Response of green and hot pepper to nitrogen and phosphorus fertilizers at Koga irrigation scheme, in west Amhara, Ethiopia

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Abstract

A field experiment was conducted to determine nitrogen (N) and phosphorus (P) rates for green pepper (*Capsicum frutescens*) yield at Koga irrigation scheme. A randomized complete block design (RCBD) with three replications was used constituting five rates of N (46, 69, 92, 115,138 kg ha^{-1}) and three rates of P_2O_5 (46, 69 and 92 kg ha^{-1}) combined in a factorial arrangement including 0,0 rates of N and P for comparison as a negative check. All TSP (P source) was applied during transplanting while urea (N source) was applied in two splits: half at transplanting and half at the start of flowering. Marekofana pepper variety was used as a test crop. The plots were irrigated by furrow every seven days. All data were collected and analyzed using SAS software and means were separated by Duncan's Multiple Range Test at 5% for significant treatment mean differences. The result showed that there was highly significant difference among treatments and years but the interaction between treatments and years was not significant. The highest marketable green pod yield (15.52 t ha^{-1}) was obtained from 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} whereas the lowest marketable yield (11.38 t ha^{-1}) was obtained from 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. The partial budget analysis for marketable yield also showed that applying 138 kg N ha^{-1} with 69 kg P_2O_5 ha^{-1} had the highest net benefit (64777.2 ETB ha^{-1}) with a MRR 546.05%. Therefore, combined application of 138 kg N ha^{-1} with 69 kg P_2O_5 ha^{-1} or 242 kg urea and 150 kg DAP ha^{-1} is recommended for Koga irrigation scheme.

Key Words: fertilizer, hot pepper, marketable yield, nitrogen, phosphorus,.

Introduction

Hot pepper (*Capsicum frutescens*.) is one of the most important spice and vegetable crops widely cultivated around the glob for its pungent flavor and aroma (Ikeh et al., 2012; Obidiebub et al., 2012). It has been a part of the human diet since about 7500 BC (Mac Neish, 1964 in Sileshi, 2011). Hot pepper belongs to the genus Capsicum and family Solanaceae. In Ethiopia, hot pepper is commonly cultivated within an altitude ranges of 1400 to 1900 meter above sea level (m.a.s.l) and extensively grown at altitude of 1100 to 1800 m.a.s.l. (MoARD, 2009; EIAR, 2007), which receives mean annual rainfall of 600 to 1200 mm, and has mean annual temperature of 25 to 28°C (EIAR, 2007).

Hot pepper is produced both in the rainy and irrigation seasons in Ethiopia. In irrigated agriculture, it is produced mainly for green pod (as vegetable) while in the rainy season for both spice and vegetable. In Ethiopia, hot pepper powder is used as an essential coloring and flavoring ingredient in traditional diets whereas the green pods are usually consumed with other foods.

In terms of total production the share of pepper is high as compared with other vegetables such as lettuce, tomatoes and others (CSA, 2013). In Ethiopia vegetable production accounts about 1.43% of the area under all crops. However, of the total estimated area under vegetables, the lion share which is about 70.89% and 18.07% was under hot peppers and Ethiopian cabbage, respectively (CSA, 2013). Production of vegetables contribute 2.95% of the total crops production, conversely, of the total production of vegetables, hot pepper and head cabbage are the highest which is about 37.14% and 43.53%; respectively (CSA, 2013). In Amhara region 1,508.06 ha of land was allocated for green pepper and 50,585.59 ha of land was allocated for dry pepper production in 2012/13 cropping season (CSA, 2013). The production of hot pepper was 12,017.43 tonnes and 97,901.92 tonnes in the same year for green and dried pod yield; respectively (CSA, 2013).

Pepper is a heavy feeder, needing large amounts of nutrients to produce quality product, mainly just after 10 days of flower initiation to the beginning of fruit ripening (Zhang et.al. 2002). Under intensive production systems, the hot pepper needs fertilizer at transplanting to promote root establishment and shoot development while at flowering to ensure flower set and fruit retention, and during harvesting for continued production (FAO, 2004).

Irrigated area has been increasing from time to time in Ethiopia (Awulachew *et al*., 2007) that needs research support including for fertilizer package. In Amhara region the newly developed irrigation schemes like Koga needs research based and area specific fertilizer recommendations. Even if, the blanket recommended fertilizer rate for hot pepper in Ethiopia is, 200 kg DAP ha^{-1} and 100 kg urea ha^{-1} (EARO, 2004), there must be area specific fertilizer recommendation.

Therefore, the objective of this research was to determine optimum nitrogen and phosphorous fertilizer rates for Koga irrigation scheme.

Materials and methods

The experiment was carried out at Koga irrigation scheme which is situated in Mecha district of West Gojam Zone, Amhara National Regional State, Ethiopia. The mean annual rainfall at Merawi town is 1589 mm and the mean annual temperature ranges from 16 to 20^{o}C (Nigussie and Yared, 2010).

The dominant soil type in Koga irrigation scheme is Nitisols (Yihenew, 2002) and it is in general moderately acidic in reaction (Yihenew, 2002; Birru *et al*., 2013). However, there are some cases where the soil is strongly acidic with high exchangeable acidity and high exchangeable Al content. It has very low organic matter and low available phosphorus content according to the category set by Clements and McGowen (1994). It also has medium total nitrogen contents (Table 1). The command area of Koga irrigation scheme is 7,000 ha (Figure 1).

Experimental setup

The field experiment was carried out in 2011 and 2013 using 16 treatments including five rates of N (46, 69, 92, 115,138 kg ha^{-1}) and three rates of P_2O_5 (46, 69 and 92 kg ha^{-1}) combined in a factorial arrangement including 0, 0 rates of N and P for comparison as a check in three replications. Triple Super Phosphate (TSP) fertilizer (as a source of phosphorus) was applied at transplanting whereas urea (as a source of N) was applied in two splits half at transplanting and half at flowering. Seedling of “Mareko Fana” variety was raised in a well prepared seed bed for 45 days before transplanting. The spacing of 30 cm between plants and 70 cm between rows was used; respectively in the field. The gross size of each experimental plot was 2.8m by 3m (8.4m^2) and a net harvested plot size of 4.5m^2. Irrigation water was supplied on weekly basis with furrow irrigation system.

Figure 1. Koga irrigation command area in the Koga watershed (Anteneh *et al*., 2014)

Data on plant height was recorded from five randomly selected plants and fruit length and fruit diameter were recorded in each harvest from ten randomly selected green pods of the net plot. Whereas, maturity, stand count, marketable fruit yield and total fruit yield were recorded from the whole plant in the net plots. (Analysis of variance (ANOVA) for yield and yield components were employed using SAS version, 9.2 (SAS, 2008). In conditions where ANOVA was significant, the treatment means were compared using Duncan's multiple range test (DMRT) at 5% probability. Economic analysis had also been performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The analysis was done in the first case with the normal prices of yield and costs of inputs. Sensitivity analysis was also performed by the assumption that the cost of fertilizer inputs increased by twenty five percent while the cost of the green pod remained constant. The analysis was made based on data collected from Mecha district office of Trade and Transport, Cooperatives and from hot pepper producing farmers' field. At Mecha, the minimum mean price of hot pepper during the study time was 5.00 ETB kg^{-1}, while the price of urea and DAP was 11.88 ETB kg^{-1} and 14.64 ETB kg^{-1}; respectively.

Results and discussions

The soil reaction (pH) of the experimental site on average was 5.2 (Table 1). According to Bruce and Rayment (1982), the soil is considered as strongly acidic and moderately good for crop production through efficient management of soil nutrients. The CEC of the soil was 25.00 cmole kg^{-1}, which is in a range of moderate to high (Bruce and Rayment, 1982). According to the ratings of Bruce and Rayment (1982) the total nitrogen of the area lies in medium range. Actually total nitrogen is an indication of the total amount of nitrogen present, but it does not guarantee for the availability of nitrogen to the plant. The highest proportion of the total nitrogen is held in by the soil organic matter and hence is not immediately available to plants (Hazelton and Murphy, 2007). Total nitrogen cannot be used as a measure of the mineralized forms of nitrogen (NH_4^+, NO_3^-, NO_2^-), as much of it is held in the organic matter. Available phosphorus was low; this could be due to low soil pH and fixation of P by Al and Fe. Soil organic matter of the site was at about the critical level. Soil organic matter plays a great role for structural stability (Charman and Roper, 2007) as well as.it influences physical and chemical properties of soils.

Table 1**.** Chemical properties of the soils of Koga irrigation scheme in 2011

pH*	TN*	Available P*	SOM*	CEC*	Texture (%)			
					Sand	Silt	Clay	Class
5.13	0.21	6.28	3.71	25.62	17.56	25.00	57.44	Clay

** pH is in water, TN is total nitrogen in % , Available P is in ppm, SOM is soil organic matter in % and CEC is cation exchange capacity in centimol per kg of soil*

The ANOVA of marketable yield showed significant difference (p<0.01) over years, but year * N * P was not significant (Table 2).

Table 2. Combined ANOVA for the effect of N and P fertilizers on marketable and total yield of hot pepper at Koga irrigation scheme

Source of variation	DF	Mean Square Value			
		Marketable pod yield	Pr > F	Total pod yield	Pr > F
Rep	2	1.5825478	0.6428	2.4438478	0.5530
N	4	18.3719844	0.0012	24.1949794	0.0005
P	2	5.5737344	0.2171	5.6889544	0.2564
Year	1	211.906777	<.0001	138.8556011	<.0001
N*P	8	2.5374303	0.6782	2.0689544	0.8464
Year*P	2	8.3444344	0.1046	7.6760211	0.1618
Year*N	4	5.2232556	0.2232	5.2399817	0.2871
Year*N*P	8	1.6731164	0.8718	1.9283683	0.8707

Except for the plant height, the interaction of N and P didn't show a significant difference (p>0.05) for all yield parameters (Table 3). The highest plant height (58 cm) was obtained from the maximum N and P rates (138 N and 92 P_2O_5 kg ha^{-1}) whereas, the lowest plant height (46.23 cm) was obtained by applying 46 N and 69 P_2O_5 kg ha^{-1} (Figure 3). This is agreed with the findings of El-Tohamy et al. (2006) and Abebayehu Aticho et al. (2014) who reported that adequate amount of nutrient supply improved the growth, height, branch and pods of hot pepper.

Table 3. Three ways ANOVA on yield components of hot pepper

Source	Variables	DF	Squares	Mean square	F Value	Pr >
N*P	Plant height	8	477.696898	59.712112	2.94	0.0079
N*P	Fruit diameter	8	0.1389489	0.0173686	0.51	0.8437
N*P	Fruit length	8	4.93460444	0.61682556	0.84	0.5744
N*P	No of fruits/plant	8	269.958524	33.7448156	1.44	0.2005

Even though, number of fruits didn't show significant difference ($p>0.05$) the highest rates (92/46; 138/92 and 138/69 N/P_2O_5 kg ha^{-1}) gave the highest number of fruits (24.83, 24.74 and 24.29; respectively) as compared to lower rates. As nitrogen and phosphorus rates increased, plants can access nutrients easily and can develop new flower buds as a consequence number of fruits increased. Positive response of fruit number for fertilizer was also reported by Amare *et al.* (2013) who recorded highest number of fruits (25.53) per plant by applying 60 kg ha^{-1} and Adugna (2008) also reported that 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 compared to the yield obtained from the control.

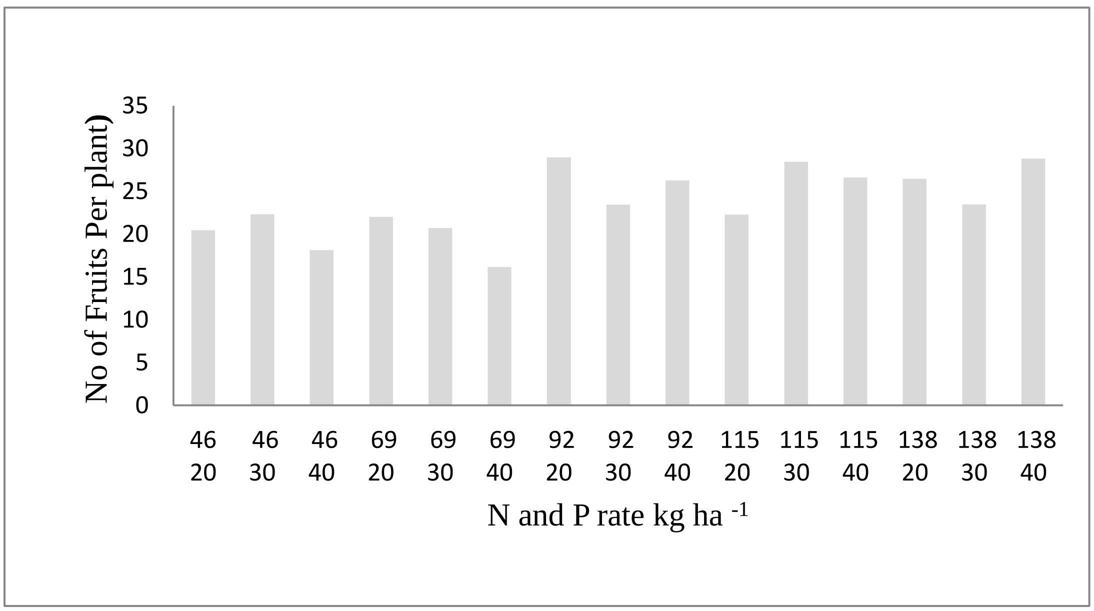

Figure 2. Effect of Nitrogen and Phosphorus Fertilizers on number of fruits per plant

Although there was a non significant difference ($p > 0.05$) between and among treatments on marketable yield, there was a 4.12 t ha^{-1} yield advantage in green pod by applying 138 kg N ha^{-1}

and 92 kg P_2O_5 ha^{-1} than applying 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} (Figure 2). Relatively high yield (15.52 t ha^{-1}) was obtained from plots receiving 138 kg N and 69 kg P_2O_5 ha^{-1}, whereas relatively low yield (11.18 t ha^{-1}) was obtained from plots receiving 46 kg N and 46 kg P_2O_5 ha^{-1}, (Figure 3). As nitrogen and phosphorus rates increased, marketable fruit yield was also relatively increased (Figure 3). This may be attributed to good plant performance by nitrogen and phosphorus fertilizer application. Marketable pod yield increment due to application of fertilizer in poor or degraded soil may be due to an increase of vegetative growth and better leaf area that improves the photosynthetic capacity and that leads to better assimilation and production of pods (Matta and Cotter, 1994). Similar was obtained by Amare et al., (2013). They obtained the highest marketable dry pod yield (1.91 t ha^{-1}) from plots received 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}.

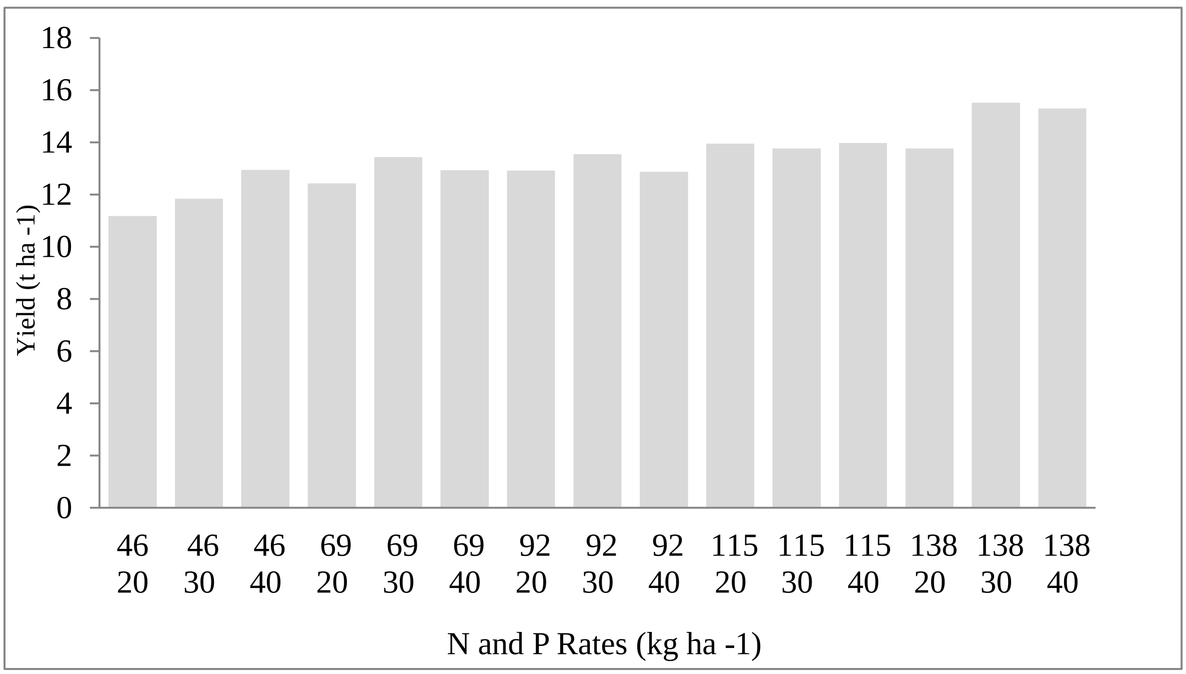

Figure 3. Effect of N and P rates rate on marketable green pod yield

Nitrogen rate independently showed a significant difference ($p<0.01$) on marketable yield (Table 2). The highest marketable yield (14.87 and 13.90 t ha^{-1}) was obtained from plots received 138 and 115 kg N ha^{-1}; respectively. It had a yield advantage of 22.08% and 14.12 % over the plots which received 46 kg N ha^{-1} (Figure 4). This could be due to nitrogen nutrient contribution for vegetative growth such as branches, leaves and height is higher. This is in line with the findings of El-Tohamy et al., (2006) who found adequate amount of nutrient supply improves the growth of hot pepper height, branch and pods.

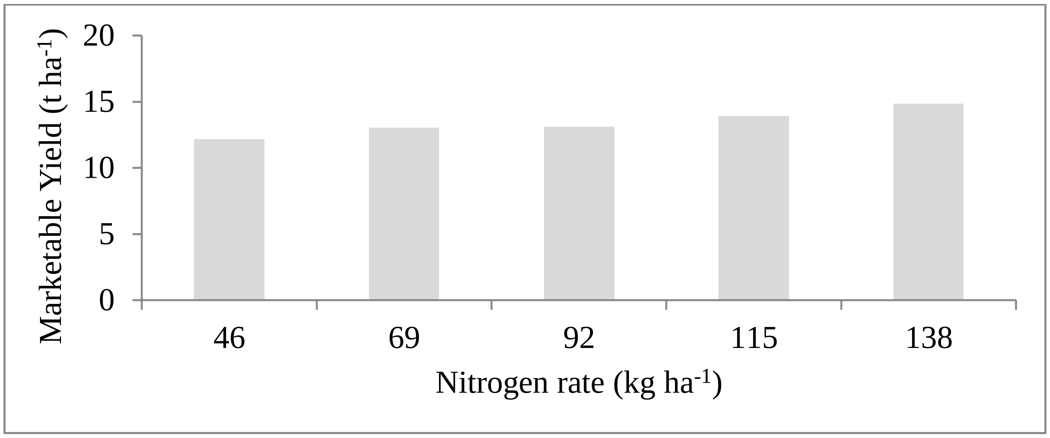

Figure 4. Contribution of nitrogen fertilizer on marketable pod yield of hot pepper

Table 3. Economic and sensitivity economic analysis for hot pepper green pod yield at Koga

	Normal Economic analysis				Sensitivity Economic analysis			
$N\text{-}P_2O_5$ (kg ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)	Rank	TVC ETB ha^{-1}	NB ETB ha^{-1}	MRR (%)	Rank
0-0	0.00	32827.5			0	32827.5		
46-46	2187.13	48122.87	699.3		2187.13	47663.6	560.6	
46-69	2686.70	50593.3	494.5		2686.7	50029.1	391.3	
69-46	2781.13	53153.87	2711.46		2781.13	52569.8	2223.5	
46-92	3186.26	55043.74	466.5		3186.26	54374.6	368.2	
69-69	3280.70	57154.3	2235.0		3280.7	56465.4	1829.7	
92-46	3375.13	54764.87	D		3375.13	54056.1	D	
69-92	3780.26	54404.74	D		3780.26	53610.9	D	
92-30	3874.70	57100.3	D		3874.7	56286.6	D	
115-46	3969.13	58805.87	239.9	2nd	3969.13	57972.4	180.9	2nd
92-92	4374.26	53540.74	D		4374.26	52622.1	D	
115-69	4468.70	57496.3	D		4468.7	56557.9	D	
138-46	4563.13	57401.87	D		4563.13	56443.6	D	
115-92	4968.26	57896.74	D		4968.26	56853.4	D	
138-69	5062.70	64777.3	546.1	1st	5062.7	63714.1	433.9	1st
138-92	5562.26	63287.74	D		5562.26	62119.7	D	

Where: TVC = Total Variable cost in Birr/ha, NB = Net benefit in Birr/ha, MRR = Marginal Rate of Return.

Although the biological yield of hot pepper was promising, the economic and profitable marketable yield should be recommended for farmers producing green hot pepper for the market.

According to CIMMYT (1988) the highest net benefit 64777.3 and 63511.63 ETB per hectare was obtained by applying 138 kg N and 69 kg P_2O_5 ha^{-1} on both dominance and sensitivity analysis; respectively. The highest rate for this particular experiment 138 kg N and 92 kg P_2O_5 ha^{-1} was dominated by 138 kg N and 69 kg P_2O_5 ha^{-1} (Table 3).

Conclusion and recommendation

Based on biological and partial budget analysis of the research applying 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} or 246 kg urea ha^{-1} and 150 kg DAP ha^{-1} gave the mean maximum marketable green hot pepper yield (15.52 t ha^{-1}). This is economical optimum and hence recommended for Koga irrigation scheme. Other soil factors like soil acidity may influence to realize achievable yield. Therefore, further research work on integrated soil fertility management including soil acidity management is critically important at Koga irrigation scheme.

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