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Full Length Research Paper

Performance of hot pepper (*Cupsicum annuum*) varieties as influenced by nitrogen and phosphorus fertilizers at Bure, Upper Watershed of the Blue Nile in Northwestern Ethiopia

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A field experiment was conducted to investigate the influence of N and P and evaluate the performance of hot pepper varieties. Treatments comprised three rates of N (0, 46 and 92 kg N ha^{-1} and three rates of P_2O_5 (0, 69 and 138 kg P_2O_5 ha^{-1})' and three hot pepper varieties (Marako fana, Melka zala and a local variety). The experiment was laid out as a randomized complete block design in a 3 x 3 x 3 factorial arrangement with three replications. The results indicated that the interaction effect of N, P_2O_5 and variety was significant on many of the parameters considered. Treatments that received fertilizer combination of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} gave maximum fresh fruit yield (10.92 t ha^{-1})(Mareko fana), highest total dry fruit yield (1.97 t ha^{-1}) and the maximum marketable yield (1.91 t ha^{-1}) in the same variety. Using N and P_2O_5 fertilizers at the rates of 92 kg N and 138 kg P_2O_5 ha^{-1} thus can feasibly be used for obtaining fresh as well as dry pods.

Key words: Generalized linear model, interaction effect, mareko fana, melka zala, (*Cupsicum annuum).*

INTRODUCTION

The genus *Capsicum* to which pepper belongs is a member of the *Solanaceae* family that consists of about 22 wild species and five domesticated species. The five domesticated species include *C. annum* L., *C. frutescens* L., *C. chinenses*, *C. baccatum* L., and *C. pubescens* R. (Bosland and Votava, 2000).

Capsicum species can be divided into several groups depending on their fruit characteristics ranging in pungency, color, shape, intended use, flavor, and size. Despite their vast trait differences, most commercially cultivated peppers in the world belong to the species *C. annum* L. (Smith et al., 1987; Bosland, 1992). *C. annum* L. is the most common species cultivated in Ethiopia.

Pepper is the leading vegetable crop produced in the country. CSA (2011) indicates that dry and green pepper production in the Amhara region was 60,801.45 t and 12,118.72 t with average productivity of 2.04 and 9.02 t ha^{-1} respectively. On the other hand, the national level production of dry and green hot pepper was 209,872.12 t and 57,772.68 t with average productivity of 2.52 and 9.98 t ha^{-1} respectively. World average green pepper productivity, on the other hand, was 15.5 t ha^{-1} compared to the pepper productivity in Ethiopia (FAO, 2009). Thus, *Capsicum* productivity in Ethiopia is far below the world average that strongly demands immediate productivity improvement.

There exists a diverse way of pepper consumption in Ethiopia. People consume pepper for intake enhancement as well as to supplement the dietary needs. It is also one of the major income-generating crops for most households of the pepper producing areas and it plays a vital role in food security in Ethiopia (Roukens, 2005).

Though Ethiopia is considered a source of pepper diversity, much work has not been done concerning hot pepper cultivars improvement. In addition, in the study area, farmers allocate relatively large areas for production

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of pepper, but constrained with a lot of problems. This could be attributed mainly to nutrient depletion (poor soil fertility), inappropriate fertilizer utilization (due to an increase in the price of fertilizers), absence of use of herbicides, lack of improved and good quality varieties, poor agronomic practices, poor disease and pest management, poor harvesting and post harvest practices (Alemu and Ermias, 2000).

With regard to fertilizer and variety utilization in the study area, producers are overcome by lack of knowledge to use the right type and rate of inorganic fertilizers in combination with the right type of variety and thus they are not getting good yield. Application of the right amounts of fertilizers in pepper production has never been given attention by the growers in areas surrounding Bure. It is a usual practice to apply nitrogen and phosphorus fertilizers at the rates of 150 kg ha^{-1} and 100 kg ha^{-1} respectively.

In order to improve the production and productivity of pepper in the study area, and ultimately to improve the livelihood options of households, it is important to undertake researches which can seek solutions to the above problems meet objectives as investigating the influence of N and P fertilizers on the yield and yield components of hot pepper varieties and evaluating the performance of hot pepper varieties with different rates of these fertilizers.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at Bure Agricultural College in Northwestern Ethiopia, which is situated at $10^o42'$ N latitude and $37^o4'$ E longitude. The altitude of this particular area is 2100 meters above sea level. The soil type is a mixture of humic nito and eutric vertisols, which is relatively fine in texture with pH of 5.8. The annual rainfall and annual mean temperature are 1800 mm and 20^oC respectively.

Experimental Materials

Planting materials

The hot pepper varieties used for this study were:

- Improved variety (*Marako fana*)
- Improved variety (*Melka zala*) and
- Local variety pepper seed (a mixed population of different varieties adapted to the area)

Fertilizer material

Urea [CO $(NH_2)_2$] (46% N) and P_2O_5 were used as a source of nitrogen and phosphorus respectively.

Treatments and Experimental Design

The treatments consisted of three levels of nitrogen (0, 46 and 92 kg N ha^{-1}), three levels of P_2O_5 (0, 69 and 138 kg ha^{-1}) and three hot pepper varieties (*Marako fana*, *Melka zala* and a local variety (a mixed population of hot pepper cultivars inter crossed through time). The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times per treatment.

Plot size was 3 m × 3.5 m =10.5 m^2. The spacing between adjacent plots was 1m. There were five rows per plot, spaced 70 cm apart and 30 cm in a row. Hence, the total number of plants per row was 10, and the total number of plants per plot was 50. Plants in the middle three rows were used for collecting data, leaving aside those at the border rows as well as those at both ends of each row to avoid edge effects.

Experimental Procedures

Soil sampling and analysis

Soil samples were collected from the experimental field following a zigzag fashion (W-shape) using an auger. Ten samples were taken from each arm and a total of 40 samples were composited. Then, one composite sample was taken for the final analysis. The soil sample was air dried and ground to pass through 2 mm sieve for physical and chemical analysis of parameters like nutrient composition, texture and pH. The result showed that the soil was having C/N ratio (15), organic carbon (3.4%), available phosphorous (1.97 ppm), total nitrogen content (0.22%) and pH of 5.8($CaCl_2$).

Raising and transplanting seedlings

Land preparation for the nursery bed and main field was done in December and January, 2010, respectively, using human labour and a tractor. The seed of the cultivar was drilled by hand onto three nursery beds of 1 m width and 4 m length at the inter-row spacing of 8 cm on March, 2011. After sowing, the beds were covered with dry grass mulch until emergence and watering the seedlings was done using watering can.

Transplanting was done on well prepared beds at a spacing of 70 x 30 cm as recommended by Matta and Cotter (1994). Seedlings were transplanted in to experimental plots after 4 to 5 weeks of sowing on seedbed or when they were about 15 cm high (Lemma *et al.,* 2008). A week before transplanting, water supply at the nursery was reduced in order to harden the seedlings to reduce transplanting shock. Before transplanting, the seedlings were watered to enhance easy uprooting and prevent too much root damage.

Method and time of fertilizer application

In the nursery, half of the nitrogen (0, 23 and 46 kg N ha^{-1}) was applied at sowing and the remaining half was applied during active stage of vegetative growth (4 weeks after transplanting). But for P_2O_5, all recommended rates (0, 69,138 kg P_2O_5 ha^{-1}) were applied at planting time along the planting row.

Plots were irrigated using boarder irrigation method (to prevent mixing up of fertilizer rates in different plots) up to the beginning of the rainy season (late May). All other recommended cultural practices were performed uniformly to all plots. The dry pod yield was harvested beginning from September 15 to October 15, 2011 in three rounds.

Data Collection

The data collection in this experiment was done on plots in the three middle rows, leaving aside plants in the border rows as well as those at both ends of each row.

Days to 50% flowering

This is the number of days taken when 50% of the selected plants start blooming from the days of transplanting.

Number of branches

The number of primary, secondary and tertiary branches from each 10 plants in each plot was recorded at the final harvest.

Fruit length and width (cm)

A random sample of 10 pods from each plot at each harvest was measured using a caliper to record their length and fruit body width at the middle of each fruit. This procedure continued until the end of harvest in order to assess possible size variation throughout the harvest period.

Fresh fruit yield (kg ha^{-1})

Weight of fresh fruits harvested at each successive harvesting from the central rows was recorded, and at the end of the experiment, all the recorded data were summed up for estimation of yield per hectare.

Fruit weight and dry matter (%)

Freshly collected 10 sample fruits were weighed and recorded immediately after each harvest, before losing weight. During the final period of the experiment, the fruit fresh weight in each plot was summed up for analysis.

The dry matter (%) of the fruit was taken after drying sample fruits in an oven at 70°C for 72 hours until constant weight was attained. For dry matter percent, 200g fruit samples were taken three times for the whole period of the experiment. The first is conducted during early period of harvesting, the second at the peak (middle) of harvesting period, and finally the third at the end of harvesting.

The dry matter percent was calculated as:

$$DM = \left(\frac{(DW + CW) - CW}{(FW + CW) - CW} \right) X100$$

Where, DM=Dry matter (%)
DW=Dry weight (g)
CW=Container weight (g) and
FW=Fresh fruit weight (g)

Number of fruits per plant

The number of physiologically matured pods from five randomly taken plants was taken at each successive harvest and recorded. At the final stage of the experiment, the overall recorded data were summed up.

Total dry fruit yield (t ha^{-1})

At each successive harvesting, marketable and unmarketable yields of dry pods were recorded and the sum of both parameters was taken for estimating the total dry pod yield per hectare.

Harvest Index

The total dry fruit yield was used for calculating harvest index using the following formula:

$$HI = \left(\frac{Fruit\ yield}{Fruit\ yield + Vegetative\ yield} \right) X100$$

Where, HI is the harvest index

Dry matter yield of fruits (t ha^{-1})

The dry matter yield of fruits was taken using 200g of chopped sample of fruits and by drying in an oven at a temperature of 70°C until constant weight is attained.

Marketable yield (t ha^{-1})

The marketable pods were subjectively determined based on quality ratings. The color of the dry pods, shininess, presence of surface defects due to insect or disease damage, pod firmness and size were taken as visual parameters for marketable rating. The pods which fulfilled the above criteria were taken as marketable and those that did not were discarded and considered as unmarketable.

Table 1. Mean values of growth parameters as influenced by the interaction effect.

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Variety	Days to 50% Flowering	Number of primary Branches
0	0	Mareko fana	69.00^{cd}	4.50^{a-f}
		Melka zala	99.00^{a}	3.10^{ef}
		Local	74.00^{cd}	3.17^{def}
	69	Mareko fana	72.67^{cd}	3.40^{cdef}
		Melka zala	72.00^{cd}	4.43^{a-f}
		Local	68.00^{cd}	3.17^{def}
	138	Mareko fana	66.33^{d}	4.87^{abc}
		Melka zala	95.33^{a}	2.97^{f}
		Local	67.67^{d}	4.97^{abc}
46	0	Mareko fana	92.0^{ab}	4.67^{a-e}
		Melka zala	70.00^{cd}	3.40^{cdef}
		Local	93.00^{ab}	3.70^{b-f}
	69	Mareko fana	69.33^{cd}	4.70^{a-e}
		Melka zala	95.33^{a}	3.50^{cdef}
		Local	67.67^{d}	4.40^{a-f}
	138	Mareko fana	69.33^{d}	3.63^{cdef}
		Melka zala	68.00^{cd}	5.23^{ab}
		Local	71.00^{cd}	5.27^{ab}
92	0	Mareko fana	93.33^{ab}	3.70^{b-f}
		Melka zala	94.33^{ab}	3.23^{def}
		Local	96.00^{a}	3.43^{cdef}
	69	Mareko fana	66.67^{d}	4.97^{abc}
		Melka zala	87.33^{b}	4.63^{a-e}
		Local	72.67^{cd}	4.93^{abc}
	138	Mareko fana	71.00^{cd}	4.50^{a-f}
		Melka zala	67.00^{d}	5.60^{a}
		Local	75.67^{c}	4.60^{a-e}
SEM			22.95	0.94
LSD			7.85	1.59
CV			6.09	23.36
R^2			0.91	0.50
Significance			**	*

Means sharing the same letter within a column are not significantly different at 5% level of significance; *= significant at 5% probability level;** = significant at 1% level of probability.

Dry biomass yield (t ha^{-1})

Dry biomass yield was assessed by chopping the entire plant and drying the samples in an oven at 70^{o}C until constant weight was attained. This was done three times (*i.e.*, at each round of harvesting). Then, the mean weight was taken for analysis and interpretation.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using the Generalized Linear Model (GLM) of SAS Statistical Software. Significant differences between treatment means were separated using the Fisher's LSD test at P< 0.05 level of significance.

RESULTS AND DISCUSSION

Plant Growth

Days to 50% flowering

The analysis of variance showed that the interaction effect of nitrogen, phosphorus and variety caused significant (P<0.01) effect on the number of days required

Table 2. Interaction effect of N, P_2O_5 and variety on yield parameters.

N (kg ha^{-1})	**P_2O_5 (kg ha^{-1})**	**Variety**	**Fruit Weight (g)**	**Fresh Fruit Yield (t ha^{-1})**	**Fruit Dry Matter (%)**
0	0	Mareko fana	15.30^{d-h}	8.79^{a-g}	30.92^{abc}
		Melka zala	13.40^{hi}	7.10^{fgh}	28.38^{fghi}
		Local	14.99^{ghi}	9.67^{abcd}	31.12^{abc}
	69	Mareko fana	12.24^{i}	6.88^{gh}	28.36^{fghi}
		Melka zala	18.31^{ab}	10.00^{abc}	30.89^{abc}
		Local	15.53^{c-h}	7.85^{c-h}	27.65^{i}
	138	Mareko fana	17.29^{a-f}	9.22^{a-f}	30.38^{abc}
		Melka zala	13.33^{hi}	7.24^{fgh}	28.58^{e-i}
		Local	18.75^{ab}	10.44^{ab}	31.33^{abc}
46	0	Mareko fana	14.20^{ghi}	6.58^{gh}	27.86^{hi}
		Melka zala	15.08^{e-i}	9.58^{a-e}	30.05^{abcd}
		Local	14.43^{fghi}	6.64^{gh}	28.24^{ghi}
	69	Mareko fana	17.38^{a-f}	9.75^{abcd}	30.81^{abc}
		Melka zala	14.03^{ghi}	6.20^{h}	27.34^{i}
		Local	16.69^{a-g}	10.35^{abc}	29.75^{b-h}
	138	Mareko fana	15.82^{b-h}	8.41^{b-h}	29.60^{c-h}
		Melka zala	17.76^{a-e}	10.37^{ab}	30.67^{abc}
		Local	18.91^{a}	10.60^{ab}	30.56^{abcd}
92	0	Mareko fana	13.24^{hi}	6.39^{h}	28.70^{d-i}
		Melka zala	13.13^{hi}	6.42^{h}	29.70^{c-h}
		Local	13.98^{hi}	7.32^{e-h}	28.05^{ghi}
	69	Mareko fana	16.93^{a-g}	8.89^{a-g}	31.64^{ab}
		Melka zala	18.82^{ab}	10.54^{ab}	29.94^{a-g}
		Local	16.57^{a-g}	10.38^{ab}	30.62^{abcd}
	138	Mareko fana	18.46^{abc}	10.92^{a}	31.71^{a}
		Melka zala	18.55^{abc}	10.17^{abc}	31.69^{ab}
		Local	17.31^{a-f}	9.36^{a-e}	30.58^{abc}
		SEM	3.47	2.06	1.37
		LSD	3.06	2.35	1.92
		CV	11.70	16.40	3.90
		R^2	0.50	0.49	0.51
		Significance	*	*	*

Means sharing the same letter within a column are not significantly different at 5% level of significance;
* = significant at 5% probability level;** = significant at 1% level of probability.

for 50% of the plants in a plot to start flowering (Table 1). The variation in days to 50% flowering in response to the three way interaction of factors is attributed to the rationale that time of flowering in pepper is governed by genetic factors responsible for earliness or prolonged start of blooming (varietal differences) and the type and rate of nutrient supply rather than due to the individual or two way interaction effects of the three factors.

The result indicated that the maximum number of days for fifty percent of the plants in a plot to flower was taken by variety *Melka zala* (99 days) in plots treated with 0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1} of the fertilizers (control). On the other hand, *Mareko fana* was the earliest to flower taking 66 days in plots treated with 0 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}.

This is in line with the findings of Sleshi (2011) in his study of hot pepper variety trial at Jimma, who reported that the variety *Melka zala* took longer period (71) days for 50% the plants in a plot to start flowering. For this study, the extra number of days required by *Melka zala* to flower might have been caused by environmental factors which may have resulted in extended and continuous vegetative growth of the variety as it was grown in a relatively higher altitude as compared to the place where

Table 3. Interaction effect of N, P_2O_5 and variety on growth on different parameters.

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Variety	Number of fruits per Plant	Pod Length (cm)	Pod Width (cm)
0	0	Mareko fana	18.53^{abcd}	7.78^{abcd}	2.30^{a-h}
		Melka zala	16.77^{bcde}	6.06^{fgh}	2.12^{f-j}
		Local	10.13^{hi}	5.72^{gh}	1.95^{hij}
	69	Mareko fana	16.23^{b-f}	5.97^{gh}	1.93^{ij}
		Melka zala	14.67^{c-i}	7.55^{a-f}	2.12^{f-j}
		Local	12.60^{e-i}	6.11^{efgh}	2.13^{e-j}
	138	Mareko fana	14.60^{c-i}	5.71^{gh}	2.21^{d-j}
		Melka zala	12.40^{e-i}	6.25^{efgh}	2.51^{a-f}
		Local	23.53^{a}	7.91^{abc}	1.98^{hij}
46	0	Mareko fana	18.83^{abcd}	6.41^{c-h}	2.14^{e-j}
		Melka zala	12.07^{e-i}	5.78^{gh}	1.94^{hij}
		Local	15.13^{c-i}	6.44^{c-h}	2.43^{a-f}
	69	Mareko fana	18.87^{abcd}	8.29^{a}	2.34^{a-h}
		Melka zala	9.60^{i}	5.50^{h}	2.24^{e-j}
		Local	10.57^{ghi}	5.77^{gh}	2.01^{ghij}
	138	Mareko fana	12.77^{e-i}	6.17^{efgh}	2.23^{c-i}
		Melka zala	19.23^{ab}	7.03^{a-h}	2.39^{a-f}
		Local	15.60^{c-h}	6.52^{d-h}	2.41^{a-f}
92	0	Mareko fana	11.10^{fghi}	5.76^{gh}	1.87^{j}
		Melka zala	16.00^{b-g}	6.91^{a-h}	2.27^{b-i}
		Local	15.77^{b-h}	6.34^{d-h}	2.42^{a-f}
	69	Mareko fana	21.37^{ab}	7.49^{a-g}	2.64^{a}
		Melka zala	19.97^{abc}	6.43^{c-h}	2.37^{a-f}
		Local	18.83^{abcd}	7.90^{abc}	2.53^{abcd}
	138	Mareko fana	18.83^{abcd}	8.15^{ab}	2.56^{abc}
		Melka zala	23.50^{a}	6.76^{b-h}	2.60^{ab}
		Local	14.07^{d-i}	6.96^{a-h}	2.58^{abc}
SEM			11.88	0.82	0.05
LSD			1.88	0.49	0.12
CV			21.60	13.60	9.70
R^2			0.50	0.49	0.51
Significance			*	*	*

Means sharing the same letter within a column are not significantly different at 5% level of significance; * = significant at 5% probability level;** = significant at 1% level of probability.

it was particularly adapted (Melkasa). According to Lemma (2008), the nutrient supply is also responsible for earliness or late start of blooming. The result showed that plots that received higher levels of both fertilizers exhibited prolonged time to commence blooming. For example, when the level of nitrogen and phosphorus was increased from 0 kg ha^{-1}, there existed an increase in the parameter by 2.9% and 2.3% in the *M. fana* and local variety respectively.

Number of primary branches

The three way interaction of nitrogen, phosphorus and variety affected the number of primary branches significantly (P<0.01) (Table 1). An increase in the number of primary branches in response to varietal differences and the applied nitrogen and phosphorus is due to the accumulation of assimilates in the growing seedlings that initiates the rise of new primary branches. Variety is also the major factor that is responsible to determine the number of primary branches.

The highest number of primary branches (5.60) was recorded in *Melka zala* with fertilizer combination of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. The minimum number of primary branches (2.97) was also observed in variety *Melka zala* with fertilizer rates of 0 kg N ha^{-1} and 138 kg

Table 4. Interaction effects of N and P_2O_5 on total dry fruit yield and harvest index.

Treatment N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Total dry fruit yield (t ha^{-1})	Harvest Index (%)
0	0	0.47^{dc}	20.61^{bcd}
	69	0.37^{de}	18.86^{cd}
	138	0.52^{dc}	20.37^{bcd}
46	0	1.19^{e}	17.16^{d}
	69	1.65^{abc}	22.15^{abc}
	138	1.62^{bcd}	20.59^{bcd}
92	0	1.18^{e}	17.12^{d}
	69	1.87^{ab}	23.38^{ab}
	138	1.97^{a}	25.04^{a}
Significance		**	*
SEM		0.29	4.04
LSD		0.27	3.83
CV		18.72	19.65
R^2		0.64	0.52

Means sharing the same letter within a column are not significantly different at 5% level of significance; * and ** represent level of significance at 5% and 1% of probability.

P_2O_5 ha^{-1}. However, the number of primary branches in all varieties treated with combination of 0 levels nitrogen and all levels of phosphorus did not show significant variation. Sileshi (2011) indicated that variety is one of the major factors determining the number of primary branches in hot peppers.

Quality

Pod length (cm)

Pod length increased significantly (P<0.01) in response to the interaction effect of nitrogen, phosphorus and variety. Uptake enhancement as a result of application of increasing level of nitrogen and phosphorus fertilizers increases pod length. The analysis of variance showed that the maximum pod length (8.29 cm) was obtained from the variety *M. fana* from plots treated with 46 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} followed by the same variety, measuring 8.15 cm in plots supplied with N and P fertilizers at the rate of 92 and 138 kg ha^{-1} respectively (Table 3). Similarly, the minimum pod length (5.5 cm) was recorded for the variety *Melka zala* with combined use of 46 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}.

The result of MARC (2005) and Sileshi (2011) are consistent with the results obtained in this study. In their findings they reported that the shortest pod length was recorded for the variety *Melka zala*, which was 7.00 cm and 6.78 cm respectively.

The result is in line with the finding of MARC (2005) which reported that the longest (15cm) and the shortest (7cm) pod lengths recorded in the varieties *M. fana* and local variety respectively. The variations were most probably being attributed to their inherited traits or the growing environment.

Pod length is directly related with the amount of nutrients taken and the vegetative status of the plant. The result indicated that plots that received higher level of nitrogen exhibited longer fruits. Parameters of growth and yield were positively correlated with plant height (except number of days to fifty percent flowering). This might be because plants that exhibit vigorous growth characteristics are those plants that acquired sufficient amount of essential nutrients. These nutrients in turn are translocated into the fruits (as sink of nutrients) and result in fruit enlargement.

Pod width (cm)

Like pod length, pod width can also be influenced by the nutrient supply (*i.e*., nitrogen and phosphorus) as well as varietal differences. The third order interaction effect of nitrogen, phosphorus and variety significantly (P<0.01) influenced pod width. This significant interaction effect of the three factors on fruit diameter might be due to the reason that the thickness of fruits is influenced by varietal traits or the nutrient supply in the growing environment. Fruit diameter is an important quality indicator parameter in hot pepper markets. The thicker the fruit, the higher will be the surface area of the pod outweighing the contents of the seed when it is ground for spice or other preparations. The maximum cross-section (2.64 cm) of

Table 5. Interaction effect of N, P_2O_5 and variety on yield parameters.

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Variety	Dry Matter Yield of Fruits (t ha^{-1})	Marketable Yield (t ha^{-1})	Dry Biomass Yield (t ha^{-1})
0	0	Mareko fana	1.44^{abc}	1.26^{c-f}	7.77^{ab}
		Melka zala	1.34^{b-e}	1.35^{b-f}	6.59^{f}
		Local	1.36^{a-e}	1.15^{defg}	7.18^{cde}
	69	Mareko fana	0.68^{h}	1.06^{efg}	7.23^{cde}
		Melka zala	1.35^{a-e}	1.22^{c-f}	7.65^{abc}
		Local	1.33^{a-e}	1.23^{c-f}	7.09^{edf}
	138	Mareko fana	1.38^{a-e}	1.34^{abc}	7.73^{abc}
		Melka zala	1.00^{efgh}	1.09^{defg}	6.82^{ef}
		Local	1.69^{a}	1.65^{abc}	7.83^{ab}
46	0	Mareko fana	0.91^{efgh}	0.88^{g}	6.91^{ef}
		Melka zala	1.29^{a-f}	1.28^{c-f}	7.08^{edf}
		Local	0.99^{efgh}	0.86^{g}	6.74^{abc}
	69	Mareko fana	1.57^{ab}	1.79^{ab}	7.95^{ab}
		Melka zala	1.02^{d-h}	1.36^{bcde}	6.76^{ab}
		Local	1.27^{b-f}	1.17^{defg}	7.60^{abc}
	138	Mareko fana	1.12^{c-g}	1.22^{c-f}	7.75^{abc}
		Melka zala	1.69^{a}	1.72^{bcde}	7.88^{ab}
		Local	1.12^{c-g}	1.35^{b-f}	7.77^{ab}
92	0	Mareko fana	1.03^{d-h}	0.99^{fg}	6.98^{ef}
		Melka zala	1.07^{c-h}	0.99^{efg}	7.02^{cde}
		Local	0.84^{gh}	0.89^{gg}	6.69^{f}
	69	Mareko fana	1.67^{ab}	1.85^{a}	8.05^{a}
		Melka zala	1.43^{abd}	1.39^{bcde}	7.96^{ab}
		Local	1.66^{ab}	1.60^{abc}	8.00^{ab}
	138	Mareko fana	1.55^{ab}	1.91^{a}	7.49^{bcd}
		Melka zala	1.64^{ab}	1.71^{bcde}	7.85^{ab}
		Local	1.59^{ab}	1.54^{abcd}	7.68^{abc}
SEM			0.25	0.08	0.10
LSD			0.41	0.46	0.52
CV			19.26	21.30	4.30
R^2			0.69	0.50	0.49
Significance			*	*	*

Means sharing the same letter within a column are not significantly different at 5% level of significance; * = significant at 5% probability level;** = significant at 1% level of probability .

fruits was recorded in the local variety with fertilizer rates of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. The thinnest fruit (1.87cm) was obtained from the variety *Mareko fana* from plots with fertilizer application of 92 kg N ha^{-1}and 0 kg P_2O_5 ha^{-1}.

The result indicated that plots treated with relatively higher rates of nitrogen and phosphorus gave fruits with larger cross-sections. The result is in agreement with that of Hegde (1997) who reported that application of nitrogen and phosphorus fertilizers increase pod quality parameters including pod width in pepper.

The result agrees with MARC (2005), who obtained the highest value of pod diameter of 2 cm in the variety *Mareko Fana*. This pod width difference among varieties is attributed to variation in dry matter partitioning ability of plants and the soil fertility status of the growing locations. Larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in markets (Beyene and David, 2007).

When sufficient nutrient supply is available in the soil, fruits as other vegetative parts of the plant take part in assimilating portion of the nutrient and would acquire larger and thicker sizes (Hegde, 1997).

Yield and Yield Related Attributes

Fresh fruit yield (t ha^{-1})

The analysis of variance showed that nitrogen, phosphorus, and variety interacted to influence the parameter significantly (P<0.01). Fresh fruit yield was found to increase in response to the combined action of nitrogen, phosphorus and variety rather than the individual or two way interaction effects of the three factors.
The highest record for fresh fruit yield was for variety *Mareko fana* which was about 10.92 t ha^{-1} in treatments that received fertilizer combination of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} followed by the local variety (10.60 t ha^{-1}) with fertilizer combination of 46 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. On the other hand, *Melka zala* gave the least fresh fruit yield, which was about 6.20 in pots treated with 46 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}.
Sleshi (2011) in his variety trial at Jimma found that *Melka zala* was low yielding. The low fresh fruit productivity of *Melka zala* may be attributed to the less adaptability and low performance of the variety to the local environmental conditions. The variety was found to exhibit abortion of flowers and fruits with a continuous vegetative growth. This resulted in low fresh fruit yield as compared to the other varieties.
Bosland and Votava (2000) noted that primary and secondary branches were locations of fruit buds and thus foundation of new fruit bud development in hot peppers. *Marko fana* and the local variety pepper had relatively higher number of primary and secondary branches as compared to the variety *Melka zala*. Thus, the better total fresh fruit yield productivity of *M. fana* and the local variety might have been the results of these characteristics.

Fruit dry matter (%)

The interaction effect of nitrogen, phosphorus and variety affected that parameter significantly (P<0.01). There was a general increase in fruit dry matter yield with increasing level of nitrogen and phosphorus. For example, as the levels of nitrogen and phosphorus were increased from 0 kg ha^{-1} to 92 kg N and 138 kg P_2O_5 ha^{-1}, fruit dry matter increased by 0.79% and 3.31% for the varieties *Mareko fana* and *Melka zala* respectively. The result indicated that the highest fruit dry matter (31.71%) was recorded for *Mareko fana* treated with fertilizer rates of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. The minimum (27.34%) was obtained from the variety *Melka zala* with N and P_2O_5 combination of 46 kg ha^{-1} and 69 kg ha^{-1} respectively (Table 2).
The variation in dry matter percent of fruits is probably due to the difference in nutrient accumulation of photosynthetic products which are transported from sources (leaves) to fruits. Plants with better stands and good vegetative growth showed better fruit dry matter percent. The positive correlation coefficients of growth and yield parameters with fruit dry matter indicated that fruits which are longer, wider and having relatively larger number of fruits resulted in higher fruit dry matter.
Consistent with this result, Hedge (1997), noted that a comparable size in fruit weight and other yield related characteristics of *Mareko fana* and *Melka zala* varieties. This might be because of the genetic mix up or intercrossing of varieties which are grown in the surrounding area. The local variety used is the collection of different hot pepper varieties and thus interbred varieties of *Mareko fana* and other cultivars Guerpinar and Mordogan (2002) found that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil which also directly related with the nutrients present in the soil or the amount of organic and inorganic fertilizers applied.

Fruit weight (g)

Fruit weight was significantly (P<0.01) influenced by the interaction effect of nitrogen, phosphorus and variety. As the levels of nitrogen and phosphorus were increased, there was a significant increment in fruit weight. In *Mareko fana*, applying 92kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} resulted in an increase by 20.65% as compared with the control (Table 2).
The heaviest fruit weight (18.91 g) was recorded in local variety with combined use of 46 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} respectively. The next heaviest fruit weight (18.75 g) was recorded in *Melka zala* fertilizers combined as 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. The lightest fruit weight (12.24 g) was recorded for the *Mareko fana* with fertilizer combination of 0 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. However, the variation in fruit weight is not only attributed to the change in the rate of phosphorus but also the simultaneous change in the rate of nitrogen as the later is mainly responsible for increase in biomass.
The result implies that the higher the level of phosphorus used, the better the fruit setting characteristics of the plant with well developed larger sized fruits as their content is directly related with the amount of nutrients taken from the soil.
The increase in pod dry weight in this study is in conformity with the work of Hedge (1997), Guerpinar and Mordogan (2002) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil.
It has also been might have been used and similarity in agronomic characteristics has resulted.

Number of fruits per plant

There was a significant difference in the number of fruits per plant due to the three way interaction effect of nitrogen,phosphorus and variety (P<0.01). As the level of nitrogen and phosphorus increases, roots can easily access nutrients and there will be efficient up take. As the fruits are resource sinks, the development of new fruits increases. This is also governed by varietal traits which are responsible for the acquisition of various numbers of fruits. Thus, the interaction effect of the three factors outweighed the effects of the above factors in single or in a two way combination. The result showed that, the highest number of fruits per plant (23.53) was recorded for the local variety with combined levels of N and P_2O_5 fertilizers of 0 kg ha^{-1} and 138 kg ha^{-1} respectively. On the other hand, the *Melka zala* gave the least number of fruits per plant, which were 9.60 with N and P_2O_5 fertilizers combination of 46 kg ha^{-1} and 69 kg ha^{-1} respectively (Table 3).

Difference in fruit number might have also aroused as a result of the growing environmental factors and associated traits. As the number of primary, secondary and tertiary branches increases, fruit producing buds can have the chance to develop and give fruits. The number of fruit can also be affected by fruit abortion. The very low number of fruits per plant exhibited by the variety *Melka zala* may also be related to abortion of flowers and initiated buds, which was witnessed during the time of experimentation. Schemske (1980) reported that pollination can be the main factor limiting fruit production and resulting in low productivity. The result is also in line with the work of Adugna (2008) that treatment combinations that received high level of nitrogen and phosphorus fertilizers (150 kg N ha^{-1} with 50 kg P_2O_5 ha^{-1}) gave the highest number of pods per plant as compared to the yield obtained from the controls.

Total dry fruit yield (t ha^{-1})

Total dry fruit yield is the sum of the marketable and unmarketable yield of the dry fruit taken at each successive harvest. The result indicates that the two way interaction effect of nitrogen and phosphorus significantly (P<0.05) influenced the parameter (Table 4). The highest total dry pod yield (1.92 t ha^{-1}) was obtained from plots that received the maximum (92 and 138 kg ha^{-1}) of N and P_2O_5 respectively. On the other hand, with N and P_2O_5 combinations of 0 and 69 kg ha^{-1}, the least total dry pod yield (0.37 t ha^{-1}) was recorded. A general linear increasing trend of total dry fruit yield was observed in response to increasing level of both fertilizers. For example, by increasing the level of fertilizers from 0 kg N to 92 kg N and 138 kg $P_2O_5ha^{-1}$, there exists an increase in total dry fruit yield by 1.5 t ha^{-1}. Fruits are sites of sinks of nutrients. The main nutrients supplied (nitrogen and phosphorus) are taken easily by the plants and are being utilized for the growth and development of the fruits. This results in formation of fruits which are bigger in size and number. Thus, the acquisition of fruits with the above characteristics is attributed to the combined influence of nitrogen and phosphorus.

The linear relationship between total dry fruit yield and fertilizer rates indicates that with increasing level of nitrogen and phosphorus, the nutrient sink (especially phosphorus) in fruits will be high thereby increasing the size fruits. At higher levels of both fertilizers, the total dry fruit yield (1.92 t ha^{-1}) obtained is comparable and even higher than the total dry fruit yield (1.7 t ha^{-1}) obtained by Melkasa Agricultural Research Center (2005).

Harvest index (%)

Significant interaction (P<0.05) effect was observed between nitrogen and phosphorus (Table 4). The result indicated that the maximum harvest index (25.04%) was recorded for the local variety with combined level of N and P_2O_5 fertilizers of 92 kg ha^{-1} and 138 kg ha^{-1} (*i.e.*, a 4.67 increase in harvest index as compared with the control). On the contrary, the least harvest index (17.12%) was obtained from the variety *M. fana* in treatments with 92 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}. This indicates that phosphorus is a determinant factor for fruit yield in pepper.

Plots that were treated with highest level of both fertilizers gave the higher harvest index values depicting that at higher rates of nitrogen and phosphorus, fruits have the chance to take sufficient amounts of these nutrients for their full development and the acquisition of heavier dry weight of fruits. Sufficient availability of these nutrients also enables the plant to acquire higher number of pods per plant and seeds per pod. This partly contributes the plant to have higher value of harvest index.

Lemma *et al*. (2008) reported that with an increase in the number of seeds per pod, the size of pods increases linearly. Similarly, Russo (2003) and Aleemulah *et al.* (2000) also noted that pod size increases with the number of seeds per pod. Thus, anything which contributes to yield directly increases harvest index.

The correlation coefficients of yield and yield related parameters with harvest index exhibited positive relationship indicating that any factor that improves yield related characteristics of varieties can also increase the harvest index. The strong positive relationship between yield parameters with harvest index implies that this parameter is a good indicator of yield or yield related characteristics.

Dry matter yield of fruits (t ha^{-1})

The interaction effect of nitrogen, phosphorus and variety caused significant (P<0.05) effect on dry matter yield of fruits. An increase in the dry matter yield of fruits with increasing levels of nitrogen and phosphorus indicates that sufficient uptake leads to accumulation of nutrients (nitrogen and phosphorus) which contribute for the dry matter yield. The result showed that the highest dry matter yield (1.69 t ha^{-1}) of fruits was obtained from the local variety in plots treated with 0 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. The next highest dry matter yield of fruits (1.67 t ha^{-1}) was also obtained from the variety the *M. fana* with combined level of N and P_2O_5 fertilizers 92 and 69 kg ha^{-1} respectively. The least dry matter yield of fruits (0.68 t ha^{-1}) was obtained from the variety *M. fana* in plots that received 92 kg N ha^{-1} and 69 kg P_2O_5.

The result indicated that application of N and P_2O_5 at rates of 0 and 138 kg ha^{-1} in the local variety increased the dry matter yield of fruits by 24.26% as compared with the control plots. This increase in dry matter yield of fruits with increasing level of nitrogen and phosphorus fertilizers is in conformity with the result of Hegde (1997) who noted that dry matter yield of pepper fruits is directly correlated with the amount of nutrient supplied to the plant.

Marketable yield (t ha^{-1})

The result indicated that there was a significant (P<0.01) difference in marketable yield in response to the interaction effect of nitrogen, phosphorus and variety (Table 5). The marketable yield is a good indicator of the performance of the variety for undertaking economic analysis and to choose the best options (highest benefit cost ratio). The result showed that the highest marketable yield (1.91 t ha^{-1}) was obtained from variety *M. fana* in plots treated with fertilizer rates of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}. On the other hand, from plots treated with 46 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1} the minimum marketable yield of 0.86 t ha^{-1} was recorded. This shows that by applying 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}, the marketable yield can be increased by 51.6% compared with the control plots.

The variation in marketable yield among pepper varieties might be due to the genetic makeup (variety), varying levels of fertilizer treatments and the nutrient status of the growing environment. Fekadu and Dandena (2006) reported that the influence of genetic variability and heritability are necessary in systematic improvement of hot pepper varieties for fruit yield and related traits.

Marketable pod yield increase in response to addition of nutrients in nutrient deficient soils (Matta and Cotter, 1994), which agrees with the results of this study that application of essential nutrients increases vegetative growth, leaf area, photosynthetic capacity and better partitioning of assimilate towards the pods. This in turn had resulted in development of pods which are relatively healthy, attractive and acceptable in markets.

Dry biomass yield (t ha^{-1})

The interaction effect of nitrogen, phosphorus and variety resulted in significant (P<0.01) differences in dry biomass yield of fruits. As the biomass yield is the total (ground and above ground) of the entire plant's yield, significant differences arose due to the joint effects of the three factors rather than the individual or two way interaction influences.

The maximum dry biomass yield (8.05 t ha^{-1}) was obtained from variety *M. fana* in treatments that received 92 kg N ha^{1-} and 69 kg P_2O_5 ha^{-1} respectively. On the other hand, the minimum dry biomass yield (6.59 t ha^{-1}) was also recorded in *Melka zala* with fertilizer levels of 0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1} (Table 5).

A general increasing trend of dry biomass yield was observed with increasing level of nitrogen and phosphorus. For example, when the levels of nitrogen and phosphorus were increased from 0 kg to 92 kg N ha^{-1} and 0 kg to 138 kgP_2O_5 ha^{-1}, the dry biomass yield increased by 19.12 and 6.7% in the varieties *Melka zala* and *Mareko fana* respectively.

Treatments with better fruit yield did not necessarily give higher dry biomass yield. This is because there might have been treatments with vigorous vegetative stand with larger stems which may contribute to the steerage of larger dry biomass yield. The maximum dry biomass yield of *Melka zala* might be attributed to the extensive vegetative growth and development of thick stems which resulted in higher production of dry biomass as compared to the vegetative growth and the stem morphology of other (*Mareko fana* and local variety) pepper cultivars.

Thus, the dry biomass yield as an indicator of better yield may be misleading in that varieties exhibiting better dry biomass may not necessarily give better pod (fresh or dry) yield and this parameter may not be taken a good indicator of yield or yield related characteristics.

SUMMARY AND CONCLUSIONS

In order to attain better yields in pepper varieties and to maintain the production level sustainably, studies in the type and right usage of inorganic fertilizers as well as the type of varieties are relevant. The research aimed at observing the influence of nitrogen and phosphorus fertilizers on yield and yield components as well as evaluating performance of hot pepper varieties.

The outcome of the experiment indicated that there were significant interaction effects on many of the parameters considered. The result also showed that there was an increase in marketable yield by 24.23% as a result of application of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} in relation to the control. Applying 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} resulted in highest total fresh fruit yield (10.92 t ha^{-1}) for *M. fana* and the minimum (6.20 t ha^{-1}) was recorded for *Melka zala* in pots treated with 46 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Plots treated with fertilizer rates of 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-}1, gave the highest marketable yield (1.91 t ha^{-1}) in the variety *M. fana*.

On the other hand, from plots treated with 46 kg N ha^{-1}

and 0 kg P_2O_5 ha^{-1} the least marketable yield of 0.86 t ha^{-1} was recorded depicting that by applying 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}, the marketable yield can be increased by 54.0% compared with the control plots.

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