Effects of foliar fertilizer application on the growth and fruit quality of commercial melon varieties grown in a soilless culture system

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Several factors influence the quality of melon fruits and foliar fertilizer application is one method for improving their quality. The objectives of this study were: (1) to investigate the response of commercial melon varieties to a soilless culture system in Nakhon Si Thammarat Province, Thailand, and (2) to evaluate the quality of melon fruit under various foliar fertilizer treatments. The experiment was arranged as a completely randomized block design with four replications. Eight commercial melon varieties, including four orange pulp melons (Sandee, Baramee, Sanwan, and Melon cat 697) and four green pulp melons (Kissme, Snowgreen, Melon princess, and Kimoji), were used in this study. At 1–5 weeks after planting, the growth of the melons was measured using agronomic traits. Four foliar fertilizers (distilled water, micronutrients, secondary nutrients + micronutrients, and amino acid + micronutrients) were sprayed on the melon leaves at 1–5 weeks after pollination, and the growth of the melons, using fruit traits, was recorded. After harvesting, the melons were assessed for the quality of the fruit. This study was conducted at the School of Agricultural Technology and Food Industry's greenhouse and the Food Chemistry Laboratory of the Center for Scientific and Technological Equipment, Walailak University. In nearly all of the observed growth weeks, the data demonstrate that most agronomic and fruit traits were significantly different between the melon varieties. Sandee, Baramee, Melon cat 697, and Melon princess are recommended for planting under Nakhon Si Thammarat's climate, based on fruit size and quality. Foliar fertilizer application impacted the shape, skin color, and quality of the melon. Melons treated with micronutrients, secondary nutrients and micronutrients, and amino acids and micronutrients exhibited better measures of fruit quality than those treated with non-foliar treatments. There was also an interaction observed between melon variety and foliar fertilizer application. Based on measures of fruit quality, Baramee, Melon cat 697, Kissme, and Melon princess were more responsive to foliar fertilizer application than other melon varieties tested.

Effects of Foliar Fertilizer Application on the Growth and Fruit Quality of Commercial Melon Varieties Grown in a Soilless Culture System

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Abstract

Several factors influence the quality of melon fruits and foliar fertilizer application is one method for improving their quality. The objectives of this study were: (1) to investigate the response of commercial melon varieties to a soilless culture system in Nakhon Si Thammarat Province, Thailand, and (2) to evaluate the quality of melon fruit under various foliar fertilizer treatments. The experiment was arranged as a completely randomized block design with four replications. Eight commercial melon varieties, including four orange pulp melons (Sandee, Baramee, Sanwan, and Melon cat 697) and four green pulp melons (Kissme, Snowgreen, Melon princess, and Kimoji), were used in this study. At 1–5 weeks after planting, the growth of the melons was measured using agronomic traits. Four foliar fertilizers (distilled water, micronutrients, secondary nutrients + micronutrients, and amino acid + micronutrients) were sprayed on the melon leaves at 1–5 weeks after pollination, and the growth of the melons, using fruit traits, was recorded. After harvesting, the melons were assessed for the quality of the fruit. This study was conducted at the School of Agricultural Technology and Food Industry's greenhouse and the Food Chemistry Laboratory of the Center for Scientific and Technological Equipment, Walailak University. In nearly all of the observed growth weeks, the data demonstrate that most agronomic and fruit traits were significantly different between the melon varieties. Sandee, Baramee, Melon cat 697, and Melon princess are recommended for planting under Nakhon Si Thammarat's climate, based on fruit size and quality. Foliar fertilizer application impacted the shape, skin color, and quality of the melon. Melons treated with micronutrients, secondary nutrients and micronutrients, and amino acids and micronutrients exhibited better measures of fruit quality than those treated with non-foliar treatments. There was also an interaction observed between melon variety and foliar fertilizer application. Based on

40   measures of fruit quality, Baramee, Melon cat 697, Kissme, and Melon princess were more
41   responsive to foliar fertilizer application than other melon varieties tested.
42
43   **Introduction**
44   Melon, or sweet melon (*Cucumis melo* L.), a member of the Cucurbitaceae family, is one
45   of the world's most well-known fruit crops and is an excellent source of phytonutrients such as
46   cucurbitacin, lithium, and zinc (Yavuz et al., 2021). Because of their high antioxidant content,
47   anti-inflammatory qualities, antidiabetic advantages, antiulcerogenic activity, and antibacterial
48   capabilities, melons have significant human health benefits (Bianchi, 2016). Melon fruit
49   production depends on several factors such as variety, growing season, soil property, pollination,
50   irrigation, and fertilization (Nerson, 2011; Martuscelli et al., 2016). Fertilization is critical to
51   melon fruit quality. Several studies have found that a lack or imbalance of plant nutrients causes
52   melon fruit quality to deteriorate. For example, cracked melons are associated with numerous
53   elements including K, P, Ca, Mg, Mn, Na, B, and Zn (Lopez-Zaplana et al., 2020). Some of the
54   fruit quality attributes of melons, such as fruit firmness, pulp thickness, rind thickness, and TSS,
55   are influenced by nitrogen associated with phosphorus (Bouzo, Céccoli & Muñoz, 2018).
56   Foliar fertilizer application, where plant minerals are dissolved in a solution and sprayed
57   directly onto plant leaves, is a technique used to improve fruit quality and productivity in a
58   variety of horticulture crops (Muñoz, Ruiz & Bouzo 2017). Minerals are absorbed through the
59   stomata and epidermis of the leaves (Patil & Chetan, 2017). However, because this procedure
60   may be detrimental to plant leaves, it is only recommended for low-concentration fertilizers.
61   Foliar fertilization and spraying are regularly used in melon cultivation. In one study, the
62   appearance of melon fruits significantly improved following the foliar fertigation of several
63   micronutrients (Lopez-Zaplana et al., 2020). Early flowering, fruit number, and total yield are all
64   promoted by the foliar fertigation of potassium and calcium fertilizers alone, or in combination
65   with borax (Srilatha, Padmodaya & Kumar, 2017). In another study, the foliar spray of some
66   plant growth stimulants, such as plant amino acid and yeast extract, along with nitrogen
67   fertilization, improved some melon plant growth characteristics (plant length, leaf area, weight of
68   shoots per plant) and fruit qualities (fruit diameter, fruit weight, fresh yield, nutrient uptake, total
69   sugar, and TSS) (Morsy, Abdel-Salam & Shams, 2018).
70   A soilless culture system is a method of growing plants which does not require the use of
71   soil as a growing medium. Plants acquire nutrients by irrigation water, which is referred to as
72   "nutrient solution." The advantages of a soilless culture system include a reduction or
73   elimination of soil-borne diseases, the ability to control the amount of water and nutrients used,
74   and an increase in nutrient availability (Putra & Yuliando, 2015). This technique is utilized in a
75   wide range of vegetable and horticultural crops, such as lettuce, strawberry, tomato, and melon
76   (Savvas & Gruda, 2018). Melons planted in a soilless culture system have higher values of stem
77   height, leaf number per plant, total leaf number, fruit per plant, fruit weight, and total fruit yield,
78   than melons planted using soil cultivation (Singer et al., 2013). High quality melon fruit

79 production requires appropriate nutrient management. It is crucial for melon cultivation in
80 Southern Thailand to determine the best foliar fertilizer treatment for various melon varieties.
81   The objectives of this study were: (1) to investigate the response of commercial melon
82 varieties to a soilless culture system in Nakhon Si Thammarat Province, Thailand and (2) to
83 evaluate the quality of melon fruit under various foliar fertilizer applications.
84

Materials & Methods
1. Melon varieties and experimental design
87   This study was conducted in the greenhouse of the School of Agricultural Technology
88 and Food Industry (8°38'43.1"N 99°54'04.4"E) and the Food Chemistry Laboratory of the Center
89 for Scientific and Technological Equipment (8°38'29.5"N 99°53'42.6"E), Walailak University,
90 Nakhon Si Thammarat, Thailand. The greenhouse is 240 square meters, with a width of 8 meters
91 and a length of 30 meters. Eight marketable melon varieties were chosen for this investigation,
92 including four orange pulp melon varieties: Sandee (V1), Baramee (V2), Sanwan (V3), and
93 Melon cat 697 (V4), and four green melon varieties: Kissme (V5), Snowgreen (V6), Melon
94 princess (V7), and Kimoji (V8). Melon seeds were sown in a planting tray, using peatmoss as the
95 seed germination medium. Germinated seeds were then transplanted to plastic bags (8 x 13 inch)
96 ten days after germination, with a 1:1 combination of chopped coconut mesocarp and coconut
97 coir used as the plant medium. The melons were spaced out in a four-block, randomized
98 complete block design (RCBD), with four plants in each block used for data collection. Each
99 melon was given its own automated water application system. Fertigation was carried out using
100 Cosme et al. (2017)'s modified approach. The fertilizer was prepared from calcium nitrate (89.5
101 g 100 L^{-1}), potassium nitrate (74 g 100 L^{-1}), monoammonium phosphate (19.2 g 100 L^{-1}),
102 magnesium sulfate (40 g 100 L^{-1}), copper sulfate (0.08 g 100 L^{-1}), zinc sulfate (0.14 g 100 L^{-1}),
103 magnesium sulfate (0.19 g 100 L^{-1}), boric acid (0.06 g 100 L^{-1}), sodium molybdate (0.013 g 100
104 L^{-1}), and Fe-EDTA (1.63 100 L^{-1}). Fertilization was applied to the melons four times per day (8
105 am, 11 am, 2 pm, and 5 pm).
106   Each of the four groups contained all eight melon varieties, which were each sprayed 1–5
107 weeks after pollination with 200 ml of one of four possible foliar fertilizer treatments: distilled
108 water (control): C; micronutrients: M (0.134 mM ferrous sulfate ($FeSO_4$), 0.057 mM zinc
109 sulphate ($ZnSO_4$), 0.096 mM manganese sulfate ($MnSO_4$), 0.090 mM sodium borate
110 ($Na_2B_4O_7 \cdot 5H_2O$), 0.024 mM copper sulfate ($CuSO_4$), and 0.005 mM sodium molybdate
111 (Na_2MoO_4); secondary nutrients and micronutrients: S + M (0.214 mM calcium oxide (CaO),
112 0.275 mM magnesium oxide (MgO), 0.134 mM $FeSO_4$, 0.057 mM $ZnSO_4$, 0.096 mM $MnSO_4$,
113 0.090 mM $Na_2B_4O_7 \cdot 5H_2O$, 0.024 mM $CuSO_4$, and 0.005 mM Na_2MoO_4); or amino acid +
114 micronutrients: A + M (20 gL^{-1} combined amino acids, 0.134 mM $FeSO_4$, 0.057 mM $ZnSO_4$,
115 0.096 mM $MnSO_4$, 0.090 mM $Na_2B_4O_7 \cdot 5H_2O$, 0.024 mM $CuSO_4$, and 0.005 mM Na_2MoO_4).
116 The combined amino acids were alanine (2.08%), arginine (3.82%), aspartic acid (3.4%), cystine
117 (0.64%), glutamic acid (7.2%), glycine (4.22%), histidine (0.47%), isoleucine (0.99%), leucine

118 (1.05%), lysine (3.15%), methionine (0.31%), phenylalanine (1.14%), proline (3.01%), serine
119 (4.24%), threonine (2.81%), tyrosine (0.47%), and valine (2.01%).
120   The experiment was conducted between November 2021 and February 2022. During the
121 experiment, the temperature ranged between 21.5 and 33.9 °C, with February as the hottest
122 month. Monthly rainfall ranged between 27.6 and 446.8 mm, and the relative humidity ranged
123 between 84 and 93 percent, with the highest amount of rainfall and humidity occurring in
124 November, and the highest relative humidity in February. The weather data was recorded by the
125 greenhouse's weather station.
126
127 **2. Data collection**
128   Plant growth and flowering characteristics, including stem diameter (measured at the
129 middle of stem), stem length, leaf width, leaf length, leaf number, days to male flowering, and
130 days to female flowering, were recorded 1–5 weeks after transplanting. Fruit growth
131 characteristics, including fruit weight, fruit height, and fruit perimeter, were recorded 1–6 weeks
132 after pollination. Ripe melons were harvested at 6 to 7 weeks after pollination for the fruit
133 quality assessment. The fruits were measured and analyzed for fruit cavity size, pulp thickness,
134 rind thickness, firmness, total soluble solid (TSS), juice electrical conductivity (EC), juice pH,
135 titratable acidity (TA), and pulp color ($L*$, $a*$, $b*$, hue, and chroma ($c*$)). A portable Hunterlab
136 ColorFlex®EZ device (Hunter Assoc. Laboratory; VA, USA) was used to collect colorimetric
137 data. A white and black standard were used to calibrate the device. The following measurement
138 modes were chosen: tristimulus $L*$ (lightness), $a*$ (redness/greenness), and $b*$
139 (yellowness/blueness). The $L*$-axis measures lightness on a scale of 0 (black) to 100 (white). The
140 $a*$-axis goes from green ($-a*$) to red ($+a*$), while the $b*$-axis runs from blue ($-b*$) to yellow
141 ($+b*$). Hue is defined as the color appearance parameters of a color, also known as color tone or
142 color name. Chroma is a color's saturation level, with possible chroma values: clear, bright, or
143 brilliant.
144   A Brix refractometer (Sinotech (Thailand) CO., LTD., model RHB-18ATC) was used to
145 measure the TSS, with results expressed as °Brix. TSS measures the balance of sugars and acids
146 in a matrix, which affects fruit flavor (Fundo et al., 2018). EC and pH meters (Hanna
147 Instruments, Inc., edge® model HI2030) were used to determine the electrical conductivity and
148 pH of the juice. The TA was determined by titrating juice extract to pH 8.1 with 0.1 M NaOH
149 and then measuring the percentage of citric acid in the samples (Piñero et al., 2020).
150
151 **3. Data analysis**
152   The variance of melon parameters was calculated using ANOVA. The means were
153 compared using Duncan's multiple range test (DMRT) and differences were reported as
154 significant at the $p < 0.05$ or $p < 0.01$ levels. The melon fruit traits were analyzed using a
155 principal components analysis and the first two components were plotted. All statistical analyses
156 were performed using the R software (version 3.6.1) with the Agricolae and Devtools packages
157 (de Mendiburu, 2021; Wickham et al. 2021)

158
159 **Results**
160 **1. Melon agronomic traits**
161   *Table 1* shows the analysis of variance of agronomic traits among the eight melon
162 varieties. Most agronomic traits were significantly different ($p < 0.05$ or 0.01) between the melon
163 varieties in all observed weeks, except for stem diameter at the first and third weeks after
164 planting. *Figure 1* illustrates melon growth based on agronomic traits. Five weeks after planting,
165 V8 and V7 (1.02 ± 0.02 and 1.00 ± 0.03 cm) produced the biggest stem diameter and V7, V4, V3,
166 and V1 (259.06 ± 7.15, 258.50 ± 7.04, 251.56 ± 6.62, 241.31 ± 5.08 cm) produced the longest stem
167 length. V1 (27.38 ± 0.46 and 24.78 ± 0.41 cm) produced the widest and longest leaf and V2
168 (38.38 ± 0.52) produced the highest number of leaves. V8 (14.88 ± 0.43 days) had the earliest male
169 flowers and V2, V5, V1, V3, and V7 (23.88 ± 0.29, 24.00 ± 0.43, 24.56 ± 0.27, 24.56 ± 0.42,
170 24.81 ± 0.61 days) had the earliest female flowers.
171
172 **2. Melon fruit traits**
173   *Figure 2* illustrates melon fruit characteristics under various foliar fertilizer applications.
174 Melon shape and color intensity are affected by foliar fertilizer application. *Table 2* shows the
175 analysis of variance of melon fruit traits. All fruit traits were significantly different (at $p < 0.01$)
176 between the melon varieties in all observed weeks, except for the melon fruit cavity size. *Table 2*
177 shows that most fruit traits were significantly different between foliar fertilizer treatments (at $p <$
178 0.05 or 0.01) in most observed weeks except: fruit weight in the first week, fruit height in all
179 observed weeks, fruit perimeter in the first and third weeks, fruit cavity, *L** values, and *c**
180 values.
181   *Figure 3* illustrates melon growth, based on fruit traits. Six weeks after pollination, V7
182 (2.07 ± 0.09 kg) produced the heaviest fruit while the lowest fruit weight was obtained from V6
183 (1.00 ± 0.05 kg). V7, V4, V1, V2, and V5 (15.59 ± 0.20, 14.91 ± 0.23, 14.90 ± 0.16, 14.86 ± 0.26,
184 14.42 ± 0.14 cm) produced the longest fruit and V6 (12.00 ± 0.15 cm) produced the shortest fruit.
185 V7, V5, and V4 (49.25 ± 0.77, 47.50 ± 0.65, 46.35 ± 0.54 cm) produced the fruit with the largest
186 perimeter, and the smallest fruit perimeter was obtained from the fruit of V6 (39.90 ± 0.58 cm).
187 Among foliar fertilizer applications at six weeks after pollination, melons treated with A+M
188 (1.64 ± 0.13 kg and 45.69 ± 1.22 cm), S+M (1.59 ± 0.14 kg and 44.94 ± 1.26 cm) and M (1.50 ± 0.09
189 kg and 44.24 ± 0.79 cm) had larger fruit weights and fruit perimeters than melons under the non-
190 foliar fertilizer application (control: C). There were no significant differences in fruit height
191 between the four foliar fertilizer treatment groups.
192   *Table 3* shows the mean comparison among the melon fruit traits. Among the melon
193 varieties, V7 produced the thickest (4.16 ± 0.18 cm), firmest (1.11 ± 0.04 N), and brightest (*L**;
194 73.46 ± 0.67) fruit pulp. V4 produced the thinnest fruit rind (0.58 ± 0.03 cm). V3 produced the
195 highest juice EC ($6,840.50\pm113.32$ μS cm^{-1}), juice pH (7.08 ± 0.05), and yellowest (*b**) pulp
196 (39.93 ± 0.38). V6, V1, V3, V4, and V2 (12.18 ± 0.25, 11.88 ± 0.35, 11.73 ± 0.65, 11.66 ± 0.40, and
197 11.51 ± 0.38 °Brix) produced the sweetest fruit pulp, and V6 had the highest TA ($0.23\pm0.01\%$

198   citric acid). Among the foliar fertilizer applications, *Table 3* shows that melons treated with
199   foliar fertilizers had better results than control melons for all fruit traits except for fruit cavity
200   size, *a**, and *c** values, which were not significantly different. Melons treated with M, S+M, and
201   A+M had the thickest (3.75±0.08, 3.63±0.08, 3.69±0.10 cm) and firmest pulp (0.89±0.03,
202   0.92±0.04, 0.93±0.04 N). Melons treated with S+M had the brightest (*L**; 66.02±0.68) pulp.
203   Melons treated with A+M had the sweetest pulp (12.84±0.33), highest juice EC
204   (6,431.46±138.66 µS cm^{-1}), juice pH (6.78±0.03), TA (0.18±0.01), and yellowest (*b**) pulp
205   (35.49±0.55).
206   *Figure 4* illustrates the biplot between the first two principal components of melon fruit
207   quality under various foliar fertilizer applications. V7 is the largest cluster in the first principal
208   component and dominates in *L**, hue, and fruit cavity size, while V6 is the smallest cluster and
209   dominates in TA. The fruits of V1-V4 dominate EC, TSS, *a**, *b**, and *c**.
210

211   **Discussion**
212   This study shows that most melon agronomic and fruit traits are significantly different
213   between melon varieties in all observed growth periods. Melons treated with foliar fertilizers had
214   better measures of fruit quality including: fruit weight, fruit height, fruit perimeter, pulp
215   thickness, rind thickness, firmness, TSS, EC, TA, and pulp colors. According to Zaniewicz-
216   Bajkowska et al. (2010), foliar feeding is an effective method of supplying nutrients during the
217   period of intensive plant growth when it can most improve the mineral status of the plants and
218   increase crop yield. Melon is a polymorphic taxon with many botanical and physiological
219   varieties. Melon fruits also have a wide range of features, such as color, shape, size, skin pattern,
220   sweetness level, and odor (Lima & Beevy, 2021).
221   Foliar fertilizer application is widely used as a technique to improve the fruit quality and
222   productivity of horticultural crops (Santos, 2013). This type of direct application can help to
223   reduce the overall quantity of fertilizer needed in plant production while preserving fertilizer
224   efficiency. Furthermore, foliar fertilizer application helps minimize the adverse consequences of
225   excessive fertilizer usage, such as soil acidification, salinization, and nutrient unavailability (Niu
226   et al., 2021). Foliar fertilizer also impacts the quality of melon fruits. To prevent melon fruit
227   cracking, which has been linked to a number of elements (B, Ca, K, Mg, Mn, Na, P, and Zn),
228   Lopez-Zaplana et al. (2020) utilized calcium fertilizers, micronutrient fertilizers, and a mixture
229   of calcium and micronutrient fertilizers. Another study, Muñoz, Ruiz & Bouzo (2017) sprayed
230   varying quantities of calcium nitrate every week after fruit set and found that fruits were firmer
231   at 2.6 and 5.2 g L^{-1} calcium nitrate concentrations. Srilatha, Padmodaya & Kumar (2017) applied
232   a mixture of borax, potassium nitrate, and calcium nitrate and found the combination was
233   effective in promoting early flowering, fruit number, and fruit yield.
234   The resistance and hardness of melon fruit skin are both influenced by calcium, which, as
235   a molecular signaling agent, is a mineral that helps to strengthen plant cell walls and fruit skin
236   (Cybulska, Zdunek & Konstankiewicz, 2011). Magnesium (Mg) is an important component of
237   the chlorophyll molecule, which is necessary for photosynthesis and protein synthesis in plants.

238   Mg has been associated with other elements in melon fruit, such as calcium, potassium, and
239   manganese, according to several studies. Mg is also a cofactor for several enzymes involved in
240   cell wall formation, including glutamine synthetase, xylose isomerase, and isocitrate lyase
241   (Lopez-Zaplana et al., 2020). Iron is a necessary micronutrient for plant metabolism, including
242   photosynthesis, respiration, DNA synthesis, and metabolic activators in a variety of pathways. It
243   is a component of a number of key enzymes, including cytochromes, which are a crucial
244   component of the electron transport chain in cellular respiration (Rout & Sahoo, 2015). Zinc is
245   engaged in the ion transport mechanism in plant cells. Zinc maintains the balance between the
246   phospholipid levels and membrane integrity, which affects plant water absorption and racking
247   (Dang et al., 2010). Manganese also has an impact on various plant cell functions, such as amino
248   acid synthesis and lignin biosynthesis. The hardness of the melon fruit peel is affected by low
249   manganese levels, resulting in fruit cracking (Chen et al., 2016). Boron is required for the
250   formation of new tissues and the production of cell walls. It has a relationship with the cell
251   membrane's integrity and permeability. Higher calcium levels are produced by an increase in
252   Boron in the melon pulp and rind (Lewis, 2019; Lopez-Zaplana et al., 2020). Copper is an
253   essential element of cellular physiological activities, such as energy generation. It is often used
254   as a foliar fertilizer and stays on the leaf surface. Through antagonist and synergistic actions,
255   excess copper has a negative impact on root metabolic activity and nutrient absorption (Torre,
256   Iovino & Caradonia, 2018). Molybdenum is a trace element that plants need for development and
257   for a variety of metabolic processes. It regulates the oxidation and reduction reactions of
258   enzymes, and is an essential component of organic molecules known as molybdenum co-factors
259   (Kaiser et al., 2005). Plant amino acids are precursors of a number of chemicals that are involved
260   in cell activity. They are involved in the production of nitrogenous bases (purine and
261   pyrimidine), alkaloids, and terpenoids. These compounds are required for pollination and fruit
262   formation (Morsy, Abdel-Salam & Shams, 2018). In future investigations, other fruit quality
263   attributes, such as vitamins and non-vitamin phytochemicals like flavonoids, should be included
264   as they might also be affected by foliar fertilizer application.
265

Conclusions

267   Most agronomic traits were significantly different between the melon varieties in all
268   observed growth weeks, except for stem diameter in the first and the third weeks after planting.
269   All fruit traits were significantly different between the melon varieties in all observed growth
270   periods. Sandee, Baramee, Melon cat 697, and Melon princess are recommended for planting
271   under Nakhon Si Thammarat's climate, based on fruit size and quality. Most fruit traits were
272   significantly different between the different foliar fertilizer treatment groups in most observed
273   growth weeks. The shape, skin color, and quality of the melon were all affected by foliar
274   fertilizer application. Melons treated with micronutrients, secondary nutrients and
275   micronutrients, and amino acids and micronutrients had higher measures of fruit quality than
276   melons grown with non-foliar applications. There were also interactions observed between
277   melon variety and foliar fertilizer application. Based on measures of fruit quality, Baramee,

278   Melon cat 697, Kissme, and Melon princess were more responsive to foliar fertilizer application
279   than other melon varieties tested.
280

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285

286   **References**

287   Bianchi T, Guerrero L, Gratacos-Cubarsí M, Claret A, Argyris J, Garcia-Mas J, Hortos M. 2016.
288   Textural properties of different melon (*Cucumis melo* L.) fruit types: sensory and
289   physical-chemical evaluation. *Scitia Horticulturae* 201: 46−56. DOI:
290   10.1016/j.scienta.2016.01.028
291   Bouzo CA, Céccoli G, Muñoz F. 2018. Effect of potassium and calcium upon the yield and fruit
292   quality of *Cucumis melo*. *Agriscientia* 35: 25-33.
293   Chen Z, Yan W, Sun L, Tian J, Liao H. 2016. Proteomic analysis reveals growth inhibition of
294   soybean roots by manganese toxicity is associated with alteration of cell wall structure
295   and lignification. *Journal of Proteomics* 143: 151−160. DOI: 10.1016/j.jprot.2016.03.037
296   Cosme, CR, Dias NS, Silva, KMP, Silva, CVT, Queiroz, ISR, Reboucas, TC, Rernandes, CS.
297   2017. Yield and quality of 'gália' melon grown in coconut fiber under different
298   concentrations of macronutrients in the nutrient solution. *Idesia (Arica)* 35: 119-128.
299   DOI: 10.4067/S0718-34292017000400119
300   Cybulska J, Zdunek A, Konstankiewicz K. 2011. Calcium effect on mechanical properties of
301   model cell walls and apple tissue. *Journal of Food Engineering* 102: 217−223. DOI:
302   10.1016/j.jfoodeng.2010.08.019
303   Dang HK, Li RQ, Sun YH, Zhang XW, Li YM. 2010. Absorption, accumulation and distribution
304   of Zinc in highly yielding winter wheat. *Agricultural Sciences in China* 9: 965−973. DOI:
305   10.1016/S1671-2927(09)60178-4
306   de Mendiburu F. 2021. Agricolae package. Available at *https://cran.r-*
307   *project.org/web/packages/agricolae/index.html* (accessed 27 December 2021).
308   Fundo JF, Miller FA, Garcia E, Santos JR, Silva CL, Brandão TR. 2018. Physicochemical
309   characteristics, bioactive compounds and antioxidant activity in juice, pulp, peel and
310   seeds of Cantaloupe melon. *Journal of Food Measurement and Characterization* 12: 292-
311   300. DOI: 10.1007/s11694-017-9640-0
312   Kaiser BN, Gridley KL, Brady JN, Phillips T, Tyerman SD. 2005. The role of molybdenum in
313   agricultural plant production. *Annals of Botany* 96: 745-754. DOI: 10.1093/aob/mci226
314   Lewis DH. 2019. Boron: The essential element for vascular plants that never was. *New*
315   *Phytologist* 221: 1685−1690. DOI: 10.1111/nph.15519
316   Lima M, Beevy SS. 2021. A review on the diversity of melon. *Plant Science Today* 8: 995-1003.
317   DOI: 10.14719/pst.1300

318   Lopez-Zaplana A, Bárzana G, Agudelo A, Carvaja M. 2020. Foliar mineral treatments for the
319   reduction of melon (*Cucumis melo* L.) fruit cracking. *Agronomy Journal* 10: 1-21. DOI:
320   10.3390/agronomy10111815

321   Martuscelli M, Mattia CD, Stagnari F, Speca S, Pisante M, Mastrocola D. 2015. Influence of
322   phosphorus management on melon (*Cucumis melo* L.) fruit quality. *Journal of the*
323   *Science of Food and Agriculture* 96: 2715–2722. DOI: 10.1002/jsfa.7390

324   Morsy NM, Abdel-Salam MA, Shams AS. 2018. Comparing response of melon (*Cucumis melo*)
325   to foliar spray of some different growth stimulants under two nitrogen fertilizer forms.
326   *Egyptian Journal of Horticulture* 1: 81- 91. DOI: 10.21608/EJOH.2018.3192.1055

327   Muñoz FF, Ruiz VE, Bouzo CA. 2017. Effect of preharvest foliar sprays of calcium nitrate on
328   melon fruit quality. *Journal of Experimental Botany* 86: 131-136. DOI:
329   10.32604/phyton.2017.86.131

330   Nerson H. 2011. Growing season is an essential factor in seed production and quality of melon.
331   *Seed Science and Biotechnology* 5: 1-6.

332   Niu J, Liu C, Huang M, Liu K, Yan D. 2021. Effects of foliar fertilization: a review of current
333   status and future perspectives. *Journal of Soil Science and Plant Nutrition* 21: 104-118.
334   DOI: 10.1007/s42729-020-00346-3

335   Patil B, Chetan HT. 2018. Foliar fertilization of nutrients. *Marumegh* 3: 49-53.

336   Piñero MC, Otálora G, Collado-González J, López-Marín J, del Amor FM. 2020. Differential
337   effects of aquaponic production system on melon (*Cucumis melo* L.) fruit quality.
338   *Journal of Agricultural and Food Chemistry* 68: 6511-6519. DOI:
339   10.1021/acs.jafc.0c01124

340   Putra AP, Yuliando H. 2015. Soilless culture system to support water use efficiency and product
341   quality: a review. *Agriculture and Agricultural Science Procedia* 3: 283-288.

342   Rout G, Sahoo S. 2015. Role of iron in plant growth and metabolism. *Reviews in Agricultural*
343   *Science* 3: 1-24. DOI: 10.1016/j.aaspro.2015.01.054

344   Santos BM. 2013. Foliar nutrition to enhance horticultural crop production and quality: an
345   introduction. *HortTechnology* 23: 535-535. DOI: 10.21273/HORTTECH.23.5.535

346   Savvas D, Gruda N. 2018. Application of soilless culture technologies in the modern greenhouse
347   industry – a review. *European Journal of Horticultural Science* 83: 280–293. DOI:
348   10.17660/eJHS.2018/83.5.2

349   Singer SM, El-Tanahy AMM, El-Behairy UA, Abd El-Samad EH. 2013. Growth and
350   productivity of cantaloupe plants grown under different soilless culture systems. *Journal*
351   *of Applied Sciences Research* 9(8): 5294-5302.

352   Srilatha V, Padmodaya B, Kumar KS. 2017. Effect of foliar application of fertilizer on yield and
353   flowering of muskmelon (*Cucumis melo*). *Andhra Pradesh journal of Agricultural*
354   *Sciences* 3: 149-152.

355   Torre AL, Iovino V, Caradonia F. 2018. Copper in plant protection: current situation and
356   prospects. *Phytopathologia Mediterranea* 57: 201−236. DOI:
357   10.14601/Phytopathol_Mediterr-23407

358 Wickham H, Hester J, Chang W, Bryan J. 2021. Devtools package. Available at *https://cran.r-*
359   *project.org/web/packages/devtools/index.html* (accessed 27 December 2021).
360 Yavuz D, Seymen M, Yavuz N, Coklar H, Ercan M. 2021. Effects of water stress applied at
361   various phenological stages on yield, quality, and water use efficiency of melon.
362   *Agricultural Water Management* 246: 106673. DOI: 10.1016/j.agwat.2020.106673
363 Zaniewicz-Bajkowska A, Kosterna E, Franczuk J, Rosa R. 2010. Yield quality of melon
364   (*Cucumis melo* L.) depending on foliar feeding. *Acta Scientiarum Plonorum-Hortorum*
365   *Cultus* 9: 55-63.

Figure 1

Melon growth, based on agronomic traits.

(a) stem diameter, (b) stem length, (c) leaf width, (d) leaf length, (e) leaf number, and (e) days to flowering. V1: Sandee, V2: Baramee, V3: Sanwan, V4: Melon cat 697, V5: Kissme, V6: Snowgreen, V7: Melon princess, and V8: Kimoji. The black horizontal line in each box indicates the mean. The upper and lower boundaries of the box indicate the 75th and 25th percentiles of the data. The upper and lower whiskers indicate the maximum and minimum data points. The circles above or below the box indicate outlier data points.

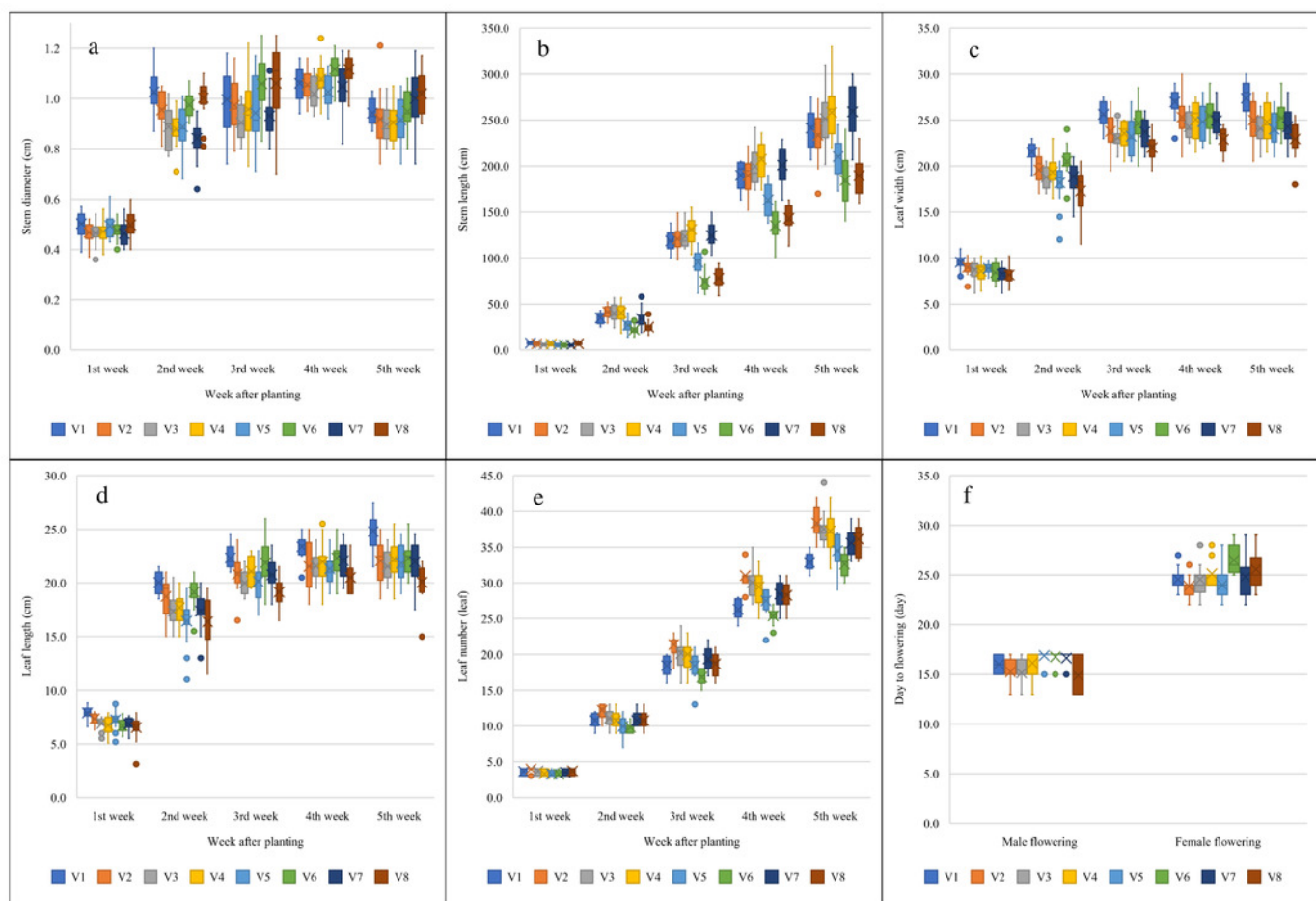



Figure 2

Melon fruit characteristics under various foliar fertilizer applications.

V1: Sandee, V2: Baramee, V3: Sanwan, V4: Melon cat 697, V5: Kissme, V6: Snowgreen, V7: Melon princess, and V8: Kimoji. C: Control, M: Micronutrient, S + M: Secondary nutrient + Micronutrient, and A + M: Amino acid + Micronutrient.

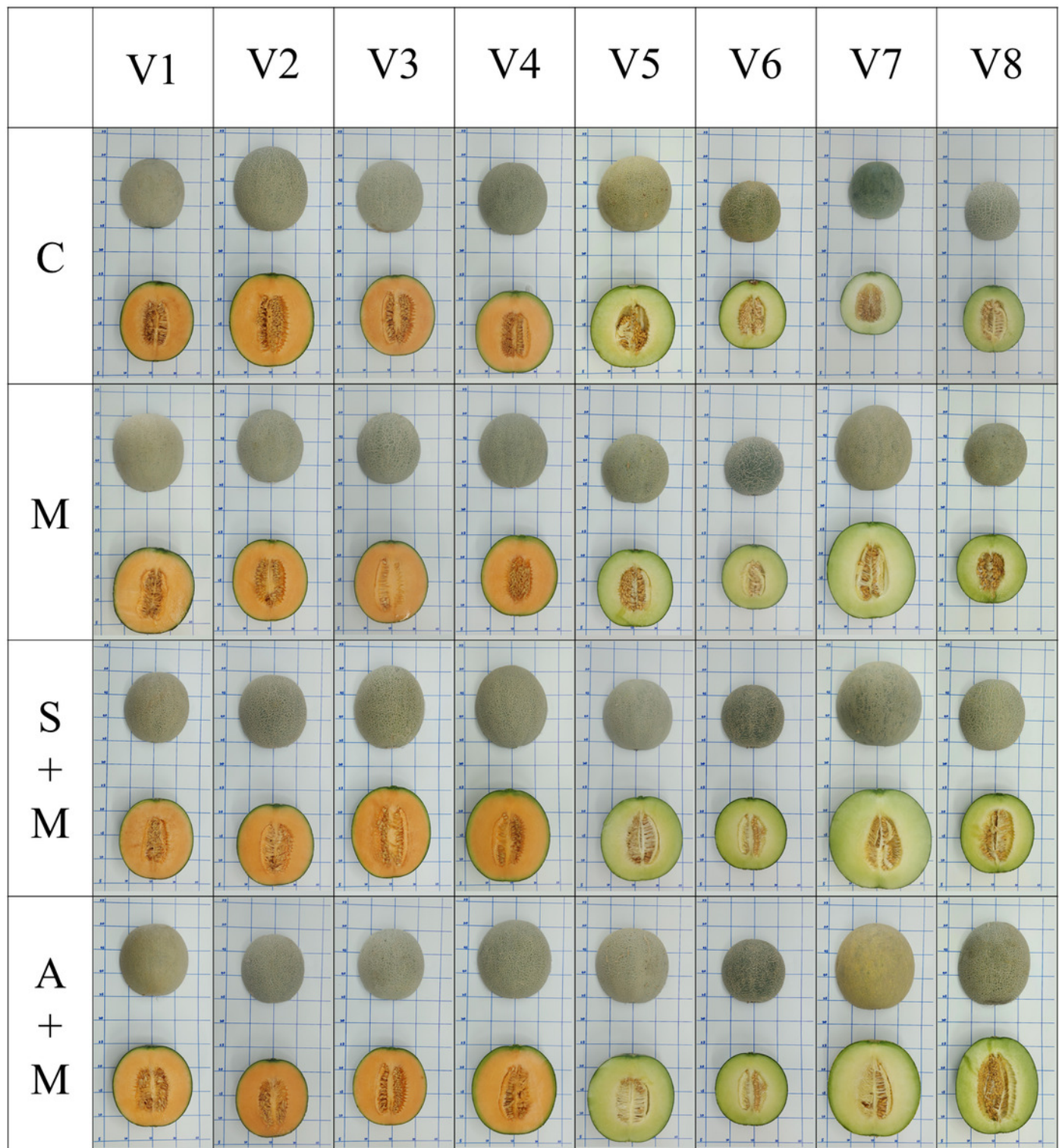



Figure 3

Melon growth, based on fruit traits.

(a) fruit weight, (b) fruit height, and (c) fruit perimeter under various foliar fertilizer applications. V1: Sandee, V2: Baramee, V3: Sanwan, V4: Melon cat 697, V5: Kissme, V6: Snowgreen, V7: Melon princess, and V8: Kimoji. C: Control, M: Micronutrient, S + M: Secondary nutrient + Micronutrient, and A + M: Amino acid + Micronutrient. The black horizontal line in each box indicates the mean. The upper and lower boundaries of the box indicate the 75th and 25th percentiles of the data. The upper and lower whiskers indicate the maximum and minimum data points. The circles above or below the box indicate outlier data points.

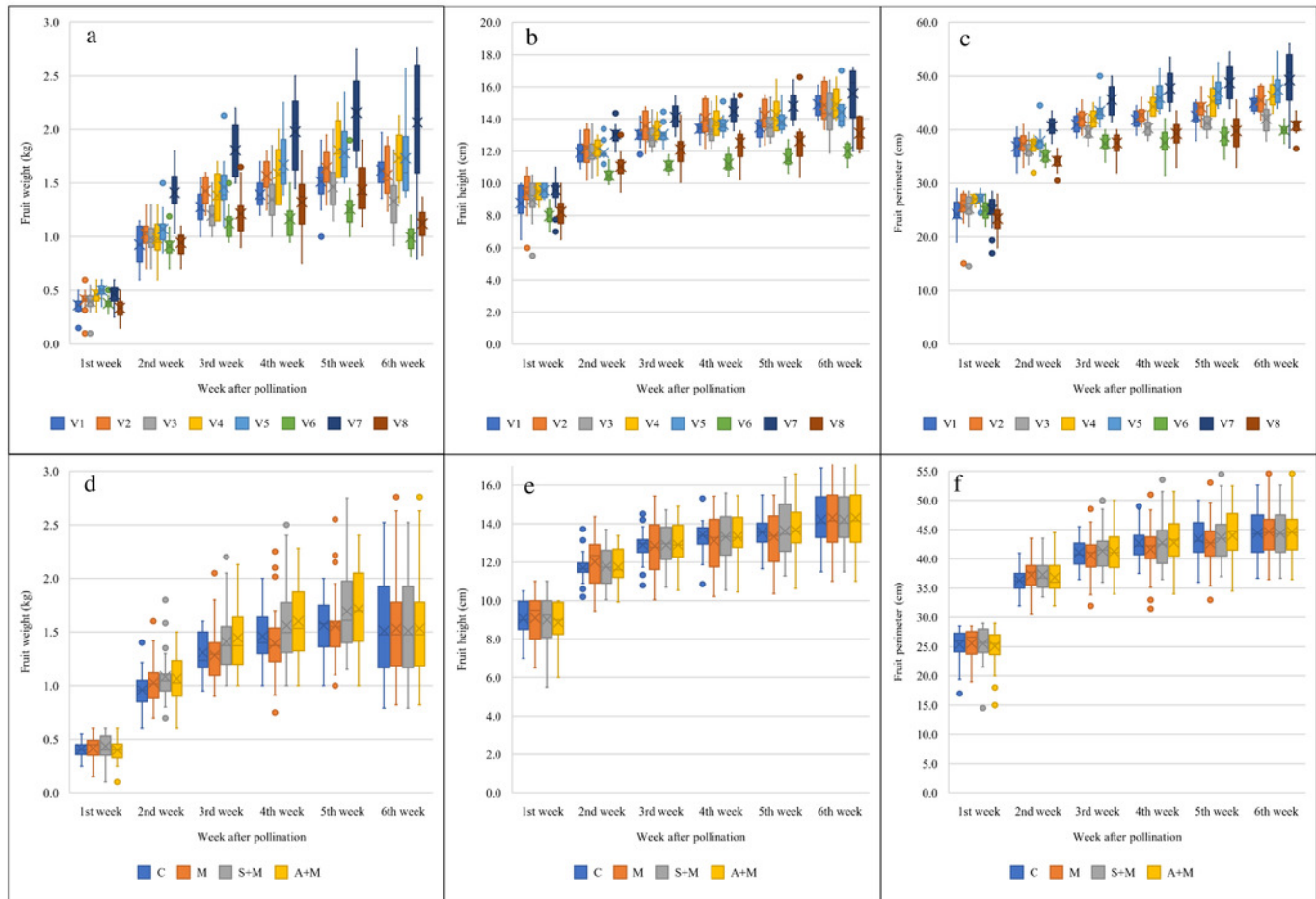
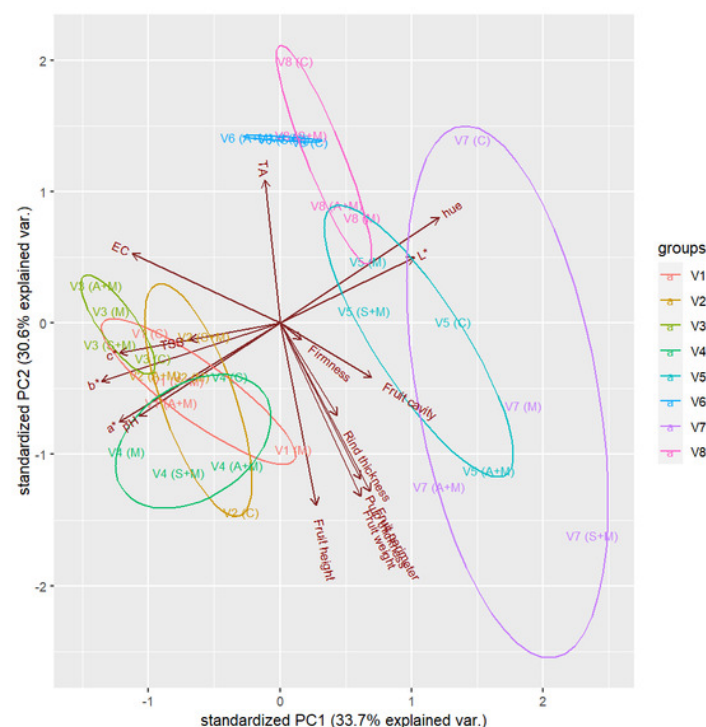



Figure 4

Biplot between the first two PCs of melon fruit quality under various foliar fertilizer applications.

V1: Sandee, V2: Baramee, V3: Sanwan, V4: Melon cat 697, V5: Kissme, V6: Snowgreen, V7: Melon princess, and V8: Kimoji. C: Control, M: Micronutrient, S + M: Secondary nutrient + Micronutrient, and A + M: Amino acid + Micronutrient. PC1 and PC2 are the first and second principal components. The clusters represent the distribution of melon fruit quality under various foliar fertilizer applications. Arrows indicate the direction of melon fruit quality characteristics.

Analysis of variance of melon agronomic traits.

1 **Table 1:**

2 **Analysis of variance of melon agronomic traits.**

Sources	Week after planting	Block MS	Treatment MS	Error	C.V. (%)
Stem diameter (cm)	1st week	0.002^{ns}	0.004^{ns}	0.002	15.70
	2nd week	0.007^{ns}	0.071^{*}	0.006	8.08
	3rd week	0.826^{ns}	0.496^{ns}	0.627	7.16
	4th week	0.011^{ns}	0.022^{**}	0.004	6.23
	5th week	0.045^{**}	0.032^{**}	0.006	8.75
Stem length (cm)	1st week	4.032^{ns}	12.829^{**}	1.603	20.93
	2nd week	319.800^{**}	932.600^{**}	50.600	21.49
	3rd week	1649.000^{**}	8416.000^{**}	181.000	12.52
	4th week	6716.000^{**}	12316.000^{**}	155.000	6.98
	5th week	9728.000^{**}	14504.000^{**}	401.00	8.77
Leaf width (cm)	1st week	0.622^{ns}	3.262^{**}	0.765	10.07
	2nd week	21.632^{**}	27.496^{**}	2.424	8.09
	3rd week	40.220^{**}	18.710^{**}	2.030	6.01
	4th week	53.240^{**}	20.870^{**}	1.880	5.49
	5th week	53.360^{**}	26.830^{**}	2.530	6.43
Leaf length (cm)	1st week	0.976^{ns}	3.220^{**}	0.542	10.5
	2nd week	18.705^{**}	27.285^{**}	2.352	8.57
	3rd week	27.106^{**}	16.687^{**}	1.631	6.15
	4th week	29.995^{**}	11.179^{**}	1.872	6.27
	5th week	29.296^{**}	27.001^{**}	2.207	6.76
Leaf number (cm)	1st week	0.5208^{ns}	0.9821^{**}	0.200	12.67
	2nd week	0.687^{ns}	8.464^{**}	1.134	9.91
	3rd week	9.438^{**}	30.554^{**}	2.382	8.06
	4th week	25.93^{**}	56.82^{**}	2.420	5.5
	5th week	56.2^{**}	73.23^{**}	3.050	4.91
Day to male flowering (day)	-	0.448^{ns}	9.853^{**}	1.311	7.18
Day to female flowering (day)	-	1.271^{ns}	11.750^{**}	2.700	6.01

3 ns is not significantly different, *, ** are significantly different at $p<0.05$ and 0.01, respectively.

Analysis of variance of melon fruit traits.

1 **Table 2:**

2 **Analysis of variance of melon fruit traits.**

Sources	Week after pollination	Block MS	Treatment (a) MS	Fertilizer (b) MS	a*b	Error	C.V. (%)
Fruit weight (kg)	1st week	0.01^{ns}	0.05^{**}	0.01^{ns}	0.01^{**}	0.01	20.83
	2nd week	0.07^{*}	0.42^{**}	0.09^{**}	0.03^{ns}	0.02	13.95
	3rd week	0.25^{**}	0.74^{**}	0.19^{**}	0.04^{*}	0.02	10.82
	4th week	0.57^{**}	1.02^{**}	0.27^{**}	0.07^{**}	0.03	11.31
	5th week	0.68^{**}	1.25^{**}	0.23^{**}	0.07^{*}	0.04	11.48
	6th week	0.41^{**}	0.99^{**}	0.24^{**}	0.14^{**}	0.05	11.40
Fruit height (cm)	1st week	1.96^{*}	6.32^{**}	0.36^{ns}	1.84^{**}	0.66	9.03
	2nd week	1.88^{**}	9.52^{**}	0.63^{ns}	0.88^{*}	0.44	5.58
	3rd week	7.56^{**}	13.54^{**}	0.03^{ns}	0.70^{**}	0.28	4.11
	4th week	10.25^{**}	16.67^{**}	0.56^{ns}	0.93^{**}	0.33	4.32
	5th week	11.92^{**}	16.93^{**}	0.77^{ns}	1.04^{**}	0.45	4.97
	6th week	5.17^{**}	10.77^{**}	1.70^{ns}	1.45^{ns}	1	4.65
Fruit perimeter (cm)	1st week	12.00^{ns}	26.35^{**}	1.78^{ns}	12.99^{**}	5.38	9.14
	2nd week	9.79^{*}	61.35^{**}	6.33^{ns}	4.23^{ns}	3.01	4.70
	3rd week	50.36^{**}	127.64^{**}	3.72^{ns}	5.00^{**}	2.12	3.54
	4th week	60.04^{**}	186.46^{**}	9.53^{*}	4.96^{ns}	3	4.08
	5th week	97.81^{**}	197.52^{**}	10.94^{*}	5.67^{ns}	3.49	4.30
	6th week	34.48^{**}	88.18^{**}	17.06^{*}	11.90^{*}	5.25	4.19
Fruit cavity (cm)	6th week	4.59^{ns}	14.29^{ns}	19.88^{ns}	10.51^{ns}	9.87	60.05
Pulp thickness (cm)	6th week	0.74^{**}	3.84^{**}	3.01^{**}	0.93^{**}	0.11	9.36
Rind thickness (cm)	6th week	0.03^{ns}	0.09^{**}	0.03^{*}	0.03^{**}	0.01	23.02
Firmness (N)	6th week	0.04^{ns}	0.77^{**}	0.17^{**}	0.13^{**}	0.02	16.43
TSS (°Brix)	6th week	13.58^{**}	24.04^{**}	71.47^{**}	15.17^{**}	1.91	15.15
EC (µS cm^{-1})	6th week	$2,809,610^{**}$	$8,031,763^{**}$	$1,665,111^{**}$	$1,590,383^{**}$	344,379	9.44
pH	6th week	0.01^{ns}	1.67^{**}	0.28^{**}	0.30^{**}	0.02	2.00

TA (% citric acid)	6th week	0.01**	0.02**	0.01*	0.01**	0.01	14.44
L*	6th week	143.60**	729.80**	123.40**	174.80**	25.2	7.64
a*	6th week	1.00ns	4384.00**	1.00ns	4.00**	1.00	15.67
b*	6th week	10.10ns	411.10**	21.50**	9.50**	4.3.	5.97
hue	6th week	18.00ns	5688.00**	126.00**	29.00**	14.00	8.02
c*	6th week	0.03ns	0.10**	0.01ns	0.01ns	0.02	41.27

3   ns is not significantly different, *, ** are significantly different at $p < 0.05$ and 0.01, respectively.

Mean comparison of melon fruit traits.

1 **Table 3:**

2 **Mean comparison of melon fruit traits.**

Treatments	Fruit cavity (cm)	Pulp thickness (cm)	Rind thickness (cm)	Firmness (N)	TSS (°Brix)	EC (µS cm⁻¹)	pH	TA (% Critic acid)	L*	a*	b*	hue	c*
V1	4.79±0.17	3.90±0.13^b	0.44±0.02^{cd}	0.66±0.04^d	11.88±0.35^a	6,549.58±175.58^{ab}	6.81±0.04^c	0.15±0.01^d	62.43±0.70^c	18.66±0.40^c	36.66±0.48^c	31.30±0.56^d	0.36±0.03^{ab}
V2	6.95±0.10	3.51±0.06^c	0.49±0.03^{bc}	0.96±0.05^b	11.51±0.38^a	6,392.08±99.78^{ab}	6.84±0.03^{bc}	0.15±0.01^d	63.10±0.59^c	19.18±0.41^c	38.98±0.39^{ab}	30.66±0.54^d	0.36±0.03^{ab}
V3	4.84±0.12	3.20±0.05^d	0.40±0.03^d	1.09±0.05^a	11.73±0.65^a	6,840.50±113.32^a	7.08±0.05^a	0.18±0.01^c	63.11±0.47^c	21.55±0.16^a	39.93±0.38^a	31.55±0.50^d	0.40±0.03^a
V4	4.90±0.15	3.76±0.08^b	0.58±0.03^a	0.81±0.04^c	11.66±0.40^a	6,170.83±70.31^{bc}	6.92±0.04^b	0.16±0.01^{cd}	56.21±3.45^d	20.59±0.28^b	37.68±0.49^{bc}	32.87±0.80^d	0.39±0.03^{ab}
V5	5.60±0.13	3.79±0.09^b	0.49±0.03^{bc}	0.90±0.01^{bc}	10.37±0.30^b	5,730.83±109.93^c	6.56±0.01^d	0.16±0.00^d	69.99±0.68^{ab}	-5.37±0.16^e	30.41±0.50^e	59.61±0.84^{bc}	0.28±0.03^{bc}
V6	4.50±0.12	3.18±0.09^d	0.50±0.02^{abc}	0.93±0.03^b	12.18±0.25^a	6,601.67±58.43^{ab}	6.64±0.03^d	0.23±0.01^a	69.21±0.46^b	-4.90±0.14^e	32.29±0.50^d	57.55±0.98^c	0.28±0.02^{bc}
V7	5.35±0.12	4.16±0.18^a	0.53±0.03^{ab}	1.11±0.04^a	10.14±0.51^b	5,039.96±165.98^d	6.33±0.08^e	0.17±0.00^{cd}	73.46±0.67^a	-5.08±0.12^e	29.09±0.46^e	60.60±1.30^{ab}	0.21±0.02^c
V8	4.93±0.16	3.04±0.08^d	0.42±0.02^{cd}	0.62±0.03^d	9.40±0.50^b	6,418.75±272.73^{ab}	6.38±0.05^e	0.21±0.01^b	68.48±0.63^b	-5.60±0.21^e	32.30±0.48^d	63.16±0.90^a	0.30±0.03^{ab}
F-test	ns	**	**	**	**	**	**	**	**	**	**	**	**
C	5.19±0.08	3.20±0.06^B	0.51±0.02^A	0.80±0.04^B	10.13±0.24^C	6,316.69±135.29^{AB}	6.60±0.06^C	0.18±0.01^{AB}	67.64±0.78^{AB}	7.31±1.83	34.04±0.62^B	47.52±2.21^A	0.32±0.02
M	4.75±0.10	3.75±0.08^A	0.45±0.02^B	0.89±0.03^A	10.39±0.28^C	6,068.33±113.02^B	6.67±0.04^{BC}	0.17±0.01^B	63.74±2.01^B	7.33±1.84	34.22±0.76^B	46.92±2.25^A	0.32±0.02
S+M	4.83±0.11	3.63±0.08^A	0.47±0.02^{AB}	0.92±0.04^A	11.07±0.32^B	6,055.63±124.36^B	6.72±0.05^{AB}	0.18±0.01^{AB}	66.02±0.68^A	7.29±1.87	34.93±0.64^{AB}	45.25±2.24^B	0.33±0.02
A+M	6.15±0.12	3.69±0.10^A	0.49±0.02^{AB}	0.93±0.04^A	12.84±0.33^A	6,431.46±138.66^A	6.78±0.03^A	0.18±0.01^A	65.59±0.73^{AB}	7.57±1.87	35.49±0.55^A	43.96±1.98^B	0.31±0.02
F-test	ns	*	*	**	**	**	**	*	**	ns	**	**	ns
C : V1	5.12±0.28	3.38±0.10^{abc}	0.42±0.05^{abc}	0.67±0.13^{bcd}	12.57±0.20^{abc}	7,356.67±51.23^a	6.63±0.03^{abc}	0.17±0.00^{abc}	62.58±1.08^{hi}	18.99±0.60^{bcde}	37.64±0.78^{bc}	31.87±1.77^c	0.43±0.05^a
C : V2	5.37±0.13	3.60±0.15^{abc}	0.67±0.04^a	0.76±0.02^{abcd}	10.20±0.00^{abc}	6,450.00±6.32^{ab}	7.02±0.00^{ab}	0.13±0.00^{abc}	61.80±0.22^{hi}	18.42±0.49^{cde}	38.48±0.38^{abc}	32.27±0.79^c	0.35±0.07^{abcd}
C : V3	5.22±0.22	3.10±0.07^{abc}	0.50±0.08^{abc}	0.86±0.04^{abcd}	9.90±0.33^{abc}	6,585.33±209.76^{ab}	7.11±0.03^{ab}	0.14±0.01^{abc}	64.57±0.68^{efghi}	21.36±0.33^{ab}	38.54±0.51^{abc}	31.13±0.60^c	0.42±0.04^{abc}
C : V4	5.12±0.22	3.37±0.13^{abc}	0.63±0.06^{ab}	0.63±0.07^{bcd}	9.82±0.13^{abc}	6,241.67±99.38^{abc}	6.80±0.11^{abc}	0.14±0.00^{abc}	63.90±1.28^{fghi}	20.53±0.47^{abc}	36.30±0.85^{bcde}	36.42±2.56^c	0.36±0.06^{abc}
C : V5	5.30±0.27	3.68±0.11^{abc}	0.62±0.03^{abc}	0.88±0.02^{abcd}	10.03±0.02^{abc}	5,636.67±177.46^{abc}	6.56±0.03^{abc}	0.16±0.00^{abc}	72.23±0.66^{abc}	-5.44±0.13^f	28.66±0.73^{hi}	61.72±1.18^{ab}	0.21±0.02^{bcd}
C : V6	4.95±0.16	3.00±0.06^{abc}	0.48±0.03^{abc}	0.84±0.09^{abcd}	10.55±0.23^{abc}	6,240.00±76.11^{abc}	6.62±0.03^{abc}	0.22±0.01^{ab}	70.59±0.55^{bcd}	-5.09±0.12^f	31.06±0.53^{ghi}	57.84±1.45^{ab}	0.31±0.03^{abcd}
C : V7	5.45±0.20	2.92±0.20^{bc}	0.40±0.04^{bc}	1.22±0.11^{abc}	7.93±0.39^{bc}	5,061.50±135.47^{abc}	5.84±0.04^c	0.18±0.01^{abc}	75.95±1.51^a	-5.07±0.25^f	29.57±0.37^{ghi}	64.98±1.61^a	0.20±0.03^{cd}
C : V8	5.03±0.28	2.55±0.08^c	0.40±0.04^{bc}	0.54±0.03^d	10.05±1.28^{abc}	6,961.67±732.76^{ab}	6.24±0.11^{bc}	0.26±0.03^a	69.53±1.45^{bcd}	-5.24±0.63^f	32.06±1.51^{fghi}	63.92±1.21^a	0.31±0.06^{abcd}
M : V1	4.62±0.36	4.78±0.17^a	0.42±0.05^{abc}	0.71±0.10^{bcd}	9.60±0.36^{abc}	5,955.00±217.02^{abc}	6.74±0.05^{abc}	0.13±0.02^{abc}	64.73±1.20^{efghi}	17.03±0.57^e	35.64±1.41^{cdef}	31.01±0.45^c	0.24±0.03^{abc}
M : V2	4.90±0.12	3.45±0.15^{abc}	0.42±0.03^{abc}	0.72±0.03^{abcd}	9.72±0.16^{abc}	6,083.33±151.96^{abc}	6.87±0.01^{ab}	0.13±0.00^{abc}	65.90±0.57^{defgh}	20.13±0.67^{abcd}	39.31±0.53^{abc}	32.19±1.12^c	0.40±0.07^{abcd}
M : V3	4.65±0.13	3.30±0.11^{abc}	0.35±0.03^c	1.12±0.07^{abcd}	13.65±0.25^a	7,175.00±251.19^{ab}	6.83±0.13^{abc}	0.21±0.01^{ab}	63.77±0.76^{fghi}	22.02±0.31^a	41.96±0.54^a	33.48±1.54^c	0.37±0.07^{abcd}
M : V4	4.00±0.19	3.80±0.13^{abc}	0.57±0.06^{abc}	0.86±0.01^{abcd}	10.03±0.02^{abc}	5,676.67±2.11^{abc}	7.06±0.00^{ab}	0.12±0.00^b	64.00±9.60^{efghi}	20.25±0.37^{abcd}	36.98±0.49^{bcd}	31.68±0.54^c	0.39±0.08^{abcd}
M : V5	5.62±0.21	3.57±0.09^{abc}	0.38±0.05^{bc}	0.91±0.02^{abcd}	11.20±0.16^{abc}	6,416.67±8.43^{ab}	6.57±0.04^{abc}	0.18±0.00^{ab}	68.96±1.33^{bcde}	-4.42±0.23^f	28.81±0.83^{hi}	60.84±2.15^{ab}	0.31±0.05^{abc}
M : V6	4.07±0.17	3.35±0.08^{abc}	0.57±0.02^{abc}	0.97±0.01^{abcd}	12.15±0.49^{ab}	6,925.00±42.64^{ab}	6.51±0.00^{abc}	0.23±0.01^{ab}	69.75±1.01^{bcd}	-5.31±0.28^f	32.37±1.50^{efgh}	58.62±3.10^{ab}	0.26±0.05^{abc}
M : V7	5.45±0.15	4.30±0.14^{abc}	0.53±0.03^{abc}	1.11±0.06^{abcd}	9.53±0.22^{abc}	5,005.00±161.76^{bc}	6.28±0.04^{bc}	0.18±0.00^{ab}	73.52±1.40^{ab}	-5.13±0.16^f	28.01±0.80^i	62.36±1.59^a	0.24±0.05^{abc}
M : V8	4.82±0.11	3.45±0.08^{abc}	0.40±0.04^{bc}	0.70±0.04^{bcd}	7.25±0.11^c	5,310.00±93.99^{abc}	6.54±0.00^{abc}	0.15±0.01^{ab}	68.46±0.88^{cdef}	-5.90±0.15^f	30.65±0.82^{ghi}	65.17±1.69^a	0.36±0.06^{abc}
S+M : V1	4.02±0.24	3.83±0.16^{abc}	0.43±0.05^{abc}	0.59±0.03^{cd}	11.57±0.17^{abc}	5,886.67±61.19^{abc}	6.91±0.03^{ab}	0.14±0.01^{abc}	62.08±1.22^{hi}	18.93±0.94^{bcde}	36.29±0.93^{bcde}	29.47±0.95^c	0.38±0.06^{abc}
S+M : V2	5.13±0.27	3.57±0.14^{abc}	0.40±0.04^{bc}	1.28±0.03^{ab}	12.00±0.11^{abc}	6,560.00±38.82^{ab}	6.58±0.01^{abc}	0.18±0.00^{ab}	62.17±1.18^{hi}	17.78±0.99^{de}	37.69±1.21^{bc}	29.04±0.88^c	0.33±0.08^{abc}
S+M :V3	4.60±0.32	3.22±0.09^{abc}	0.37±0.05^{bc}	1.01±0.03^{abcd}	8.95±1.75^{abc}	6,418.33±175.18^{ab}	7.32±0.04^a	0.15±0.00^{abc}	62.64±0.50^{hi}	21.29±0.24^{ab}	39.81±0.59^{abc}	31.41±0.58^c	0.45±0.03^a
S+M : V4	5.17±0.20	4.02±0.11^{abc}	0.57±0.06^{abc}	0.80±0.11^{abcd}	13.15±0.25^{ab}	6,393.33±43.41^{ab}	7.06±0.00^{ab}	0.20±0.01^{ab}	62.63±1.30^{hi}	21.89±0.34^a	39.88±0.54^{abc}	31.33±1.02^c	0.43±0.08^{ab}
S+M : V5	5.37±0.21	3.52±0.10^{abc}	0.49±0.06^{abc}	0.86±0.04^{abcd}	10.67±0.89^{abc}	5,695.00±8.85^{abc}	6.55±0.02^{abc}	0.14±0.00^{abc}	69.10±1.26^{bcde}	-5.97±0.33^f	32.24±0.65^{efgh}	58.45±1.06^{ab}	0.36±0.06^{abc}
S+M : V6	4.70±0.17	3.32±0.15^{abc}	0.48±0.06^{abc}	0.97±0.02^{abcd}	12.98±0.10^{ab}	6,671.67±81.38^{ab}	6.81±0.03^{abc}	0.24±0.01^{ab}	68.17±0.40^{cdef}	-4.70±0.37^f	32.20±1.01^{efgh}	56.27±1.66^{ab}	0.21±0.05^{bc}
S+M : V7	5.23±0.32	4.65±0.15^{ab}	0.63±0.05^{ab}	1.12±0.07^{abcd}	9.15±0.49^{abc}	4,125.00±288.48^c	6.31±0.09^{abc}	0.14±0.01^{abc}	73.27±0.83^{ab}	-5.28±0.29^f	28.01±1.34^i	62.47±1.83^a	0.22±0.03^{abcd}
S+M : V8	4.40±0.27	2.90±0.10^{bc}	0.42±0.03^{abc}	0.72±0.04^{abcd}	10.12±0.08^{abc}	6,695.00±17.84^{ab}	6.27±0.02^{bc}	0.22±0.01^{ab}	68.11±1.68^{cdef}	-5.59±0.20^f	33.34±0.50^{defg}	63.59±0.61^a	0.31±0.07^{abcd}
A+M : V1	5.40±0.26	3.62±0.11^{abc}	0.50±0.04^{abc}	0.69±0.07^{bcd}	13.77±0.40^a	7,000.00±429.34^{ab}	6.96±0.09^{ab}	0.18±0.01^{ab}	60.35±1.76^i	19.67±0.74^{abcd}	37.07±0.63^{bcd}	32.84±0.61^c	0.38±0.04^{abcd}
A+M : V2	5.18±0.22	3.42±0.07^{abc}	0.47±0.04^{abc}	1.09±0.08^{abcd}	14.13±0.44^a	6,475.00±363.07^{ab}	6.89±0.02^{ab}	0.17±0.01^{ab}	62.53±1.54^{hi}	20.38±0.62^{abcd}	40.45±0.30^{ab}	29.14±0.84^c	0.36±0.05^{abc}

A+M : V3	4.88±0.25	3.18±0.09abc	0.37±0.03bc	1.37±0.07a	14.42±0.34a	7,183.33±62.65ab	7.07±0.04ab	0.22±0.01ab	61.47±1.31hi	21.53±0.41ab	39.44±0.69abc	30.17±0.66c	0.36±0.05abcd
A+M : V4	5.40±0.15	3.87±0.15abc	0.57±0.04abc	0.95±0.01abcd	13.65±0.66a	6,371.67±106.66abc	6.77±0.06abc	0.19±0.01ab	63.42±1.40ghi	19.69±0.70abcd	37.57±1.33bc	32.06±0.75c	0.37±0.06abcd
A+M : V5	5.90±0.28	4.40±0.14ab	0.47±0.04abc	0.94±0.01abcd	9.58±0.73abc	5,175.00±181.16abc	6.58±0.02abc	0.14±0.01ab	69.67±1.80bcd	-5.66±0.22f	31.95±0.88fghi	57.44±1.84ab	0.23±0.05abcd
A+M : V6	4.30±0.31	3.03±0.30abc	0.48±0.06abc	0.92±0.03abcd	13.05±0.18ab	6,570.00±18.26ab	6.63±0.02abc	0.23±0.01ab	68.34±1.24cdef	-4.51±0.27f	33.51±0.69defg	57.48±1.62ab	0.33±0.04abcd
A+M : V7	5.27±0.28	4.77±0.23a	0.57±0.04abc	1.00±0.05abcd	13.95±0.44a	5,968.33±197.58abc	6.90±0.02ab	0.16±0.01ab	71.10±0.97bc	-4.86±0.28f	30.78±0.44ghi	52.57±2.16b	0.17±0.03b
A+M : V8	5.48±0.45	3.27±0.11abc	0.47±0.02abc	0.53±0.05d	10.17±1.31abc	6,708.33±696.91ab	6.47±0.11abc	0.19±0.02ab	67.81±1.07cdefg	-5.67±0.56f	33.15±0.43defg	59.96±2.66ab	0.25±0.05abcd
F-test	ns	**	**	**	**	**	**	**	**	**	**	**	**

3 ns is not significantly different, *, ** are significantly different at p<0.05 and 0.01, respectively. Values with the same alphabetical

4 superscript within the same column are not significantly different based on Duncan's multiple range test.