

Article

Watermelon Genotypes and Weed Response to Chicken Manure and Molasses-Induced Anaerobic Soil Disinfestation in High Tunnels

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Abstract: Weed and disease management in organic watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] production is challenging. Yellow nutsedge (*Cyperus esculentus* L.) and Palmer amaranth (*Amaranthus palmeri* S. Wats.) are two competitor weeds in watermelon plasticulture production systems. Anaerobic soil disinfestation (ASD) is an emerging non-chemical approach to control weeds and soilborne plant pathogens, especially in organic farming. The effect of ASD treatments on weeds and soilborne diseases is being documented on different specialty crops. However, the impact of ASD treatments on the crop and crop genotypes; specifically watermelon has not been elucidated. Therefore, the impact of chicken manure and molasses (CMM)-induced ASD on twenty commercially available watermelon genotypes/rootstocks and major weed species was evaluated in a high tunnel experiment. The experiment was constructed as a randomized complete block design with three replications. The treatments consisted of a factorial of carbon source (1) non-treated check (CK), (2) CMM by twenty watermelon genotypes and rootstock. Soil treated with carbon CMM demonstrated significantly greater cumulative anaerobicity (246,963) activity relative to CK (575,372). Under anaerobic conditions, CMM achieved 91% weed control compared to CK. A lower number of yellow nutsedge (2) and Palmer amaranth (1) counts were recorded in CMM compared to CK (8) and (28), respectively. Among watermelon genotypes, 'Extazy', 'Powerhouse', 'Sangria', and 'Exclamation' had greater vigor 8.5, 8.4, 8.4, and 8.3, respectively, at 28 days after transplanting in CMM-treated soil. Greater watermelon plant fresh biomass was recorded in CMM-treated soil for 'Extazy' (434 g), 'Powerhouse' (409 g), 'Exclamation' (364 g), and 'Sangria' (360 g). This study demonstrated the variable response of watermelon genotypes to CMM-induced ASD and provides a guide for germplasm selection in organic watermelon production under field conditions.

Keywords: *Amaranthus palmeri* S. Wats.; anaerobic soil disinfestation; *Citrullus lanatus* (Thunb.) Matsum. & Nakai; cumulative anaerobicity; *Cyperus esculentus* L.



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1. Introduction

In 2023, a total of 1.68 billion kg of watermelon were produced in the United States (U.S.) [1]. The United States (U.S.) total melon (cantaloupe, honeydew, and watermelon)

consumption per capita was recorded as 22.5 lbs/person in 2022, whereas the watermelon consumption per capita was higher with 15.3 lbs/person [2]. The Southeastern U.S. is \$215 million industry with 7% of the organic watermelon coming from this region [3]. Since 2007, organic watermelon sales increased more than 80%, and the organic watermelon wholesale price is twice that of conventional watermelon. Also, 80% of organic products are sold within 500 miles of the farm [3]. Therefore, the Southeastern U.S. has unmet organic watermelon industry potential. However, weeds and diseases are two major production problems in organic watermelon and require the development of effective and sustainable management systems customized for organic watermelon production.

In the humid subtropical region of the Southeastern U.S., weeds pose a significant threat to conventional and organic watermelon production, resulting in yield reduction. Conventional watermelon production in the Southeastern U.S. relies on synthetic preemergence and postemergence herbicides [4], which are not permitted in organic production. Weeds compete with the crop for space, water, light, and nutrients. In addition, weeds can harbor plant pathogens and harmful insects [5]. For example, different weed species, i.e., balsam apple (*Momordica charantia* L.), smellmelon [*Cucumis melo* var. *dudaim* (L.) Naud.], creeping cucumber (*Melothria pendula* L.) can act as reservoir of pathogens like squash vein yellowing virus transmitted by whitefly that cause watermelon vine decline a serious disease of squash and watermelon [6,7]. Polyethylene mulch is commonly used in watermelon production to prevent weed emergence, conserve soil moisture, promote early ripening, and prevent fruit rot [8–10]. However, yellow nutsedge (*Cyperus esculentus* L.) and Palmer amaranth (*Amaranthus palmeri* S. Wats.) are two problematic weeds in Southeastern plasticulture vegetable production system [11,12].

Yellow nutsedge is ubiquitous in distribution and propagates through seeds and tubers. Sharp leaves and strong midrib of yellow nutsedge can perforate polyethylene mulch [13]. In a single year, a yellow nutsedge tuber can expand to cover an area of 34 square feet and can produce up to 6900 new shoots [14]. For example, yellow nutsedge densities of 2 and 25 plants/m² decreased watermelon yield by 10 and 50%, respectively, compared to the weed-free treatments [15].

Palmer amaranth is a problematic weed in vegetable production in the Carolinas and was reported as a major pest in North Carolina watermelon production [11]. Accumulation of higher biomass [16] and rapid growth under drip-irrigation [17] make Palmer amaranth more competitive and challenging to control relative together weed species of the *Amaranthus* genus. A single Palmer amaranth plant has incredible fecundity and can produce up to 100,000 in competition with crops and 600,000 when grown in isolation [16,18]. Minimal research is available to compare watermelon yield loss in response to Palmer amaranth competition. Palmer amaranth population densities of 4 plants/hole decreased watermelon marketable yield by 41%, 38%, and 65% for the watermelon varieties 'Exclamation', 'Carnivor' and 'Kazako', respectively [19].

Weed management options in organic watermelon productions are limited. Integrated weed management typically employs a combination of practices, including cover cropping, stale seedbed preparation, crop rotation, tillage, mechanical weeding, and the selection of competitive varieties [20]. All these weed management practices are available; however, the cost of hand weeding is 20 times higher than a conventional herbicide program, which is not practical to adopt in organic production [21]. Fusarium wilt caused by *Fusarium oxysporum* f.sp. *niveum* (FON) is a commonly reported soil-borne disease observed globally in watermelon [22]. Nearly 75% of the total watermelon produced in the U.S. are susceptible to FON [23], and controlling fusarium wilt in conventional and especially in organic watermelon, is challenging due to the lack of effective synthetic and organic fungicides for this

disease. Hence, weed competition and soil-borne diseases remain the two major problems in organic watermelon production systems, which require a strategic and holistic approach.

Anaerobic soil disinfestation (ASD) is a promising preplant non-synthetic chemical approach that has the potential to manage weed emergence, soil-borne disease, and nematodes, in a wide range of environments and crop production systems [24,25]. This has been developed and practiced in Japan, the Netherlands, and the U.S. [26]. Anaerobic soil disinfestation is a practice where readily available carbon sources are incorporated into the soil, followed by tarping the soil with plastic mulch and irrigating to the field saturation, which creates an anaerobic hostile environment that is toxic to soil-borne plant pathogens [25,27]. Shifts in soil microbial communities, production of volatile organic compounds (VOCs), low soil pH, and reduced soils result in pest suppression facilitated by ASD [25,28]. These studies have shown the potential for ASD to reduce fusarium incidence in strawberry, tomato, and spinach [25].

Previous studies have shown the impact of ASD on different weed and disease management in conventional vegetable production system [25,29]. However, the effectiveness of ASD has not been evaluated in organic watermelon production [25]. The demand for organic watermelon has increased for the crop despite the pest management challenges. Also, growers in the coastal region of South Carolina are transitioning from conventional to organic farming due to the higher profits of organic produce in the local markets and to lower the adverse effects of chemicals. Therefore, ASD has the potential for managing weeds and soil-borne plant pathogens in plasticulture organic watermelon production. However, the phytotoxic effect of ASD-induced VOCs on crop plant health is a major concern among growers. In one study, phytotoxic effects on tomato plants were observed when transplanted immediately after ASD termination [30]. Similarly, sweet potato slips showed necrosis when transplanted after ASD termination [31].

To our knowledge, there are no previous studies that have evaluated the effectiveness of ASD for weed management in organic watermelon production. Therefore, the objectives of this study were to evaluate the impact of chicken manure and molasses-induced (CMM) ASD on organic watermelon plant vigor, fresh biomass, plant length, and its effectiveness on weed control percentage, yellow nutsedge, and Palmer amaranth emergence. Therefore, it is hypothesized that CMM-induced ASD will significantly reduce germination of yellow nutsedge, Palmer amaranth, enhance weed control, and improve watermelon plant vigor, fresh biomass and plant length. Overall, this study aims to establish baseline data to guide the best germplasm selection for organic watermelon production and the efficacy of CMM-induced ASD for weed management under plasticulture production systems.

2. Materials and Methods

2.1. Experiment Location and Experimental Setup

High tunnel experiments were conducted at the United States Department of Agriculture Vegetable Laboratory (USVL), in Charleston, SC, USA (32°48'5" N 80°3'50" W). The experimental study was repeated in space and time, with the first experiment initiated on 27 July 2022 and the second experiment initiated on 1 August 2022. Experiments 1 and 2 were ended on 29 September and 3 October 2022, respectively. The experiment was constructed as a randomized complete block design with three replications. The treatments consisted of a factorial of two carbon source combinations (1) non-treated check (CK) and (2) chicken manure (CM) + molasses (M) together, by twenty watermelon genotypes and rootstock. Carbon source (CM) (Pearl Valley Organix, Peral City, IL, USA) and liquid (M) (Unsulfered Blackstrap Molasses, North Georgia Still Co., Dahlonega, GA, USA) were used at a rate of 20.34 t/ha and 13.5 m³/ha, respectively. The rates of carbon sources were based

on previous studies [30]. The CMM was added to the microcosm served as the anaerobic soil disinfestation (ASD) treatment.

The experimental soil material was collected from the upper profile (0–15 cm) at USVL organic field and the soil physiochemical characteristics are presented in (Table 1).

Table 1. Soil physiochemical characteristics used in high tunnel experiments conducted at the United States Vegetables Laboratory, Charleston, SC, USA.

Soil Origin	Soil Texture	Organic Matter (%)	Soil pH	P (lbs/A)	K (lbs/A)	Ca (lbs/A)	Mg (lbs/A)	Zn (lbs/A)	Mn (lbs/A)	Cu (lbs/A)	B (lbs/A)	Na (lbs/A)
Charleston, SC	Sandy loam	2.4	6.3	65	205	1123	198	4.8	16	0.9	0.6	52

The soil was sun dried, pulverized, homogenized, and then passed through 4 mm sieve. The soil was filled into 19,000 cm³ plastic containers (microcosms) having dimensions of 37 cm height and 30 cm diameter (The Home Depot, Charleston, SC, USA). The CMM was uniformly mixed in upper 0–20 cm of the soil column. Liquid (M) was diluted with water (1:1 on *v/v*) before application. After mixing the CMM into the soil, 100 seeds of Palmer amaranth and 15 tubers of yellow nutsedge were planted in each microcosm. All seeds and tubers were placed uniformly on top 0–15 cm soil. The seeds of Palmer amaranth and tubers of yellow nutsedge were purchased from Azlin Seed Services, Leland, MS, and Chufa Seed Ranch, Odessa, FL, USA, respectively.

To monitor soil conditions, oxidation reduction potential sensors (S550C-ORP; Sen-sorex, Garden Grove, CA, USA) were installed in the center of microcosm at a depth of 15 cm. All sensors were connected to a data logging system (CR-1000X with AM 16/32 multiplexers, Cambell Scientific, Logan, UT, USA) which recorded the output from each sensor every 30 s and reported an hourly average. To initiate the ASD process, microcosms were irrigated to saturation and covered with 1.25 mil impermeable film (TIF) polyethylene-black standard mulch (Berry Global Group, Inc., Evansville, IN, USA). Rubber bands (Global Industries, Buford, GA, USA) were used to secure the plastic mulch, avoiding air entering the microcosms. Microcosms were setup on the ground surface of the high tunnel for a 4 week ASD process.

All genotypes used in this study consisted of diploid and triploid watermelons and rootstocks, which are presented in (Table 2). One seed of each watermelon and rootstock genotype was seeded in a 98-cell plug tray (T.O. Plastics, Clearwater, MN, USA) and grown in a soilless mix, Metro-Mix 360 (Sungro Horticulture Canada Ltd., Bellevue, WA, USA). All seedlings were three weeks old and had 3 to 5 leaves at the time of transplanting. One seedling per microcosm was transplanted after ASD termination. All seedlings were grown for 4 weeks after ASD termination. The schematic research methodology and experimental design are presented in Figure 1.

Table 2. Watermelon genotypes and rootstocks used in high tunnel experiments at United States Vegetable Laboratory, Charleston, SC, USA.

Genotypes	Abbreviation	Type
Tri-X-313	TRI	Triploid
Captivation	CAP	Triploid
Dark Knight	DK	Triploid
Estrella	EST	Triploid
Extazy	EX	Triploid
Excursion	EXC	Triploid

Table 2. Cont.

Genotypes	Abbreviation	Type
Exclamation	EXL	Triploid
Fascination	FAS	Triploid
Melody	MEL	Triploid
Powerhouse	PH	Triploid
Calhoun Gray	CAL	Diploid
Black Diamond	BD	Diploid
Charleston Gray	CHS	Diploid
Crimson Sweet	CS	Diploid
Sangria	SAN	Diploid
Sugar Baby	SB	Diploid
Top Gun	TG	Diploid
Ojjakkyo	OJJ	Watermelon (rootstock)
USVL-351	351	Bottle gourd (rootstock)
USVL-482	482	Bottle gourd (rootstock)

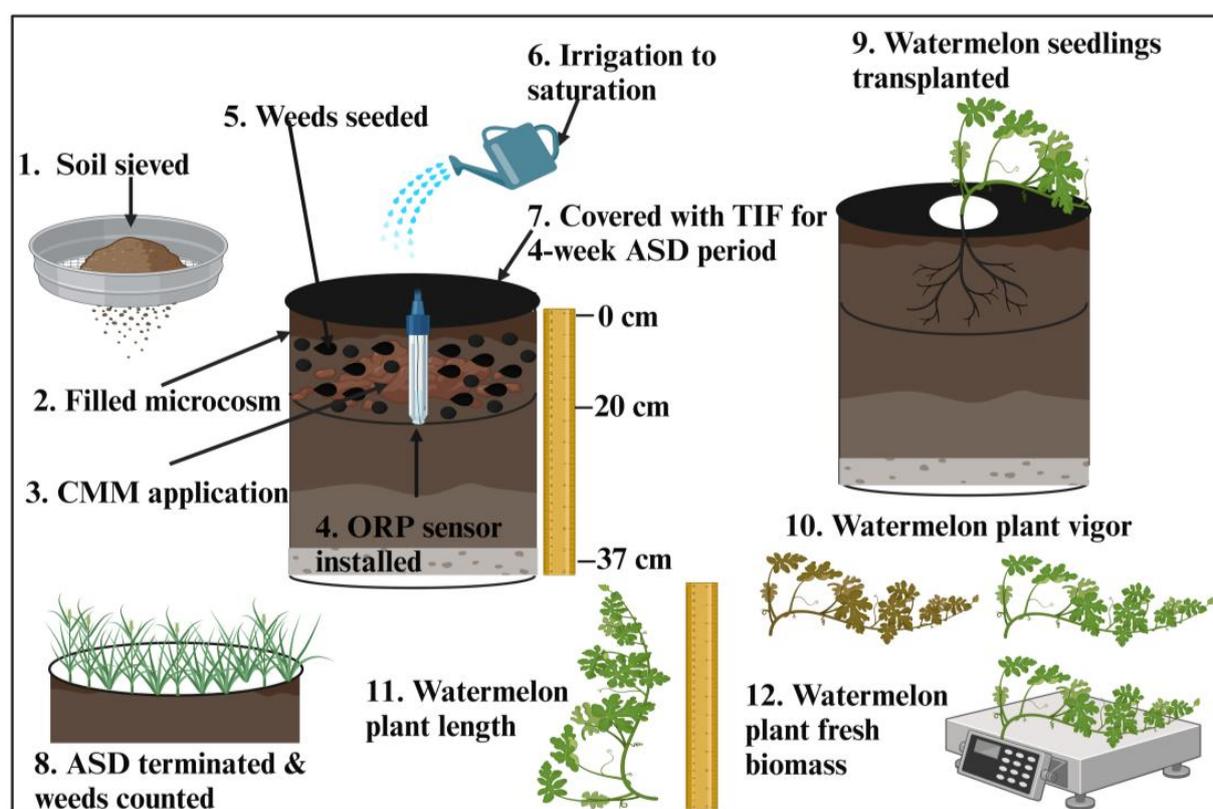


Figure 1. Schematic diagram of the experimental design and research methodology. The figure created with Biorender (<https://biorender.com/>, accessed on 25 January 2025).

2.2. Data Collection

The ASD was terminated after 4 weeks by puncturing the plastic mulch in the center and left open for 1 week. Raw soil redox potential data were downloaded from data logger at ASD termination and correlated to link redox potential described by [32] the standard hydrogen electrode. Anaerobic condition of the soil was specified based on average hourly readings of soil redox potential, which were below critical redox potential (CEh). The CEh was calculated using following formula: $CEh = 595 \text{ mV} - (60 \text{ mV} \times \text{soil pH})$. Soil pH was determined at ASD treatment termination by taking the soil samples and used it for soil pH analysis to calculate CEh. Over 4 weeks of ASD process, for values below CEh, the absolute

value difference between a given value and CEh were summed to calculate cumulative redox potential of the soil [26].

Weed ratings and individual weed counts were recorded immediately at the time of ASD termination. The percent of weed control was estimated visually on a scale of 0–100% by comparing non-treated CK treatment as most weed infested with CMM-induced ASD in each replication; whereas 0% weed control refers to CK and 100% refers to CMM treatment with complete weed mortality in microcosms. Yellow nutsedge and Palmer amaranth individual shoot counts were also recorded. Watermelon plant vigor, length and aboveground fresh biomass were recorded 4 weeks after ASD termination to determine the impact of CMM-induced ASD on all genotypes. During this period, phytotoxicity symptoms such as necrosis and chlorosis, were evident. Plant vigor was recorded at 7 days after transplant (DAT), 14 DAT, and 28 DAT. Plant vigor estimate was taken on a scale of 0–10 where 0 = dead plant and 10 = most healthy plant without the symptoms of necrosis and chlorosis. Plants were clipped from each microcosm to measure the plant length using ruler; followed by weighing the aboveground plant fresh biomass.

2.3. Data Analysis

Statistical analyses were performed using mixed-model approach in JMP version 17 (SAS Institute Inc., Cary, NC, USA). Treatment, genotypes, and their interaction were considered fixed effect while replication nested with experiment was considered the random effect. Treatment was considered fixed effect for cumulative anaerobicity, weed control percentage, individual weed count while replication nested with experiment was considered the random effect. Due to absence of treatment by experiment interaction, data from both experiments were pooled for cumulative anaerobicity, weed control percentage, individual weed count, plant vigor, plant length, and plant fresh biomass. The assumptions of normality and homogeneity of variance were verified using Shapiro—Wilk and Anderson—Darling tests, respectively. Treatments means were separated using Tukey's Honestly Significant Difference post hoc test at $p \leq 0.05$.

3. Results and Discussion

3.1. Impact of Chicken Manure and Molasses-Induced ASD on Cumulative Anaerobicity

Soil amended with (CMM) showed significantly greater cumulative redox potential (246,963) compared to the non-treated check (CK) (57,372) ($p = 0.0244$) (Figure 2). These higher values in carbon-amended soil indicate enhanced reducing conditions compared to soil without a carbon source. These results demonstrate that soil anaerobicity can be achieved through carbon amendments, confirming the effectiveness of CMM-induced ASD in establishing anaerobic conditions. These findings align with the previous studies [33–38] where carbon-amended soil, regardless of carbon source type, significantly increased cumulative anaerobicity. The CMM provides the food source for microorganisms. The enhanced microbial respiration in response to organic carbon amendments leads to depletion of oxygen and subsequent solely anaerobic decomposition [39–41]. Greater anaerobic conditions in soil are considered an important indicator of effective weed control [35]. The enhanced reducing conditions created by CMM treatment promote redox reactions that generate volatile organic compounds (VOCs), methane, and shifts in microbial communities while lowering soil pH. These cumulative effects are toxic to weeds [25,28,42,43] resulting in a decreased weed emergence.

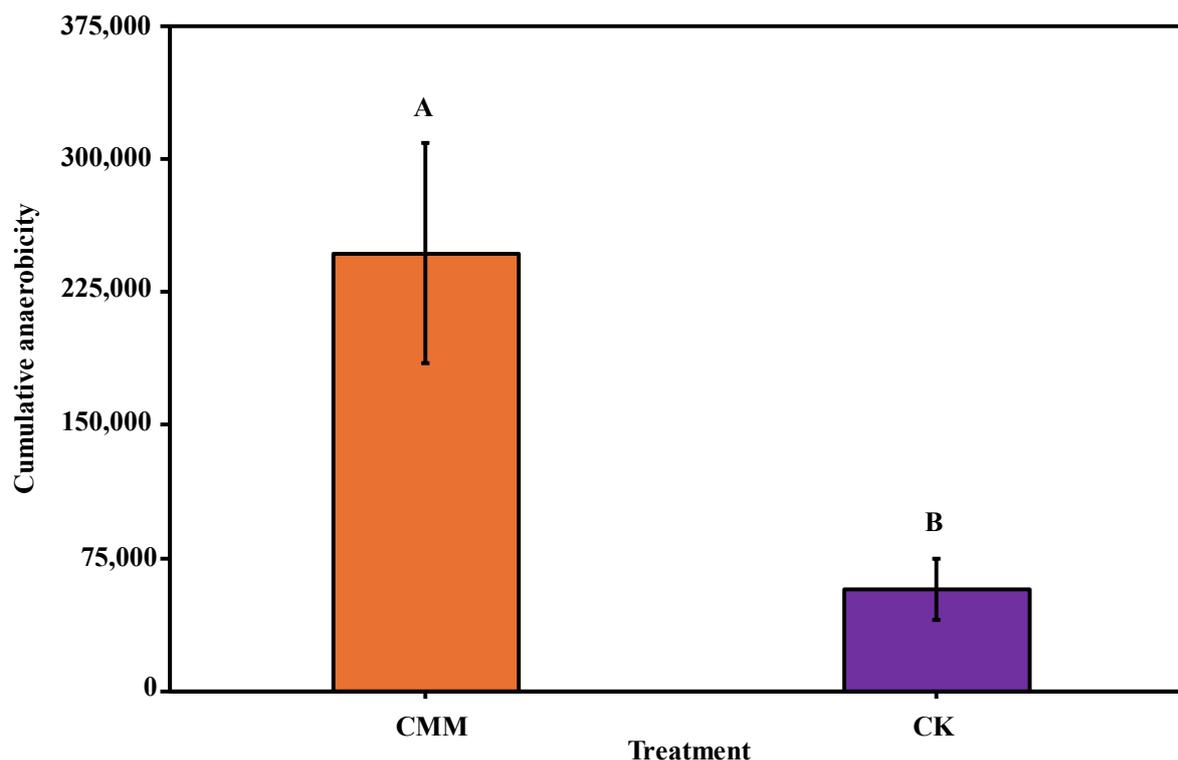


Figure 2. Impact of chicken manure and molasses (CMM)-induced anaerobic soil disinfestation on cumulative anaerobicity in microcosms under high tunnel conditions. Error bars indicate the standard error of mean. Means followed by different letters are significantly different at p -value ≤ 0.05 according to Tukey's HSD test.

3.2. Impact of Chicken Manure and Molasses-Induced ASD on Weed Control

3.2.1. Percent Weed Control

The ASD has been successfully evaluated as a proven strategy for soil-borne plant pathogens and weed control using various carbon amendments in greenhouse and field conditions [25,44]. Therefore, this study investigated the effectiveness of CMM-induced ASD on weed control in polyethylene mulched organic watermelon production in high tunnels. Soil treated with CMM significantly improved weed control percentage and showed an inhibitory effect on the germination of weeds. There was a statistically significant difference between CMM and CK ($p < 0.0001$). CMM exhibited 91% weed control compared to CK treatment, which was 14% (Figure 3a). These findings align with those previously reported by [30,45], where ASD treatments improved weed control up to 92% and 85%, respectively, using different carbon sources for the ASD process. In addition, the ASD process was shown to control weeds up to 89%, 79%, 96%, and 75% when molasses was used in combination with chicken manure, corn gluten meal, mustard meal, and sweet potato, respectively, compared to no carbon treatment [46]. Moreover, molasses is a chelating agent and organic stimulant when mixed with other organic sources, which is a readily available source of carbon energy and carbohydrates to feed and increase the growth of beneficial microorganisms.

3.2.2. Weed Counts

Yellow nutsedge is a primary weed, and Palmer amaranth is a secondary weed; both significantly influence watermelon production in the plasticulture production system and have specialized morphological features such as strong midribs and sharp leaf tips. These features allow yellow nutsedge to puncture the plastic mulch, reducing the longevity and durability of plastic mulch in addition to competing with the crop for resources [47,48]. In

this study, CMM significantly decreased individual weed shoot counts for yellow nutsedge and Palmer amaranth ($p < 0.0001$). Shoot counts were lowest in microcosms where soil was treated with CMM. On average, 1.7 and 8.3 yellow nutsedge shoot counts per microcosm were recorded in CMM and CK, respectively (Figure 3b). Germination and/or emergence of yellow nutsedge was reduced by 79% in the CMM-treated soil compared to the CK-treated soil, which is in agreement with the findings of other studies where the ASD process significantly decreased the germination of yellow nutsedge [26,49–51] and reduced seed vitality [52], regardless of the carbon source.

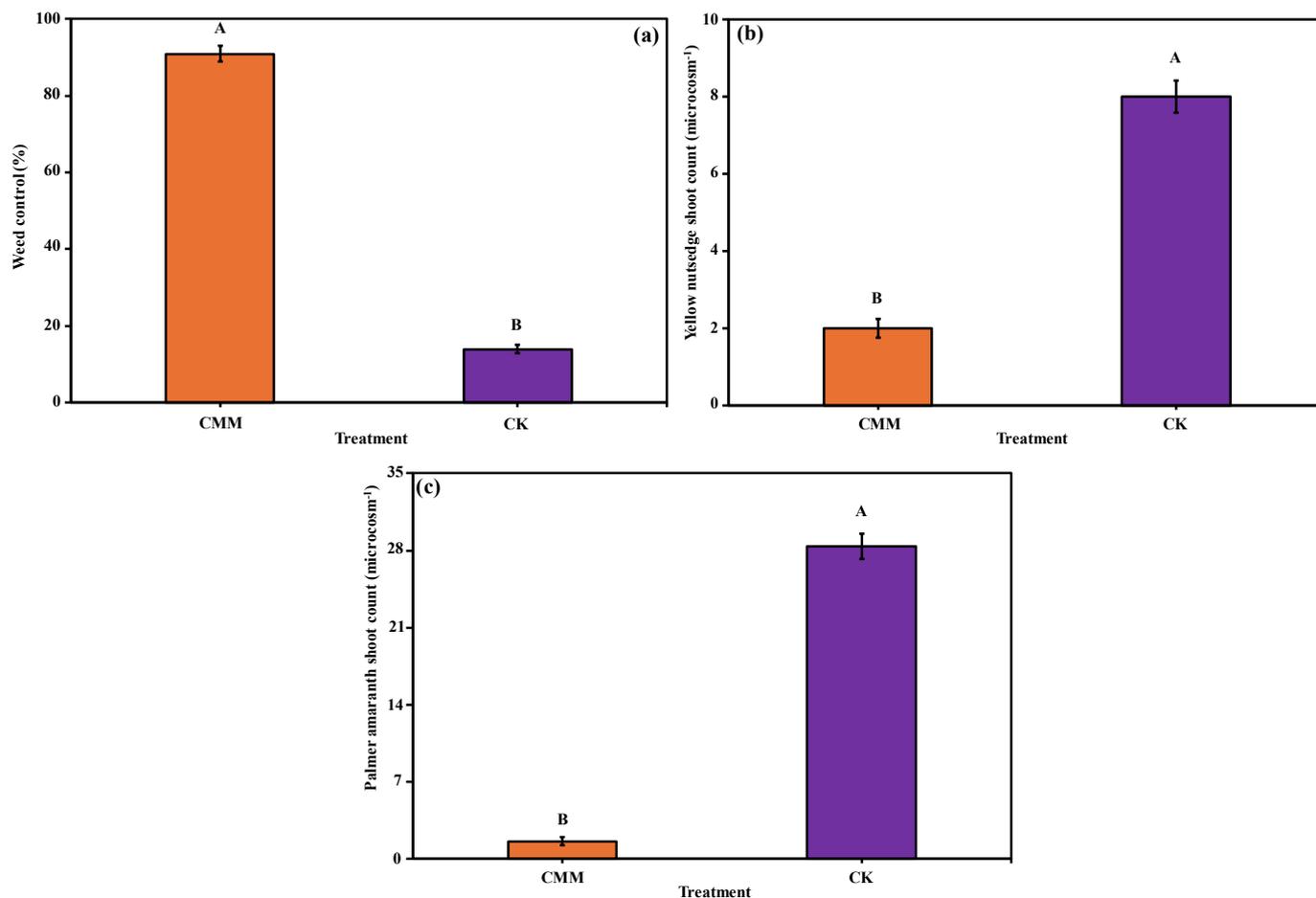


Figure 3. Impact of chicken manure and molasses (CMM)-induced anaerobic soil disinfestation on (a) percent weed control, (b) *Cyperus esculentus* L. shoot count, (c) *Amaranthus palmeri* S. Wats. shoot count taken after 4 weeks of ASD in microcosms under high tunnel conditions. Error bars indicate the standard error of mean. Means followed by different letters are significantly different at p -value ≤ 0.05 according to Tukey's HSD test.

In the case of Palmer amaranth shoot counts, 1.1 and 28.4 counts per microcosm were observed in the CMM and CK treatments, respectively (Figure 3c). Soil treated with CMM reduced Palmer amaranth germination by 96% relative to that treated with CK. There are no previous studies available describing how CMM affects the emergence and/or germination of Palmer amaranth. However, a study conducted by Singh et al. [30] showed that ASD significantly reduced Palmer amaranth emergence regardless of the carbon source under plastic mulch. The findings from our study suggest that CMM-induced ASD created anaerobic conditions in the soil and possibly reduced the viability of Palmer amaranth seeds and yellow nutsedge tubers as well as improving percent weed control. Another reason for weed inhibition could be the production of VOCs, organic acids, and toxic gases, which are produced during the ASD process [53,54]. As indicated in this study,

CMM-induced ASD can be a holistic approach for weed control in organic watermelon production in field conditions.

3.3. Impact of Chicken Manure and Molasses-Induced ASD on Watermelon Genotypes Plant Vigor, Plant Length, and Plant Fresh-Biomass

The suppression of weed germination during ASD occurs through the release of phytotoxic volatile organic compounds, organic acids, and toxic gases [25,28,55].

However, farmers remain concerned about the potential phytotoxicity effect of ASD on crop health [30,56]. Therefore, selecting genotypes that perform better under CMM-induced ASD conditions and exhibit vigorous growth is crucial. In this study, the response of the watermelon genotypes to the CMM amendment was variable when transplanted after ASD termination. At 7 DAT, phytotoxic symptoms included leaf yellowing and stunted growth for the EXC, MEL, OJJ, TG, and CS genotypes. The CMM treatment significantly improved plant vigor in most genotypes compared to CK treatment ($p = 0.0121$); however, EXC, FAS, OJJ, and TG exhibited reduced vigor and sensitivity to CMM-induced ASD at 7 DAT (Table 3). By 14 DAT, SAN, EX, and EXL showed greater vigor in the CMM-treated soil. Genotypes EXC, FAS, OJJ, and TG exhibited the lowest vigor regardless of the treatment. Similar genotype sensitivity patterns to CMM-treated soil persisted at 28 DAT for EXC, FAS, OJJ, and TG genotypes (Table 3 and Figure 4).

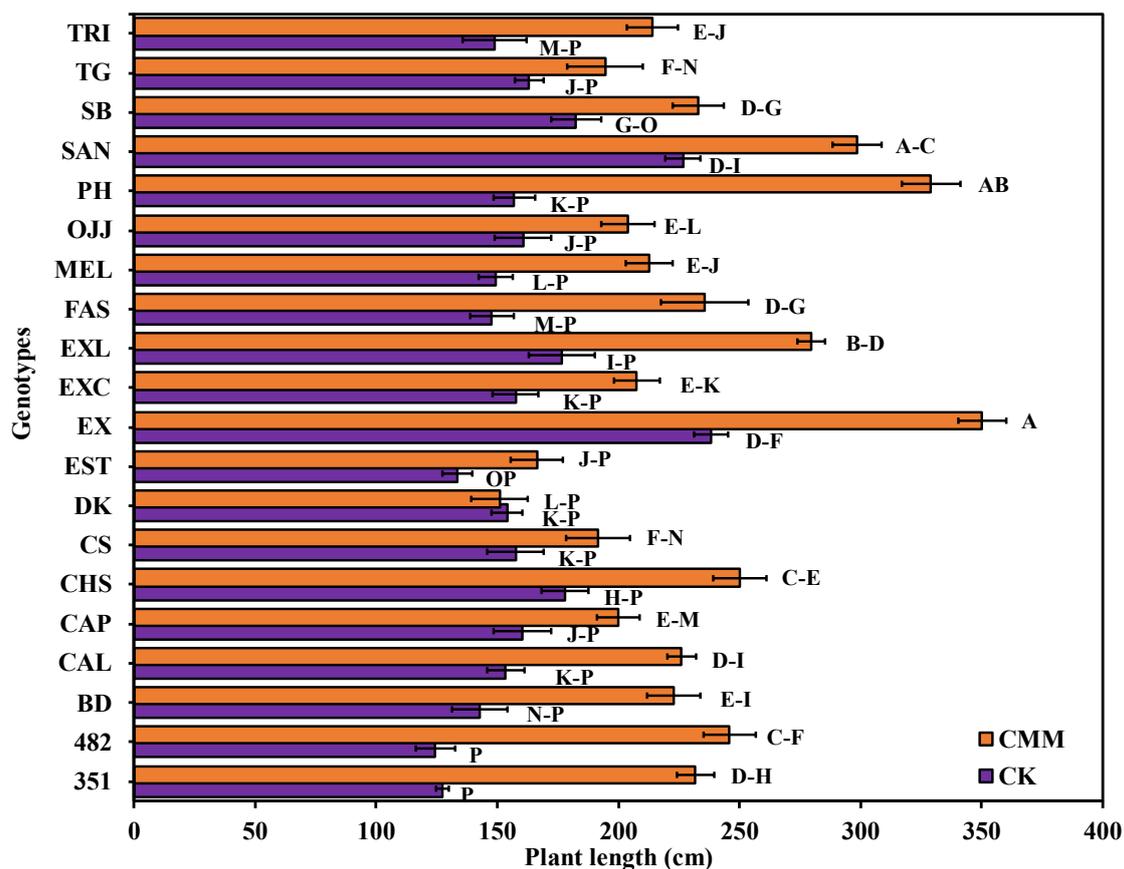


Figure 4. Impact of chicken manure and molasses (CMM)-induced anaerobic soil disinfestation on plant length of different watermelon genotypes and rootstocks at 28 days after transplant under high tunnel conditions. Error bars indicate the standard error of mean. Means followed by different letters are significantly different at p -value ≤ 0.05 according to Tukey’s HSD test. Refer to Table 2 for genotypes abbreviation.

Table 3. Impact of chicken manure and molasses (CMM)-induced ASD on watermelon genotypes and rootstock plant vigor (0–10) estimate taken after 7 days after transplant (DAT), 14 DAT, and 28 DAT under high tunnel conditions.

Treatment	Genotypes	Plant vigor Estimate (0–10)		
		7 DAT	14 DAT	28 DAT
CMM	351	4.6 D–J	5.3 E–I	6.5 B–D
CK		4.6 E–J	4.7 F–K	5.2 C–H
CMM	482	5.5 A–I	5.5 D–H	6.8 A–C
CK		5.6 A–H	5.0 E–K	4.7 D–I
CMM	BD	4.2 H–J	4.5 H–L	5.7 C–G
CK		4.6 D–J	4.6 H–K	3.7 H–J
CMM	CAL	4.6 E–J	4.7 F–K	5.9 C–F
CK		4.6 D–J	4.6 G–K	4.0 G–J
CMM	CAP	4.1 IJ	4.0 KL	5.2 C–H
CK		4.0 J	4.0 KL	4.1 F–J
CMM	CHS	4.2 H–J	4.4 I–L	5.6 C–H
CK		4.1 IJ	4.1 J–L	4.3 E–J
CMM	CS	4.6 E–J	4.9 E–K	5.5 C–H
CK		4.7 D–J	4.7 F–K	4.0 G–J
CMM	DK	5.1 I	4.9 E–K	4.7 D–I
CK		4.6 D–J	4.6 G–K	4.5 E–J
CMM	EST	3.8 J	4.0 KL	4.4 E–J
CK		4.3 G–J	4.2 J–L	3.3 IJ
CMM	EX	6.4 AB	6.7 A–C	8.5 A
CK		6.0 A–E	5.7 C–F	5.6 C–G
CMM	EXC	4.3 H–J	4.3 I–L	5.7 C–G
CK		5.0 B–J	4.7 F–K	3.7 H–J
CMM	EXL	6.4 AB	7.2 A	8.3 AB
CK		5.8 A–F	5.6 D–G	5.6 C–G
CMM	FAS	4.8 C–J	4.7 F–K	5.3 C–H
CK		4.5 F–J	4.4 I–L	4.6 E–I
CMM	MEL	4.3 H–J	5.1 E–J	5.0 C–E
CK		4.7 D–J	4.6 H–K	4.4 E–J
CMM	OJJ	3.7 J	3.5 L	4.6 E–J
CK		4.7 D–J	4.4 I–L	2.6 D–I
CMM	PH	6.3 A–C	6.8 AB	8.4 A
CK		6.1 A–D	6.3 A–D	5.7 C–G
CMM	SAN	6.6 A	7.2 A	8.4 A
CK		5.7 A–G	5.9 B–E	5.4 C–H
CMM	SB	5.2 A–J	5.0 E–K	5.3 C–H
CK		4.5 F–J	4.2 I–L	4.2 F–J
CMM	TG	3.8 J	4.4 I–L	5.3 C–H
CK		4.6 D–J	4.6 H–K	4.0 G–J
CMM	TRI	5.0 B–J	5.3 E–I	6.8 A–C
CK		5.2 A–J	4.6 H–K	5.1 C–I
		<i>p</i> value		
Treatment		0.5753	<0.0001 *	<0.0001 *
Genotypes		<0.0001 *	<0.0001 *	<0.0001 *
Treatment × Genotypes		0.0121 *	<0.0001 *	0.0016 *

Note: High tunnel experiments were terminated after four weeks of planting of watermelon genotypes. Within columns, means followed by different letters are significantly different according to Tukey's HSD test (p -value ≤ 0.05). Plant vigor was visually assessed with a score of 0–10 where 0 is the dead plant and 10 is the healthiest plant. Refer to Table 2 for genotypes abbreviation. * p -value ≤ 0.05 .

The CMM treatment significantly influenced plant length ($p < 0.0001$), with greater plant lengths recorded in CMM than the CK. There was significant difference between

genotypes plant length ($p < 0.0001$); however, treatment by experiment interaction were not significant ($p = 0.9789$). Genotypes EX, PH, SAN, and EXL exhibited greater plant length compared to other genotypes (Figure 4). For aboveground plant fresh biomass, genotypes were significantly different ($p < 0.0001$) and treatment by experiment were not significant ($p = 0.5010$). The CMM treatment significantly increased plant fresh biomass relative to CK ($p < 0.0001$). Genotypes EX, PH, EXL, and SAN produced the highest fresh biomass at 434, 409, 364, and 360 g, respectively (Figure 5). The biomass increases align with who reported significantly higher fresh biomass in lettuce and mustard greens grown in soil treated with carbon amendments compared to CT [55] and higher biomass in tomato and sweet potato were recorded in soil treated with carbon sources compared to CT [30,34].

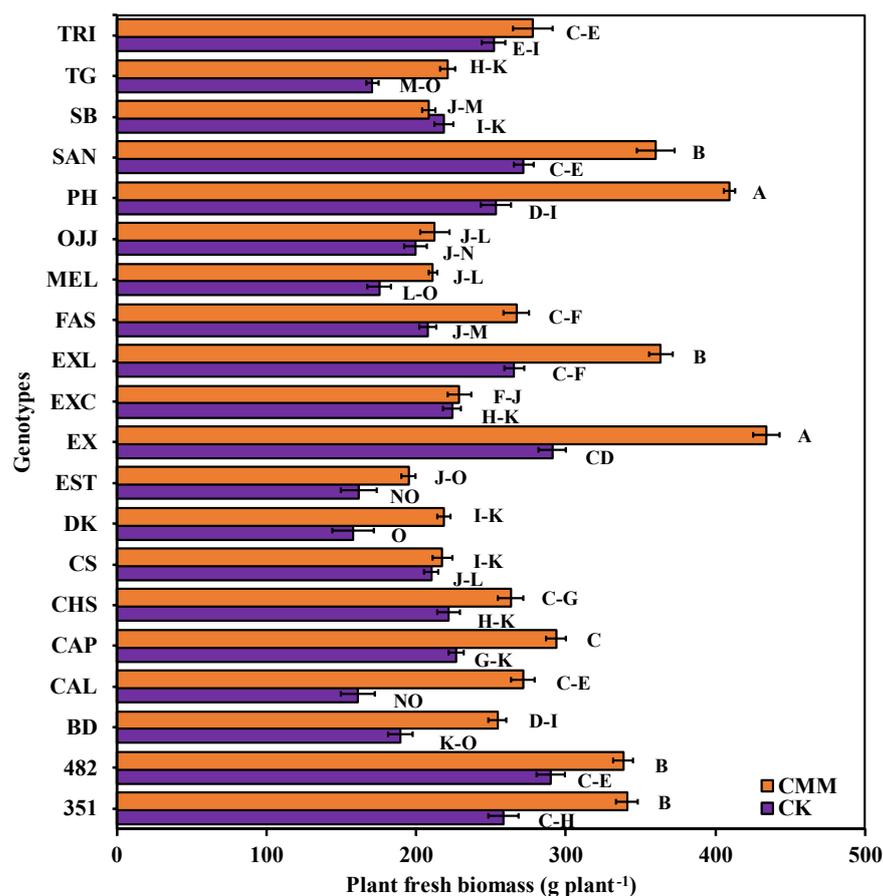


Figure 5. Impact of chicken manure and molasses (CMM)-induced anaerobic soil disinfestation on plant fresh biomass of different watermelon genotypes and rootstocks at 28 days after transplant under high tunnel conditions. Error bars indicate the standard error of mean. Means followed by different letters are significantly different at p -value ≤ 0.05 according to Tukey's HSD test. Refer to Table 2 for genotypes abbreviation.

The higher plant vigor observed in EX, PH, EXL, and SAN watermelon genotypes (Table 3) corresponds with their increased plant length (Figure 4) and fresh biomass (Figure 5) after CMM treatment. Overall, CMM improved plant vigor, length, and fresh biomass, possibly due to reduced weed pressure, improved plant nutrition, and/or genetic makeup. Furthermore, higher plant vigor in carbon-amended soil is also previously reported by [30,34,37] and the decomposition of organic amendments during ASD improved the soil microbial profile, and these microbes positively correlate with soil nutrient mobilization and plant growth [55]. Several genotypes showed tolerance to CMM-induced ASD conditions under CMM amendments (Figure 6). Optimizing watermelon genotype selec-

tion based on CMM-amended soil responses in high tunnels and controlled environments will be crucial for successful field cultivation.

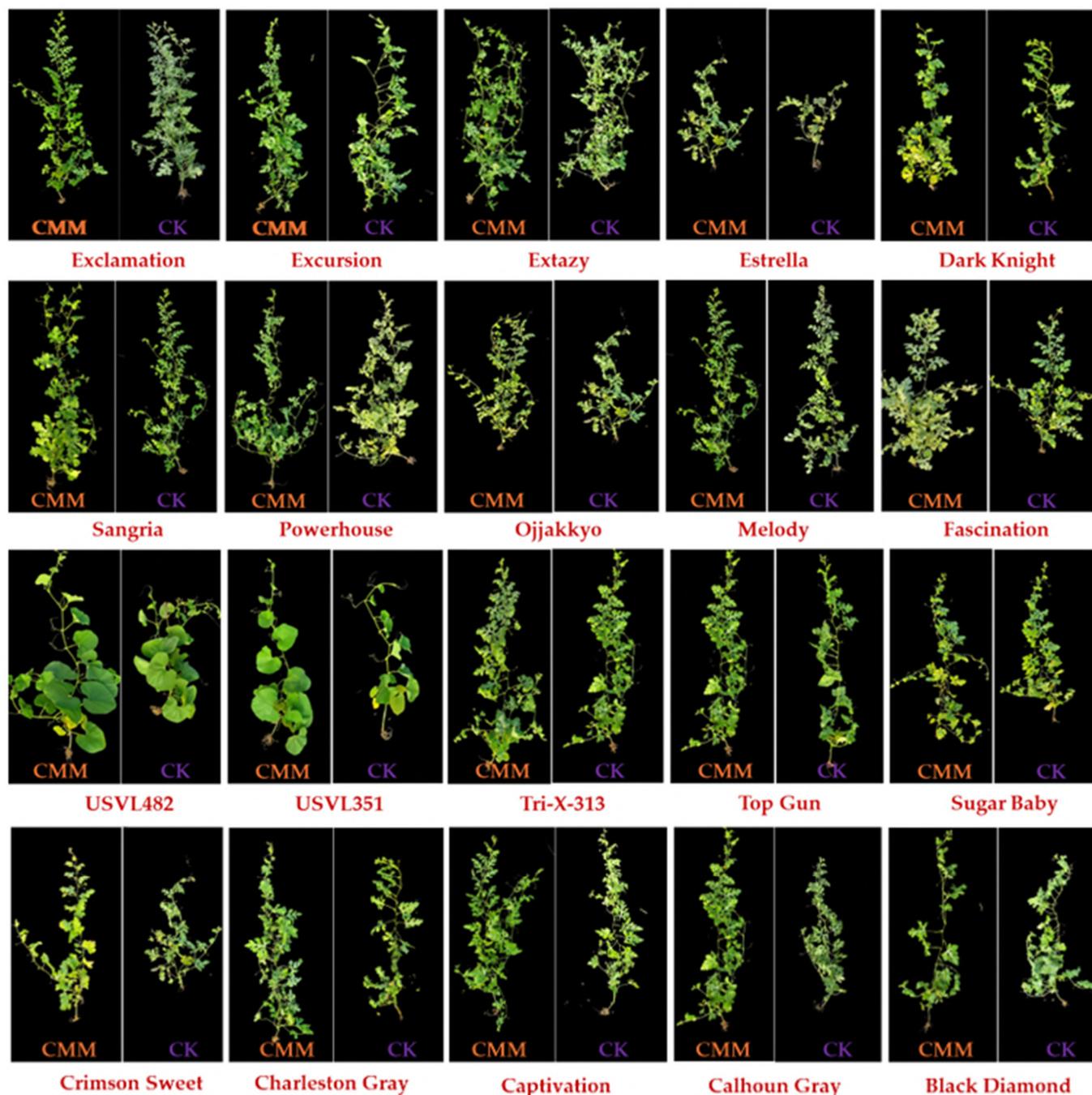


Figure 6. Impact of chicken manure and molasses (CMM)-induced anaerobic soil disinfestation on watermelon genotypes and rootstocks after 4 weeks of anaerobic soil disinfestation termination.

4. Conclusions

Organic watermelon demand has significantly increased in the Southeastern U.S. with growers transitioning to organic cultural practices over conventional. However, the lack of efficient chemical approaches for weed and soil-borne pathogen management in organic watermelon production remains a major challenge. Anaerobic soil disinfestation (ASD) is a potential alternative to replace preplant chemical pesticides. This can be a feasible option for organic watermelon to manage weed and soil-borne pathogens without using pesticides. Relative to field conditions, this simulated chicken manure + molasses-induced

ASD study in microcosms using field soil allows screening of watermelon genotypes and rootstock ahead of intensive field trials. This microcosm study showed that chicken manure + molasses-induced ASD, provided greater anaerobic conditions and an acceptable level of weed control, and was effective in decreasing the emergence of yellow nutsedge and Palmer amaranth. In addition, watermelon genotypes ‘Extazy’, ‘Powerhouse’, ‘Sangria’, and ‘Exclamation’ exhibited less sensitivity to chicken manure + molasses-induced ASD and improved plant vigor, fresh biomass, and plant length. In addition, this study provided a guide for organic watermelon genotype selection to explore chicken manure + molasses-induced ASD under intensive field conditions. Further research is also needed to explore more locally available carbon sources that are economically affordable and facilitate better control of weeds in organic plasticulture systems.

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