academicresearchJournals

Vol. 6(7), pp. 380-391, September 2018
DOI: 10.14662/ARJASR2017.022

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Response of Tomato (*Solanum lycopersicum L*) to Foliar Application of Humic Substances and Potassium Fertilizer in the Central Rift Valley of Ethiopia

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Accepted 21 September 2018

The effectiveness of foliar application of humic substances including 22.5 % total humic and fulvic acid with 7.1 % water soluble potassium oxide (HFA) was evaluated in the Central Rift Valley of Ethiopia on tomato (*Solanum lycopersicum* L.) (chali variety) at Melkassa, Meki and Merti. Different levels of HFA liquid fertilizer in combination with chemical fertilizer were evaluated for two consecutive cropping seasons (2015-2017). The experiment was laid out in randomized complete block design and replicated three times. The product solution was prepared as per factory (ES'SERRA®) recommendations (2.5 L of the product in1000L of water per hectare with and/or without, half, full doses of inorganic fertilizers applied in band) and as foliar spray at five different growth stages (before flower initiation and after fruit setting). The result revealed that foliar application of 1.25L and 1.875 L ha^{-1} humic and fulvic acid and recommended rate of NPK (46N, $46P_2O_5$ and $51K_2O$ kg ha^{-1}) and 2.5L ha^{-1} of humic and fulvic acid and half recommended rate of NPK (23N, $23P_2O_5$ and 25.5 K_2O kg ha^{-1}) significantly improved tomato marketable yield by 34.5, 28.7 and 40.5% at Merti, and at Melkassa foliar application of 2.5L of HFA plus half rr NPK fertilizers boosted the tomato marketable yield by 20%. At Meki the tomato marketable yield was improved by the foliar application of humic substances up to 60% though statistically not significant. The partial budget analysis also indicated that the application of 2.5L ha^{-1} of HFA and half rr of NPK (23N, $23P_2O_5$ and $30K_2O$ $kgha^{-1}$) gave maximum marginal rate of return 741.1% with highest net benefit at Melkassa. At Merti also this rate gave the maximum marginal rate of return 1587.33% with highest net benefit.

Key words: foliar application, humic and, fulvic acid, band application, marginal rate of return

Cite this article as: Israel, B., Gebreyes, G. (2018).Response of Tomato (Solanum lycopersicum L) to Foliar Application of Humic Substances and Potassium Fertilizer in the Central Rift Valley of Ethiopia. Acad. Res. J. Agri. Sci. Res. 6(7): 380-391

INTRODUCTION

Organic inputs contain nutrients that are released at a rate determined in part by their chemical characteristics or organic resource quality. However, organic inputs applied at realistic levels seldom release sufficient nutrients for optimum crop yield. Combining organic and mineral inputs has been advocated as a sound management principle for smallholder farming in the tropics because neither of the two inputs is usually available in sufficient quantities and hence both inputs are needed in the long term to sustain soil fertility and crop production (Fairhurst. 2012).

For the soil having low organic carbon content like Ethiopia, integrated application of organic and inorganic sources of input is very important in scaling up agricultural production and productivity. Utilization of organic-mineral fertilizers in agriculture has increased currently (Doran, 2003). One of the common organic-mineral fertilizers is humic substances. Humic substance is a commercial product that contains many elements which improve the soil fertility status and increase the availability of nutrients and consequently increase plant growth and yield.

Humic substances (Humic acids and Fulvic acids) improve growth and yields of different crops including vegetables (Atiyeh *et al.,* 2002; Zandonadi *et al.,* 2007). Among different mechanisms in vegetable crops, one of which was their beneficial effects on nutrient uptake (Akinremi *et al.,* 2000; Cimrin and Yilmaz, 2005; Zandonadi *et al.,* 2007), humic substances (HSs) have been suggested to account for this stimulatory effect.

The foliar application of humic acid (HA) to tomato and other crops generally shows beneficial effects on growth and yield parameters. Effects of HA extracted from leonardite or peat on tomato plants found that growth was stimulated based on fresh weight, as was general ion uptake especially that of Fe, investigated by Adania et al. (1998). Similarly, foliar and soil application of HA has resulted in an increase of early yield, and total yield in tomato (Yildirima, 2007). Karakurt et al. (2009) reported applied HA by spraying and drenching increased mean and total fruit weights in peppers. It has also been demonstrated that HA could serve as growth regulators to control hormone levels, enhance plant growth and increase stress tolerance (Stevenson, 1982; Serenella et al., 2002). Moreover, studies explaining the effects of HA suggested that its effect is demonstrated through increasing enzyme catalysis, enhancing respiration and photosynthesis, and stimulating nucleic acid metabolism (Dell'Agnola and Nardi, 1987; Nardi et al., 1988; Muscolo et al., 1999; Serenella et al., 2002). Although positive influence of HAs on plant growth and development have been well established for many species (Atiyeh et al., 2000, 2002; Dursun et al., 2002; Turkmen et al., 2004).

There are many benefits of using humic substances for growing crops. Their primary asset is how they naturally facilitate the crop's absorption and use of nutrients. Fulvic acids are natural chelates. When they are introduced to the soil, the fulvic acids form bonds with the micronutrients to protect them from reacting with other ions in the plant's environment and potentially being overpowered by them. Bonded to the chelate, the nutrients can travel up the plant's roots into its tissue, where the chelator can release them.

Chelation makes otherwise insoluble nutrients soluble, increasing their bioavailability to crops. In addition to making more nutrients available to the crops, humates promote root growth. More roots mean more avenues for nutrient absorption for the crops, and within those avenues, chelators carry and protect the building blocks for healthy and hardy crops.

The Humic substance effects on fruit yield especially integrated with and without inorganic fertilizers on tomato have not received much attention in Ethiopia. Therefore, this study was initiated to evaluate the effectiveness of the foliar application of organic liquid fertilizer Humic and Fulvic acid as a supplementary nutrient required for tomato production in different areas of the Central Rift Valley (CRV) of Ethiopia under irrigation condition, and to see the economic feasibility of the new product for the production of tomato in the study areas

MATERIALS AND METHODS

Area Description

The study areas are located in the Central Rift Valley of Ethiopia. Merti is situated at Merti Jeju District 210 km away from Addis Ababa, 08°37' North latitude and 39°45' East longitude with the altitude of 1443 meter above sea level (masl), Meki is located at Dugda District 130km away from Addis Ababa, 08°09' North latitude and 38°50' East longitude with the altitude of 1634 masl. Melkassa is located at Adama District about 107km away from Addis Ababa, 08°25' North latitude and 39°19' East longitude with the altitude of 1540 masl. The textural class of soils at the study areas are: loamy (Melkassa), sandy clay loam (Merti) and sandy loam (Meki) and slightly alkaline in reaction. The areas are continually cropped with onion, tomato and maize. The quality of irrigation water used (Awash River) at Melkassa and Merti areas was soft water (EC < 0.50 dS/m).

Treatment arrangement and preparation of Spray Solutions

Humic and Fulvic Acid (HFA) which is organic liquid fertilizers is composed of 45 % total organic matter, 22.5 % total humic and fulvic acids, 1.76 % total nitrogen (TN), 0.25 total phosphorus penta oxide (P_2O_5) and 7.1 % water soluble potassium oxides (K_2O)(Table 1)

Treatments application method: Humic Acid **(**HA) and Fulvic Acid (FA) was measured and mixed into a 2 liter pressurized hand sprayer with a single applicator nozzle and sprayed until the leaves of the tomatoes were sufficiently wetted. Triple supper phosphate (TSP) and Murate of potash (KCl) were applied as basal fertilizers, whereas half urea was applied during planting and the remaining half rate was top dressed after a month of transplanting tomato.

The gross experimental plot size was 3m by 3.3m having five rows of tomato and 10 plants per row and thus having a total of 50 plants per plot (50,000 plants/ha). The tomato variety used was Chali.

Three middle rows were considered for data collection and measurement. All agronomic practices, fertilizer application and other crop management practices were used accordingly.

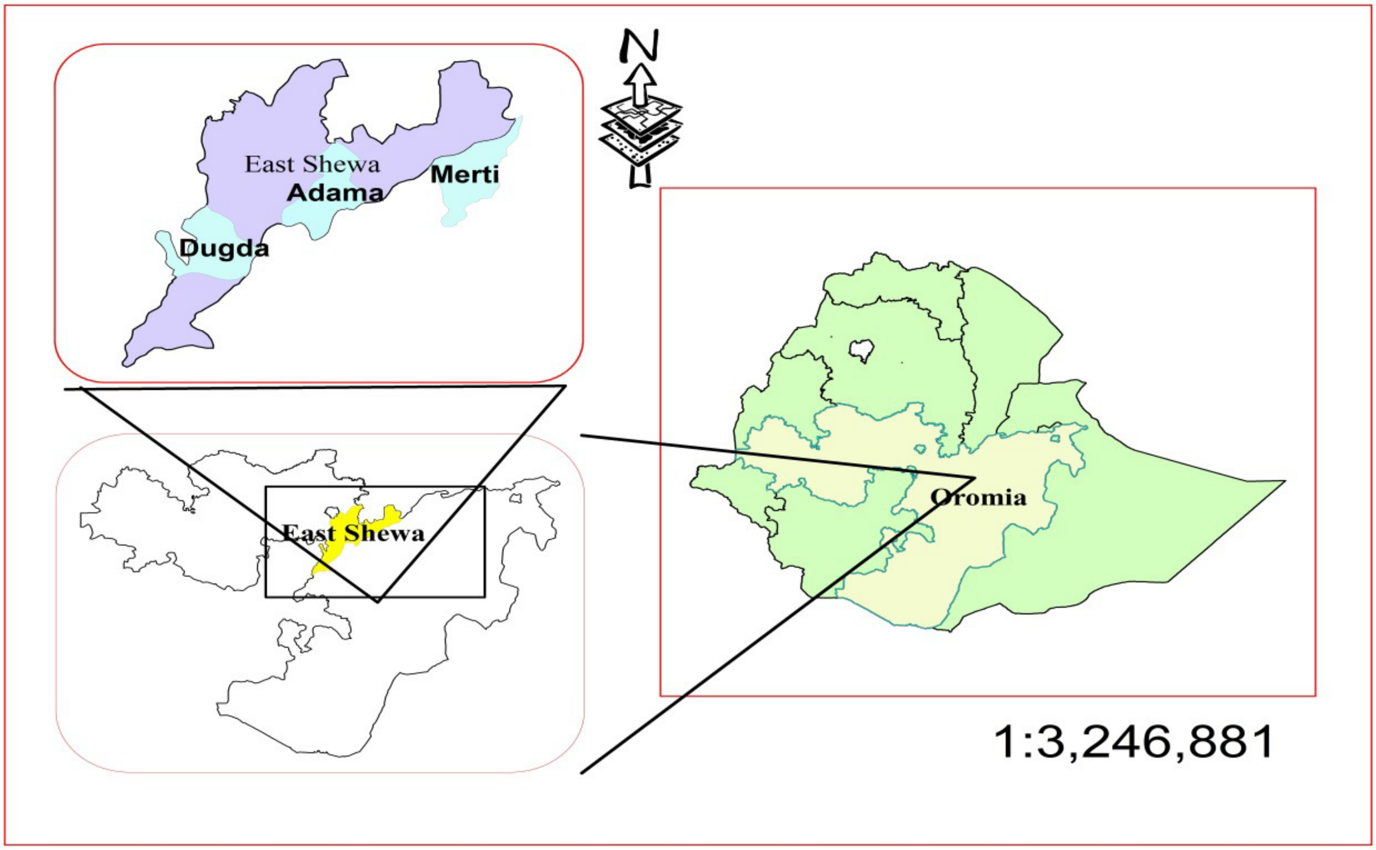

Figure 1: Study location, Oromia Region, Ethiopia

Table 1: The analysis result of the product (ES'SERRA) and analytical method

The analysis	Result/Unit	Analysis Method
Total Humic-Fulvic Acid	22.5%w/w	TS 5869 ISOm5073 January2003
Total OM	45.00%w/w	AOAC1995 (70®CHumid550"C Dry Firing)
Organic nitrogen	1.76%w/w	1965 Bremner
Total P_2O_5	0.25%w/w	Mitschella1972
Water soluble K_2O	7.1%w/w	Gravimetric
pH	6.54	Gravimetric

NB: Cevirme KONYA LABORATUVAR DEPOCULKAS, AGRICULTURAL LABORATORY ANALYSIS.

The detail treatment plan and appropriate treatment application period (at crop development stage) are shown below. The treatments were arranged in randomized complete block design (RCBD) with three replications. Applications of HA and FA was based on the product formulation and recommendations (Table 2 & 3).

Soil Sample Collection and Analysis

Composite soil samples were collected from 0-20cm depth before planting from all experimental sites using auger. Soil sub-samples of each experimental site were mixed in plastic bags to make one composite sample per trial site that makes a total of three composite samples. The soil samples were prepared according to the usual procedure and brought to laboratory for analysis.

Particle size distribution of the soil samples was determined by hydrometer method (Bouyoucos, 1962). Soil bulk density was determined on the undisturbed core sampling method after drying the soil samples in an oven at 105^{o}C to constant weights (Blake and Hartge, 1986). Potentiometric method using a glass calomel combination electrode was used to measure pH of the soils in water

Table 2: Treatment arrangement

No	Treatments
1	Control (No fertilizer)
2	100% Recommended Rate of NPK (64 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 + 51 kg ha^{-1} K_2O)
3	100% Recommended Rate of HFA (2.5L in1000L of water ha^{-1})
4	50% Recommended Rate of HFA and 100% Recommended Rate of NPK
5	75% Recommended Rate HFA and 100% Recommended Rate of NPK
6	100% Recommended Rate of HFA and 50% Recommended Rate of NPK
7	150% Recommended Rate of HFA
8	200% Recommended Rate of HFA

Table 3: Spray Schedule and Date of Planting Tomato (2015-2017)

	Merti	Melkassa	Meki	Merti	Melkassa	Meki
Planting Date	8/10/15	12/10/15	22/10/15	30/08/16	18/02/17	17/02/17
Spray						
1st	22/10/15	26/10/15	05/11/15	13/09/16	03/03/17	03/03/17
2nd	05/11/15	10/11/15	19/11/15	28/09/16	17/03/17	17/03/17
3rd	19/11/15	25/11/15	03/12/15	12/10/16	31/03/17	31/03/17
4th	03/12/15	10/12/15	17/12/15	26/10/16	13/04/17	13/04/17
5th	17/12/25	25/12/15	31/12/15	09/11/16	27/04/17	27/04/17

Suspension in a 1:2.5 (soil: water ratio) (Van Reeuwijk, 1992). Electrical conductivity (EC) was measured using a conductivity meter from the same soil water suspension extract. The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon (OC) content. Total nitrogen content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was determined using the standard Olsen *et al*. (1954) extraction methods. The absorbance of available P extracted was measured using spectrophotometer after color development.

Exchangeable cations (Ca, Mg, K and Na) were determined after extracting the soil samples by 1N neutral ammonium acetate (1N NH_4OAc) solution adjusted to a pH 7.0. Exchangeable Ca and Mg in the extract were measured by atomic absorption spectrophotometer (AAS) whilst K and Na were determined using flame photometer from the same extract (Okalebo *et al.,* 2002). Cation exchange capacity of the soils was determined from the ammonium acetate saturated samples through distillation and measurement of ammonium using the modified Kjeldhal procedure as described by Okalebo *et al.* (2002). Micronutrients (Fe, Mn, Zn, and Cu) were extracted by Di-ethyl Tri-amine Penta-acetic acid (DTPA) as described by Tan (1996) and all these micronutrients were measured by AAS. The methods used for available phosphorus, exchangeable bases and available micronutrients were Mehlich-3 extraction and the extract was read using ICP.

Data Analysis and Interpretation

The collected data were subjected to analysis of variance using Statsix 10 software program. Tests of difference between and among treatment means were assessed using the Least Significant Difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984). Standard values reported by Cottenie (1980), FAO (2006), Jacobsen *et al.* (2005), Jones and Benton (2003),Landon (1991), Marx *et al.* (1999), Tekalign (1991) were used as soil analysis result guide for diagnosing nutrient status of the soil in the test sites.

Partial budget analysis was performed to investigate the economic feasibility of the treatments after checking for the presence of significance difference in the mean fruit yields of tomato among the treatments. Dominance, sensitivity and marginal analyses were performed. The average yields were adjusted downwards by 10%, to reflect the difference between the experimental plot yield and the yield farmers expect from the same treatment.

The average open market prices for tomato (5.00 ETB kg^{-1}), for TSP (17.00 ETB kg^{-1}), Urea (14.00 ETB kg^{-1}), Murate of potash (15.00 ETB kg^{-1}) and humic and fulvic acid fertilizer with its trade name ES'SERRA was 100.00 ETB L^{-1}. Accordingly, fertilizers inputs were considered as variable costs and all others were considered as constant factor for all treatments. The minimum acceptable marginal rate of return (MRR) was set at 100% based on the suggestion by CIMMYT (1988). Sensitivity analysis outputs were conducted by assuming an

Table 4. Soil analysis result of the testing sites

		Locations			Location				
Parameters	**Units**	**Meki**	**Merti**	**Standards**	**Rating**	**Melkassa**	**Rates**	**Standards**	**Methods**
Sand		572.5	617.5						
Clay	g kg^{-1}	127.5	180						
Silt		300	202.5						
Textural Class		SL	SL			SCL			
BD	g cm^{-3}	1.14	1.30		Low-Medium	1.1	Low		
pH (water)		8.2	8. 3	Jones and Benton (2003)	M. alkaline	7.58	S. alkaline	Jones and Benton (2003)	ISO 10390
EC	dS m^{-1}	0.58	0.37	Jones and Benton (2003)	Low	0.58	Low	Jones and Benton (2003)	ISO 10390
AP	mg kg^{-1}	29.75	15.14	Cottenie (1980)	High-Medium	20.29	Medium	Jones and Benton (2003)	Mehlich-3
TN	g kg^{-1}	1.8	2.4	Tekalign (1991)	Medium	1.0	Low	Jones and Benton (2003)	Kjeldahl Method ISO 1261
OC		10.1	10.3	Tekalign (1991)	Low	12.0	Medium	Charman and Roper (2007).	Walkey and Black Method
Na		0.07	0.93	FAO(2006)	Low-high	0.48	High	FAO(2006)	
K		3.90	2.56	FAO(2006)	V. High	2.52	V. High	FAO(2006)	Mehlich-3
Ca		18.42	21.05	FAO(2006)	high	16.38	High	FAO(2006)	
Mg	Cmol(+)kg^{-1}	4.93	3.17	FAO(2006)	high	3.05	High	FAO(2006)	
CEC		33.24	44.56	Landon (1991)	High-V. High	-			Kjeldahl Method ISO 1261
Cu		1.17	1.07		High	1.19	High		
Fe		17.08	2.79	Jones and Benton (2003)	V. Hgh-Low	81.26	V. high	Jones and Benton (2003)	
Mn		25.53	3.99		V.High	237.45	V.high		
Zn	mg kg^{-1}	2.19	0.27		High-Low	2.25	High		Mehlich-3
S		-	-			8.65	Medium	Marx. et,al, 1999	
B		-	-			0.58	Medium	Jacobsen et al., 2005.	
Al		-	-			855.46			

increase or decrease by 15% (scenario 1) and decrease or increase both the price of fertilizers and tomato by 15 % (scenario 2)

RESULT AND DISCUSSION

Initial physico-chemical Analysis of soils

The soil analysis result of the study sites depicted that the soil reaction of the study sites were rated from slightly to moderately alkaline (Benton, 2003) whereas the electrical conductivity is rated as low. The available P and Total N were medium to high and low to medium respectively (Cottenie, 1980; Tekalign, 1991; Jones and Benton, 2003). Organic carbon was low to medium (Tekalign, 1991). The exchangeable bases except Na at Meki were high to very high in all experimental sites (FAO, 2006). The CEC of the testing sites for Meki and Merti were high according to Landon (1991). According to the standard given by Jones and Benton (2003), the micronutrient status was low to very high. Sulfur and boron contents of the soils at Melkassa were rated as medium (Marx.E.S et al., 1999 and Jacobsen et al., 2005).

Tomato Total Yield

The result of application of humic and fulvic acid (HFA) alone and with inorganic NPK fertilizers on tomato total

Table 5: Tomato total minimum and maximum yield and mean yield with standard deviation as influenced by the application of Humic and, fulvic acids with and without NPK fertilizers at Melkassa. Meki and Merti

Treat	Melkassa		Meki		Merti	
	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD
			Mtha^{-1}			
Control (No fertilizer)	12.52-30.09	19.75±7.12^{cd}	9.86-33.56	18.84±7.91^{c}	8.97-19.07	15.30±3.49^{d}
Rec. NPK	17.64-45.60	26.90±9.86^{ab}	10.42-40.86	25.74±11.78^{bc}	18.85-33.62	25.02±5.08^{bc}
Rec. HFA (2.5Lha^{-1})	12.17-26.10	18.54±5.36^{d}	15.97-33.69	22.01±6.81^{bc}	18.10-29.09	22.28±4.25^{c}
50% Rec. HFA (1.25L ha^{-1})+ Rec. NPK	16.12-37.47	26.39±9.93^{ab}	21.47-48.53	30.32±9.80^{ab}	28.19-38.54	32.37±4.22^{a}
75% Rec. HFA (1.88L ha^{-1}) + Rec. NPK	20.58-35.95	26.84±5.65^{ab}	24.97-57.83	38.49±12.18^{a}	23.39-36.86	30.03±5.68^{ab}
150% Rec. HFA (3.75L ha^{-1})	13.87-33.08	21.86±7.93^{abc}	14.75-41.56	28.81±8.97^{abc}	10.67-26.83	20.60±5.48^{cd}
Rec. HFA (2.5L ha^{-1}) +50% Rec. NPK	11.77-41.97	29.67±12.10^{a}	17.90-42.71	29.07±9.61^{abc}	20.51-47.35	33.63±8.66^{a}
200% Rec. HFA (5L ha^{-1})	14.28-36.03	25.96±7.49^{abc}	13.90-38.06	26.33±10.44^{bc}	16.31-25.21	21.09±3.19^{cd}
CV (%)		**22.08**		**35.7**		**21.05**
LSD$\leq$0.05		**6.32**		**11.45**		**6.16**

CV= Coefficient of Variability; LSD= List Significant Difference at the 5% level, Mtha^{-1} = Metric ton per ha; Rec.HFA= recommended rate of humic and fulvic acids, Rec.NPK= Recommended rates of NPK

and marketable yield is presented in Table 5 and 6.

The analysis of variance over years revealed that at Melkassa research station tomato total yield significantly influenced ($p<5\%$) by the application of recommended HFA with half recommended NPK fertilizers and it improved the yield by 10% (Table 5).

At Meki, the application of 50% HFA (1.25L ha^{-1}) and 75% HFA (1.875L ha^{-1}) with 100% recommended rate of NPK; and 100% HFA (2.5L ha^{-1}) with 50% recommended NPK boosted tomato total yield significantly ($p<5\%$) by 17.8%, 49.5% and 12.9% respectively, as compared to the 100% recommended rate of NPK fertilizers (Table 5).

At Merti, tomato total yield was increased significantly ($p<5\%$) by 20% due to application of 75% HFA with 100% NPK while it gave 29.4% yield advantage by the application of 50% HFA with 100% NPK. A 34.4% yield increase was also recorded by application of 50% HFA with 50% NPK all being compared with the 100% NPK (Table 5).

Tomato Marketable Yield

The analysis of variance over years revealed that at Melkassa the foliar application of 100% HFA with 50% recommended NPK fertilizers influenced tomato marketable yield significantly ($p<5\%$). The application of this rate boosted the tomato marketable yield by 20% when compared with 100% recommended NPK fertilizers.

At Merti, tomato marketable yield was significantly increased ($p<5\%$) by 28.7%, 34.5% and 40.5% due to application of 75% HFA with 100% recommended NPK fertilizers; 50% HFA with 100% recommended NPK fertilizers; and 100% HFA with 50% recommended NPK fertilizers respectively when compared with the 100% recommended inorganic NPK fertilizers (Table 6). Similar findings were observed in tomato fruit by Atiyeh *et al.* (2002) who determined that Humic Acid treatment at different concentrations significantly boosted tomato yield. Also, improvement in yield, and fruit quality characteristics in response to Humic Acid treatment are also reported by Adani et al. (1998) and Padem and Ocal (1999).

At Meki, application of 75% of HFA with 100% recommended NPK, 150% HFA alone and 100% HFA with 50% recommended NPK boosted tomato marketable yield by 66.5, 28 and 22.6% respectively as compared to the 100% recommended inorganic NPK fertilizers though not significantly different from each other ($p>5\%$). In agreement to this study, Dogan and Demir (2004) reported that tomato yield is not significantly influenced by the addition of Humic Acid.

As clearly observed from the above results, the response of the test crop (tomato) to the application of humic substances does not have clear pattern and it differs with locations ascribed to several chemical and soil factors. The above finding is line with the reports of Mylonas and McCants (1980b) where root proliferation of crops is a benefit from applications of humic and fulvic acids at low concentrations. These stimulatory effects also have been directly correlated with enhanced uptake of N, P, S, Zn, and Fe. However, the use of these compounds at high concentrations also has been shown to decrease root and shoot growth.

Marketable tomato fruit weight, fruit diameter and fruit length

Tomato fruit weight, fruit diameter and fruit length did not show significant differences by the foliar application of humic substance in all experimental locations as compared to the agronomic control (Table 7). Even though these parameters were statistically insignificant, the foliar application of humic substance improved the fruit weight, fruit diameter and fruit length in the study sites.

Partial Budget Analysis

Melkassa

Results of Partial budget analysis showed that the application of the rr of humic and fulvic acid (2.5L ha^{-1})

Table 6: Tomato marketable minimum and maximum yield and mean yield with standard deviation as influenced by the application of HFA with and without NPK at Melkassa, Meki and Merti.

Treat	Melkassa		Meki		Merti	
	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD
	Mtha^{-1}					
Control (No fertilizer)	8.97-23.39	15.156±6.45[cd]	8.94-30.65	16.87±7.4	6.87-17.62	12.99±3.49[c]
Rr NPK	13.17-35.93	19.767±8.22[abc]	9.62-35.72	22.07±9.55	13.44-25.82	19.90±4.28[b]
Rr HFA (2.5Lha^{-1})	9.10-20.58	13.648±4.29[d]	14.63-32.77	20.10±6.93	15.03-21.59	18.14±2.17[b]
50% Rr HFA (1.25L ha^{-1})+ Rr NPK	12.69-27.89	19.836±7.64[abc]	19.61-41.29	26.26±8.59	23.86-32.73	26.76±3.44[a]
75% Rr HFA (1.88L ha^{-1}) + Rr NPK	16.16-27.46	20.563±4.33[ab]	21.82-53.39	33.31±11.51	18.79-33.13	25.62±5.44[a]
150% Rr HFA (3.75L ha^{-1})	10.10-27.41	16.256±6.58[bcd]	14.22-36.71	24.50±7.98	10.67-21.17	17.61±3.85[c]
Rr HFA (2.5L ha^{-1}) +Half Rr NPK	9.08-33.24	23.762±9.74[a]	16.00-36.81	26.04±9.30	16.98-32.32	27.96±5.70[a]
200% Rr HFA (5L ha^{-1})	10.24-25.60	19.333±5.76[abc]	12.82-33.00	22.54±8.03	10.34-22.95	16.40±4.28[bc]
CV		**22.56**		**36.49**		**20.43**
LSD		**4.885**		**NS**		**4.93**

NB: CV= Coefficient of Variability; LSD= List Significant Difference; Mtha^{-1} = Metric ton per ha; Rr. HFA= recommended rate of humic and fulvic acids, Rr NPK= Recommended rates of Nitrogen, Phosphorus and Potassium

Table 7.Tomato fruit weight, fruit diameter and fruit length as influenced by the application of HFA with and without NPK at Melkassa, Meki and Merti

Treatments	MARC			Meki			Merti		
	FWt	FD	FL	FWt	FD	FL	FWt	FD	FL
	g	cm		g	cm		g	cm	
Control (No fertilizer)	87.2	5.1	6.0	61.0	4.4	5.3	69.9	4.2	5.3
Rr NPK (46N+ 46P_2O_5+ 51K_2O Kg ha^{-1})	90.4	5.2	6.1	62.2	4.5	5.4	75.1	4.3	5.4
Rr HFA (2.5L ha^{-1})	97.2	5.2	6.2	56.9	4.3	5.1	73.4	4.3	5.3
50% rr HFA (1.25L ha^{-1}) + rr NPK	92.5	5.3	6.0	64.4	4.5	5.3	79.5	4.4	5.6
75% rr HFA (1.88L ha^{-1}) + rr NPK	94.4	5.2	5.7	69.3	4.4	5.4	74.4	4.3	5.5
150% Rr HFA (3.75L ha^{-1})	93.9	5.2	6.1	74.9	4.5	5.4	80.4	4.4	5.6
Rr HFA (2.5L ha^{-1}) + Half rr NPK (23N + 23P_2O_5+ 25.5K_2O Kg ha^{-1})	92.0	5.3	6.2	76.4	4.6	5.5	79.3	4.5	5.8
200% rr HFA (5L ha^{-1})	92.1	5.4	6.4	71.0	4.4	5.3	78.8	4.4	5.5
CV(%)	**11.97**	**8.34**	**4.65**	**16.14**	**4.55**	**3.56**	**5.28**	**3.09**	**3.53**
$LSD_{(0.05)}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

cm= Centimeter, FD= Fruit diameter, FL= Fruit lengthFWt= Fruit weightandg= gram

with 50% rr of NPK provided the highest net benefit (103,103.5 ETB/ha) with high marginal rate of the return (MRR) 741.14 %. The result which is greater than the minimum acceptable rate of return (MARR) =100 (CIMMYT, 1988) (Table 8). Hence, for each birr invested in rr of HFA acid (2.5L ha^{-1}) for the production of tomato, farmers could earn birr 7.41 after recovering their cost of production compared to the other options.

Merti

Results of partial budget analysis at Merti showed that the foliar application of rr of HFA (2.5L) ha^{-1} with half recommended NPK gave the highest net return 121,999 ETB ha^{-1} with (MRR) of 1,587. 33% (Table 9). This implies that for each birr invested in the production of tomato, farmers could earn ETB 15.87 after recovering their cost of production by applying rr of HFA (2.5L) ha^{-1} with half recommended NPK fertilizer rate compared to the other options.

Sensitivity analysis

The result of the dominance analysis described that except for treatments 150% rr of HFA (3.75Lha^{-1}), 200% rr of HFA alone (5Lha^{-1}) and recommended HFA (2.5Lha^{-1}) with 50%RNPK the remaining were dominated by the alternatives with lower

Table 8. Partial budget analysis of humic and fulvic acid with and/or without NPK on tomato at Melkassa

	MY	10%AMY	GB	TC V	N Benefit	MRR
Treatment	**Mtha^{-1}**			**ETB**		**%**
Control (No fertilizer)	15.15	13.64	68,188.50	0	68,188.50	
Rr HFA (2.5Lha-1)	13.65	12.28	61,411.50	1,210	60,201.50	D
150% rr HFA (3.75 Lha-1)	16.26	14.63	73,156.50	1,335	71,821.50	272.13
200% rr HFA (5 Lha-1)	19.33	17.4	86,998.50	1,460	85,538.50	10973.6
Rr HFA (2.5Lha-1)+50% rr NPK	23.76	21.9	106,933.50	3,830	103,103.50	741.14
Rr NPK	19.77	17.79	88,942.50	4,920	84,022.50	D
50% rr HFA (1.25L ha-1)+rr NPK	19.84	17.85	89,266.50	6,005	83,261.50	D
75% rr HFA (1.88L ha-1)+rr NPK	20.56	18.51	92,533.50	6,068	86,465.50	D

10% AMY= 10% adjusted marketable yield, D= dominated treatment, ETB= Ethiopian Birr , GB = Gross benefit, MRR=Marginal rate of return, Mtha^{-1}=Metric ton per hectare, MY=Marketable yield, N. benefit= Net benefit, TCV= Total cost that varies.

Table 9: Partial budget analysis of humic and fulvic acid with and without NPK on tomato at Merti

	MY	10%AMY	GB(ETB)	TC V	N Benefit	MRR
Treatment		**Mtha^{-1}**		**ETB**		**%**
Control (No fertilizer)	12.99	11.69	58446	0	58446	
Rr HFA (2.5Lha-1)	18.14	16.32	81621	1210	80411	1815.29
150% rr HFA (3.75 Lha-1)	17.61	15.84	79222.5	1335	77887.5	D
200% rr HFA (5 Lha-1)	16.40	14.76	73791	1460	72331	D
Rr HFA (2.5Lha-1)+50% rr NPK	27.96	25.166	125829	3830	121999	1587.33
Rr NPK	19.90	17.91	89550	4920	84630	D
50% rr HFA (1.25L ha-1)+rr NPK	26.76	24.086	120429	6005	114424	D
75% rr HFA (1.88L ha-1)+rr NPK	25.62	23.06	115276.5	6068	109208.5	D

Table 10: Sensitivity analysis (increasing/decreasing the price of tomato by 15%) at Melkassa Scenario 1

	Marketable Fruit Yield	10%AMFY	GFB 15%<	TC V	N Benefit	MRR
Treatment	**Kg ha^{-1}**			**ETB ha^{-1}**		**%**
Control No fertilizer	15153	13637.7	57960.23	0	57960.23	
150% rr HFA (3.75 Lha^{-1})	16257	14631.3	62183.03	1335	60848.03	216.3146
200% rr HFA (5 Lha^{-1})	19333	17399.7	73948.73	1460	72488.73	9312.56
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	23763	21386.7	90893.48	3830	87063.48	614.9684
	Marketable Fruit Yield	**10%AGY**	**GFB 15%>**	**TC V**	**N Benefit**	**MRR**
Treatment	**Kg ha^{-1}**			**ETB ha^{-1}**		**%**
Control No fertilizer	15153	13637.7	78416.78	0	78416.78	
150% rr HFA (3.75 Lha^{-1})	16257	14631.3	84129.98	1335	82794.98	327.9551
200% rr HFA (5 Lha^{-1})	19333	17399.7	100048.3	1460	98588.28	12634.64
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	23763	21386.7	122973.5	3830	119143.50	867.3101

total costs that varied. Therefore, these treatments were used for the sensitivity analysis at Melkassa. (Table 11)

The sensitivity analysis (scenario 1) suggested that the lowest net benefit was obtained from the control 57,960.23 ETB ha^{-1} and the highest was obtained from recommended HFA (2.5Lha^{-1}) with 50% RNPK (87,063.48 ETB ha^{-1}) which suggests that even if price fluctuates in disservice of tomato price by 15% the treatment with highest yield will continue to provide the economic advantage. The MRR

Table 11: Sensitivity analysis (decreasing the price of tomato by 15% and decreasing/ increasing the cost of fertilizers by 15%) at Melkassa, Scenario 2

Treatment	Marketable Fruit Yield	10%AMFY	GFB 15%<	TC V<15%	N Benefit	MRR
	Kg ha-1			ETB ha-1		%
Control No fertilizer	15153	13637.7	57960.23	0	57960.23	0
150% rr HFA (3.75 Lha^{-1})	16257	14631.3	62183.03	1278.75	60904.28	230.23
200% rr HFA (5 Lha^{-1})	19333	17399.7	73948.73	1385	72563.73	10973.6
Rr HFA (2.5Lha^{-1})+50% rr NPK	23763	21386.7	90893.48	3447.5	87445.98	721.56

Treatment	Marketable Fruit Yield	10%AMFY	GFB 15%<	TC V>15%	N Benefit	MRR%
	Kg ha-1		ETB ha-1			%
Control No fertilizer	15153	13637.7	57960.23	0	57960.23	
150% rr HFA (3.75 Lha^{-1})	16257	14631.3	62183.03	1391.25	60791.78	203.53
200% rr HFA (5 Lha^{-1})	19333	17399.7	73948.73	1535	72413.73	8084.83
Rr HFA (2.5Lha^{-1})+50% rr NPK	23763	21386.7	90893.48	4212.5	86680.98	532.86

Table 12: Sensitivity analysis (increasing the price of tomato by 15% and decreasing/ increasing the cost of fertilizers by 15%) of humic and fulvic acid with and without NPK at Melkassa, Scenario 2

Treatment	Marketable Fruit Yield	10%AMFY	GFB 15%>	TC V<15%	N Benefit	MRR
	Kg ha-1			ETB ha-1		%
Control No fertilizer	15153	13637.7	78416.78	0	78416.78	
150% rr HFA (3.75 Lha^{-1})	16257	14631.3	84129.98	1278.75	82851.23	346.78
200% rr HFA (5 Lha^{-1})	19333	17399.7	100048.3	1385	98663.28	14881.93
Rr HFA (2.5Lha^{-1})+50% rr NPK	23763	21386.7	122973.5	3447.5	119526	1011.53

Treatment	Marketable Fruit Yield	10%AMFY	GFB 15%>	TC V>15%	N Benefit	MRR%
	Kg ha-1		ETB ha-1			%
Control No fertilizer	15153	13637.7	78416.78	0	78416.78	
150% R HFA (3.75 Lha^{-1})	16257	14631.3	84129.98	1391.25	82738.73	310.65
200% R HFA (5 Lha^{-1})	19333	17399.7	100048.3	1535	98513.28	10973.60
R HFA (2.5Lha^{-1})+50%RNPK	23763	21386.7	122973.5	4212.5	118761	756.22

was well above the MMRR (Table 11). When the price fluctuates in favor of tomato price by 15% the recommended HFA (2.5Lha^{-1}) with 50% RNPK (119,143.50 ETB ha^{-1}) with highest yield will continue to provide the economic advantage. The MRR was well above the MMRR = 100

Decreasing both tomato price by 15% and fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5Lha^{-1}) with 50% RNPK which is 87445.98ETB ha^{-1}, and with MRR 721.56 % which is above the MARR. (Table 12)

Decreasing tomato prices by 15% and increasing fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5Lha^{-1}) with 50% RNPK which is 86,680.98 ETB ha^{-1}, and with MRR 532.86 % which is above the MARR=100.

Increasing tomato prices by 15% and decreasing fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5Lha^{-1}) with 50% RNPK which is 119,526.00 ETB ha^{-1}, and with MRR 1011.53 % which is above the MARR=100. (Table 13)

Increasing both tomato prices by 15% and fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5Lha^{-1}) with 50% RNPK which

Table 13: Sensitivity analysis (decreasing/increasing the price of tomato by 15%) at Merti, Scenario 1

Treatment	Marketable Fruit Yield	10%AMFY	GFB<15%	TC V	N Benefit	MRR
	Kg ha^{-1}			ETB ha^{-1}		%
Control No fertilizer	12988	11689.2	49679.1	0	49679.1	
Rr HFA (2.5Lha-1)	18138	16324.2	69377.85	1210	68167.85	1528.00
Rr HFA (2.5Lha-1)+50% rr NPK	27962	25165.8	106954.7	3830	103124.7	1334.23
Treatment	**Marketable Fruit Yield**	**10%AMFY**	**GFB>15%**	**TC V**	**N Benefit**	**MRR**
	Kg ha^{-1}			ETB ha^{-1}		%
Control No fertilizer	12988	11689.2	67212.9	0	67212.9	
Rr HFA (2.5Lha-1)	18138	16324.2	93864.15	1210	92654.15	2102.58
Rr HFA (2.5Lha-1)+50% rr NPK	27962	25165.8	144703.4	3830	140873.4	1840.43

Table 14: Sensitivity analysis (decreasing the price of tomato by 15% and decreasing/increasing the cost of fertilizers by 15%) at Merti, Scenario 2

Treatment	Marketable Fruit Yield	10%AMFY	GFB<15%	TC V<15%	N Benefit	MRR
	Kg ha^{-1}		ETB ha^{-1}			%
Control No fertilizer	12988	11689.2	49679.1	0	49679.1	
Rr HFA (2.5Lha^{-1})	18138	16324.2	69377.85	1172.5	68205.35	1580.06
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	27962	25165.8	106954.7	3447.5	103507.2	1551.73
Treatment	**Marketable Fruit Yield**	**10%AMFY**	**GFB<15%**	**TC V>15%**	**N Benefit**	**MRR**
	Kg ha^{-1}		ETB ha^{-1}			%
Control No fertilizer	12988	11689.2	49679.1	0	49679.1	
Rr HFA (2.5Lha^{-1})	18138	16324.2	69377.85	1247.5	68130.35	1479.058
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	27962	25165.8	106954.7	4212.5	102742.2	1167.346

is 118,761.00 ETB ha^{-1}, and with MRR 756.22 % which is above the MARR=100.

The result of the dominance analysis at Merti revealed that except for treatments rr of HFA (2.5Lha^{-1}) and rr of HFA with half less than rr of NPK the remaining were dominated by the alternatives with lower total costs that varied. Therefore, these treatments were used for the sensitivity analysis.

The sensitivity analysis (scenario 1) suggested that the lowest net benefit was obtained from the control 49,679.1 and 67212.9 ETB ha^{-1} and the highest was obtained from recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK (103,124.70 ETB ha^{-1}) which suggests that even if price fluctuates in disservice of tomato price by 15% the treatment with highest yield will continue to provide the economic advantage. The MRR was well above the MMRR=100 (Table 14).

When the price fluctuates in favor of tomato price by 15% the recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK (140,873.4 ETB ha^{-1}) with highest yield will continue to provide the economic advantage. The MRR was well above the MMRR = 100

At Merti, decreasing both tomato price and fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK which is 103,507.2 ETB ha^{-1}, and with MRR 1551.73 % which is above the MARR=100. (Table 15)

Decreasing tomato prices by 15% and increasing fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK which is 102, 742.2 ETB ha^{-1}, and with MRR 1167.35 % which is above the MARR=100.

At Merti, increasing tomato price and decreasing fertilizers cost by 15% (scenario 2) resulted in highest net

Table 15: Sensitivity analysis (increasing the price of tomato by 15% and decreasing/increasing the cost of fertilizers by 15%) at Merti, Scenario-2

Treatment	Marketable Fruit Yield	10%AMFY	GFB>15%	TC V<15%	N Benefit	MRR
	Kg ha^{-1}			ETB ha^{-1}		%
Control No fertilizer	12988	11689.2	67212.9	0	67212.9	
Rr HFA (2.5Lha^{-1})	18138	16324.2	93864.15	1172.5	92691.65	2173.03
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	27962	25165.8	144703.4	3447.5	141255.9	2134.69
Treatment	**Marketable Fruit Yield**	**10%AMFY**	**GFB>15%**	**TC V>15%**	**N Benefit**	**MRR**
	Kg ha^{-1}			ETB ha^{-1}		%
Control No fertilizer	12988	11689.2	67212.9	0	67212.9	
Rr HFA (2.5Lha^{-1})	18138	16324.2	93864.15	1247.5	92616.65	2036.373
Rr HFA (2.5Lha^{-1})+ 50% rr NPK	27962	25165.8	144703.4	4212.5	140490.9	1614.644

benefit from the same treatment recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK which is 141, 255.9 ETB ha^{-1}, and with MRR 2134.69 % which is above the MARR=100.

Increasing both tomato prices and fertilizers cost by 15% (scenario 2) resulted in highest net benefit from the same treatment recommended HFA (2.5 L ha^{-1}) with half less than rr of NPK which is 140, 490.9 ETB ha^{-1}, and with MRR 1362.60 % which is above the MARR=100 (Table 16).

Based on the statistical significance and partial budget analysis treatments that showed higher net benefit from the control were recommended rate (rr) of humic and fulvic acid (HFA) (2.5L ha^{-1}) with 50% rr of NPK at Melkassa and Merti, leading to highest marginal rate of return from other treatments. The sensitivity analysis also reflected that the same treatment combinations to give the best return. Therefore, further on farm verification trials need to be conducted for further recommendation taking economically feasible treatments in all experimental sites.

CONCLUSION AND RECOMMENDATIONS

The HFA liquid organic fertilizer trials conducted for two seasons in three locations (Melkassa, Merti and Meki) to evaluate the effectiveness of this new product on Tomato. The result revealed that tomato yield was boosted and significantly influenced by the foliar application of 2.5L of HFA in 1000L of water ha^{-1}with half recommended rates of NPK fertilizers. This result also supported by partial budget analysis. However, HFA liquid organic fertilizer alone could not improve tomato yield in the testing sites. Thus, HFA organic liquid fertilizer is a supplementary product which can boost tomato yield when applied in foliar form, integrated with NPK fertilizers.

Hence, based on the finding of this experiment the following recommendation can be made:

Rr of HFA (2.5L ha^{-1}dissolved in 1000L of water) applied in foliar form integrated with 50% NPK can used for tomato production at Melkassa and Merti areas and similar locations.

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