Yield and Quality of Watermelon as affected by Organic and Inorganic Nitrogen Sources

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ABSTRACT— ***Changes in growth, fruit yield and selected quality parameters were studied in watermelon plants subjected to two different sources of nitrogen. The research was conducted at Kenya Agricultural Research Institute Regional Research Center at Marigat for two seasons in 2006/2007. The two sources of nitrogen were cattle manure applied at the rates of 0 kg (0 ton ha^{-1}), 2.4 kg (3 ton ha^{-1}), 4.8 kg (6 ton ha^{-1}) and 7.2 kg (9 ton ha^{-1}), and Calcium Ammonium Nitrate (CAN) fertilizer at the rates of 0 kg (0 kg ha^{-1}) , 280 g (35 kg ha^{-1}), 560 g (70 kg ha^{-1}) and 840 g (105 kg ha^{-1}) per plot and a combination of the two. Application of cattle manure and CAN, in all cases, either singly or in combinations resulted in significant increase in total and marketable yield, fruit numbers, and average fruit weight, compared to the control. Fruit shape, fruit skin colour, total soluble solids (ºBrix) and rind (cortex) thickness were not influenced by the increase in application rates of the manures and CAN fertilizer. The manure and fertilizer applied either singly or in combinations, promoted growth and development of the crop in terms of the leaf area index, leaf numbers, and vine length. However, branching (secondary vines) did not respond to treatments. From the studies it was observed that a combination of 6.0 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN increased the marketable yield. The supply of N and organic matter to semi-arid agricultural land is therefore essential in increasing watermelon yield.***

Keywords— *Citrullus lanatus*, cattle manure, Watermelon, Brix, nitrogen sources

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1. INTRODUCTION

Watermelon (*Citrullus lanatus*) is a widely cultivated and most consumed cucurbit in the world (Huh, et al., 2008). Major producers of the crop include China, Turkey, United States, Iran and Republic of Korea (Huh, et al., 2008). The crop accounts for about 6.8% of the world area devoted to vegetable production (Goreta, et al., 2005). Watermelon grows best on fertile sandy or sandy loam soils with good drainage. Nutrient requirement for the whole production period of watermelon is in the ratio of N: P_2O_5: K_2O) is 3.28: 1: 4.33 (Zhejiang Agricultural University, 1985). The amount of N, P_2O_5, K_2O absorbed by watermelon plant depends on the growth stage, with seedling stage requiring 0.003, 0.008, 0.0022, while fruit growth stage requires 0.44, 0.127, 0.624 g/plant/day respectively (Zhejiang Agricultural University, 1985). It is now recognized that mineral fertilizers alone cannot increase crop productivity optimally. At the same time, the movement towards agricultural sustainability and farming systems has revived farmer's interest in using compost and other organic sources of nutrients (Roe, 1998).

Organic manure is an important source of nitrogen for crop production in the smallholder sector and can help farmers reduce inputs of commercial/mineral fertilizers and increase enterprise profitability (Aguyoh, et al., 2011). Addiscot, et al. (1991) concluded that manure has a persistent effect on the soil for many years and annual application of manure may lead to improvement of soil fertility and reduce the risk of serious nitrate losses in drainage water. Baker, et al. (1998) reported that both yield and number of melons were significantly higher in plants fertilized with poultry litter and that doubling both poultry litter and commercial fertilizer rates did not significantly affect yield but increased average melon mass. They concluded that composted poultry litter is a viable alternative to commercial fertilizers for production of triploid watermelon. Aguyoh et al. (2011) reported an increase in total yields by between 25% and 31% when tithonia was applied at 5.4 t/ha compared to the yields obtained from the untreated plots.

Integrated nutrient management might offer a more sustainable production of watermelon as the different nutrient sources complement one another. Although very few studies have been conducted on watermelon production in this regard, a number of studies have been conducted to determine the combined effect of mineral (inorganic) and organic fertilizers on crop production. Moutonnet (2000) reported that the combined effect of mineral fertilizers and organic matter at 40 kg P_2O_5 ha^{-1}, 60 kg N ha^{-1} and 2.7 t ha^{-1}, respectively, increased millet grain yield by 87% and cowpea grain yield by 200% in a continuous cropping system, and that the use of manure alone or in combination with the phosphogypsum (PG) and Taiba phosphate rock (PR) mix significantly increased peanut yield. Mugwira and Murwira (1997) also evaluated the effects of annual application of low rates of manure and castor cake with combinations of N and P, at varying rates, on sandy soil at Makoholi, and reported positive interactive effects with nitrogen but not with phosphorus on both maize and soybean.

When basal farmyard manure was applied at 30 t ha^{-1} on poor sandy soil with 0.3 to 0.5 % humus content on 'Charleston Gray' watermelon, N: P_2O_5: K_2O at 150: 100: 100 kg ha^{-1} produced maximum leaf photosynthetic activity and highest fruit yield of 42.4 t ha^{-1} (Spirescu, 1986). In Kenya, the recommended levels of N: P_2O_5: K_2O is 70: 70: 0, with a basal farmyard manure application of 10 t ha^{-1} (Ministry of Agriculture and Livestock Development, 2003b).

2. MATERIALS AND METHODS

The experiment on the effects of two sources of nitrogen on the performance of watermelon was done at Kenya Agricultural Research Institute - Perkerra, between 2006 and 2007. The site is at an altitude of 1065 m above sea level. and received mean rainfall of 322.5mm during the research period with mean daily temperatures of 30.2°C and 28.9°C respectively. The soils which were predominantly clay loam had a near alkaline pH. The soil also had low organic matter and nitrogen (%) (Table 1).

Experimental plots were ploughed and harrowed to a fine tilth during the dry period for maximum weed control (MOA, 2003b). Cattle manure treatments were applied two weeks before planting the seeds. The seeds of Ashley purchased from Kenya seed were planted in ridges placed 4 m apart at a depth of 3 cm. The intrarow spacing was 1 m. Each plot row had 5 plants. Cultural practices such weeding and supplementary irrigation was frequently done once per week until flowering, Vines were trained into their own plots. Spraying against anthracnose, fusarium wilt and insect pests was done on a weekly basis

Based on the soil analysis results (Table 1), uniform application of TSP (48%P_2O_5) and KNO_3 (13%N, 46% K_2O) was carried out in each plot at the rates of 5.15 – 22.27 g (12.875 – 55.675 kg ha^{-1}) and 7.22 – 55.31 g (18.05 – 138.275 kg ha^{-1}) respectively. Four meter wide plots were then laid in a factorial randomized complete block experimental design with three replications, Cattle manure was applied at the rates of 0, 3, 6, and 9 tons ha^{-1} while CAN was applied at topdressing at the rates equivalent to 0, 35, 70 and 105 kg N ha^{-1} in two splits at 21 and 35 days after emergence. Other treatments were the combinations of cattle manure and CAN tested at all the rates

The collected data was subjected to the analysis of variance using SAS version 9.1 and significantly different means were separated using the Least Significant Difference test at P = 0.05. Linear regression was done to establish relationships between variables. Results revealed significant variation in all the yield components that were measured.

2.1. Data Collection and Analysis

2.1.1. Growth parameters

Data on the number of leaves, vine length and number of secondary vines were recorded from three plants per plot and averaged for analysis. All the data were recorded on the 25th, 35th and 45th day after seedling emergence (DAE). Leaf length and leaf width measurements were taken from a randomly selected 5th leaf from the shoot tip, at 30, 35 and 45 DAE. Individual leaf area (LA) was calculated from leaf length and leaf width, using the equation adopted by Young et al. (2007):
$LA = -210.61 + 13.358W + 0.5356LW$; Where L is the leaf length; W is the leaf width. From the LA, Leaf Area Index (LAI) was calculated as: LAI = Total Leaf Area/Total area

2.1.2.. Plant yield

Number of fruits and weights were used to quantify the yield of the crop. All fruits that had reached physiological maturity from the three plants were counted 60 DAE. The first harvest was done 72 days from planting. Three harvested fruits from each plot were weighed using an electronic weighing scale (Model: Tanita KD 200-510, 5000g x 5g). The average fruit weight was then computed for each treatment.

2.1.2. Fruit shape and skin colour Measurement:

Fruit shape and fruit skin colour were determined using the standards set by USDA/ARS/GRIN descriptors for watermelon and the UPOV descriptors (UPOV, 2004):

Descriptor	Descriptor Name	Descriptor State
No. 29 UPOV (modified)	Fruit shape	1. Flattened 2. Round 3. Broad elliptic 4. Elliptic 5. Pyriform 6. Cylindrical
Stripecol (ARS-GRIN)	Fruit Skin Colour	1. Light green 2. Medium green 3. Dark green 4. White 5. Yellow 6. Brown 99. Other (specify)

2.1.3. Total soluble solids measurement

Total soluble solids content was measured using a hand-held refractometer (0-30 ºbrix) on three mature fruits from each plot from the first harvest. Total soluble solid levels are an indication of sweetness of the fruits. The average values were then used as the representative values per treatment.

2.1.4. Fruit rind thickness measurement:

Rind thickness was measured using a veneer caliper from the same fruits that ºbrix were measured.

3. RESULTS

3.1. Effects of Calcium Ammonium Nitrate and Cattle manure on watermelon selected growth parameters

3.1.1. Leaf number

Cattle manure at lower rates (0 – 3.0 ton ha^{-1}) had no effect on the leaf numbers in seasons I and II, but when the application rate was increased to 6.0 ton ha^{-1}, the number of leaves per plant was significantly increased by 14-24% compared to the control (Table 2)

3.1. 2. Number of branches

The number of secondary vines was not influenced by the application of different manure. However, CAN significantly increased the number of secondary vines under all the plots treated compared to the control.

3.1. 3. Vine length

While cattle manure application rate had no influence on the vine length, an increase in the CAN application rates significantly increased the vine length. The highest vine length increase of 15% was observed in plants that received 405 kg ha^{-1} of CAN in season 2 (Table 2).

3.1.4. Leaf area index (LAI)

Response of leaf area index (LAI) to the fertilizer and manure application rates varied with the tested nutrient sources (Fig, 1). With CAN fertilizer, increase in application rate in the tested range of 0 to 405 kg ha^{-1} (0 to 105 kgN/ha) led to linear increase ($y = 0.49 + 0.225x$, $R^2 = 0.988$, $P<0.05$. The application rates of 270 (70 kg N/ha) and 405 (105 kg N/ha) of CAN resulted in significantly higher LAI than the control in both seasons. Cattle manure application rates at low levels of 0 and 3 ton ha^{-1} (0 to 105 kg N/ha) did not affect the LAI, but at 6.0 ton ha^{-1} (70 kg N/ha) the LAI was significantly increased by between 29% and 34% in both seasons. However further increase in application rate did not lead to LAI increase. The difference in response of LAI to the manures implies that not all equivalent N supplied was utilized by the crop, especially at high manure application rates possibly because of high C/N ratio and increase microbial activity under such conditions.

3.2. Effect of Combined Cattle manure and CAN fertilizer and rates on the growth characteristics of watermelon

The application of 6.0 ton ha^{-1} Cattle manure + 405 kg ha^{-1} CAN fertilizer significantly affected LAI, leaf numbers and number of branches per plant as well as the average vine length in both seasons (Table 3). Also, the combination of 9 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN fertilizer and 6.0 ton ha^{-1} cattle manure + 270 kg ha^{-1} CAN resulted in consistently high values for the components investigated.

3.2.1. Leaf Area Index

The highest LAI response was obtained with the combined use of 6.0 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN, followed by the use of 9.0 ton ha^{-1} cattle manure + 270 kg ha^{-1} CAN in season one. The results in the second season were similar to those of season one except that the second highest LAI was obtained with the application of 6.0 ton ha^{-1} cattle manure + 270 kg ha^{-1} CAN.

3.2.2. Number of leaves

In the first season, combined treatment of 6.0 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN and 9.0 ton ha^{-1} cattle manure + 270 kg ha^{-1} CAN, led to the first and second highest number of leaves obtained in the study.

3.2.3. Number of branches

The number of branches responded significantly to the treatment combination of 6.0 ton ha^{-1} cattle manure + 270 - 405 kg ha^{-1} CAN in both the seasons. Apart from the above combinations, number of branches per plant was also high at 405 and 135 kg ha^{-1} of CAN fertilizer applied alone.

3.2.4. Vine length

The longest main vine was achieved with the combined application of 6.0 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN, followed by 9.0 ton ha^{-1} cattle manure + 270 kg ha^{-1} CAN, in season I. In the second season, combining 9.0 ton ha^{-1} cattle manure + 135 – 270 kg ha^{-1} CAN, and 6.0 ton ha^{-1} cattle manure + 405 kg ha^{-1} CAN resulted in main vine lengths that were not significantly ($p \leq 0.05$) different from each other.

3.3. Effect of Cattle manure and CAN application rates on the yield components.

3.3.1. Total and marketable yield

Response of watermelon yield to the two sources on nitrogen varied with the fertilizer type (Figure 2A and 2B). Application of CAN significantly increased the growth and total yield of watermelon. Cattle manure applied at low rates of 3.0 ton ha^{-1} did not result in any increase in marketable yield of watermelon (Figure 3), while higher application rates of 6.0 and 9.0 ton ha^{-1} achieved significantly higher total and marketable yield. The response of watermelon total yield to CAN and cattle manure application rates had the same trend as the response of leaf area index but not other growth parameters in this study.

3.3.2. Fruit weight

Average fruit weight was increased when CAN was applied at the higher rates of more than 270 kgN/ha compared to the control. However, the average fruit weight of plants grown with cattle manure were only enhanced when the manure was applied at the maximum rate of 9 tons/ha (105 kgN/ha) (Fig. 4).

3.4. Effect of Cattle manure and CAN application rates on fruit quality components

3.4.1. Total soluble solids

Application of CAN and cattle manure did not significantly affect the total soluble solids content comparing with no fertilizer application in both seasons (Table 4)

3.4.2. Rind thickness

Fruit rind thickness increased with the increase in CAN application rate in the range 0 – 270 kg ha^{-1}, while further increase of CAN application rate led to reduced response. At the CAN application rate of 405 kg ha^{-1}, rind thickness was similar to those of the control plots. Cattle manure application led to thinner fruit rind in the range of 0 – 6 ton ha^{-1}, while there was no significant difference between cattle manure application rates of 3, 6 and 9.0 ton ha^{-1}.

3.4.3. Fruit shape and fruit skin colour

The fruit shape was more broad elliptic with increase at higher CAN application rate of 270 – 405 kg ha^{-1} (Table 4). The same shape changes was observed in fruits subjected to cattle manure application rates of more than 3 tons/ha. On fruit colour, increased application rates of CAN and cattle manure led to higher level of fruit skin colour, tending towards the dark green colour. The darkest green skin colour was obtained with the highest application rates of 405 kg CAN ha^{-1} and cattle manure rates of 9 tones/ha (Table 4)

4. DISCUSSION

Soil amendments using organic and inorganic nitrogen sources have been reported to improve soil conditions and enhance plant growth through replenishment of soil nitrogen. In this study, the growth components investigated significantly responded to application rates of these nutrient-sources compared to the control. The leaf area index, leaf numbers, number of branches, and vine (stem) length were affected by the treatments. Cattle manure application rates at 6.0 ton ha^{-1} (70 kg N/ha) the LAI significantly increased by between 29% and 34% in both seasons. However further increase in application rate did not lead to LAI increase. The response of LAI to the at high rates probably implies that not all equivalent N supplied was utilized by the crop, especially at high manure application rates possibly because of high C/N ratio and increase microbial activity under such conditions. These results are similar to other studies (Jama, et al., 2000; ICRAF, 1997; Pholsen and Suksri, 2004, Gungula, et al., 2005) on various crops. The results showed that CAN releases N more quickly than the manures, and the crop was able to utilize most of the nutrient during its short growing period (72 days). The organic N could have been slow to release N during the short watermelon growth period. The reduction in vine length at the highest application rates of cattle manures was possibly caused by the temporary fixation of the N as a result of heightened microbial activity. Indira, (2005) attributed the increase in the number of leaves with increasing nutrient application to better root development and increased translocation of carbohydrates from source to growing points. It is also possible that increased number of leaves also had enhanced solar radiation interception.

The mean number of fruits per plant was 1.16 in season I and 1.31 in season II. Rashidi and Keshavarzpour (2007) found a maximum value of number of fruits per plant of 1.56 and a minimum value of 1.40. The low fruit numbers per plant was probably due to low fruit set and high incidences of melon fly attack. The results suggest that increased CAN application rates increased the average fruit weight of watermelon in this study. The findings are similar to those by Silvia, et al. (2007) and Chatzitheodorou, et al, (2004). The observation that only CAN significantly increased fruit weight, manure did not, could probably be implying that CAN readily supplied N at increasing rates which in turn enhanced photosynthetic activity and other growth parameters leading to high amounts of dry matter accumulation in the fruits. However, the inability of the manures to increase fruit weight could be attributed to the fact that manures tend to be fixed in the soil in the short-run due to high C/N ratio associated with high rates of application. Increase in fruit numbers significantly affected total and marketable yield. These results are similar to that reported by Ertek, et al. (2007) on the significant positive correlations ($p<0.05$) between mean fruit weight and fruit yield, and between vine length and fruit yield of green pepper (*Capsicum annum* L.). Increasing manure plus CAN application significantly increased fruit yield probably due to the role nitrogen plays in crop maturation, flowering and fruiting (Indira, 2005). The results suggest that high amounts/concentration of nutrient sources, particularly N supply, are required to enhance watermelon growth and development in arid and semi-arid areas as we observed in Marigat soils

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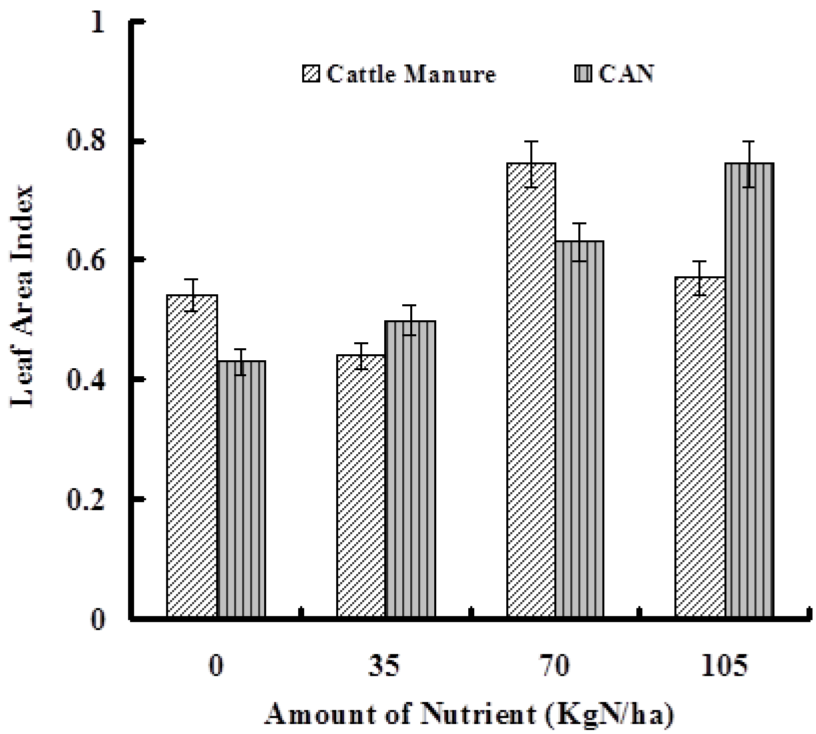

Figure 1. Response of 'Crimson Sweet' watermelon LAI to application rates of CAN and Cattle manure at 45 days after emergence.

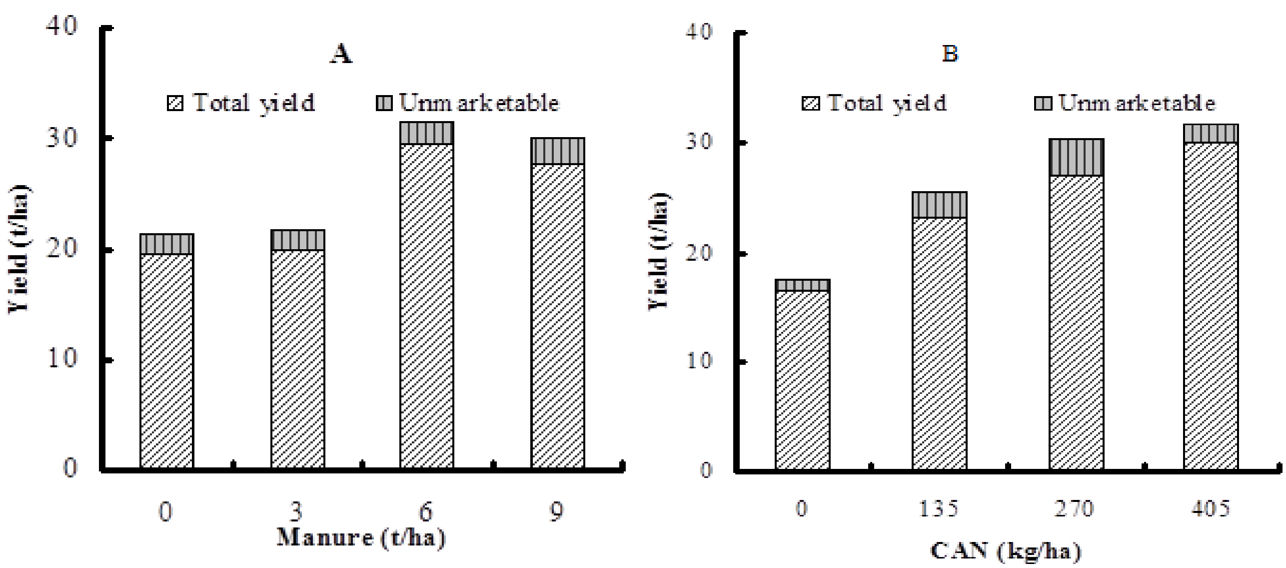

Figure 2. Effect of cattle manure **(A)** and Calcium Ammonium Nitrate (**B**) on total and unmarketable yield of watermelon 'Crimson Sweet'.

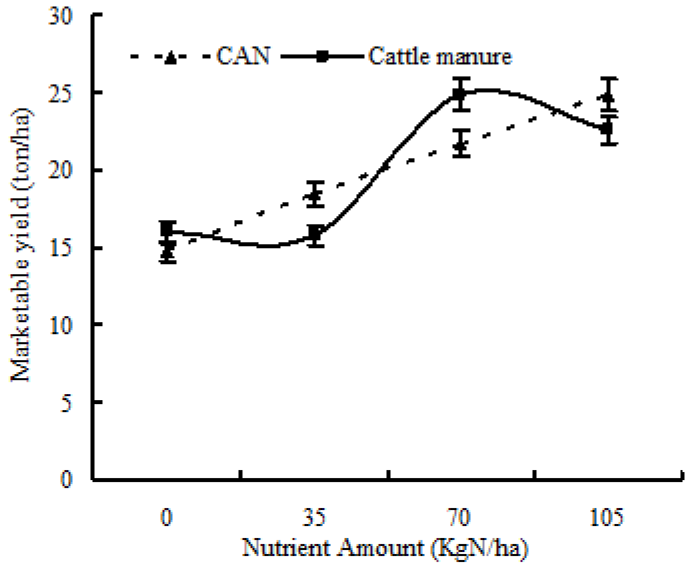

Figure 3. Effect of cattle manure and Calcium Ammonium Nitrate on marketable yield of watermelon 'Crimson Sweet'

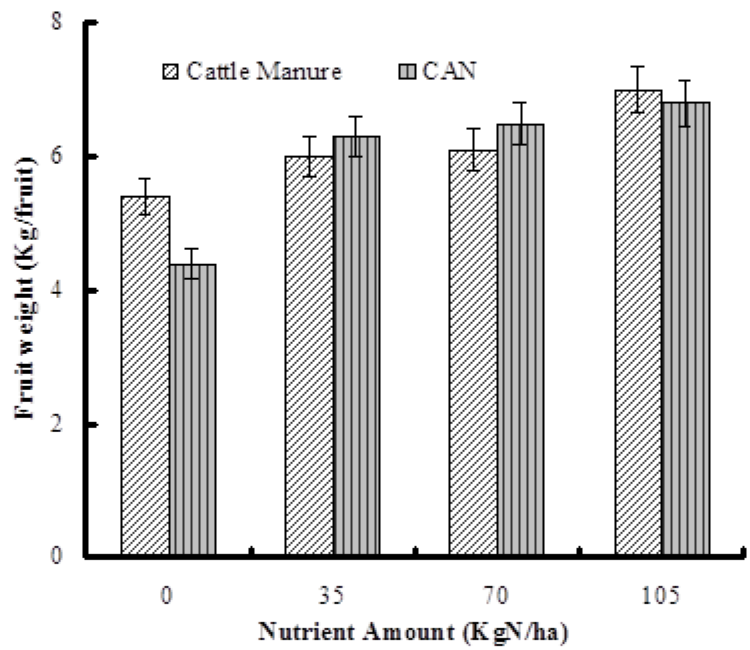

Figure 4. Effect of CAN and cattle manure on average fruit weight of watermelon 'Crimson Sweet' fruit
* To achieve the equivalent N application rate of 0, 15, 70, and 105 kg/ha, CAN applied at rates of 0, 135, 270, and 405 kg/ha and cattle manure applied at the rates of 0, 3.0, 6.0, and 9.0 tons/ha.

Table 1a: Chemical analysis of the cattle manure used in the experiments

% Nutrient					**Mg/kg**			
N	P	K	Ca	Mg	Fe	Cu	Mn	Zn
1.36	0.56	1.39	1.31	1.04	5.44	43	1113	135

Table 1b. Soil characteristics of the experimental plots (40-cm depth)

Characteristic	Season I		Season II	
	Before	After	Before	After
Soil PH	7.29	7.28	7.14	7.03
Total N %	0.08	0.07	0.05	0.06
Org. Carbon %	0.96	1.03	0.93	0.95
Phosphorus ppm	19.00	17.00	20	27
Potassium me%	1.82	1.61	1.49	1.41
Calcium me%	8.0	7.2	6.8	6.2
Magnesium me%	4.86	4.74	5.00	5.20
Manganese me%	0.69	0.55	0.54	0.53
Copper ppm	0.07	0.53	Trace	Trace
Iron ppm	39.4	31.6	48.7	44.7
Zinc ppm	6.06	9.05	5.53	5.55
Sodium me%	0.52	0.52	0.64	0.54
EC (Ms/cm)	0.45	0.35	0.32	0.35

Table 2. Effects of Calcium Ammonium Nitrate and Cattle manure on watermelon selected growth parameters

Nitrogen	Season 1			Season 2		
Source	Leaf number	Branches	Vine length (cm)	Leaf number	Branches	Vine length (cm)
Cattle manure (tons/ha)						
0.00	165.2b	3.9[y]a	205.4a	143.8c	4.1a	378.2ab
3.00	157.1b	3.6a	204.4a	129.4c	3.9a	370.6b
6.00	190.1a	4.0a	227.6a	190.0a	4.1a	384.5ab
9.00	166.3b	3.9a	225.3a	168.6ab	3.9a	403.4a
CAN (kg/ha)						
0.00	148.7c	3.3b	181.1c	116.0c	3.5b	343.8b
135.00	166.7bc	3.8a	211.8b	150.0b	4.1a	388.3a
270.00	172.9ba	4.1a	234.4a	174.3ab	4.1a	398.9a
405.00	190.2a	4.1a	235.4a	191.0a	4.3a	405.9a

[y]Means within columns for each treatment, followed by the same letter are not significantly at P≤ 0.05 according to Least Significant Difference (LSD). *To achieve the equivalent N application rate of 0, 15, 70, and 105 kg/ha, CAN applied at rates of 0, 135, 270 and 405 kg/ha

Table 3. Effect of combining Cattle manure and CAN fertilizer on leaf area index, leaf number, number of branches and vine length of 'Crimson Sweet' watermelon

Parameter	Cattle manure t/ha	Calcium Ammonium Nitrate (kg/ha) 0	135	270	405	LSD
Leaf Area Index (LAI)	**0.0**	0.42*g	0.56fedc	0.57edc	0.64dc	
	3.0	0.39g	0.51gfed	0.45gfe	0.43gf	
	6.0	0.41g	0.47gfe	0.85b	1.29a	
	9.0	0.50gfe	0.47gfe	0.66c	0.66c	0.114
Leaf numbers (plant^{-1})	**0.0**	145.9gf	167.3edc	168.8dc	178.6c	
	3.0	140.5g	165.0edc	170.2dc	152.6gfe	
	6.0	143.6gf	172.8dc	195.4b	248.4a	13.962

	9.0	164.9edc	161.7ed	157.1fed	181.3cb	
Number of branches (plant^{-1})	**0.0**	3.50fe	4.57a	3.76edc	4.64a	
	3.0	3.38f	4.13cb	4.12cb	3.90dc	
	6.0	3.53fed	4.08cb	4.45ba	4.44ba	
	9.0	3.59fed	3.75fedc	3.98c	4.08cb	0.342
Vine length (cm)	**0.0**	332.86h	390.60ed	390.62ed	398.87dc	
	3.0	335.96h	371.27fe	386.56ed	388.78ed	
	6.0	348.51hg	364.53gf	403.69dcb	421.42ba	
	9.0	357.69gf	426.89a	414.85cba	414.32cba	18.342

*Parameter means within columns and rows followed by the same letter are not significantly different at P≤ 0.05 according to Duncan's Multiple Range Test (DMRT).

Table 4: Effect of Calcium Ammonium Nitrate and Cattle manure on watermelon fruit quality.
Nitrogen Source

			Rind thickness	**Total soluble solids**
t/ha	**Skin Colour**	**Fruit shape**	**(mm)**	**(ºbrix)**
		Cattle manure		
0.00	2.146b	2.04*a	16.9a	8.11a
3.00	2.292ba	2.25a	15.3b	8.10a
6.00	2.333ba	2.31a	15.2b	8.34a
9.00	2.479a	2.25a	15.7b	7.97b
		CAN		
0.00	1.813c	1.917b	15.3bc	8.11a
135.00	2.208b	2.313a	16.0ba	8.08a
270.00	2.333ba	2.438a	16.7a	8.03a
405.00	2.500a	2.583a	15.1c	8.03a

*Means within columns for each treatment, followed by the same letter are not significantly at P≤ 0.05 according to Least Significant Difference (LSD).