Effects of Aqueous extract of Moringa (*Moringa oleifera* Lam.) and Nitrogen rates on some Physiological attributes and yield of Tomato

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Abstract--Field experiments in 2009 and 2010 rainy seasons were carried out at the Teaching and Research Farm, Faculty of Agriculture, Bayero University, Kano, Nigeria to study the effects of aqueous extract of moringa and nitrogen rates on some physiological attributes and yield of tomato. Moringa shoot were crushed with water (10 kg of fresh material in 1 liter of water) and filtered out. Liquid extract were then diluted with water in the following concentrations; 0 %, 3 %, 4 % and 5 %. These concentrations with 3 N rates: 0, 40, 80 kg N ha-1 in a factorial combination were tested on tomato in an experiments laid out in a randomized complete block design with three replications. Foliar spray of moringa concentrations started at 2 WAT and continued forthnightly until 8WAT. Data were collected on plant height, plant dry weight, CGR, NAR and fruit yield and were subjected to analysis of variance. Results showed significant effects of aqueous extract of moringa and N rates with interactions on the parameters. Based on the result it was concluded that aqueous extract of moringa can compliment N on the production of tomato; effects were more apparent at low N rates. Thus, 80 kg N ha-1 with 3 % should be adopted.

Keywords-- Aqueous Extract Of Moringa, Nitrogen Rates, Tomato.

I. Introduction

The role of Moringa (*Moringa oleifera* Lam.) extract as a plant growth hormone which enhances seed germination, growth and yield of crops [1] - [2] - [3] had attracted the attention of agronomist more especially in the developing coumtries where crops yields are very low. Juice from fresh moringa leaves increased crops yields by 25 – 30 % [4] - [1]. Increase in plant height, leaf area, LAI and dry herb weight of Kalmegh (*Andrographis paniculata*) from 22.7 cm to 27.22 cm at 60 days after planting (DAP) and 50.15 cm to 56.98 cm at 90 DAP with moringa leaf extract at 2 % concentration [5].

The use of chemical fertilizers was reported to increase yields of crops.

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Application of 110 kg N ha^{-1} resulted in higher plant height (81.7 cm) followed by 80 kg N ha^{-1} (71.2 cm) and lowest with 50 kg N ha^{-1}(53.8 cm) [6]. Also found to be affected was fruit yield of tomato, 110 kg N ha^{-1} gave higher fruit yield. Significant increased in CGR were reported in GA with N at 80 kg N ha^{-1} [7]. Etherel with N increased number of pods per plant [8].

Tomato is the most important vegetable crop in Nigeria and indeed the rest of the world. It is considered for its rich source of vitamins and minerals with various culinary uses either in its fresh form as salad or as puree in stew and soups. Increase in its yield is very vital. One of the strategies in achieving yield increase is the use of plant growth regulators (PGR). In Nigeria not much work has been done on the use of PGR more especially the use of natural product such as moringa extract to improve crop yield. Moringa is a common plant in households in this sub region, if its extract can increase crops yields farmers will embrace the technology and utilize the available resource with little or no cost. Furthermore, even though chemical fertilizers were reported to improve crops yields they are scarce and when available they are beyond the reach of a poor resource farmer (s). Therefore, there is the need to explore substitute and/or synergist to minimize its use and meet up with fertilizer demands.

This research therefore, was aimed at revalidating and if possible improves on the previous findings in other countries by determining if moringa can improve tomato yield and compliment N fertilizer in Nigeria. Thus, fills in the gap in the dearth of information and recommends its use to improve crop production and yield.

II. Materials and Methods

Two years field studies (2009 and 2010 rainy seasons) were conducted at the Teaching and Research Farm, Faculty of Agriculture, Bayero University, Kano located in the Sudan Savanna agro - ecological zone of Nigeria (Latitude 11^0 58' N and Longitude 8^0 25' E at an altitude of 458 m) to study the effects of aqueous extract of moringa and nitrogen rates on some physiological attributes and yield of tomato. Moringa shoots (about 40 days) were crushed with water (10 kg of fresh material in 1 litre of water) and filtered out. Liquid extract obtained were diluted with water in the following concentrations: 0%, 3%, 4% and 5%. These concentrations with three N rates (0, 40, 80 kg N ha^{-1}) factorially combined were tested on tomato (Variety: ROMA VF) in an experiments laid out in a randomized complete block design with 3 replications during the seasons. Foliar spray started at 2 WAT (weeks after transplanting) and continued fortnightly until 8 WAT [9]. Half of N in form of urea and a blanket application of 60 kg ha^{-1} P_2O_5 and K_2O fertilizer in form of single super phosphate (SSP) and muriate of potash (K_2O), respectively were applied to tomato at transplanting. The remaining half of N was applied at 5 WAT. Land for the experiments were prepared by harrowing and ridging at a spacing of 0.75 m between rows, thereafter were marked into 36 plots with gross plot sizes of 4.5 m x 3 m = 13.5 m^2 and net plot sizes of 2.1 m x 1.5 m = 3.15 m^2. Soil samples were collected in the seasons randomly at a depth of 0 - 15 cm and 15 – 30 cm using soil auger its physical and chemical properties determined (Table I). One plant from seedlings earlier raised in the nursery was transplanted per stand to give a plant population of 26667 plants ha^{-1}. Transplanting was on 3rd September, 2009 and 11th July, 2010. Weeds were controlled by spraying Pendimethalin (500 EC) at 1.5 L ha^{-1} using CP 20 knapsack sprayer and were supplemented by hoe weeding at 3 and 7 WAT. Insects pest were controlled using BEST ACTION (cypermethrin 30 gm/l plus dimethoate 25 gm/l) at 1L ha^{-1} at flowering and fruiting using the above sprayer. Data were collected on plant height: heights of five tagged plants from each plot were measured at 5 and 7 WAT, and at harvest; measurement started from ground level to terminal bud average determined and recorded. Weight of biomass: destructive samples of five plants from each plot were oven dried at 80 ^{0}C for 8 hours, means determined and recorded at 5 and 7 WAT and at harvest. Crop Growth Rate (CGR) (g w^{k-1}) at 7 WAT and at harvest: this was determined as follows: CGR = $(W_2 – W_1)/(T_2 – T_1)$; where W_1 and W_2 are shoot dry weights taken at two consecutive harvests over time intervals T_1 and T_2. Net Assimilation Rate (NAR) (g cm^{-2} wk^{-1}) at 7 WAT and at harvest: this was determined as follows: NAR = $(W_2 – W_1) (\text{Log}_e\, L_2 – \text{Log}_e\, L_1)/(t_2 - t_1)(L_2 - L_1)$; where W_2 and W_1 are shoot dry weights taken at two consecutive harvests over time t_1 and t_2 when the corresponding leaf area was L_2 and L_1, respectively. Fruit yield ha^{-1}: yield of net plots were harvested and were converted to fruit yield ha^{-1}. Data collected were subjected to analysis of variance using SAS system for windows [10].

III. RESULTS

The results of composite soil samples for the two seasons are presented in Table I. Soils of the experimental sites were silty clay and slightly acid; total Nitrogen was moderately high. Also presented in the Table are results of OC, OM, CEC, available P and exchangesble bases. The effects of aqueous extract of moringa and N rates on tomato plant height in 2009 and 2010 rainy seasons and combined are presented in Table II. There was no significant effect of N rates in the seasons at 5 and 7 WAT and in 2009 rainy season at harvest. Highly significant effect were recorded in 2010 rainy season and combined at harvest with 80 kg N ha^{-1}. Shorter plants were with 0 kg N ha^{-1} in 2010 rainy season and in the combined. Significant effect of aqueous extract of moringa on tomato plant height was observed in 2009 rainy season at 5 and 7 WAT (Table II). Highly significant effect in 2010 rainy season and combined at 5 WAT and at harvest were also recorded. Also recorded were significant effects in 2009 rainy season at harvest and combined at 7 WAT. Except in 2010 rainy season at 5 WAT were 4 % that had statistically similar effect with 3 and 5 % had taller plants (33.93 cm); 3 % with statistically similar plant height with 4 % in the combined at 5WAT; with 5 % in the combined at 7 WAT and in 2010 rainy season at harvest had taller plants; 41.71 cm, 54.19 cm and 68.00 cm in the combined at 5 and 7 WAT and at harvest, respectively; 54.47 cm and 79.50 cm in 2009 and 2010 rainy seasons at harvest, respectively. Shorter plants were with 0 % in all seasons except in 2009 rainy season at harvest where 5% recorded lower plants. Highly significant interactions of N rates with aqueous extract of moringa were recorded on plant height in the seasons at 5 WAT and at harvest, and in 2009 rainy season at 7 WAT. Significant interaction was also recorded in the combined at 7 WAT (Table III). In 2009 rainy season at 5 and 7 WAT and at harvest taller plants were in 0 kg N ha^{-1} with 3 % aqueous extract of moringa; 59.33 cm, 61.93 cm and 66.53 cm, respectively. While shorter plants were in 0 kg N ha^{-1} with 0 % aqueous extract of moringa. In 2010 rainy season taller plants were in 0 kg N ha^{-1} with 4 % aqueous extract of moringa (43.89 cm) at 5 WAT; at harvest in 80 kg N ha^{-1} with 3 % aqueous extract of moringa (93.47 cm); shorter plants were in 0 kg N ha^{-1} with 0 % aqueous extract of moringa. In the combined taller plants were in 0 kg N ha^{-1} with 4 % aqueous extract of moringa at 5 WAT; 0 kg N ha^{-1} with 3 % aqueous extract of moringa at 7 WAT and 80 kg N ha^{-1} with 3 % aqueous extract of moringa at harvest. While shorter plants were in 0 kg N ha^{-1} with 0 % aqueous extract of moringa.

Table IV shows the effects of aqueous extract of moringa and N rates on CGR of tomato in the seasons and combined. There was no significant effect of N rates in the seasons at 7 WAT. There was a significant effect of N rates in 2009 rainy season at harvest. Also recorded was a highly significant effect of N rates in 2010 rainy season and combined at harvest. In 2009 rainy season 0 kg N ha^{-1} with statistically similar effect with 5 % had higher CGR (27.06 gwk^{-1}); while 40 kg N ha^{-1} had lower CGR (17.20 gwk^{-1}). In 2010 rainy season and combined 40 kg N ha^{-1} had higher CGR; 109.50 gwk^{-1} and 63.35 gwk^{-1}, respectively and 0 kg N ha^{-1} had lower CGR (Table IV). Aqueous extract of moringa had no significant effect on CGR in the two seasons at 7 WAT. Significant effect in the combined season at 7 WAT and highly significant effects in the seasons at harvest were recorded (Table IV). In the combined at 7 WAT and in 2009 rainy season at harvest 4 % had higher CGR; 42.54 gwk^{-1} and 33.24 gwk^{-1}, respectively; while 0 % had lower CGR; 27.27 gwk^{-1} and 10.69 gwk^{-1}, respectively. In 2010 rainy season and combined at harvest 3 % had higher CGR; 111.78 gwk^{-1} and 71.44 gwk^{-1}, respectively. Least CGR were with 4 % in 2009 rainy season and in the combined with 0 %. There was no significant interaction of N rates with aqueous extract of moringa in the seasons at 7 WAT and in 2009 rainy season at harvest. Highly significant interaction were recorded in 2010 rainy season and combined at harvest (Table IV). Interaction that recorded highest CGR (Table V) was 40 kg N ha^{-1} with 3 % aqueous extract of moringa and least CGR was in 0 kg N ha^{-1} with 0 % aqueous extract of moringa.

Table IV shows no significant effect of N rates in the seasons at 7 WAT on NAR. At harvest significant effect in 2009 rainy season and highly significant effects in 2010 rainy season and combined were recorded. In 2009 rainy season 0 kg N ha^{-1} and 80 kg N ha^{-1} had the same effect with higher NAR (0.02 $gm^{-1}wk^{-1}$). In 2010 rainy season 40 kg N ha^{-1} had higher NAR (0.05 $gm^{-1}wk^{-1}$); while least NAR was recorded in 0 kg N ha^{-1} (0.02 $gm^{-1}wk^{-1}$). In the combined, 40 kg N ha^{-1} and 80 kg N ha^{-1} had the same effect with higher NAR (0.03 $gm^{-1}wk^{-1}$). There was a highly significant effect of aqueous extract of moringa on NAR in 2009 rainy season at 7 WAT and at harvest, and in 2010 rainy season and combined at harvest. In 2009 rainy season at 7 WAT and at harvest; 4 % had higher NAR; 0.02 $gm^{-1}wk^{-1}$ and 0.03 $gm^{-1}wk^{-1}$, respectively, while 0 % had lower NAR. In 2010 rainy season and combined at harvest higher NAR were with 3 %; 0.05 $gm^{-1}wk^{-1}$ and 0.03 $gm^{-1}wk^{-1}$, respectively; and with 4 % (0.02 $gm^{-1}wk^{-1}$) in 2010 rainy season and combined (Table IV). There was no significant interaction of N with aqueous extract of moringa in the seasons at 7 WAT. At harvest significant interaction in 2009 rainy season and highly significant interaction in 2010 rainy season and combined were recorded (Table IV). In 2009 rainy season 0 kg N ha^{-1} with 4 % aqueous extract of moringa had higher NAR (0.04 $gm^{-1}wk^{-1}$). Other interactions were statistically similar and had lower NAR. In 2010 rainy season 40 kg N ha^{-1} with 0 % aqueous extract of moringa had higher NAR (0.07 $gm^{-1}wk^{-1}$). The remaining interactions were statistically similar to 0 kg N ha^{-1} with 0 % aqueous extract of moringa and recorded the lowest NAR (Table V).

The effects of N rates and aqueous extract of moringa on tomato plant dry weight in seasons and combined is presented in Table VI. Highly significant effect of N rates in 2009 rainy season at 5 WAT and 2010 rainy season and combined at harvest were recorded. Significant effects in 2010 rainy season at harvest were also recorded. There was no significant effect of N rates in 2010 rainy season and combined at 5 WAT and in the seasons at 7 WAT. Nitrogen at 40 kg ha^{-1} had higher plant dry weight in the seasons at harvest and least with 0 kg N ha^{-1}. There were highly significant effect of aqueous extract of moringa on plant dry weight in 2009 rainy season at 5 and 7 WAT and at harvest; 2010 rainy season at harvest and combined at 5 and 7 WAT and at harvest. Aqueous extract of moringa at 3 % had higher plant dry weight in the seasons; 95.46.g, 175.48 g and 299.94 g in 2009 rainy season at 5 and 7 WAT and at harvest, respectively; 550.00 g in 2010 rainy season at harvest and 66.17 g, 139.18 g and 424.97 g in the combined at 5 and 7 WAT and at harvest, respectively (Table VI). Highly significant interactions of N rates with aqueous extract of moringa were recorded in 2009 rainy season at 5 WAT and at harvest and in 2010 rainy season and combined at 7 WAT and at harvest (Table VI). Interaction that manifested higher plant dry weight in 2009 rainy season at 5 WAT (Table VII) was 80 kg N ha^{-1} with 3 % aqueous extract of moringa (116.25 g). Least plant dry weight was in 80 kg N ha^{-1} with 5 % aqueous extract of moringa (17.70 g). In 2010 rainy season and combined at 7 WAT, 0 kg N ha^{-1} with 3 % aqueous extract of moringa had higher plant dry weight; 132.00 g and 149 g, respectively. Least plant dry weight were with 0 kg N ha^{-1} with 0 % aqueous extract of moringa (65.00 g) in 2010 rainy season and 62.80 g in the combined. At harvest higher plant dry weight was in 0 kg N ha^{-1} with 4 % aqueous extract of moringa (390.17 g), in 2009 rainy season; 40 kg N ha^{-1} with 3 % aqueous extract of moringa (693.33 g), in 2010 rainy season and 492.08 g in the combined. Least plant dry weight was in 0 kg N ha^{-1} with 0 % aqueous extract of moringa.

Table VI shows no significant effect of N rates on fruit yield per hectare of tomato in the seasons. Similarly, no significant effect of aqueous extract of moringa in 2010 rainy season and combined was observed. Significant effect of aqueous extract of moringa was recorded in 2009 rainy season; 3 % had higher fruits yield (1276.7 kg ha^{-1}) and lower with 5 % (716.4 kg ha^{-1}). Highly significant interaction of N with aqueous extract of moringa on fruit yield was recorded in 2009 rainy season. There were no interactions in 2010 rainy season and the combined (Table VI). Higher fruit yield was in 0 kg N ha^{-1} with 4 % aqueous extract of moringa (2052.38 kg ha^{-1}) and lower in 80 kg N ha^{-1} with 4 % aqueous extract of moringa (Table VII).

IV. Discussion

The variation in the physico – chemical properties in the seasons might be due to the residual soil nutrient of 2009 rainy season which made that of 2010 rainy season higher. Organic carbon was high probably due to higher organic matter content of the soil. Total nitrogen was also moderately high this might be due to the high organic carbon in the soils since organic carbon is an index of soil fertility. The non – significant effect of N on plant height of tomato in the seasons at 5 and 7 WAT; in 2009 rainy season at harvest might be due to the size of the seedlings which were from the same source and same height at transplanting. The significant effect of N on plant height which resulted to highly significant effect in the combined might be due to the nature of the season which was favourable for plant growth, there were stable rainfall which might have allowed N responsed. The significant effect of N on CGR at harvest might be due to the fact that CGR increases with increase in plant growth which resulted to high dry matter accumulation which was partitioned to developing tissues. The significant effect of N on NAR might be due to increase in leaf area which might have increased the photosynthetic ability of the plant. The significant effect of N on tomato weight of biomass in 2009 rainy season at 5 WAT and in the seasons at harvest might be attributed to the significant effect of some characters such as plant height and NAR which improves CGR by accumulating more dry matter. The non – significant effect of N in the other seasons might be attributed to residual soil nutrients which might have influenced growth and development which resulted to little or no variation in dry matter. The non – significant effect of N on tomato fruit yield might be due to the role of N in increasing vegetative growth at the expense of yield.

The non – significant effect of aqueous extract of moringa on plant height in 2009 rainy season at 5 and 7 WAT, and in 2010 rainy season at 7 WAT might be due to the season; 2009 season were not favourable for plant growth as compared to 2010 rainy season; rainfall and high sunshine might have affected treatments responsed. In 2010 rainy season, non – significant effect might be due to residual soil nutrient which gave the plants adequate nutrients and thus suppressing the treatment effect. The significant effect of aqueous extract in the remaining periods of observation may be due to the role of PGR in promoting growth and development of plants. Earlier, reports showed that foliar spray of PGR increased plant height of tomato [11]. The non – significant effect of aqueous extract of moringa on tomato CGR in the two seasons at 7 WAT might be due to the stage of the plants at their succulent stage dry matter accumulation have just started and variation of treatments were yet to manifest. The result agreed with [12] that CGR increased with crop growth. This might have informed the significant effect on the remaining period. The significant effect of aqueous extract of moringa on NAR might be due to higher LAI and higher chlorophyll content of the leaves. Earlier report showed that total chlorophyll content of plants increased by PGR [13]. The significant effect of aqueous extract of moringa on plant dry weight in the seasons except in 2010 rainy season at 5 and 7 WAT might be attributed to the significant effect of aqueous extract of moringa on NAR. The significant effect on plant dry weight might be due to the ability of PGR to improve effective partitioning and translocation of assimilates from source to sink in field crops [14]. The significant effect of aqueous extract of moringa in 2009 rainy season on tomato fruit yield per hectare might be connected with the role of PGR in improving crop growth and hence yield.

The significant effect of treatments might be the reason for interaction of N with aqueous extract of moringa on plant height The result was in line with the earlier report of [15] that plant growth hormone in small amounts modify a given physiological process and rarely act alone as the action of two or more are necessary to produce a physiological effect. Response to individual treatments might have resulted to highly significant interaction of N with aqueous extract of moringa on CGR; and where treatments were not significant application of the two treatments synergized each other and triggered interaction. Synergy might also be responsible for significant interaction on NAR, plant dry weight and fruit yield per hectare.

V. Conclusion and Recommendations

Based on the result moringa extract can compliment N on the production of tomato and its effects were more apparent at low N rates; 80 kg N ha^{-1} with 3 % aqueous extract of moringa should be adopted. Further research with more crops should be carried out. Federal Ministry of Agriculture and Rural development and related bodies should consider financing such research. Modern method of extraction and packaging should be explored.

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Table 1. Soil physical and chemical properties of the field experiments in 2009 and 2010 rainy seasons.

Soil properties	2009		2010	
	0 – 15 cm	15 – 30 cm	0 -15 cm	15 – 30 cm
Soil pH (H_2O)	6.70	5.90	5.60	5.51
Organic carbon (g kg^{-1})	3.90	1.00	9.70	8.90
Organic matter (g kg^{-1})	6.72	1.72	16.72	15.34
Total N (g kg^{-1})	0.98	1.26	1.90	1.40
Available P (mg kg^{-1})	5.13	5.02	6.01	6.05
C.E.C (cmol kg^{-1})	9.67	5.94	6.92	4.30
Exchangeable K (cmol kg^{-1})	0.96	1.26	4.40	4.6
Exchangeable Na (cmol kg^{-1})	0.32	0.35	0.30	0.35
Exchangeable Ca (cmol kg^{-1})	0.04	0.05	0.28	0.73
Exchangeable Mg (cmol kg^{-1})	0.35	0.28	0.27	0. 27
Textural class	Silty clay	Silty clay	Silty clay	Silty clay

Table II. Effects of aqueous extract of moringa and nitrogen rates on plant height (cm) of tomato in 2009 and 2010 rainy seasons and combined.

Treatments	5 weeks after transplanting			7 weeks after transplanting			Harvest		
	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Nitrogen (kg ha^{-1})									
0	47.65	30.89	39.27	51.05	49.14	50.09	53.69	65.2c	59.48c
40	44.78	29.95	37.37	47.93	48.97	48.09	50.90	73.81	62.36b
80	48.92	31.22	40.07	51.18	51.28	51.23	53.78	79.62a	66.70a
Level of significance	NS	NS	NS	NS	NS	NS	NS	**	**
SE (±)	1.38	0.97	1.19	1.33	2.45	1.97	1.13	0.93	1.03
Aqueous extract of moringa (% concentration)									
0	46.06	25.85b	35.96c	48.83	44.11	46.47b	51.15b	63.02c	57.08d
3	50.94	32.48a	41.71a	53.15	55.22	54.19a	56.47a	79.53a	68.00a
4	45.70	33.93a	39.81ab	49.63	48.30	48,97b	52.57b	69.57b	61.07c
5	45.77	30.48a	38.13bc	48.60	51.55	50.08ab	50.98b	79.40a	65.19b
Level of significance	NS	**	**	NS	NS	*	*	**	**
SE (±)	1.59	1.12	1.38	1.54	2.82	2.27	1.3	1.07	1.19
Interactions	**	**	**	**	Ns	*	**	**	**

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. *= significant at 5% level of probability using DMRT. ** = highly significant at 1 % level of probability using DMRT. NS = not significant using DMRT.

Table III. Interaction between aqueous extract of moringa and nitrogen rates on plant height (cm) of tomato in 2009 and 2010 rainy seasons and combined.

	Aqueous extract of moringa (%)											
	5 WAT[a] 2009 rainy season				5 WAT 2010 rainy season				Combined			
Nitrogen (kg ha^{-1})	0	3	4	5	0	3	4	5	0	3	4	5
0	40.84c	59.33a	44.77c	45.67bc	20.56e	26.78d	43.89a	32.33bcd	30.70e	43.06ab	44.33a	38.99abcd
40	43.00c	47.15bc	45.54bc	43.44c	27.78d	35.22bc	29.00cd	27.78d	35.39de	41.19abc	37.27cd	35.61de
80	54.33ab	46.33bc	46.78bc	48.22bc	29.22bcd	35.44b	28.87cd	31.33bcd	41.78abc	40.89abcd	37.83bcd	39.78abcd
SE (±)	2.76				1.94				2.39			
	7 WAT 2009 rainy season				Combined							
0	43.96c	61.93a	49.38bc	48.93bc	38.64c	58.36a	52.36ab	52.02ab				
40	45.60c	49.92bc	50,15bc	46.04c	47.47b	49.40ab	49.02b	47.91b				
80	56.94ab	47.60c	49.38bc	50.82bc	53.30ab	54.80ab	45.52bc	51.30ab				
SE (±)	2.66				3.94							
	Harvest 2009 rainy season				Harvest 2010 rainy season				Combined			
0	45.70d	66.53a	51.64cd	50.86cd	40.46g	73.36d	65.96ef	81.02bc	43.09f	69.95ab	58.82de	65.94bc
40	48.20cd	52.68cd	54.09bc	48.964cd	72.40d	71.78d	79.71c	71.36de	60.30de	62.23cd	66.90b	60.00de
80	59.54b	50.20cd	51.98cd	53.42bc	76.20cd	93.47a	63.00f	85.82b	67.87ab	71.83a	57.49e	69.62ab
SE (±)	2.25				1.86				2.06			

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. a = weeks after transplanting.

Table IV. Effects of aqueous extract of moringa and nitrogen rates on crop growth rate (gwk^{-1}) and net assimilation rate (gm^{-2}wk^{-1}) of tomato in 2009 and 2010 rainy seasons and combined.

Treatments	Crop growth rate						Net assimilation rate					
	7 weeks after transplanting			Harvest			7 weeks after transplanting			Harvest		
	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Nitrogen (kg ha^{-1})												
0	27.74	33.79	30.76	27.06a	47.77c	37.45b	0.02	0.01	0.01	0.02a	0.02c	0.02c
40	45.99	37.33	41.66	17.20b	109.5a	63.35a	0.01	0.01	0.01	0.01b	0.05a	0.03a
80	37.85	36.25	37.05	25.18a	61.98b	43.58b	0.02	0.01	0.01	0.02a	0.03b	0.03a
Level of significance	NS[a]	NS	NS	*	**	**	NS	NS	NS	*	**	**
SE (±)	2.45	3.74	4.61	2.42	4.31	3.49	0.002	0.002	0.002	0.002	0.002	0.002
Aqueous extract of moringa (% concentration)												
0	23.09	31.44	27.27a	10.69b	59.33c	35.01c	0.01b	0.01	0.01	0.01c	0.03b	0.02b
3	48.69	33.00	36.51ab	31.12a	111.78a	71.44a	0.01b	0.01	0.01	0.02b	0.05a	0.03a
4	40.01	36.39	42.54a	33.24a	46.11c	39.67bc	0.02a	0.02	0.02	0.03a	0.02a	0.02b
5	36.99	42.33	39.66a	17.55b	75.11b	46.33b	0.01b	0.01	0.01	0.01c	0.03a	0.02b
Level of significance	NS	NS	*	**	**	**	**	NS	NS	**	**	**
SE (±)	2.82	4.31	5.31	2.80	4.97	4.03	0.002	0.002	0.002	0.002	0.003	0.002
Interactions	NS	NS	NS	NS	**	**	NS	NS	NS	*	**	**

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. *= significant at 5% level of probability using DMRT. ** = highly significant at 1 % level of probability using DMRT. a = not significant using DMRT.

Table V. Interaction between aqueous extract of moringa and nitrogen rates on crop growth rate (g wk^{-1}) and net assimilation rate ($gm^{-2}wk^{-1}$) of tomato in 2009 and 2010 rainy seasons and combined.

	Aqueous extract of moringa (%)											
	Crop growth rate											
	Harvest 2009 rainy season				Combined							
Nitrogen ($kg\ ha^{-1}$)	0	3	4	5	0	3	4	5	0	3	4	5
0	8.75g	71.17d	50.67e	60.50de	6.83f	53.06cd	50.98cd	38.80de				
40	120.50b	153.50a	59.00de	105.00c	64.53bc	90.10a	39.08de	59.70bc				
80	48.75e	110.67bc	28.67f	59.83de	33.67e	71.18b	28.96e	40.50de				
SE (±)	8.61				6.99							
	Net assimilation rate											
	Harvest 2009 rainy season				Harvest 2010 rainy season				Combined			
0	0.01c	0.02bc	0.04a	0.01c	0.01d	0.03c	0.02cd	0.02cd	0.01c	0.02bc	0.03ab	0.01c
40	0.01c	0.02bc	0.01c	0.01c	0.07a	0.06ab	0.02cd	0.05b	0.04a	0.04a	0.02bc	0.03ab
80	0.02bc	0.02bc	0.03ab	0.01c	0.02cd	0.05b	0.02cd	0.02cd	0.02bc	0.04a	0.03ab	0.02bc
SE (±)	0.004				0.005				0.004			

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. WAT = weeks after transplanting.

Table VI. Effects of aqueous extract of moringa and nitrogen rates on plant dry weight (g) and fruit yield ($kg\ ha^{-1}$) of tomato in 2009 and 2010 rainy seasons and combined.

Treatments	Plant dry weight									Fruit yield		
	5 weeks after transplanting			7 weeks after transplanting			Harvest					
	2009	2010	CMBD[a]	2009	2010	CMBD	2009	2010	CMBD	2009	2010	CMBD
Nitrogen ($kg\ ha^{-1}$)												
0	41.33b	29.28	35.29	133.31	103.92	118.61a	241.56a	295c	268.28b	9649.0	8312.0	8980.2
40	59.30a	31.08	45.19	132.80	98.67	106.72a	183.58b	536.67a	360.12a	9909.5	8317.0	9113.3
80	57.09a	24.58	40.84	114.77	97.08	114.94a	233.50a	345.00b	289.25b	9186.6	9689.0	9438.0
Level of significance	**	NS[b]	NS	NS	NS	NS	*	**	**	NS	NS	NS
SE (±)	3.53	6.74	5.39	10.06	3.41	7.51	13.76	16.51	15.20	314.97	452.96	201.18
Aqueous extract of moringa (% concentration)												
0	43.33b	35.33	39.33b	89.50c	98.22	93.86c	132.25b	335.56c	233.9c	9109.5a	9562.0	9336.0
3	95.46a	36.89	66.17a	175.48a	102.89	139.18a	299.94a	550.00a	424.97a	9276.7a	9871.0	9573.9
4	41.90b	19.44	30.67bc	139.28b	92.22	115.75b	272.21a	276.67d	274.44b	8978.9ab	9892.0	9435.5
5	29.60c	21.56	25.58c	108.58c	106.22	104.90b	173.78b	406.67b	290.22b	8716.4b	9943.4	9329.9
Level of significance	**	NS	**	**	NS	**	**	**	**	*	NS	NS
SE (±)	4.08	7.78	6.21	11.6	3.94	8.66	15.87	19.04	17.53	121.08	327.91	232.08
Interactions	**	NS	NS		**	**	**	**	**	**	NS	NS

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. *= significant at 5% level of probability using DMRT. ** = highly significant at 1 % level of probability using DMRT. b = not significant using DMRT. a = combined.

Table VII. Interaction between aqueous extract of moringa and nitrogen rates on plant dry weight (g) and fruit yield (kg ha^{-1}) of tomato in 2009 and 2010 rainy seasons and combined.

	Aqueous extract of moringa (%)											
	Plant dry weight											
	5 WAT[a] 2009 rainy season				7 WAT 2010 rainy season				7 WAT Combined			
Nitrogen (kg ha^{-1})	0	3	4	5	0	3	4	5	0	3	4	5
0	30.70cd	59.57b	46.50bc	28.55cd	65.00e	132.00a	94.00cd	124.67a	62.80e	149.02a	139.50ab	123.1abcd
40	60.55b	110.55a	23.55cd	42.55bc	118.00ab	79.33de	97.33bcd	100.00bcd	106.39bcd	131.68abc	95.42d	93.39d
80	38.75bcd	116.25a	55.65b	17.70d	111.67abc	97.33bcd	85.33de	94.00cd	112.40bcd	136.86ab	112.33bcd	98.18cd
SE (±)	7.08				0.83				15.02			
	Harvest 2009 rainy season				Harvest 2010 rainy season				Combined			
0	80.25e	305.83b	390.17a	190.00cd	100.00f	416.67c	296.67d	366.67cd	90.13f	361.25bc	343.42c	278.3de
40	129.00de	290.83b	170.13cd	144.33de	600.00ab	693.33a	333.33cd	520.00b	364.50bc	492.08a	251.73e	332.2cd
80	187.50cd	303.17b	256.33bc	187.00cd	306.67d	540.00b	200.00e	333.33cd	247.08e	421.58b	228.17e	260.2c
SE (±)	27.52				33.01				30.39			
	Fruit yield											
	2009 rainy season											
0	7640.7e	8517.5abc	9052.4a	7535.9e								
40	8047.7bcde	8339.7bcd	7476.2e	7774.6de								
80	8640.2ab	7973.0bcde	7407.9e	7838.6cde								
SE (±)	209.97											

Means in the same column followed by the same letter (s) are not significantly different at 5 % level of probability using DMRT. a = weeks after transplanting.