Growth and Productivity of Hot Pepper (*Capsicum annuum* L.)as Affected by Variety, Nitrogen and Phosphorous at Jinka, Southern Ethiopia

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Abstract
A field experiment was conducted to assess the growth and productivity of hot pepper (Capsicum annuum L.) at Jinka, southern Ethiopia during the 2009 cropping season under rain fed condition using supplementary irrigation. The study consisted of 3 released hot pepper varieties (Mareko Fana, Melka Shote and Melka Zala), 4 levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and 4 levels of phosphorous (0, 46, 92 and 138 kg P_2O_5 ha^{-1}) in Split- Split plot design with three replications where, variety was assigned as main plot factor nitrogen and phosphorous were arranged as sub and sub-sub plot factors, respectively. Melka zala variety failed to grow after transplanting due to bad season. Data were collected for phenology, growth, fruit yield and yield components. Analysis of variances (ANOVA) revealed that varieties differed significantly ($P \leq 0.05$) in number of leaves, stem diameter, fruit length, fruit number per plant, fruit diameter, fruit dry weight, seed number per fruit, total biomass and harvest index. Nitrogen affected positively and significantly ($P \leq 0.05$) days to flowering, days to fruiting, days to maturity, plant height, number of leaves, leaf area index, branch number, fruit yield, fruit length, fruit number per plant, fruit diameter, fruit dry weight, seed number per fruit and total biomass but had no significant effect on thousand seed weight and harvest index. Days to flowering, days to fruiting, days to maturity, plant height, number of leaves, leaf area index, stem diameter, fruit yield, fruit length, fruit number per plant, fruit diameter, thousand seed weight, total biomass and harvest index of hot pepper responded positively and significantly ($P \leq 0.05$) to increasing phosphorous level; but phosphorous had no significant effect on branch number, fruit dry weight, seed number per fruit. There was no significant interaction between variety, nitrogen and phosphorous levels for all observed parameters except for fruit dry weight and harvest index. In this study, the highest dry fruit yield was achieved using Mareko Fana variety at 150 kg N/ha and phosphorus at 138 kg P_2O_5/ha which was by 91% higher than the control. However, according to the partial budget analysis, the highest economic benefits of 74,096 birr/ha was obtained at 50 kg N/ha and 92 kg P_2O_5/ha. Therefore, Mareko Fana with application of 50 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} could be appropriate for hot pepper production in the test area. However, further testing is required in different locations and on different soils.
Keywords: Hot pepper, Variety, Nitrogen, Phosphorus, Growth, Yield.

1.INTRODUCTION

Pepper *(Capsicum annuum)* is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments (Acquaah, 2004). The total area devoted to pepper world wide is estimated at 4 million hectare with an average annual increase of 5% (Weiss, 2002). In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2008 was estimated to be 8580.69 ha, and 110405.89 ha respectively (CSA, 2009). In southern region of Ethiopia the total area covered with pepper and total production in years 2005-2008 were 37562 ha and 27352 tons, respectively and the productivity of pepper in SNNPR was 0.73 t/ha, where as the average dried yield obtained in research condition 1.8-2.5 t/ha (OoARD, 2007). The world average yield of pepper is 3.75 t/ha (CSA, 2005). Average yield of pepper in the country was about 0.6 t/ha but the yield estimate in small farmer was about 0.4 t/ha, while the average marketable yield in state farms was 0.3 - 0.9 t/ha where as in research condition 1.8-2.5 t dried pepper /ha and 15 - 20 t/ha green pepper (lema *et al.*, 2008). To narrow the yield gap a number of options can be taken including evaluating different hot pepper varieties for adaptation, and determining the optimum fertilizer rate. Pepper require adequate amount of most major and minor nutrient but the nutrient mostly used on pepper are nitrogen and phosphorous (Bosland and Votava, 2000).

Girma *et al*. (2001) reported that application of 200 kg/ha of DAP and 100 kg/ha of urea was found optimum for better yield at Abobo. However, Jackson *et al*. (1985) recommended that application of 140 kg/ha of P_2O_5 before sowing or transplanting, and split application of 130 kg/ha of N. Application of 207 kg of DAP and 137 kg of urea per hectare gave optimum yield of pods in hot pepper variety Odaharo at Bako (MoARD, 2005). However, the actual amount of fertilizer to apply depends on soil fertility, fertilizer recovery rate and soil organic matter content. Application of 100 kg DAP before planting and split application of 100 kg urea, 50 kg at 20 days after transplanting and the other 50-kg at the time of flowering is, generally recommended for Ethiopian soil (IAR, 1996).

Although imported and local pepper varaties are available in Ethiopia, their adaptation and suitability for different agro ecologies of the country has not been determined fully; data on appropriate N and P levels that is required to achieve at each locality is not available. This is particularly true to Jinka area where there had been no research effort to evaluate varaties and to determine optimum rate and combination of NP fertilizer for profitable hot pepper production, Thus the main objective of the current study was to assess the growth and yield response of three different hot pepper varieties to different levels of NP fertilizers with a view to determine the optimum NP levels most appropriate hot pepper cultivar suitable for Jinka area, Southern Ethiopia.

2. MATERIALS AND METHODS

A field experiment was conducted at Jinka agricultural research center, which is located at 5°52' latitude N, 36°38' longitude E, and 1450 m above sea level. The total precipitation and monthly average temperature of the area during the crop growth period was 99.5 mm and 22.3ºC, respectively. The soil of the experimental site is sandy loam, a pH value of 6.42, the soil organic matter content was 4.83%, available P was 3.54 mg kg^{-1},total N was 0.18% and the CEC value was 33.13 cmol kg ^{1}on the basis of soil analysis taken before planting. The experiment was conducted during May to November, 2008 under rain fed condition by using supplementary irrigation.

The experiment consisted of three varieties of hot pepper (Mareko Fana, Melka Shote and Melka zala), four levels of phosphorous fertilizers (0, 46, 92 and 138 kg P_2O_5 ha^{-1}) and four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}). The treatments were combined factorially resulting in a total of 48 treatment combinations. The experiment was laid out in a split-split-plot design with three replications. Varieties, nitrogen levels and phosphorous levels were assigned to main plot, sub-plot and sub-sub plot, respectively. Each replication consisted of 48 plots corresponding to the 48 treatment combinations. Plot size was 19.2 m^2 (4.0 m x 4.8 m). The spacing between rows and plants were 60 and 40 cm, respectively. There were 8 rows per plot and 10 plants per row with a total of 80 plants per plot. Seeds of the three varieties were sown on nursery beds at the rate of 600 gm/ha on rows separated by 15 cm and at the depth of 1.5 cm, keeping 4 cm distance between seeds then seedlings with 10-12 cm height, 4-5 true leaves and with no disease and pest sign were transplanted one seedling/hill for all varieties.

Nitrogen fertilizer was applied by split application method in the form of urea the first three weeks after transplanting and the second at first fruiting. Phosphorus was applied in the form of TSP at the time of transplanting. Standard cultural practices such as weeding, pest and disease control were carried out uniformly in all plots. Data were collected on phonology, growth, yield and yield related traits of pepper. Pre-sowing soil, soil samples after harvest and the plant tissue samples for N and P concentration were analyzed following standard laboratory procedures as outlined by Sahlemedhin and Taye, (2000).

3. RESULTS AND DISCUSSIONS

The experiment was started with three commercial varieties of hot pepper (Mareko Fana, Melka Shote and Melka zala) but variety Malka zala failed to grow after transplanting due to bad cropping season of the area. The variety was then excluded from the analysis.

3.1. Phenology and Growth Parameters

Analysis of variances (ANOVA) revealed that differences in days to 50 % flowering, fruiting and maturity among varieties were not significant but the application of N and P fertilization had significant effect (Table 1). Increasing N application increased number of days taken to 50% flowering, fruiting and maturity where as Days to 50 % flowering, fruiting and maturity decreased with increasing level of P fertilization (Table 1). This showed that nitrogen had delayed flowering, fruiting and maturity while Phosphorus enhances flowering, fruiting and maturity. This result is in agreement with Brady and Weil (2002) who stated that phosphorous is helpful in flowering and hastens maturity of crops. Similarly, Michael, (2003) indicated that application of N fertilizer is beneficial to vegetative growth and prolongs flowering, fruiting and maturity period. Similarly, Bosland and Votava (2000) stated that excess application of nitrogen stimulate secondary growth and delays maturity. No significant differences were found for the variety, N and P interaction effect on days to 50 % flowering, flowering and maturity.

Analysis of variances (ANOVA) revealed that varieties differed significantly ($P \leq 0.05$) in number of leaves, while no significant difference on mean plant height, branch number and stem diameter of pepper at all growth stages (except 1MAT). At 3 MAT, both Mareko Fana and Melka Shote recorded the highest mean number of leaves per plant. The variety Mareko Fana had lower number of leaves per plant than Melka Shote throughout its growth stage and at harvesting times. Mean number of leaves per plant of the two varieties increased with increasing MAT reaching a maximum at 3 MAT (Table 2 and 3). N affected positively and significantly ($P \leq 0.05$) plant height, number of leaves, leaf area index, branch number (Table 2, 3 and 4).
The reason might be due to the increased vegetative growth with increasing N and this could be due to increase

in N supply leads utilization of carbohydrate to form protoplasm and more cells to enhance growth. Plants deprived of N show decreased cell division and expansion (Hewitt and Smith, 1974). N is known to promote both cell division and elongation which may explain way treatments with high N had high mean plant height number of leaves, branch number. Similarly, AL-Shooke (1985) reported that the vegetative growth significantly improved through N fertilization. Mean LAI increased with increasing age of plants and reached a maximum of 2.94 at 3 MAT then it was declined at 4 MAT (Table 4). This showed that the effect of N was more pronounced at early growth stage (1 to 2 MAT) than late growth stage prior to senescence (3 to 4 MAT). Plant height, number of leaves, leaf area index, stem diameter of hot pepper responded positively and significantly ($P \leq 0.05$) to increasing phosphorous level; but phosphorous had no significant effect on branch number. The differences in plant height, number of leaves, leaf area index, stem diameter between all phosphorous levels were not significant but all P levels were significantly different from the control (Table 2, 3, and 4). Mean plant height of hot pepper is increased due to P nutrition and as P level increases the height increases till 4MAT. Mehrotra (1986) reported that P ranging from 20 kg ha^{-1} to 140 kg Pha^{-1} influence pepper height. Mean leaf number per plant increased with increasing P level and age of plants up to 3 MAT and then after no more marked change at 4MAT while the minimum values were recorded from the control at 1MAT (Table 2). That is due to the increase in leaf number with phosphorous may be phosphorous increased the growth parameters since it promotes plant growth (Mengel and Kirkby, 1987). Similarly, Stroeheline *et al*. (1979) reported that plants suffering from P deficiency produced low lateral shoots which result in to developed low number of leaves.

Mean plant stem diameter of hot pepper is increased due to P nutrition as P application increased stem diameter increases. Similarly, Sundstom *et al*. (1984) in their study of N and P and plant spacing on mechanically harvested tobasco pepper found that stem diameter increased rapidly with the application of P at early growth stage and reached a point where it increased at decreasing rate of growth. Mean LAI value increased linearly from 1 MAT to 3 MAT and then declined at 4 MAT (Table 4). This showed the fact that during juvenile phase vegetative parts such as plant height, branches, stem and leaf production increased to the maximum, and then remain constant at reproductive phase; which reduced at maturity due to leaf abscission senescence, bending downward and contraction. This contributed to the reduction in LAI at 4 MAT (maturity). All interaction effects of variety, N and P on plant height, branch number, stem diameter, leaf number, leaf area index were non-significant ($P \leq 0.05$) at all growth stages.

3.2. Fruit Yield and Yield Components

Analysis of variances (ANOVA) revealed that varieties differed significantly ($P \leq 0.05$) in fruit length, fruit number per plant, fruit diameter, seed number per fruit, and total biomass. Mareko Fana variety had significantly higher fruit length, fruit diameter, seed number per fruit and also Higher total biomass per plant than Melka Shote but Melka Shote variety had significantly higher fruit number per plant Melka Shote (Table 5). Nitrogen affected positively and significantly ($P \leq 0.05$) fruit yield, fruit length, fruit number per plant, fruit diameter, seed number per fruit and total biomass but had no significant effect on thousand seed weight. In this study generally he highest dried fruit yield, fruit number per plant, fruit number per plant, seeds per fruit and total biomass were recorded from 150 kg N ha^{-1} while the lowest was from 0 kg N ha^{-1}. This result suggests that N application to the soil is important to improve fruit yield and yield components of pepper significantly. This might be due to nitrogen is an integral component of many essential plant compounds like chlorophyll, proteins and it is a major part of all amino acids (Brady and Weil, 2002). It increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased yield of plants (Mengel and Kirkby, 1987). This result also agree with Baghour *et al*. (2001) who reported that fruit setting in pepper was related to phytohormone activity and N nutrition. Similarly, Luia and John (1995) reported that nitrogen fertilization at the higher rate increased number of fruits, yield and total biomass.

Fruit yield, fruit length, fruit number per plant, fruit diameter, thousand seed weight, and total biomass of hot pepper responded positively and significantly ($P \leq 0.05$) to increasing phosphorous level; but phosphorous had no significant effect on branch number, and seed number per fruit. The lowest fruit yield, fruit number per plant, fruit diameter, and total biomass were obtained from 0 kg P ha^{-1} whereas the highest was obtained from 138 kg P ha^{-1} (Table 5). Generally in this study increasing P level increased fruit yield, and yield components except some in consistency in fruit length and thousand seed weight. In this study it was also observed that the yield improvement due to P application was mainly attributed to the accompanying improvement in yield component as fruit number per plant, fruit length, fruit diameter, number of seeds per fruit and also leaf area index. This result is in agreement with observation of Baghour *et al*. (2001) who reported that vegetative growth yield and quality of pepper significantly improved through nitrogen and phosphorous fertilization. This could be attributed to the important role of each nutrient affecting growth and yield.

Nitrogen is an essential constitute of protein and enzyme which directly affects several biochemical process mainly the photosynthetic activity (Marschner, 1993). Phosphorous is required for producing well developed and highly efficient rooting system (Havlin *et al*., 1999). There was no significant interaction between variety, nitrogen and phosphorous levels for all observed parameters except for fruit dry weight and harvest index.

4. CONCLUSION

Results of the present experiment indicated that the highest dry fruit yield was achieved using Mareko Fana variety at 150 kg N/ha and phosphorus at 138 kg P_2O_5/ha which was by 91% higher than the control. However, according to the partial budget analysis, the highest economic benefits of 74,096 birr/ha was obtained by using Mareko Fana variety and application of 50 kg N/ha and 92 kg P_2O_5/ha. Therefore, Mareko Fana variety with application of 50 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} could be appropriate for hot pepper production in the test area. However, further testing is required in different locations and on different soils.

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ACKNOWLEDGMENTS

The authors wish to acknowledge RCBP, SARI for sponsoring the project. The authors would also like to thank Eden Markos for her encouragement

Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.17, 2014

Table 1. Days to 50% flowering, days to 50% fruiting, days to 50% maturity of pepper as affected by varieties, nitrogen, and phosphorous at Jinka, in 2009

Treatments	DTFL	DTFR	DTMT
Variety			
Marako Fana	44.66a	93.6a	121.6a
Melka Shote	46.29a	95.29a	124.44a
LSD 0.05	NS	NS	NS
CV%	9.5	7.23	6.5
Nitrogen (kg ha^{-1})			
0	44.04b	93.04b	121.54b
50	44.92b	93.92ab	122.42ab
100	45.58b	94.46ab	123.46ab
150	47.38a	96.38a	124.67a
LSD 0.05	2.25	2.91	2.5
CV%	7.9	4.9	3.2
Phosphorous(kg ha^{-1})			
0	49a	98a	126.17a
46	46.92a	96.33ab	124.83a
92	44.67b	93.11bc	122.04ab
138	41.33c	90.33c	119.04b
LSD 0.05	2.17	3.71	5.13
CV%	8.22	6.78	7.18

DTFL=Days to 50% flowering, DTFR= Days to 50% fruiting, DTMT= Days to 50% maturity
Note: Means with the same letters within the columns are not significantly differ at $P < 0.05$

Table 2. Mean Branch number **plant^{-1}** and stem diameter (cm) of pepper as affected by varieties,

	LN				PH			
	1MAT	2MAT	3MAT	4MAT	1MAT	2MAT	3MAT	4MAT
Variety								
Marako Fana	150.2b	218.03b	239.95b	239.7b	25.88a	37.98a	45.09a	50.09a
Melka Shote	174.44a	232.97a	262.48a	261.1a	25.24a	35.41a	42.65a	47.75a
LSD 0.05	10.34	14.92	16.75	20.96	NS	NS	NS	NS
CV%	7.25	7.53	7.59	9.53	10.06	8.33	9.77	8.8
N (kg ha^{-1})								
0	142.83b	201.17b	232.33b	232.58b	23.52a	34.02b	40.88c	45.88c
50	164.27a	227.98a	256.65a	254.73a	24.19a	34.03b	41.25bc	46.25bc
100	164.15a	233.08a	255.94a	251.77a	26.23a	37.94a	45.06ab	50.06ab
150	178.02a	239.77a	259.94a	258.44a	28.29a	40.79a	48.29a	53.29a
LSD 0.05	16.38	17.63	15.75	15.62	NS	3.7	4.15	4.15
CV%	16.04	12.43	9.97	9.92	15.52	16.02	15.05	13.51
P (kgha^{-1})								
0	124.13c	192.73c	215.7c	214.96c	23.33a	31.72b	38.29b	43.29b
46	154.08b	221.5b	246.1b	247.08b	25.6a	37.77a	41.19b	50.19a
92	175.48a	237.15a	263.3ab	264.31ab	25.73a	37.73a	45a	50a
138	195.58a	250.63a	279.8a	275.17a	27.56a	39.56a	47a	52a
LSD 0.05	20.16	14.55	20.01	17.94	NS	2.86	3.12	3.12
CV%	11.11	11.39	13.72	12.34	17.60	13.41	12.24	11

nitrogen, and phosphorous at Jinka, 2009
PH=Plant height, LN=Leaf number, MAT= Months after transplanting
Note: Means with the same letters within the columns are not significantly differ at $P < 0.05$

Table 3. Mean Branch number **plant**$^{-1}$ and stem diameter (cm) of pepper as affected by varieties, nitrogen, and phosphorous at Jinka, 2009

	BN				SD			
	1MAT	2MAT	3MAT	4MAT	1MAT	2MAT	3MAT	4MAT
Variety								
Marako Fana	6.07a	11.07a	13.07a	15.57a	0.677a	1.0a	1.13a	1.32a
Melka Shote	5.25a	10.25a	12.25a	14.75a	0.61b	0.97a	1.11a	1.34a
LSD 0.05	NS	NS	NS	NS	0.05	NS	NS	NS
CV%	24.8	13.22	11.14	9.3	8.29	14.04	23.45	19.77
N (kg ha^{-1})								
0	5.35b	10.35b	12.35b	14.85b	0.611a	0.95a	1.07a	1.28a
50	5.40b	10.4b	12.4b	14.9b	0.636a	1.02a	1.11a	1.32a
100	5.67ab	10.67ab	12.67a	15.17ab	0.646a	0.99a	1.12a	1.33a
150	6.23a	11.23a	13.25a	15.73a	0.678a	1.01a	1.17a	1.38a
LSD 0.05	0.61	0.61	0.61	0.61	NS	NS	NS	NS
CV%	17.21	9.14	7.7	6.5	14.44	12.15	15.66	13.32
P (kg ha^{-1})								
0	5.38a	10.38a	12.38a	14.88a	0.568b	0.92b	1.05b	1.26b
46	5.63a	10.63a	12.63a	15.13a	0.663a	1.02a	1.15a	1.36a
92	5.79a	10.79a	12.79a	15.29a	0.646a	1.0a	1.13a	1.34a
138	5.85a	10.85a	12.85a	15.35a	0.696a	1.04a	1.16a	1.37a
LSD 0.05	NS	NS	NS	NS	0.07	0.05	0.08	0.08
CV%	19.54	0.38	8.74	7.3	17.48	8.11	11.67	9.83

BN=Branch number, SD=Stem diameter, MAT= Months after transplanting

Note: Means with the same letters within the columns are not significantly differ at P < 0.05

Table 4. Mean leaf area index of pepper as affected by varieties, nitrogen, and phosphorous at Jinka, in 2009

	LAI			
	1MAT	2MAT	3MAT	4MAT
Variety				
Marako Fana	1.83a	2.7a	2.97a	2.82a
Melka Shote	1.63a	2.34a	2.56a	2.44a
LSD 0.05	NS	NS	NS	NS
CV%	14.99	19.19	19.8	19.59
N (kg ha^{-1})				
0	1.63b	2.44b	2.69b	2.55b
50	1.71b	2.48ab	2.73ab	2.59ab
100	1.70b	2.47b	2.71ab	2.58ab
150	1.89a	2.69a	2.94a	2.8a
LSD 0.05	0.122	0.21	0.23	0.222
CV%	11.25	8.8	8.88	8.81
P (kgha^{-1})				
0	1.40a	2.21b	2.47b	2.33b
46	1.62a	2.39b	2.63b	2.49b
92	1.88a	2.7a	2.96a	2.83a
138	2.02a	2.78a	3.08a	2.89a
LSD 0.05	NS	0.21	0.24	0.22
CV%	12.27	14.54	14.61	14.55

LAI= Leaf area index, MAT= Months after transplanting

Note: Means with the same letters within the columns are not significantly differ at P < 0.05

Table 5. Yield and yield components of pepper as affected by varieties, nitrogen, and phosphorous at Jinka, in 2009

Treatments	FRY	FNPP	FL	FD	TSW	SNPF	HI	FDW	TBM
Variety									
Marako Fana	2.49a	31.45b	11.43a	1.98a	7.09a	128.5a	0.5b	2.47a	4.98a
Melka Shote	2.29a	55.24a	9.9b	1.21b	7.01a	69.79b	0.52a	1.52b	4.41b
LSD 0.05	NS	7.83	0.55	0.14	NS	2.62	0.016	0.16	0.37
CV%	12.15	20.57	5.85	9.97	8.44	3.0	3.6	20.38	8.89
N (kg ha^{-1})									
0	2.15b	34.48c	9.78b	1.38c	7.02a	94.67c	0.52a	1.81b	4.15c
50	2.31a	39.98b	10.20b	1.52b	6.9a	95.88bc	0.5ab	1.97b	4.59b
100	2.54a	47.77a	11.17a	1.77a	7.06a	102.13ab	0.51ab	2.08a	4.93a
150	2.55a	51.17a	11.5a	1.72a	7.14a	103.92a	0.49b	2.12a	5.11a
LSD 0.05	0.2	4.82	0.57	0.07	NS	6.61	NS	0.16	0.24
CV%	10.97	17.66	8.49	6.54	8.14	10.6	6.33	12.63	8.26
P (kg ha^{-1})									
0	2.27b	34.75c	9.22b	1.41b	6.76b	97.04a	0.5a	1.88a	4.46b
46	2.18b	43.75b	10.93a	1.61a	7.26a	97.63a	0.48b	1.96a	4.48b
92	2.53a	45.73ab	11.28a	1.66a	6.79a	102.54a	0.52a	2.03a	4.89a
138	2.58a	49.15a	11.23a	1.70a	7.38a	99.38a	0.52a	2.12a	4.95a
LSD 0.05	0.17	4.89	0,56	0.1	0.34	NS	0.02	NS	0.2
CV%	11.99	19.43	9.13	10.52	8.2	11.15	6.12	15.44	7.26

FRY= Fruit yield (t/ha), FNPP=Fruit number per plant, FL= Fruit length (cm), FD= Fruit diameter (cm), TSW= 1000 seeds weight (g), SNPF= Seed number per fruit, HI=Harvest index, FDW=Fruit dry weight (g) TBM=Total Biomass (t/ha)

Note: Means with the same letters within the columns are not significantly differ at $P < 0.05$