Fruit Quality And Net Income Response Of Tomato (Lycopersicon Esculentum Mill.) To Different Levels Of Nitrogen And Plant Population In Alamata, Ethiopia

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Abstract: A study was conducted in the 2007 and 2008 cropping seasons to determine the effects of nitrogen and plant population on quality and net income of tomato (Lycopersicon esculentum Mill.) in northern Ethiopia. The design was a randomized complete block design with three replications. Data collected and analyzed included crop quality attributes and partial budget analysis. Application of N fertilizer significantly increased Total Soluble solid (TSS), fruit dry matter percentage (DM %) and fruit diameter. Higher fruit TSS and DM % were obtained at 230 kg N/ha compared to the other treatments. Intermediate N rate application (138 kg/ha) gave the highest values of fruit yield parameters and net return profits compared to the control. Similarly, Plant population had significant influence on fruit d DM % and fruit diameter.

Keywords: Fruit quality, Income, Nitrogen fertilizer, plant population, Response, tomato.

1 Introduction

TOMOTO is one of the most popular vegetables in the world (Rick, 1978; FAO, 1994). Small farmers and commercial growers in Ethiopia produce different types of fruit vegetables. Of these, tomatoes are predominant (Ministry of Agriculture, MoA, 1988). According to Ethiopian Fruits and Vegetables Enterprise, (EFVE) report of 1984-1987, small farmers scattered along riverbanks and lakes in the central, eastern, and northern Ethiopia are the major producers of tomato. Tomato production is found to be influenced by various factors, among the major ones are native soil fertility and cultural practices. Various studies have indicated that cultural practices such as high plant population, variable fertilizer rates, undetermined irrigation depth and seasons remarkably affect the yield and quality of tomatoes (Sims et al, 1979). Alamata, the district in Ethiopia where this study was conducted, is also characterized by relatively low soil fertility status especially N and P (FAO, 2007), high temperature, and high infestation of pests, diseases and weeds. As a result the farmer in the area produces tomato with poor fruit quality and low return. Wondimu and Getachew (1997) pointed out that high plant population density is likely to deplete soil fertility and moisture. Establishing the optimum plant population per unit area for tomato appeared to be important for improving water and nutrient use efficiency. Thus, to sustain quality tomato production, integrated soil fertility and plant population management are of paramount importance in the Alamata area of Ethiopia**.**

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2 Materials and Methods

Alamata district is located 600 km north of Addis Ababa, Ethiopia, in the Tigray region. Treatments consisted of factorial combinations of seven nitrogen rates (0, 23, 46, 92,138, 184 and 230 kg N/ha) and two population densities of 33,333 and 55,556 plants per hectare. The treatment combinations were laid out using randomized complete block design with three replications. The gross experimental plot size was 5.0 m x 3.0 m and the net experimental plot sizes were 2 m x 3 m and 3.6 x 3.0 m for the low and high plant population, respectively. The different plant population were achieved by varying inter row spacing ranging from 0.6 m to 1 m. The spacing within row was 30 cm. Urea was used as the source of nitrogen. Nitrogen was applied in two splits; half at ten days after transplanting and the rest at the beginning of fruit setting. The locally recommended (46 kg P2O5/ha) phosphorus by extension staff was applied in full dose at transplanting time uniformly to all treatments. The P source was TSP (Triple Super Phosphate). The experimental area was kept weed free by cultivation and hand pulling of weeds five times throughout the cropping season. All other cultural practices such as staking and fungicide (Riodmil MZ 68 WP) were applied uniformly to all plots as per standard recommendations by the Ministry of Agriculture. Tomato seed of Roma VF variety was sown in the nursery at a rate of 1 g/m2 in July 2007. Inter-row spacing was 20 cm with a seedling depth of 8 mm. Seedlings were transplanted at twenty-six days when they reached 15 cm high. Diameter of 10 cm randomly taken marketable fruits at harvest was measured using a calliper. Average fruit weights over all harvests were recorded and calculated as the ratio of marketable yield to marketable number. Fruit texture were measured using five randomly taken ripe fruits for each treatment plot from central rows at third harvest sing a hand penetrometer. Dry matter content (DM %) content was estimated after the whole fresh fruit weight was taken from the sample plants and chopped into pieces. The chopped sample fruit was oven dried at 70 0 C to a constant weight. The dried samples were re-weighted to calculate the percent dry weight. Total soluble solids (TSS) was measured from randomly taken ripe fruits at second harvest using A hand refractrometer (An Atago N, LosAngeles, USA) with range of

0 to 30 oBrix and resolution of 0.2 oBrix. Partial budget analysis was performed to evaluate the economic advantage of the different N treatments following the procedure of Upton (1979). The partial budget analysis involved calculation of the variable costs and benefits. At the beginning of the experiment market prices of N fertilizer was obtained from the bureau of agriculture and rural development. The price of N fertilizer (urea) purchased 368.50 ETB/quintal, and was used for the partial budget analysis.The model used for the analysis was:

Net return (NR) = Total Returns (TR) – Total Variable Costs (TVC).

A total of nine pre-plant samples (0-30 cm) were taken from the entire experimental field and analyzed for pH (1:2.5 soils to water ratio) (Jackson, 1958), percent of sand, silt and clay using hydrometer method, total N content using Kjeldahl method (Bremner and Mulvaney, 1982) and available phosphorus by the Olsen extraction method (Olsen et al., 1954). Organic carbon was determined by the wet digestion methods (Walkley and Black, 1934). Soil samples from at the same depth were also taken just after harvesting from each plot for estimation of total nitrogen and organic carbon.

The JMP-5.1 software was used for statistical analysis.

3 Results and Discussions

3.1 Pre-plant soil fertility

The results of pre-plant indicated that the experimental site was silt clay loam in texture (18.56% sand, 41.48% silt, 39.96% clay) with pH (H_2O) of 8.64, organic matter content of 3.11%, total N of 0.18 %, available P of 18.86 ppm, and CEC of 41.86 cmol (+)/kg soil (Table 1). According to Sahlemedihn (1999), values up to 0.2% for total N and 2.0 - 4.2% for OM of soil were considered as low and medium, respectively. Thus, the OM content of the site was in the medium range and the total N was in the low range. Cation exchange capacity of the site was 41.86 cmol (+)/kg which was very high and satisfactory for crop production.

Table 1. Selected physical and chemical soils properties of the Alamata experimental site

Soil PH	OC (%)	OM (%)	CEC cmol(+)/kg	Total N (%)	Available P (ppm)	Particle size distribution (%)		
						sand	Silt	Clay
8.64	1.81	3.11	41.86	0.1806	18.86	18.56	41.48	39.96

3.2 Total Soluble Solid (TSS)

Total soluble solid (TSS) content of the marketable fruits was showed significant difference among the nitrogen treatments (Table 2). Plots treated with the highest N rate (230 kg N /ha) had highest TSS content (4.27 0brix) compared to control (l3.37 0brix). Thus, increasing the level of N increases the TSS content of the fruits. This may be due to the characteristics role of N, which usually plays in increasing the amount of foliage, the quantity of chlorophyll, and ultimately the photosynthetic activity of the plant. Plant population alone as well as its interaction with nitrogen fertilizer did not show any significant difference on TSS content of the fruits.

3.3 Fruit Dry Matter Content

Tomato dry matter percentage was significantly influenced by both N rate and plant population independently (Table 2). The highest mean dry matter content (6.57%) of the tomato fruit were noted at 230 kg N/ha compared to the control (4.5%) fertilizer application. The possible reason for the highest fruit dry matter content in intermediate and higher N rate could be due to vigorous vegetative growth resulting in more photosynthetic product which was partitioning to the fruit. Similarly, the effect of plant population on tomato fruit dry matter percentage was also significant ($P < 0.05$). The highest dry matter percentage (3.36%) was obtained from the lower plant population compared to the higher plant population (5.61%) and this is because of higher vegetative development in the lower plant population per each plant. For most forms of tomato processing, the higher dry matter content of the raw product, the highest the yield of the finished product. Therefore, processors typically set a minimum dry matter content below which they will refuse to purchase the tomatoes. Dry matter content is important even for the fresh market. Tomatoes with low dry matter content will have a watery texture, those high in dry matter will be more dry meaty and will have relatively longer storage life. High dry matter content is associated with high levels of irradiance, temperature, fertilization and other cultural practices (Ewing, 1997).

3.4 Fruit Size

Application of N fertilizer significantly influenced size of the fruits (Table 2). The nitrogen rate of 92 kg/ha had highest fruit width (4.5 cm) compared to the control (4.1cm). Possible reasons for the size reduction could be the competitions for photosynthetic product among the high number of fruits per plant which was induced by higher N rates. At lower N rates reduced fruit sizes may be due to poor vegetative growth resulting in inadequate partitioning of assimilates to the fruits. This result agrees with findings of Girmachew (2007), who indicated that width of tomato fruits increased with increased N rates up to 100 kg/ha and decreases beyond that. Furthermore, it is known that fruit size is dependent on assimilate distribution which is controlled by the activity of both source and sink. Thus, where low assimilate production leads to competition between vegetative and reproductive parts, that is, among the inflorescences, and fruit sizes suffer severely on the same truss (McAvoy etal., 1989; Wein, 1997). Similarly, plant population had a significant ($P < 0.05$) difference on fruit size of tomato (Table 2). The wider inter row spacing, lower plant population, produced larger fruit sizes 4.81 cm) than the denser plant populations (3.87 cm). This could be due to the fact that the lower plant population had a wider spacing to produce more photosynthetic area. However, the N rate by plant population interaction did not significantly ($P > 0.05$) influence fruit size, although lower plant population treated with 138 kg N / ha recorded higher fruit size as compared to the other treatment combinations.

TABLE 2. EFFECT OF N RATES AND PLANT POPULATION ON FRUIT QUALITY OF TOMATO IN ALAMATA

Treatment	Fruit quality		
Nitrogen rate(kg/ha)	TSS 0 Brix	Dry matter %	Fruit Diameter (cm)
0	3.37	4.5	4.122
23	3.74	5.4	4.193
46	3.63	6.22	4.424
92	3.78	6.33	4.522
138	3.69	6.42	4.454
184	3.97	6.45	4.335
230	4.24	6.57	4.306
SE±	0.17	0.39	0.07
LSD (P<0.05	0.48	0.79	0.19
Plant population NO_ / ha)			
33,333	3.74	6.36	4.807
55,555	3.81	5.61	3.866
SE±	0.09	0.21	0.04
LSD (P< 0.05	Ns	0.6	0.1
CV %	10.5	16.05	3.64

Non significant (Ns); total soluble solid (TSS)

3.5 PARTIAL BUDGET ANALYSIS

The partial budget analysis for the N fertilizer trial is depicted in Table 3, which involved the evaluation of overall profitability of each levels of fertilizer. From the result obtained, the analysis for N rate indicated that the 138 kg / ha applied N level returned a higher profit margin than the other treatments including the non-fertilized plot. On the other hand, the lowest N level (0 kg N / ha) had a negative and lowest net return. The net return (NR) from the N fertilizer application treatment was 41379, 45918, 61236, 74484, 57987 and 52485 ETB with marginal rate of return (MRR) of -105.75, 953.69, 2390.84, 2756.42, 1044.91, and 559 for 23, 46, 92, 138, 184, and 320 kg/ha, respectively. The maximum net return (74484 ETB/ha) was obtained from 138 kg N/ha compared to control (41655). This means each additional unit of 1 Birr per fertilizer cost increment resulted in additional 9.54, 23.91, 27.56, 10.44 and 5.60 ETB benefit for 46, 92, 138, 184, and 320 kg N/ha, respectively. Assuming that capital is not a constraint, the technology with the highest net return is chosen. However, new technologies normally require investment, therefore additional capital is necessary. When capital is limited, the extra (marginal) cost should be compared with the extra (marginal) net benefit. The application of 138 kg N/ha has got higher net return compared to the control. The difference in the net return per treatment was due to the difference in fruit yield of the crop in each treatment, which can be affected by the difference in N rate application. The higher NR and MRR in 138 kg N/ha was due to the optimum N supplementation, which resulted in higher marketable fruit yield (50.45 ton / ha) as compared to the other treatments. This indicates that the optimum amount of N fertilizer received result in higher fruit yield and better net return from same area of land. In a nutshell, the result of this study suggested that application of 138 kg N/ha was the optimum rate of N fertilizer for tomato in the study area is potentially more profitable and economically beneficial than the other level of fertilization.

TABLE 3. PARTIAL BUDGET ANALYSIS OF THE N FERTILIZER RATE EXPERIMENTAL TRIAL IN ALAMATA

N-rate(Kg N /ha)	0	23	46	92	138	184	230
Fertilizer application cost (ETB)	0	75	75	75	75	75	75
Transport cost (ETB)	0	2	4	8	12	16	20
Fertilizer cost (ETB)	0	184	368	736	1104	1472	1840
TVC (ETB)	0	261	447	819	1191	1563	1935
Marketable yield(kg/ha)	27770	27760	30910	41370	50450	39700	36280
TR (ETB/ha)	41655	41640	46365	62055	75675	59550	54420
NR (ETB/ha)	41655	41379	45918	61236	74484	57987	52485
ΔTVC	-	261	447	819	1191	1563	1935
ΔTR	-	-15	4710	20400	34020	17895	12765
ΔNR	-	-276	4263	19581	32829	16332	10830
MRR (ratio)	-	-1.06	9.54	23.91b	27.56a	10.45	5.6
MRR %	-	-105.75	953.69	2390.8	2756.4	1044.91	559.69

Total variable cost(TVC), Total return(TR), net return (NR), change total variable cost (ΔTVC), change total return(ΔTR), change net return(ΔNR).MRR % = Marginal Rate of return with respect to the control (0 kg N /ha).
ETB= Ethiopian birr. 1 quintal (100kg)Urea= 368.50 ETB using 2008/2009 exchange rate

4 CONCLUSIONS

Pre-sowing surface soil analysis, fruit quality parameters, yield and partial budget analysis for N were investigated. Analysis of surface soil sample revealed the soil to be silt clay loam in texture with pH of 8.64. The soil was low in total N (0.1806), and medium in OM. CEC of the experimental site (41.86 Coml.(+)/kg) was very high and considered to be satisfactory for agriculture with the use of fertilizer. The analysis of marketable tomato fruit yield per hectare was significantly affected by both the main effects of N rates and plant population independently. The highest mean marketable and total tomato fruit yield was obtained in 138 kg N/ha as compared to the lowest mean marketable yield recorded in the check and 23 kg N/ha. Similarly, the marketable fruit yield significantly enhanced due to higher plant population compared the lower plant population. The fruit quality parameters; TSS, DM and fruit size showed significant difference among the treatments. Increasing the level of N increased the TSS content of the fruit. Maximum TSS and DM content (4.27 0Brix, 6.57% respectively) was abstained from the highest N application (230 kg/ha). However, higher fruit diameter (4.52 cm) was abstained at 92 kg N/ha compared to the control. Similarly, plant population was also showed significant effect on the DM content and size of the fruit. From the partial budget analysis the higher NR (74484 ETB/ha) and MRR (2756.42%) in 138 kg N/ha was due to the optimum N supplementation, which resulted in higher marketable fruit yield (50.45 ton/ha) as compared to the other treatments.

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REFERENCES

[1] Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen Total. In: page AL (Eds.). Method of soil Analysis: Part 2. Chemical and Micro-Biological properties.Ameri. Soci. Agronomy. Madison, Wisclusa. 12: 595-624.

[2] Ethiopian Fruits and Vegetables Enterprise. Annual report. 1984 - 1987.

[3] Ewing, E.E. 1997. Potato. In: Wien, H. C. 1997.The physiology of vegetable crops.Cab international.USA.FAO. 1994. FAO production year book, vol.47, 1993. Food and Agriculture organization, Rome.

[4] FAO. 2007. Integrated plant nutrition information system. Retrieved April10, 2007, from http://www.fao.org/ag/agl/agll/ipnis/districtdata.asp?districtid=ETH011003??6 - 14k –

[5] Girmachew T. 2007. Effects of Planting Methods and Nitrogen Rate on Yield and Quality of Tomato. MSc Thesis submitted to the school of graduate studies, Alemaya University, Ethiopia.

[6] Jacson, M.L., 1958. Soil chemical analysis. Prentice-Halls Inc., Madison, Wisconsin, USA p.545-566.

[7] McAvoy, R.J., H.W., Janes, B.L. Godfriaux, M. Secks, D. Duchai and W.K. Wittman, 1989. The effect of total available photosynthetic photon flux on single truss tomato growth and production. J. Hort. Sci. 64: 331-338.

[8] Ministry of Agriculture. 1988. Agriculture development department horticulture section survey data.

[9] Olsen, S.R., C.V. Cole, F.S. Watenabe and L.A. Dean, 1954. Estimation of available phosphorus in soils by extraction with Sodium Bicarbonate. U.S. Government Printing office, Wash. Circular no. 939. 19:99-105.

[10] Rick,C.M. 1978. The tomato. Scientific American Journal. 239(8), 67-76.

[11] Sahlemedhin Sertsu, 1999. Draft guideline for regional soil testing laboratories. NFIA, Addis Abeba, Ethiopia.

[12] Sims,W. et al. 1979. Mechanized growing and harvesting of processing tomatoes. University of California leaflet No.2686.

[13] Upton, M. 1979.Farme management in Africa: The principle of production and Planning. Oxford university press, Great Britain. Pp.

[14] Walkey, A. and I.A. Black, 1934. An experimentation of the digestion method for determination of organic matter and proposed modification of the chronic acid titration methods. Journal of Soil Science. 37:29-38.

[15] Wendmu, B. and A. Getachew. 1997. Soil management and crop technologies for improved crop production. In: Beyene S. and D. Abera (eds.) 1998.Agricultural research and technology transfer attempts and achievements in northern Ethiopia. Proceedings of the forth technology generation, transfer and gap analysis workshop. 18-21 March 1997,Bahir Dar Ethiopia.

[16] Wien, H.C., 1997. The Physiology of Vegetable Crops. CAB International, UK. 662p.

APPENDIX

APPENDIX 1. ANALYSIS OF VARIANCE FOR FRUIT LENGTH (FL), FRUIT WIDTH (FW), TOTAL SOLUBLE SOLID (TSS), FIRMNESS AND DRY MATTER (DM) OF TOMATO

Source of variation	DF	Mean Square				
		FL (cm)	FW(cm)	TSS 0Brix	Firmness (kg)	DM (%)
Replication	2	0.419	0.02	0.475	1.846	1.153
Plant population (A)	1	0.027	9.302**	0.053	0.316	5.802*
N - rate (B)	6	0.096	0.124**	0.448*	1.001	3.475*
AB	6	0.098	0.025	0.045	3.924	0.621
Error	32	0.138	0.025	0.194	2.08	0.981
C. Total	41					

***, * = Statistically significant at P< 0.01 and P<0.05 levels respectively.*

APPENDIX 2. SIMPLE CORRELATION COEFFICIENT AMONG DIFFERENT PARAMETERS

	Leaf NO./m2	2 0 branch e/m2	LAIf	LAIm	Shoot Dm/m2	Fruit DM/m2	TotalD M/m2	MFY	MFNo./ha
Leaf NO./m2	__								
2 0 branche/m2	0.9433**	_							
LAIf	0.8429**	0.9036**	_						
LAIm	0.8928**	0.9246**	0.9576**	_					
Shoot Dm/m2	0.6253**	0.6512**	0.7869**	0.7582**	_				
Fruit DM/m2	0.567***	0.547***	0.6826**	0.6785**	0.7258**	_			
Total DM/m2	0.646***	0.6543**	0.7998**	0.7795**	0.9561**	0.8956**	_		
AFW	-0.26	-0.27	-0.08	-0.12	-0.23	-0.08	-0.18		
MFY	0.6699**	0.7371**	0.7345**	0.7522**	0.6821**	0.5907**	0.6929**	_	
MF No./ha	0.5748**	0.6418**	0.6419**	0.5958**	0.6071**	0.4236**	0.5732**	0.7102**	_
TY	0.679***	0.7457**	0.7368**	0.7546**	0.6818**	0.5876**	0.6913**	0.9997**	0.7154***

PH = plant height,, LAIF = leaf area index at flowering, LAIM = leaf area index at maturity, DM = fruit dry matter, AFW =Average fruit width, MFY = marketable fruit yield, MFN = marketable fruit number, NMY = non marketable yield, NMFNo. = non marketable fruit number, TY = total yield

, **, * = Statistically significant at P< 0.05, P<0.01and P< 0.001 levels respectively*