of pod per plant, pod length, pod diameter and pod weight might be due temperature fluctuation and length of rain fall period which affects productive parts of plants. This result is similar with the work of Lee *et al.,* (2018) who reported significant effect of climate changes on hot pepper fruit morphologies.

Total dry yield (Kg/ha)

Analysis of variance revealed that the main effect of intra row spacing was highly significant ($P<0.01$) and the main effect of inter row spacing was significant ($P<0.05$) effect on total dry pod yield of small pod hot pepper; whereas the year effect and all the interaction effects were non-significant (Table 2). The highest (1134.2 Kg/ha) and the lowest (842.6 Kg/ha) yield were recorded from 50 cm and 80 cm inter row spacing respectively; whereas the highest (1222.1 Kg/ha) and the lowest (796.3 Kg/ha) yield were recorded from 20 cm and 40 cm intra row spacing, respectively (Table 5).

The significance difference among inter and intra row spacing on total dry pod might be due to the observation; that the yield of fruits per unit area was inversely related to the plant spacing i.e. the closer plant and row spacing produced the higher yield of fruits per plot and per hectare. The higher yield of fruits was mainly contributed by the higher plant population per unit area in closer spacing. The result of the present experiment is in agreement with the findings Islam *et al.,* (20011) reported maximum yield pod (12.78 t/ha) at the closest spacing (50cm x 30cm) and the minimum pod yield (10.84 t/ha) at widest spacing (50 cm x50 cm). Similarly the current result was parallel with the work of Sangma *et al.,* (2018).

Conclusion and Recommendation

The evaluation of inter and intra row spacing were carried out to study the effect of inter and intra row pacing on small pod hot pepper of Melka Dera variety. Significant difference was shown on growth parameter, yield related parameters and dry pod yield among inter and intra row spacing. The longest (162.2) and the shortest (158.5) days to maturity were recorded from the widest (40 cm) and from narrowest (20 cm) intra row spacing, respectively. Whereas the longest (55.17) and the shortest (49.17) plant height were recorded from narrowest (20 cm) and from widest (40 cm) intra row spacing, respectively. Similarly the maximum (1134.2 Kg/ha) and the minimum (842.6 Kg/ha) for inter row spacing; the maximum (1222.1Kg/ha) and the minimum (796.3 Kg/ha) of dry pod yield was recorded the narrowest and the widest inter and intra row spacing; respectively. Generally significant differences for a number of parameters (days to maturity, plant height,

stand count and dry pod yield) among the tested plant spacing were observed. Accordingly in the current study, 50 cm inter row and 20 cm intra row spacing gave the higher dry pod yield. Therefore 50 cm inter row and 20 cm intra row spacing was recommended for dry pod yield increment of small pod hot pepper production in the studied areas of Western Oromia.

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