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Improving Carbon Dioxide Concentration, Growth and Yield of Tomato Using Fresh Manure and Agronet Cover

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Abstract

Arable land area is declining in many tropical and sub-tropical regions and increasing tomato (*Solanum lycopersicum* L.) production is necessary due to its high demand. Food security amid scarcity of arable land could be achieved through intensification as a way of maximizing productivity per unit area of available arable land. Trials were conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro, Kenya, to evaluate effects of agronet cover and fresh manure on carbon dioxide (CO_2) concentration in the air around the crop canopy and tomato plant development. In addition to CO_2 concentration levels, stem diameter, plant height, number of internodes and branches, number of fruit and fresh fruit weight were determined. Use of agronet cover and fresh manure resulted in higher CO_2 concentration and enhanced tomato growth and yield. The highest CO_2 concentration in the air around the crop canopy was in plots treated with fresh goat dung and those covered with agronet; the lowest CO_2 concentration was in plots with no manure and those without agronet at all data collection dates. Application of fresh cow dung and covering plots with agronet stimulated tomato stem elongation; application of fresh goat dung and covering with agronet enhanced stem diameter, number of internodes and branches. Higher tomato yields were obtained with use of fresh manure and agronet cover. There were differences in response of tomato plants to fresh manure source with fresh goat dung showing greater potential for use in CO_2 enrichment and enhancing tomato crop performance. Use of fresh manure and agronet covers could enrich CO_2 levels in open field tomato production leading to improved growth and yield.

Keywords: *Solanum lycopersicum*, cow dung, goat dung, technology, crop vicinity

1. Introduction

Tomato (*Solanum lycopersicum* L.) production can be improved by increasing output or by putting more land under production. Arable land in sub-Saharan Africa has been declining especially in high rainfall areas due to rapid population growth. Food security amid scarcity of arable land could be achieved through intensification as a way of maximizing productivity per unit area of available arable land. For this to be achieved, optimum management of water, light, temperature, nutrients and carbon dioxide (CO_2) concentration need to be employed (Atwell, Kriedemann, & Turnbull, 1999).

Application of animal manure increases growth and yield of crops (S. A. Abolusoro & P. F. Abolusoro, 2012). Besides improving soil nutrient status, manure affects dynamics of soil borne pathogens by promoting antagonistic soil organisms, stimulating competitive status of non-pathogenic organisms, and by direct toxic effects on soil borne pathogens during decomposition (Bonamoni, Antignani, Capodilupo, & Scala, 2010). Application of cattle manure increase CO_2 emissions (Mapanda, Wuta, Nyamangara, & Rees, 2011). The amount of CO_2 emissions is dependent on type and level of applied organic amendments (Diacono & Montemurro, 2010), and quantity of carbon in the soil (Li et al., 2013). The CO_2 in the air around the crop canopy in crop production systems increase photosynthetic efficiency (Long, Ainsworth, Rogers, & Ort, 2004) and photo-assimilate supply leading to increased dry mass and yield.

Carbon dioxide enrichment has not been achieved in most open field production systems. Carbon dioxide enrichment, and other environmental manipulations such as change in temperature, relative humidity or solar radiation, during crop production are mostly feasible under greenhouse production. Adoption of greenhouse production by small scale farmers has been slow in developing countries due to the high costs involved in purchase and installation of the structures (Jadhav & Rosentrater, 2017).

Use of net covers in crop production offers a cheaper, less energy consuming technology, than greenhouses (Shahak, 2008). Net covers create a barrier for free exchange of gases within, and outside, the net (Tantau & Salokhe, 2006). Changes in the local microclimate under net covers modify CO_2 concentration and assimilation influencing crop growth and development (Kittas, Katsoulas, Rigakis, Bartzanas, & Kitta, 2012). Net covers have potential to reduce biotic and abiotic damage, which affect productivity and quality (Rajasekar, Arumugam, & Kumar, 2013). There are however, hardly any studies documenting the effects of integrated use of agronet covers and fresh manure on tomato performance. This study evaluated effects of use of agronet cover and fresh manure on CO_2 concentration level, growth and yield of tomato in open field tomato production.

2. Materials and Methods

2.1 Experimental Site Description

Trials were conducted from July to October 2019 and January to April 2020, at the Horticulture Research and Teaching Field of Egerton University, Njoro, Kenya, at a latitude of 0°23′ S and longitude 35°35′ E in the Lower Highland III Agro Ecological Zone (LH3), at an altitude of ≈ 2238 m above sea level. The soils are predominantly vitric mollic andosols with pH 6.0 to 6.5 (Jaetzold, Schmidt, Hornetz, & Shisanya, 2006). Mean temperature and rainfall during the study varied (Table 1).

Table 1. Average monthly air temperature (°C) and precipitation (mm) during tomato production July to October 2019 (Trial 1) and January to April 2020 (Trial 2)

	Trial 1				Trial 2			
	July	August	September	October	January	February	March	April
Air temperature	19.1	19.2	20.5	19.3	19.6	20.5	21.0	20.4
Total precipitation	146.7	76.4	89.7	161.6	83.9	40.0	62.8	303.8

2.2 Planting Material, Experimental Design and Treatments

Tomato, cv. Rio Grande (Kenya Seed Company, Nakuru, Kenya), was used. The determinate tomato produces a pear-shaped fruit weighing up to 150 g. The experimental design used was a 3 × 2 factorial arranged in a randomized complete block design with three replications. Each unit comprised of 5 beds 2 m long, 0.4 m wide and 0.2 m high in a 2 × 2 m plot separated from each other by 1 m. Each block was comprised of 6 such arrangements to accommodate treatment combinations. Individual blocks were separated from each other by 1.5 m. The two factors under study were fresh manure at three levels (cow dung, goat dung and no manure) and agronet cover at two levels (agronet and no agronet cover). Treatments were: (i) agronet cover and goat dung; (ii) agronet cover and cow dung; (iii) agronet cover and no manure; (iv) goat dung and no agronet cover; (v) cow dung and no agronet cover; and (vi) control (no agronet cover and no fresh manure). Agronet covers used were of 0.4 mm pore sourced from A to Z Textile Mills Ltd., Arusha, Tanzania. Cow and goat dung were obtained from Tatton Agriculture Park, Egerton University.

2.3 Crop Establishment, Maintenance and Treatment Application

Tomato seed were sown in rows spaced 20 cm apart in a raised nursery bed. When tomato seedlings were 5 weeks old, they were transplanted into troughs filled with soil in the field. Diammonium phosphate (DAP) fertilizer was applied at the rate of 240 $kg \cdot ha^{-1}$ (approx. 10 g per hole) (Anonymous, 2006) and thoroughly mixed with the soil prior to transplanting. Tomato seedlings were transplanted 60 cm apart within the bed for a total of 4 plants/bed and a total of 20 plants per experimental unit.

Two weeks after transplanting, fresh manure applied with protective glove, 15 $ton \cdot ha^{-1}$ (6 kg per experimental unit), was applied in furrows made adjacent to tomato plants in plots that were to receive fresh manure treatment. Where used agronet cover was mounted on plots using 5 posts, 1.2 m long to support the agronet cover where 1 post was placed at each corner of the experimental unit and at the center of the plot. The posts were grounded 20 cm deep for appropriate support. Once covered, the agronet cover was pegged at each corner to minimize effects of wind. Agronet covered plots were maintained permanently covered throughout the study period except during weeding and data collection.

Tomato plants were top dressed with calcium ammonium nitrate at 240 $kg \cdot ha^{-1}$ applied in 2 splits; the first at 3 weeks after transplanting and the second 3 weeks later. The crop was rain-fed with supplemental irrigation provided only during periods of extended dry spells with water provided manually with watering cans through the cover.

2.4 Data Collection

2.4.1 Carbon Dioxide (CO_2) Determination

Carbon dioxide level was measured using a portable carbon dioxide gas analyzer (Model SKY2000-CO2, Shenzhen YuanTe Technology Co., Ltd., Shenzhen, China) in parts per million (ppm) and reported as micromol mol^{-1}. Carbon dioxide concentration level was measured once weekly beginning 1 week after application of treatments through to the first harvest. Readings were taken between 9:00-13:00 hours (Yanfen et al., 2003; Ma, Wang, Wang, Jiang, & Nyren, 2006).

2.4.2 Plant Growth Variables

Four plants from the inner rows of each experimental unit were randomly selected and tagged. Plant growth was measured as stem diameter, plant height, number of branches and number of internodes. Plant growth data were collected on a 2 week interval beginning at the second week after application of treatments and continuing to the first harvest. At each collection date, stem diameter of the 4 tagged tomato plants was measured at ≈2 cm from the root collar. Height of each tagged plant was from the root collar to the apical growing tip, and number of internodes and branches were counted.

2.4.3 Fruit Yield

Tomato fruit per plant and fruit weight per plant were determined. Fruit from each experimental unit were harvested twice weekly at breaker stage. At each harvest fruit from each tagged plant were counted and weighed using a weighing balance (ATZ; Shangai Precision and Scientific Instrument Co., Shangai, China) and used to compute average number or weight of fruit per plant.

2.5 Data Analysis

The Proc univariate procedure of SAS (ver. 9.1; SAS Institute, Cary, NC) was used to determine normality and equal variances assumptions of analysis of variance of the data before analysis. Where assumptions were not met appropriate transformation was done. Data were subjected to ANOVA using the GLM procedure of SAS. If interactions were significant, they were used to explain results. If interactions were not significant means were separated using Tukey's honestly significant difference. Pearson correlation coefficients between CO_2 concentration and tomato plant growth and yield variables were estimated using PROC CORR procedure of SAS.

3. Results

3.1 Effects of Agronet Cover and Fresh Manure on Carbon Dioxide (CO_2) Concentration

Carbon dioxide (CO_2) concentration level was significantly influenced by agronet cover, fresh manures and days after transplanting (DAT) (Table 2). Interactions between agronet cover, fresh manure and DAT on carbon dioxide (CO_2) level were not significant (Table 2). Use of agronet cover resulted in higher CO_2 concentration in the air around the tomato plant canopy compared to no agronet cover (Table 3). The CO_2 concentration due to treatment with cow dung and goat dung was similar and different from no manure (Table 3). The main effect of days after transplanting (DAT) also affected CO_2 concentration level. CO_2 level increased with increase in number of days after transplanting (Figure 1). Although the interaction between agronet cover and fresh manure was not significant, some trend could be picked on CO_2 levels under the different treatments over the growing period whereby plots applied with goat dung and covered with agronet consistently registered highest CO_2 concentration level while control treatment (no agronet cover and no fresh manure) recorded the lowest CO_2 concentration level in all data collection dates. Among the other treatments, plots applied with cow dung and covered with agronet had slightly higher CO_2 concentration followed by those where only agronet covers were used without any organic manure applied, then in plots where goat dung was applied and lowest where only cow dung was applied in most data collection dates (Figure 2).

Table 2. ANOVA response to use of agronet, use of manure and days after transplanting on CO_2 concentration and plant growth variables

Source	CO_2 concentration	Plant height	Stem diameter	Number	
				Internodes	Branches
Net (N)	**	**	**	**	**
Manure (M)	*	*	*	**	*
DAT[a] (D)	*	**	**	**	**
N × M	ns	ns	ns	ns	ns
N × D	ns	*	ns	ns	ns
M × D	ns	*	ns	*	ns
N × M × D	ns	*	ns	*	ns

Note. ns, *, ** not significant or significant at $p \leq 0.05$ or $p \leq 0.01$, ANOVA. [a] DAT is days after transplanting.

Table 3. Effect of agronet cover and fresh manure on CO_2 concentration, stem diameter and number of branches during tomato production

Cover	CO_2 concentration (micromol·mol^{-1})	Stem diameter (mm)	Number of branches (no./plant)
Agronet cover	7.08a	10.47a	7.13a
No net	6.88b	9.34b	6.16b
Manure			
Cow	6.99a	10.22a	6.98a
Goat	7.04a	10.14a	6.84a
No manure	6.92b	9.37b	6.11b

Note. [a]Means in a column followed by the same letter within a variable are not significantly different, Tukey's honestly significant difference test at $p \leq 0.05$.

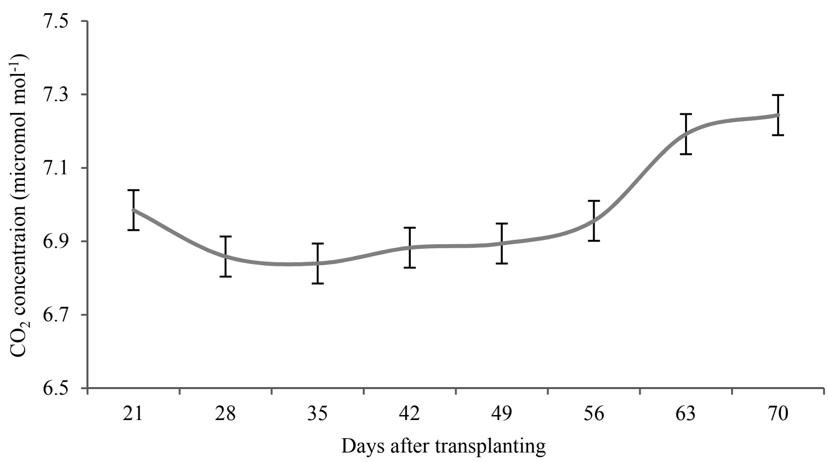

Figure 1. The main effect of days after transplanting on carbon dioxide (CO_2) concentration during tomato production. Means with error bars that do not overlap are significantly different

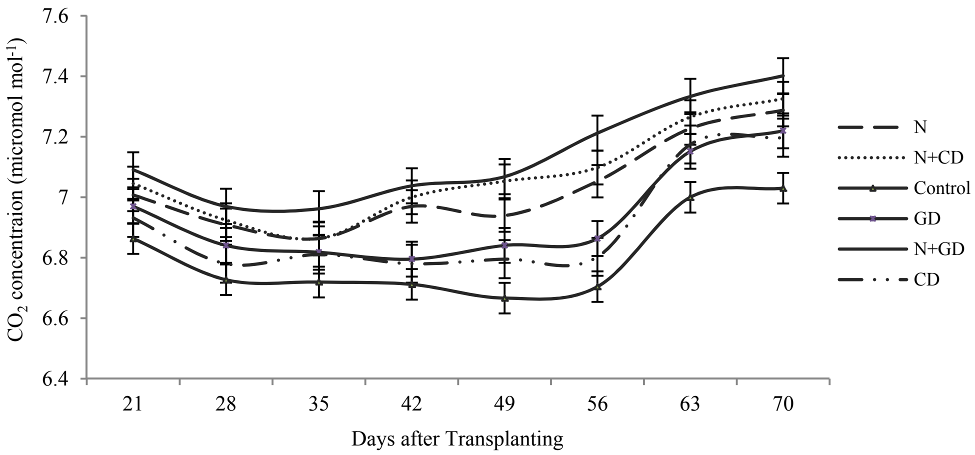

Figure 2. Effects of agronet cover and fresh manure on carbon dioxide (CO_2) concentration level overtime during tomato production. Means with error bars that overlap within a sampling date are not significantly different. N is agronet cover and no fresh manure; N + CD is agronet cover and cow dung; GD is goat dung and no agronet cover; N + GD is agronet cover and goat dung; and CD is cow dung and no agronet cover, Control is no agronet cover and no fresh manure

3.2 Effects of Agronet Cover and Fresh Manure on Tomato Plant Growth

Plant growth variables were significantly influenced by agronet cover, fresh manures and days after transplanting (Table 2). Interaction between agronet cover and DAT; fresh manure and DAT; and three way interaction between agronet cover, fresh manure and DAT on plant height and number of internodes were significant. However, interactions of agronet cover, fresh manure and DAT on stem diameter and number of branches were not significant (Table 2). Growing tomato with fresh manure and agronet cover resulted in taller plants (Figure 3).

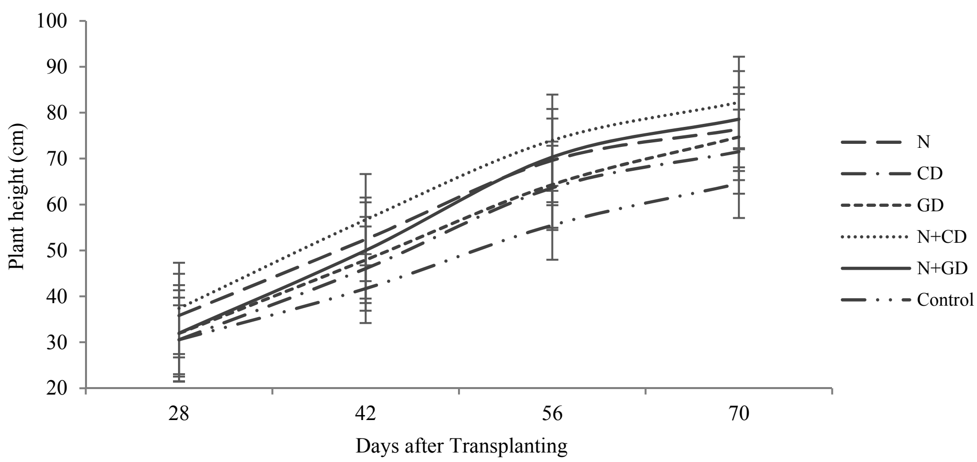

Figure 3. Effects of agronet cover and fresh manure on plant height overtime during tomato production. Means with error bars that overlap within a sampling date are not significantly different. N is agronet cover and no fresh manure; N + CD is agronet cover and cow dung; GD is goat dung and no agronet cover; N + GD is agronet cover and goat dung; and CD is cow dung and no agronet cover, Control is no agronet cover and no fresh manure

Tomato plants were tallest under the N + CD and N + GD treatments and shortest under the control treatment in most sampling dates. Plant height was also higher under agronet cover without any organic manure application compared to plots applied with either goat dung or cow dung alone without net cover during most sampling dates. During the final sampling date at 70 DAT, plants grown with cow dung and covered with net were the tallest while those under the control treatment were the shortest. Among the other treatments, plants grown with fresh goat dung and covered with net tended to be taller followed by those covered with net cover with no fresh organic manure applied, then those grown with fresh goat dung with no agronet cover, with the shortest plants being those grown with fresh cow dung with no agronet cover (Figure 3). Tomato plants under agronet cover resulted in thicker stems compared to plants grown without agronet (Table 3). Stem diameter was also slightly greater for plants grown with fresh manure compared to no fresh manure. Stem diameter due to treatment with cow and goat dungs were similar, and higher than with no manure (Table 3). Stem diameter increased significantly overtime during tomato production (Figure 4).

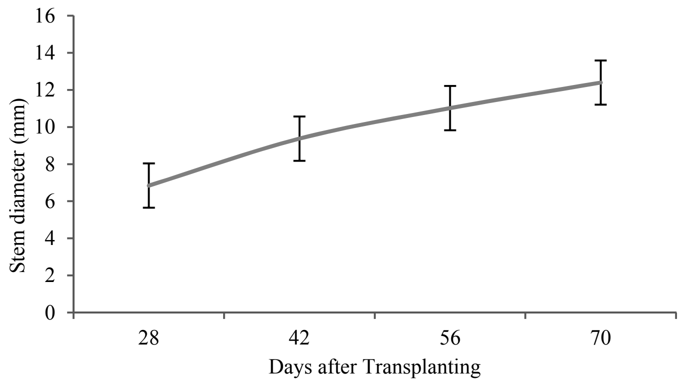

Figure 4. The main effect of days after transplanting on stem diameter during tomato production. Means with error bars that overlap are not significantly different

Tomato plant internode number was also influenced by use of agronet cover and fresh organic manure during production (Figure 5). Plant grown under agronet cover had more internodes than control plants at most sampling dates. Numbers of internodes for plants grown under agronet cover, with or without fresh manure, were not different during most sampling dates but tended to be slightly higher for plants grown with goat dung and slightly lower for plants grown under agronet cover with no fresh manure. Internode numbers tended to be slightly higher for tomato plants grown in the open without agronet cover but with fresh cow or goat dung compared to control plants during most sampling dates. Use of agronet cover and fresh manure improved plant branching (Table 3). Plants grown under agronet cover had more branches compared to those grown without agronet cover. Numbers of branches per plant was higher for plants grown with fresh manure compared to those grown without fresh manure. Numbers of branches per plant increased overtime during tomato production period (Figure 6).

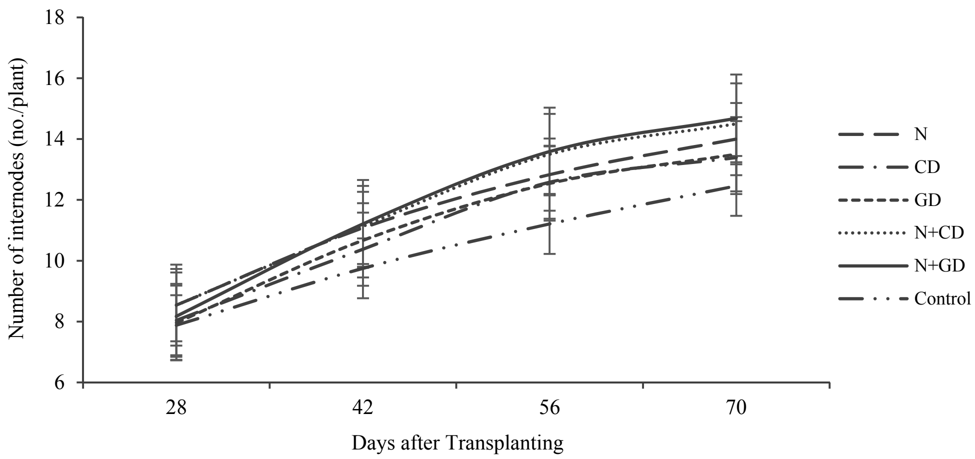

Figure 5. Effects of agronet cover and fresh manure on number of internodes overtime during tomato production. Means with error bars that overlap within a sampling date are not significantly different. N is agronet cover and no fresh manure; N + CD is agronet cover and cow dung; GD is goat dung and no agronet cover; N + GD is agronet cover and goat dung; and CD is cow dung and no agronet cover, Control is no agronet cover and no fresh manure

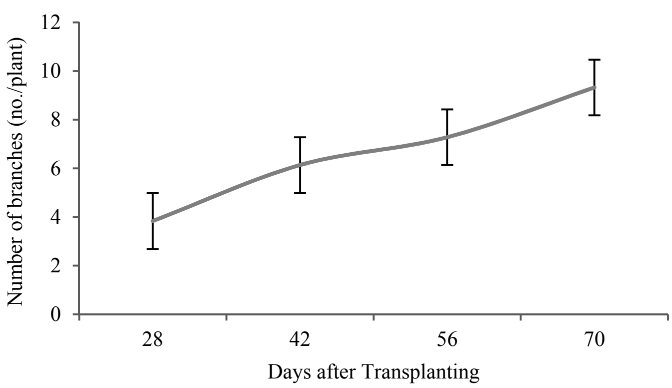

Figure 6. The main effect of days after transplanting on number of branches during tomato production. Means with error bars that overlap are not significantly different

3.3 Effects of Agronet Cover and Fresh Manure on Tomato Fruit Yield

Growing tomato plants under agronet cover and fresh organic manure improved tomato yield expressed as number of fruits per plant and fresh fruit weight per plant (Table 4). Interactions between agronet cover, fresh manure and DAT on tomato fruit yield were not significant (Table 4). Tomato plants grown under agronet cover had significantly higher fruit yield compared to yields obtained from plants grown without agronet cover (Table 5). Growing tomato with fresh manure significantly enhanced tomato fruit per plant compared to plants grown without fresh manure. On the other hand, fresh fruit weight per plant for tomato grown with fresh cow (1.96) or goat dung (2.04) tended to be slightly higher than those grown with no fresh manure (1.60), although the differences among these treatments were not significant.

Table 4. ANOVA response to use of agronet cover and use of fresh manure on yield variables

Source	Number of fruit	Fruit weight
Net (N)	**	**
Manure (M)	*	ns
N × M	ns	ns

Note. ns, *, ** not significant or significant at $p \leq 0.05$ or $p \leq 0.01$, ANOVA.

Table 5. Effect of agronet cover and fresh manure on fruit yield during tomato production

Cover	Number of fruit/plant	Fresh fruit weight (kg/plant)
Agronet cover	42.92a	2.39a
No net	31.09b	1.35b
Manure		
Cow	38.36ab	1.96a
Goat	40.50a	2.04a
No manure	32.15b	1.60a

Note. [a] Means in a column followed by the same letter within a variable are not significantly different, Tukey's honestly significant difference test at $p \leq 0.05$.

3.4 Relationship between Carbon Dioxide (CO_2) Concentration and Tomato Plant Growth and Yield Variables

Correlation analysis exhibited a significant positive correlation between CO_2 concentration within the crop vicinity with tomato plant height, stem diameter, number of internodes and numbers of branches. The CO_2 concentration did not affect numbers of fruit and fruit weight (Table 6).

Table 6. Pearson correlation coefficients for carbon dioxide (CO_2) concentration and tomato plant growth and yield variables at $p \leq 0.05$

	Plant growth and yield variables					
	Plant height (cm)	Stem diameter (mm)	No. of internodes	No. of branches	No. of fruit	Fruit weight (kg)
Carbon dioxide	0.4360	0.3262	0.4294	0.4351	0.1191	0.2930
p-value	0.0001	0.0052	0.0002	0.0001	0.6380	0.2380

4. Discussion

Organic manures have been widely used in agro ecosystems due to their positive role in soil fertility improvement and climate change mitigation via soil carbon sequestration (Gong, Yan, & Wang, 2012; Li et al., 2013). Cumulative CO_2 emission during the growing season is affected by the organic amendments applied, soil temperature and moisture (Li et al., 2013). The higher CO_2 concentration under agronet cover, and with application of fresh manure, could be attributed to a barrier for free gaseous exchange created by net cover (Tantau & Salokhe, 2006), higher soil moisture retention and air temperatures favored under net covers (Gogo, Saidi, Itulya, Martin, & Ngouajio, 2014) and CO_2 emitted by the fresh manure as it decomposes (Ma et al., 2006). The magnitude of CO_2 emissions from organic amendments is affected by particle size with enhanced emissions from smaller than from larger fractions (Fangueiro, Chadwick, Dixon, & Bol, 2007). Goat dung tends to be of smaller particle size than cow dung, which could imply that goat dug led to better enhancement of microbial activity. Smaller particles size has a larger surface area to volume ratio therefore increasing accessibility to soil microbes. Larger surface area to volume ratio of organo-mineral increases microbial biomass and residual products (Magid, De Nowina, Lindedam, & Andren, 2010). Goat dung could also provide more easily degradable, and potentially more soluble carbon, resulting in more interactions with microorganisms than cow dung resulting to greater CO_2 emission. Microbial activities are influenced by soluble carbon and nitrogen compounds in organic material added into the soils (Muhammad, Vaughan, Dalal, & Menzies, 2011; Soni et al., 2018). Goat manure is richer in total nitrogen (N) and total carbon (C) than cattle manure (Azeez & Van Averbeke, 2010). Addition of nitrogen leads to activation of soil microbial communities (Meijide, Cárdenas, Sánchez-Martín, & Vallejo, 2010), which increase organic matter mineralization leading to release of CO_2 (Bol, Moering, Kuzyakov, & Amelung, 2003). Increase in CO_2 emissions by organic waste is either a consequence of activation of soil microbial communities or a result of increased plant growth, which increase plant's respiration rate (Meijide et al., 2010). The CO_2 concentration generally tended to be higher as the crop approached maturity. Within the sampling dates, CO_2 concentration tended to be higher for treatments with more vigorous vegetative growth than those with less vegetative growth. This could likely be attributed to higher net respiration of plants leading to higher CO_2 emission and accumulation in the immediate crop vicinity.

Modified crop microclimate provided by the net cover could favor increased meristematic and physiological activities in plants leading to better plant growth. Agronet cover improves crop performance as a result of modified and stabilized crop microclimate under the cover (Gogo et al., 2014). Besides modification of crop microclimate, the net cover increases light scattering allowing light to reach a larger volume of the plant in a more homogenous way influencing plant branching and crop compactness (Abul-Soud, Emam, & Abdrabbo, 2014). Proper light distribution favors photosynthesis and metabolites translocation for better plant growth (Setiawati, Hasyim, Hudayya, & Shepard, 2014). Changes in the local microclimate under net cover, and application of fresh manure, modify CO_2 concentration and assimilation influencing crop growth and development (Kittas et al., 2012). Correlation analysis indicated CO_2 enrichment favored by use of agronet cover and fresh manure enhanced tomato plant growth. Increased CO_2 concentration could probably have led to improved plant water-use efficiency, photosynthetic efficiency and light-use efficiency leading to increased supply of photoassimilates and improved plant growth (Drake, Gonzalez-Meler, & Long, 1997; Ainsworth & Long, 2005; Ji et al., 2015). Improved plant growth following application of organic manure could have been favored by the fresh manure releasing essential nutrients as they decompose which are associated with high photosynthetic activity that promote root and vegetative growth (John, Jamer, Samuel, & Warner, 2004).

The better yield obtained with use of fresh manure and agronet cover can be attributed to enhanced vigorous growth with these treatments. Increased plant growth portrays better biomass accumulation and provides a greater bearing surface and more stored food reserves for yield. Greater carbon assimilation accelerates plant growth and development which stimulates development of new sinks through increased plant biomass production, more branching and new leaf production (Tissue, Thomas, & Strain, 1996). Plant parts develop new source surfaces favoring enhanced photosynthesis with ultimate increase in plant yield (Iqbal, Niamatullah, Yousaf, Munir, & Khan, 2011). More efficient utilization of food for reproductive growth (flowering and fruit set) and enhanced source to sink relationship of the plant results in improvement yield (Chaudhary, Sharma, Shakya, & Gautam, 2006). It is possible that higher tomato fruit yield obtained under agronet cover and application of fresh goat and cow dung could have been as a result of higher fruit set and development of more fruit per plant favored.

5. Conclusions and Recommendations

Results of the present study reveal use agronet cover and fresh organic manure application as a potential strategy for enhancing CO_2 concentration level in the immediate environment during tomato production leading to improved growth and yield of the crop. The study also shows differences in response of tomato crop to different sources of fresh manure with small particle manures showing greater potential for use in CO_2 enrichment and enhancing tomato crop performance. Results of this study also show the use of agronet cover as a potential strategy for achieving CO_2 enrichment in open field tomato production. Based on the findings of our study, we recommend that agronet cover and fresh goat dung be used by to small scale open field tomato growers for CO_2 enrichment and yield improvement in regions with similar climatic conditions to those of our study site. Studies on post-harvest analysis of tomato produce grown with fresh manure need to be conducted to determine its safety for human consumption. Further, we recommend that additional studies using the two technologies in different tomato growing regions as well as studies incorporating different fresh manure sources to further validate the viability of the technologies in tomato production.

Reference

Abolusoro, S. A., & Abolusoro, P. F. (2012). Effects of organic manure types on the growth, yield as well as root and soil populations of root-knot nematodes (*Meloidogyne incognita*) of tomato. *Scientific Journal of Agriculture, 1*(5), 138-144.

Abul-Soud, M. A., Emam, M. S. A., & Abdrabbo, M. A. A. (2014). Intercropping of some Brassica crops with Mango trees under different net house color. *Research Journal of Agriculture and Biological Sciences, 10*(1), 70-79.

Ainsworth, E. A., & Long, S. P. (2005). What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist, 165*, 351-371. https://doi.org/10.1111/j.1469-8137.2004.01224.x

Anonymous. (2006). *Fruits and vegetables*. Agricultural Information Resource Centre, Horticultural Crops Development Authority, Nairobi, Kenya.

Atwell, B. J., Kriedemann, P. E., & Turnbull, C. G. (1999). *Plants in action: Adaptation in nature, performance in cultivation*. Victoria, Macmillan Education Australia, South Yarra, Australia. Retrieved from http://plantsinaction.science.uq.edu.au/edition1

Azeez, J. O., & Van Averbeke, W. (2010). Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. *Bioresource Technology, 101*(14), 5645-5651. https://doi.org/10.1016/j.biortech.2010.01.119

Bol, R., Moering, J., Kuzyakov, Y., & Amelung, W. (2003). Quantification of priming and CO_2 respiration sources following slurry-C incorporation into two grassland soils with different C content. *Rapid Communications in Mass Spectrometry, 17*(23), 2585-2590. https://doi.org/10.1002/rcm.1184

Bonamoni, G., Antignani, V., Capodilupo, M., & Scala, F. (2010). Identifying the characteristics of organic soil amendments that suppress soil-borne plant diseases. *Soil Biology and Biochemistry, 42*, 136-144. https://doi.org/10.1016/j.soilbio.2009.10.012

Chaudhary, B. R., Sharma, M. D., Shakya, S. M., & Gautam, D. M. (2006). Effect of plant growth regulators on growth, yield and quality of chilli (*Capsicum annuum* L.) at Rampur, Chitwan. *Journal of the Institute of Agriculture and Animal Science, 27*, 65-68. https://doi.org/10.3126/jiaas.v27i0.697

Diacono, M., & Montemurro, F. (2010). Long-term effects of organic amendments on soil fertility. A review. *Agronomy for Sustainable Development, 30*(2), 401-422. https://doi.org/10.1051/agro/2009040

Drake, B. G., Gonzalez-Meler, M. A., & Long, S. P. (1997). More efficient plants: A consequence of rising atmospheric CO_2? *Annual Review of Plant Physiology and Plant Molecular Biology, 48*, 609-639. https://doi.org/10.1146/annurev.arplant.48.1.609

Fangueiro, D., Chadwick, D., Dixon, L., & Bol, R. (2007). Quantification of priming and CO_2 respiration sources following the application of different slurry particle size fractions to a grassland soil. *Soil Biology and Biochemistry, 39*(10), 2608-2620. https://doi.org/10.1016/j.soilbio.2007.05.012

Gogo, E. O., Saidi, M., Itulya, F. M., Martin, T., & Ngouajio, M. (2014). Eco-friendly nets and floating row covers reduce pest infestation and improve tomato (*Solanum lycopersicum* L.) yields for smallholder farmers in Kenya. *Agronomy, 4*(1), 1-12. https://doi.org/10.3390/agronomy4010001

Gong, W., Yan, X., & Wang, J. (2012). The effect of chemical fertilizer on soil organic carbon renewal and CO_2 emission-a pot experiment with maize. *Plant and Soil, 353*, 85-94. https://doi.org/10.1007/s11104-011-1011-8

Iqbal, M., Niamatullah, M., Yousaf, I., Munir, M., & Khan, M. Z. (2011). Effect of nitrogen and potassium on growth, economical yield and yield components of tomato. *Sarhad Journal of Agriculture, 27*(4), 545-548.

Jadhav, H. T., & Rosentrater, K. A. (2017). *Economic and environmental analysis of greenhouse crop production with special reference to low cost greenhouses: A review*. Annual International Meeting, American Society of Agricultural and Biological Engineers, July 16-19, 2017, Spokane, WA. https://doi.org/10.13031/aim.201701178

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. A. (2006). *Farm management handbook of Kenya. Natural conditions and farm information* (Vol.11/C, 2nd ed.). Ministry of Agriculture/Deutsche Gesellschaft für Technische Zusammenarbeit GmbH, German Agency for Technical Cooperation, Nairobi, Kenya.

Ji, G. A. O., Xue, H. A. N., Seneweera, S., Ping, L. I., Zong, Y. Z., Qi, D. O. N. G., & Hao, X.Y. (2015). Leaf photosynthesis and yield components of mung bean under fully open-air elevated [CO_2]. *Journal of Integrative Agriculture, 14*(5), 977-983. https://doi.org/10.1016/S2095-3119(14)60941-2

John, L. W., Jamer, D. B., Samuel, L. T., & Warner, L. W. (2004). *Soil fertility and fertilizers: An introduction to nutrient management*. Pearson Education, Delhi, India.

Kittas, C., Katsoulas, N., Rigakis, V., Bartzanas, T., & Kitta, E. (2012). Effects on microclimate, crop production and quality of a tomato crop grown under shade nets. *Horticultural Science and Biotechnology, 87*(1), 7-12. https://doi.org/10.1080/14620316.2012.11512822

Li, L. J., You, M. Y., Shi, H. A., Ding, X. L., Qiao, Y. F., & Han, X. Z. (2013). Soil CO_2 emissions from a cultivated Mollisol: Effects of organic amendments, soil temperature and moisture. *European Journal of Soil Biology, 55*, 83-90. https://doi.org/10.1016/j.ejsobi.2012.12.009

Long, S. P., Ainsworth, E. A., Rogers, A., & Ort, D. R. (2004). Rising atmospheric carbon dioxide: Plants face the future. *Annual Review of Plant Biology, 55*, 591-628. https://doi.org/10.1146/annurev.arplant.55.031903.141610

Ma, X., Wang, S., Wang, Y., Jiang, G., & Nyren, P. (2006). Short - term effects of sheep excrement on carbon dioxide, nitrous oxide and methane fluxes in typical grassland of Inner Mongolia. *New Zealand Journal of Agricultural Research, 49*(3), 285-297. https://doi.org/10.1080/00288233.2006.9513719

Magid, J., De Nowina, K. R., Lindedam, J., & Andren, O. (2010). Organic matter in size - density fractions after 16–50 years of grass ley, cereal cropping and organic amendments. *European Journal of Soil Science, 61*(4), 539-550. https://doi.org/10.1111/j.1365-2389. 2010.01247.x

Mapanda, F., Wuta, M., Nyamangara, J., & Rees, R. M. (2011). Effects of organic and mineral fertilizer nitrogen on greenhouse gas emissions and plant-captured carbon under maize cropping in Zimbabwe. *Plant and Soil, 343*, 67-81. https://doi.org/10.1007/s11104-011-0753-7

Meijide, A., Cárdenas, L. M., Sánchez-Martín, L., & Vallejo, A. (2010). Carbon dioxide and methane fluxes from a barley field amended with organic fertilizers under Mediterranean climatic conditions. *Plant and Soil, 328*, 353-367. https://doi.org/10.1007/s11104-009-0114-y

Muhammad, W., Vaughan, S. M., Dalal, R. C., & Menzies, N. W. (2011). Crop residues and fertilizer nitrogen influence residue decomposition and nitrous oxide emission from a Vertisol. *Biology and Fertility of Soils, 47*(1), 15-23. https://doi.org/10.1007/s00374010-0497-1

Rajasekar, M., Arumugam, T., & Kumar, S. R. (2013). Influence of weather and growing environment on vegetable growth and yield. *Journal of Horticulture and Forestry, 5*(10), 160-167. https://doi.org/10.5897/JHF2013.0317

Setiawati, W., Hasyim, A., Hudayya, A., & Shepard, B. M. (2014). Evaluation of shade nets and Nuclear Polyhedrosis Virus (SENPV) to control *Spodoptera exigua* (Lepidoptera: Noctuidae) on Shallot in Indonesia. *Advances in Agriculture and Botanics, 6*(1), 88-97.

Shahak, Y. (2008). Photo-selective netting for improved performance of horticultural crops. A review of ornamental and vegetable studies carried out in Israel. *Acta Horticulturae, 770*, 161-168. https://doi.org/10.17660/ActaHortic.2008.770.18

Soni, S., Kanawjia, A., Chaurasiya, R., Chauhan, P. S., Kumar, R., & Dubey, S. (2018). Effect of organic manure and biofertilizers on growth, yield and quality of Strawberry (*Fragaria* × *ananassa* Duch) cv. Sweet Charlie. *Journal of Pharmacognosy and Phytochemistry, 2*, 128-132.

Tantau, H. J., & Salokhe, V. M. (2006). Microclimate and air exchange rates in greenhouses covered with different nets in the humid tropics. *Biosystems Engineering, 94*(2), 239-253. https://doi.org/10.1016/j.biosystemseng.2006.02.016

Tissue, D. T., Thomas, R. B., & Strain, B. R. (1996). Growth and photosynthesis of loblolly pine (*Pinus taeda*) after exposure to elevated CO_2 for 19 months in the field. *Tree Physiology, 16*, 49-59. https://doi.org/10.1093/treephys/16.1-2.49

Yanfen, W., Xiuzhi, M., Baoming, J., Rui, D., Zuozhong, C., Gengchen, W., … Xiaowei, W. (2003). Diurnal and seasonal variation in methane and nitrous oxide fluxes in meadow steppe of Inner Mongolia. *Acta Phytoecological Sinica, 27*(6), 792-796. https://doi.org/10.17521/cjpe.2003.0113

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