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Jellyfish (*Aurelia aurita*) Supernatant for Cherry Tomato (*Lycopersicon esculentum Mill*) and Tomato (*Solanum lycopersicum*) Cultivation

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This study was conducted to investigate the usefulness of jellyfish (*Aurelia aurita*) supernatant for cherry-tomato (*Lycopersicon esculentum Mill*) and tomato (*Solanum lycopersicum*) cultivation. Cherry tomatoes and tomatoes were cultivated with the periodic addition of supernatant solutions of jellyfish to the culture soil. For control plots, the same volume of water was added to the soil instead of the supernatant solution. Seawater was used similarly for comparison in tomato cultivation. After harvesting the cherry tomatoes and tomatoes, their weights were measured. Then, sugar and ascorbic acid (AsA) content in the cherry tomatoes were determined. For tomatoes, acidity was ascertained instead of AsA. The sugar content and AsA concentration for cherry tomatoes cultivated using jellyfish were 13 % and 18 % higher than those for the control plots, respectively, although the fruit weight of the former was 23 % less than that of the latter. The sugar content and acidity of tomatoes cultivated using jellyfish were 16 % and 15 % higher, respectively, than those cultivated with seawater, although the former had 19 % less fruit weight than the latter. Results show that using jellyfish for cherry-tomato and tomato cultivation was effective to improve fruit quality.

Key Words : Acidity, Organic wastes, Recycling, Soil culture, Sugar content

1. Introduction

Jellyfish populations appear to be increasing in most of the world's coastal ecosystems and seas, although basic knowledge of jellyfish populations in most regions remains poor[1, 2]. Jellyfish provide various ecosystem services such as regulation, support, culture, and provisioning services[3]. However, jellyfish are usually perceived as pests that are harmful to humans because of their negative effects on fisheries, aquaculture, coastal desalination plants, nuclear and fossil-fuelled power facilities, and on coastal tourism. Additionally, it has been reported recently that jellyfish decomposition can produce detrimental effects on marine environments[4]. Jellyfish carcasses collected mechanically at power plants and captured by fishing nets have been neither used nor recycled. When vast numbers of giant jellyfish (*Nemopilema nomurai*) swarmed in the Sea of Japan in 2002-2006, a method of processing fish sauce using collected jellyfish was developed[5]. However, fish sauce is not produced now. In an effort to develop a means of using jellyfish productively, our study of jellyfish carcasses used as a supplementary fertilizer for vegetables continues[6-10]. We recently demonstrated that supernatant solutions of jellyfish (*Aurelia aurita* and *Nemopilema nomurai*) suspensions are useful for soil-less culture of the common ice plant (*Mesembryanthemum crystallinum* L.)[11].

Several reports have described the effectiveness of adding sodium chloride (or potassium chloride) or seawater (or deep seawater) to culture media (solution, soil, or molded medium) for both soil and soil-less culture of cherry tomatoes (*Lycopersicon esculentum Mill*) and tomatoes (*Solanum lycopersicum*) to improve fruit quality[12-16]. That is to say, contents of taste components (sugar, organic acids, and amino acids) and functional ingredients (lycopene and ascorbic acid, AsA) in the fruits increased. The increase of the contents is believed to result from various salt-effect responses as well as the concentration effect caused by increased osmotic pressure in the culture medium, which suppresses water absorption by tomatoes[16]. Based on the concentration effect explained above, another strategy to produce tomatoes with higher sugar-content is to restrict the soil moisture in the soil culture[14]. We have elucidated that a jellyfish supernatant is useful as a source of sodium chloride for the soil-less culture of the common ice plant[11]. Usually, sodium chloride must be added to the culture medium to grow the common ice plant. Some farmers have

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cultivated the common ice plant using seawater in Japan. Jellyfish supernatant contains similar concentrations of sodium to those for seawater.

This study demonstrates the usefulness of jellyfish (*Aurelia aurita*) supernatant as a source of sodium chloride for cherry tomato and tomato cultivation. After cherry tomato and tomato seedlings were planted, respectively into gardening soil in gardening containers and a greenhouse, supernatant solutions were added to the soil around the seedlings once a week. Similarly, the same volume of tap water was added to the soil for controls. For tomato cultivation, seawater was applied similarly to the soil for comparison. The cherry tomato and tomato growth were observed periodically, measuring the stalk height from the soil surface to the growing point. Finally, cherry tomatoes and tomatoes were harvested and weighed. Sugar contents (refractometer index: Brix) and AsA in harvested cherry tomatoes were ascertained respectively using a hand sugar-refractometer and a capillary zone electrophoresis (CZE) method developed by the authors[17]. For tomatoes, acidity was determined as well as sugar contents using a hand sugar and acidity refractometer. This report is the first describing the usefulness of jellyfish as an additive for the production of cherry tomatoes and tomatoes containing higher functional ingredients (AsA) and taste components (sugar and acidity).

2. Experimental

2.1 Preparation of the supernatant solutions of jellyfish suspensions

Jellyfish (*Aurelia aurita*) were taken from the sea at the small pond at our university, located in the coastal area of Osaka Bay in Japan during May 27-29, 2013. Collected jellyfish was kept in a freezer (−20 ℃) for one year. The frozen jellyfish were thawed at room temperature (23 ℃) on May 27-28, 2014. The suspension (6 L) was transferred to a glass vessel and was allowed to stand for two months at room temperature (21-27 ℃). Then the supernatant solution was used for cherry tomato cultivation. Jellyfish supernatant used for tomato cultivation was prepared similarly. Jellyfish (*Aurelia aurita*) collected from the same site as described above during May 28-June 4, 2013 were kept in a freezer. The frozen jellyfish (29.5 L) were kept in a lidded plastic bucket to thaw from July 14, 2015 until use. For comparison, seawater used was collected from Suma Aqualife Park KOBE on July 10, 2015.

2.2 Cultivation

2.2.1 Cherry tomato

Cherry tomatoes were cultivated according to the following procedures. Cherry tomato seeds were put between wet tissues and were kept for three days to encourage germination. After small roots appeared, the seeds were sown in a plastic container (200 small plots), including soil for seeding. After 11 days, seedlings that had several true leaves were transplanted in plastic pots (1.6 L) that contained mixed soil of Akadama soil, leaf mold (available on the market) of 7:3 by volume, 3 g/L dolomite, and 3 g/L chemical fertilizer (blended fertilizer, N:P:K = 9:6:7). After 16 days, seedlings were planted in plastic planters (10 L of soil) containing the same soil as that in the plastic pots: two seedlings were put in each planter. Six planters were prepared: three of them were used for jellyfish supernatantant; the remaining three were for controls. From 28 days after fixed planting, supernatant solutions were added to the soil around the six seedlings (100 mL/seedling) once a week. For the controls, tap water was added (100 mL/seedling) similarly. The supernatant solutions were added six times. Cherry tomato growth was recorded periodically by measuring the height from the soil surface to the growing point. When the cherry tomatoes ripened, they were picked and weighed. Then sugar contents and AsA in the fruits were ascertained.

2.2.2 Tomato

Tomatoes were cultivated according to the following procedures. Green guard seeds (as rootstock cultivars, Takii Seed, Kyoto, Japan) and Momotaro piece seeds (as scions, Takii Seed) were immersed in water for half a day. After the seed surfaces had dried, the seeds were sown in a plastic container (288 small plots) including the soil for seeding. After three weeks, grafting was conducted in a larger plastic container (128 small plots). After two weeks, the grafted seedlings were transplanted in raised seedling pots of 7.5 cm diameter. The seedlings were planted with 40 cm of spacing distance in soil that had been ridged freshly in a vinyl house after one month. Three treatments were prepared for jellyfish supernatant (one treatment), seawater (one treatment), and control (three treatments). The numbers of seedlings were, respectively, 9, 9, and 21 (7×3) in the treatments described above. From 10 days after fixed planting, the supernatant solutions were added to the soil around the 9 seedlings (100 mL/seedling) once a week for 10 weeks. For the seawater treatment and the controls, seawater and tap water were added respectively (100 mL/seedling). Fertilizer and water were added to each treatment according to normal cultivation conditions. Tomato growth was recorded periodically, just as it was for cherry tomato cultivation. Harvested tomatoes were weighed. Then sugar content and acidity of the fruits were determined. Some

harvested tomatoes were provided for taste testing.

2.3 Chemical analysis

2.3.1 Constituents in the supernatant solutions

The following CZE procedure[18] quantified the amounts of NH_4^+, Na^+, K^+, Mg^{2+}, and Ca^{2+} in a jellyfish supernatant used for cherry tomato cultivation, after filtering through 0.45-μm membrane filter (Advantec Tokyo Kaisha, Ltd., Tokyo, Japan). The capillary-electrophoresis (CE) instrument (CAPI-3300; Otsuka Electronics Co. Ltd., Osaka, Japan) was equipped with a capacitively coupled contactless conductivity detector (C^4D, TraceDec; Innovative Sensor Technology IST AG, Strasshof, Austria). A polyimide-coated fused-silica capillary (GL Sciences Inc., Tokyo, Japan) with 80 cm total length ($L_{tot.}$) (60 cm effective length ($L_{det.}$)) and 50 μm id (375 μm od) was used. The capillary was thermostated at 25 ℃. New capillaries were washed with 1 mol/L NaOH for 30 min, and with water for 30 min; then with background electrolyte (BGE; a mixture of 25 mmol/L 2-(*N*-morphorino)ethanesulfonic acid (MES), 25 mmol/L L-histidine (HIS), and 2 mmol/L 18-crown-6) for 10 min. After the capillary was filled with the BGE by vacuum for 4 min, a 500-fold diluted sample was vacuum-injected (50 kPa) into the CE apparatus for 1 s (ca. 11 nL). Voltage (20 kV) was applied for separation with the sample-inlet side as the anode. Each step was run automatically. The capillary was rinsed with 0.1 mol/L NaOH and water between runs. Calibration graphs were prepared using synthetic standards. A different CZE procedure[9], after slight modification, was used for determination of the major cations in the supernatant solution and seawater used for tomato cultivation. The CE instrument (270A-HT; PerkinElmer Inc., Foster City, CA, USA) was equipped with a UV-visible absorbance detector. A capillary with 72 cm $L_{tot.}$ (50 cm $L_{det.}$) and 75 μm id (375 μm od) was used. The detection wavelength was set at 214 nm. The capillary was thermostated at 30 ℃. New capillaries were washed with 1 mol/L NaOH for 40 min; then with water for 10 min. The capillary was filled with BGE (a mixture of 10 mmol/L *N*-methylbenzylamine, 0.4 mmol/L citric acid, and 3 mmol/L 18-crown-6 adjusted to pH 4.8 with 2-ethyl-*n*-butyric acid) by vacuum for 3 min. A 100-fold diluted sample was vacuum-injected (16.9 kPa) into the CE apparatus for 3 s (ca. 62 nL). Voltage (20 kV) was applied for separation with the sample-inlet side as the anode. Peak area, peak height, and migration time were measured using a Chromato-Integrator (D-2500; Hitachi Ltd., Tokyo, Japan). The earlier developed CZE procedure[19] was applied for determination of inorganic phosphate (PO_4^{3-}) in the supernatant solutions and seawater. The CE apparatus (270A-HT) equipped with a UV-Vis absorbance detector was used. The detection wavelength was set at 273 nm. The capillary ($L_{tot.}$ = 72 cm, $L_{det.}$ = 50 cm, 75 μm id, and 375 μm od) was filled with BGE (5 mmol/L 2,6-pyridinedicarboxylic acid (PDC, pH 3.5) containing 0.01 % (w/v) hydroxypropylmethylcellulose, HPMC) by vacuum for 3 min. A ten-fold diluted sample was vacuum-injected into the CE apparatus for 1 s (ca. 21 nL). Voltage (15 kV) was applied for separation with the sample-inlet side as the cathode.

2.3.2 Sugar and AsA contents in cherry tomato

One or half of a cherry tomato (1-4 g) was homogenized in a porcelain mortar. Sugar contents (refractometer index: Brix) of the fruit juice were determined using a Pocket Refractometer (PAL-1; Atago Co. Ltd., Tokyo, Japan). AsA extracted from harvested cherry tomatoes was determined using the analytical method developed by the authors[17]. One or half of a cherry tomato (2-3 g) was homogenized with a mixture of 4 mL of 2 % (w/v) thiourea and 10 mmol/L HCl in a porcelain mortar. Then 14 mL of 10 mmol/L HCl was added. After standing for 15 min, the homogenate was transferred into a centrifuge tube with 18 mL of water that had been used for washing the porcelain mortar. The solution was centrifuged at 3000 rpm (1630 × g) for 5 min. The supernatant solution was filtered through a 0.45-μm membrane filter. The filtrate was vacuum-injected into the capillary ($L_{tot.}$ = 62.4 cm, $L_{det.}$ = 50 cm, 50 μm id, and 375 μm od) filled with BGE (20 mmol/L sodium tetraborate (pH 9.2)) for 1 s (14 nL). The CE apparatus (CAPI-3200; Otsuka Electronics Co. Ltd.) was equipped with a UV-Vis absorbance detector. The detection wavelength was set to 270 nm. Voltage (20 kV) was applied with the sample-inlet side as the anode.

2.3.3 Sugar content and acidity in tomato

A harvested tomato put the cut in 8 equal ass side of the tomato up to half was wrapped in gauze and squeezed to take the juice in a beaker. An aliquot of the juice was used to ascertain the sugar content. To prepare the sample for acidity determination, 1 g of the juice was diluted to 50 g. Sugar content and acidity of tomato were determined using a Pocket Brix-Acidity Meter (PAL-BX|ACID3; Atago Co. Ltd.).

2.3.4 Constituents of the soil before and after tomato cultivation

Just after planting tomato seedlings, ca. 170-250 g of soil samples was collected from five sites of each treatment (one treatment each for jellyfish and seawater, and three treatments for control). After harvesting the tomatoes, ca. 130-190 g soil samples were collected from five sites around one strain base in each treatment (one treatment for

jellyfish, seawater, and control). A soil sample (ca. 25-50 g) was taken from one site at 15-20 cm distance from the strain base from 15-20 cm depth using a small shovel. The five samples were mixed well and were passed through a coarse sieve. The soil samples were pretreated for determination of their constituents except for N, based on Sediment Monitoring Method[20]. Concentrations of Na[21] and K[22] were found using flame photometry based on Testing Methods for Industrial Waste Water. ICP emission spectroscopy was used for the determination of Mg and Ca[23] and Mn and Fe[24] based on Testing Methods for Industrial Waste Water. Neutralization titration method was used for the determination of N based on Sediment Monitoring Methods[25] . Molybdenum blue absorptiometry was used for the determination of P based on Testing Methods for Industrial Waste Water[26].

3. Results and discussion

3.1 Jellyfish components

Table 1 presents concentrations of major cationic components and PO_4^{3-} in the jellyfish supernatant and seawater. Compositions of both supernatant solutions were similar to the seawater composition except for NH_4^+ and PO_4^{3-}. The supernatant solutions contained higher concentrations of NH_4^+ and PO_4^{3-} than those for seawater. The supernatant solution used for tomato cultivation contained slightly less PO_4^{3-} than that used for cherry tomato cultivation. The jellyfish used for tomato cultivation was kept in the freezer one year longer than that used for cherry tomato cultivation. Presumably, a part of PO_4^{3-} was precipitated as $CaHPO_4$ during the longer storage period. It is said that $CaHPO_4$ is useful for recovering PO_4^{3-} because of its small solubility in water (0.136 g/L saturated solution[27]) [28]. Moreover, correlation was observed between P concentration and Ca concentration in the jellyfish supernatant solutions during storage in the present study (Table 1) and the previous report[7]. The concentrations of other constituents in the supernatant solution for tomato cultivation were similar to those in the supernatant solution for cherry tomato cultivation.

3.2 Sugar and AsA contents (or acidity)

3.2.1 Cherry tomato

Table 2 presents analytical results for sugar and AsA contents in harvested cherry tomatoes along with the fruit weight and the number of cherry tomatoes. **Figure 1** depicts an electropherogram of cherry tomato extract obtained using the CZE method. Statistical analysis revealed that when jellyfish supernatant was used, the sugar and AsA contents (mean content ± standard deviation) were 13 % and 18 % higher, respectively, than those for control at a 1 % significance level. It has also been reported that these contents in cherry tomato and tomato increased when the

Table 1 Analytical results for several components in jellyfish (*Aurelia aurita*) supernatant and seawater (mg/L)

Component	Jellyfish[a] used for cherry tomato cultivation	Jellyfish[b] used for tomato cultivation	Seawater[c] used for tomato cultivation
Na^+	9390	7880	9810
K^+	410	520	350
Mg^{2+}	1100	900	1210
Ca^{2+}	350	320	430
NH_4^+-N	190	210	ND
PO_4^{3-}-P[d]	19	7	ND

[a] Collected from a small harbor at our university on May 27-29, 2013 and kept in a freezer. The frozen jellyfish were thawed on May 27-28, 2014: Na^+, K^+, Mg^{2+}, Ca^{2+}, and NH_4^+-N were determined using the CZE method[18]

[b] Collected from the same site as that shown above on May 28-June 4, 2013 and kept in a freezer. The frozen jellyfish were thawed on July 14, 2015: Na^+, K^+, Mg^{2+}, Ca^{2+}, and NH_4^+-N were determined based on the CZE method[9]

[c] Collected from Suma Aqualife Park KOBE on July 10, 2015. Components were determined using the same methods as those used for jellyfish[b] analysis

[d] PO_4^{3-}-P was determined using the CZE method[19]

Table 2 Sugar, AsA contents, and fruit weight of cherry tomatoes[a]

Treatment	Sugar content (Brix)	AsA (mg/100 g of fruit weight)	Fruit weight (g)	No. of cherry tomatoes
Jellyfish	8.8 ± 1.8	39 ± 10	3.7 ± 1.4	69
Control	7.8 ± 1.5	33 ± 6.6	4.8 ± 1.7	63

[a] Results were significant at a 1 % significance level

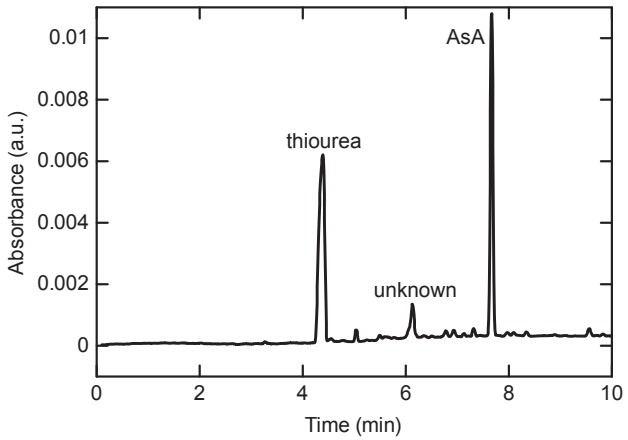

Fig. 1 Electropherogram of cherry tomato extract using the CZE method. Electrophoretic conditions: capillary, $L_{tot.}$ = 62.4 cm, $L_{det.}$ = 50 cm, 50 μm id × 375 μm od; BGE, 20 mmol/L sodium tetraborate (pH 9.2); separation voltage, 20 kV with the sample inlet side as the anode; wavelength for detection, 270 nm. Sample, cherry tomato (cultivated using jellyfish supernatant) extract; vacuum (50 kPa) injection period, 1 s (14 nL)

culture medium contained sodium chloride or seawater[12-16]. This increase derives from various salt stress responses as well as concentration effects resulting from decreased water contents of the fruits[16].

3.2.2 Tomato

Table 3 also presents sugar content and acidity in harvested tomatoes along with the fruit weight and the number of tomatoes. Statistical analyses revealed that when jellyfish supernatant was used, the sugar contents were 16 % and 10 % higher, respectively, than those for the seawater treatment and control at a 1 % significance level. No significant difference was found between the seawater treatment and control (5 % significant level). When jellyfish supernatant was used, the acidity was 15 % higher than those for seawater treatment and control at a 5 % significance level. No difference was found between the seawater treatment and control.

Taste testing was conducted two times by 17 men and women between 10's and 60's. In the first test, the tomatoes harvested on November 10 were brought with taste test votes to three homes to serve for the test. Evaluation items were sweetness, astringency, taste, freshness, and total deliciousness with five evaluation levels (larger the number, signify higher ratings) for each item. The following notes were also shown in the vote: keep the tomatoes at room temperature and eat them by the next day received them; cut the tomato into eight equal parts to stand and eat them with drinking small amount of water to keep inside of the mouth clean; don't eat the tomatoes just after a meal. In the second test, the tomatoes harvested on December 15 were brought to three homes and three restaurants. The test was conducted in the same manner as above. As a result, the average value of the evaluation number for the total deliciousness was 3.6 for jellyfish-treatment tomatoes, 3.3 for seawater-treatment tomatoes, and 3.1 for control tomatoes. Similar results were obtained for sweetness. To produce sweet and delicious tomatoes, jellyfish supernatant was more effective than seawater.

As described above, sugar content and acidity in tomatoes grown with jellyfish supernatant were significantly higher than in tomatoes grown with seawater. Furthermore, the taste of the former tomatoes was better than that for the latter tomatoes. Jellyfish contains many amino acids, but their contents are small[5]. Some amino acids in jellyfish are thought to provide higher sugar content and acidity, producing better taste of the tomatoes cultivated using jellyfish supernatant. The reasons underlying the effects described above are not clear at present but future investigations are expected to elucidate them.

3.3 Plant growth and weight of the fruits

3.3.1 Cherry tomato

Figure 2 depicts the increase in height (from the soil surface to the growing point) of cherry tomato plants after fixed planting. The height is the average value of six stumps for each treatment: use of jellyfish supernatant and control. The height increased linearly up to 54 days after planting; then it almost leveled off in each treatment. No difference was found between the height-increasing tendency for the use of jellyfish supernatant and that for control. Cherry tomato harvesting began at 42 days and continued for one

Table 3 Sugar content, acidity, and fruit weight of tomatoes[a]

Treatment	Sugar content (Brix)	Acidity (% (w/v))	Fruit weight (g)	No. of tomatoes
Jellyfish	6.4 ± 1.1	0.71 ± 0.22	156 ± 52.3	47
Seawater	5.5 ± 0.74	0.62 ± 0.16	193 ± 56.8	49
Control	5.8 ± 1.0	0.62 ± 0.18	189 ± 59.4	61

[a] Results for *t*-test are presented in the text

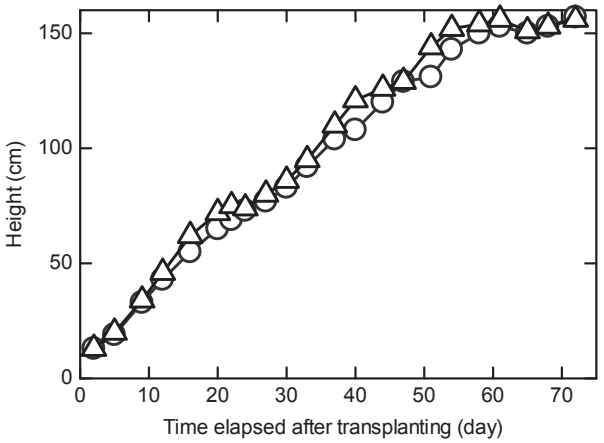

Fig. 2 Cherry tomato growth after fixed planting: ○, jellyfish supernatant solutions were added periodically; △, control (same volume of tap water was added instead of jellyfish supernatant solutions); height, from the soil surface to the growing point of cherry tomatoes

month. The fruit weight (edible portion) was measured. Cherry tomatoes cultivated using jellyfish supernatant were 23 % lighter than control tomatoes, as shown in Table 2. The results were significant at the 1 % significance level. Reportedly, when sodium chloride or seawater was added to the culture soil or solution for cultivation of cherry tomato and tomato, the fruit weight decreased compared to that for control[12-16]. This result is explainable by the increased osmotic pressure of the culture medium derived from the high sodium chloride concentration.

3.3.2 Tomato

The height of tomato plants for each treatment increased linearly until 82 days after planting (data not shown). No difference was found among the height-increasing tendency for the use of jellyfish supernatant, and that for seawater and control. Tomatoes in the jellyfish treatment were, respectively, 19 % and 17 % lighter than those in the seawater treatment and control at a 1 % significance level. No significant difference was found between the seawater treatment and control (5 % significance level) unlike the reported results (the reason remains unknown). As an example, tomatoes cultivated in undiluted and 10-fold diluted deep-seawater treatments were 45 % and 12 % lighter than those in a control, respectively[13].

3.4 Results for constituents of the soil before and after tomato cultivation

Table 4 presents analytical results for several constituents of the soil samples before and after tomato cultivation. The concentrations for the soil before cultivation for control are average values of the results for three treatments. After cultivation, the Na content of the soil samples in jellyfish and seawater treatments was, respectively, 0.31 and 0.34 μg/g dry weight higher than that before cultivation. No difference was found between the Na content before and after cultivation for control. When tomato is cultivated continually, if some amount of Na is accumulated, then the growth conditions and yield are presumably affected by the accumulated Na. Therefore, it is important to examine the cultivation soil Na content and its effect on the tomato cultivation during continuous cultivation of tomatoes. After cultivation, the N content of the soil sample in jellyfish treatment was 0.4 μg/g dry weight lower than that before cultivation. The mechanism of adsorption of fertilizer component is so complicated that the reason of the decrease is not clear now. However, NO_3^--N might be adsorbed effectively through the tomato roots because of

Table 4 Analytical results for several constituents of the soil samples[a] before and after cultivation of tomatoes[b] (μg/g dry weight)

Treatment		Na[c]	K[d]	Mg[e]	Ca[e]	Mn[f]	Fe[f]	N[g]	P[h]
Jellyfish	Before	0.31	3.7	2.6	11	0.42	23	3.0	4.8
	After	0.62	3.7	2.9	11	0.41	23	2.6	4.7
Seawater	Before	0.29	3.4	2.8	11	0.46	24	3.0	4.8
	After	0.63	3.2	2.8	11	0.40	23	3.0	4.5
Control	Before[i]	0.30	3.7	2.8	10	0.42	24	2.9	4.8
	After	0.28	3.0	2.7	10	0.38	22	2.8	4.5

[a] Soil samples (*ca.* 130-250 g) were taken from five sites in each treatment, as described in the text
[b] Sample pretreatment except for N was based on Sediment Monitoring Methods[20]
[c] Analyzed using flame photometry[21]
[d] Analyzed using flame photometry[22]
[e] Analyzed using ICP emission spectroscopy[23]
[f] Analyzed using ICP emission spectroscopy[24]
[g] Analyzed using neutralization titration[25]
[h] Analyzed using molybdenum blue absorptiometry[26]
[i] Concentrations are average values of the results for three treatments

more coexisting NH_4^+-N in the jellyfish treatment[29]. In general, when N content in the cultivation soil is too high hardly attached flowers and fruit. However, this phenomenon was not observed. No difference was found between the N content before and after cultivation for seawater treatment and control.

4. Conclusions

Results show that when jellyfish（*Aurelia aurita*）supernatant was added to the culture soil, the sugar and AsA contents of cherry tomatoes increased, although the fruit weight decreased. When jellyfish supernatant was used for tomato cultivation, sugar content and acidity were higher than those when seawater was used instead of the supernatant solutions. Moreover, fruit taste of the former was better than the latter. The reason is expected to be clarified by results of future studies. It is also necessary to examine Na accumulation in the cultivation soil and its effect on cherry tomato and tomato cultivation, especially on the yield. Finally, based on the results obtained in this study, the following additional studies would be desirable. In each developing stage（e.g. 1-3 trusses, 4-6 trusses, and 5-8 trusses）, change the concentration and volume of jellyfish supernatant added to the soil with measuring fruit weight and sugar content along with determining N content in tomato stumps and cultivation soil. As a result of above examination, if the relationship between above conditions and sugar content etc., it is expected to produce tomatoes（cherry tomatoes）with high sugar content（AsA content or acidity）with a low rate of decrease of the fruit weight and less Na accumulation using proper cultivation procedures to add the supernatant solutions.

（These results were partly presented at the 75th Analytical Chemistry Symposium in May 2015[30].）

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References

1）L. Brotz, W. W. L. Cheung, K. Kleisner, E. Pakhomov and D. Pauly, Increasing jellyfish populations: trends in large marine ecosystems, *Hydrobiologia*, **690**, 3-20（2012）
2）M. Schrope, Attack of the blobs, *Nature*, **482**, 20-21（2012）
3）W. M. Graham, S. Gelcich, K. L. Robinson, C. M. Duarte, L. Brotz, J. E. Purcell, L. P. Madin, H. Mianzan, K. R. Sutherland, S. -I. Uye, K. A. Pitt, C. H. Lucas, M. Bøgeberg, R. D. Brodeur and R. H. Condon, Linking human well-being and jellyfish: ecosystem services, impacts, and societal responses, *Front. Ecol. Environ.*, **12**, 515-523（2014）
4）C. -F. Qu, J. -M. Song, N. Li, X. -G. Li, H. -M. Yuan, L. -Q. Duan and Q. -X. Ma, Jellyfish（*Cyanea nozakii*）decomposition and its potential influence on marine environments studied via simulation experiments, *Mar. Pollut. Bull.*, **97**, 199-208（2015）
5）A. Kato and Y. Kodani, Development of the fish sauce using koji, *Bull. Soc. Sea Water Sci. Jpn.*, **70**, 303-307（2016）
6）K. Fukushi, N. Ishio, J. Tsujimoto, K. Yokota, T. Hamatake, H. Sogabe, K. Toriya and T. Ninomiya, Preliminary study on the potential usefulness of jellyfish as fertilizer, *Bull. Soc. Sea Water Sci. Jpn.*, **58**, 209-217（2004）
7）K. Fukushi, J. Tsujimoto and K. Yokota, Determination of inorganic constituents in jellyfish, *Bunseki Kagaku*, **54**, 175-178（2005）（Japanese）
8）K. Fukushi, T. Arita, S. Minami, M. Kitakata, J. Tsujimoto and Y. Yamashita, Conversion of nitrogen and phosphorus in jellyfish into an inorganic species and processing jellyfish as fertilizer, *Bull. Soc. Sea Water Sci. Jpn.*, **60**, 173-180（2006）（Japanese）
9）K. Fukushi, S. Minami, M. Kitakata, M. Nishijima, K. Yokota, S. Takeda and S. Wakida, Determination of ammonium cations and alkali and alkaline earth metal cations in jellyfish by capillary zone electrophoresis, *Anal. Sci.*, **22**, 1129-1133（2006）
10）K. Fukushi, K. Kimura and J. Tsujimoto, Concentration of supernatant solutions of jellyfish by heating *in vacuo* and resulting effects of decreasing sodium on vegetable growth, *Bull. Soc. Sea Water Sci. Jpn.*, **61**, 337-341（2007）
11）T. Hattori, Y. Hidaka, K. Fukushi, M. Hayakawa, J. Tsujimoto and T. Minato, Soilless culture for the common ice plant（*Mesembryanthemum crystallinum* L.）using supernatant solutions of jellyfish suspensions, *Bull. Soc. Sea Water Sci. Jpn.*, **68**, 25-29（2014）
12）K. Ohta, N. Ito, T. Hosoki and H. Higashimura, Influence of the concentrations of nutrient solution and salt supplement on quality and yield of cherry tomato grown hydroponically, *J. Japan. Soc. Hort. Sci.*, **60**, 89-95（1991）（Japanese）
13）Y. Kawai, S. Hiratsuka, T. Tashiro and H. Kunoh, Effects of deep seawater application on fruit qualities of satsuma mandarin and tomato, *Hort. Res.*（*Japan*）, **1**, 179-182（2002）（Japanese）
14）I. Oka, N. Sue and H. Takahashi, Effects of salt application on total soluble soils and fruit weight of tomato growth in hydroponics, *Hort. Res.*（*Japan*）, **3**, 149-154（2004）（Japanese）
15）T. Hosokawa, H. Komatsu, T. Yoshida and Y. Fukumoto, Effects of the addition of deep seawater to a nutrient solution in hydroponics on growth, fruit yield and quality of tomatoes, *J. SHITA*, **17**, 26-33（2005）（Japanese）
16）K. Zushi, Application of salt stress in production of high quality tomato, *Bull. Soc. Sea Water Sci., Jpn.*, **62**, 179-185（2008）（Japanese）
17）K. Fukushi, S. Takeda, S. Wakida, M. Yamane, K. Higashi and K. Hiiro, Determination of ascorbic acid in vegetables by capillary zone electrophoresis, *J. Chromatogr. A*, **772**, 313-320（1997）
18）K. Fukushi, Highly sensitive instrumental analytical-method for the simultaneous determination of principal components in salts, *The Salt Science Research Foundation Research Report*,（http://www.saltscience.or.jp/general_research/2014/201414.pdf）（2015）（Japanese）（accessed 2017.2.27）
19）K. Kita, K. Fukushi, A. Hiraoka, Y. Suzuki, A. Soejima and T. Miyado, Determination of chloride, inorganic phosphate,

and citric acid in human serum using capillary zone electrophoresis, *Bunseki Kagaku*, **60**, 671-674 (2011) (Japanese)
20) Ministry of the Environment, Wet Decomposition Method in Sediment Monitoring Methods: p. 115, Tokyo (2012) (Japanese)
21) Japanese Standards Association, Flame Photometry in Testing Methods for Industrial Waste Water, JIS K 0102: pp. 194-195, Tokyo (2013) (Japanese)
22) Japanese Standards Association, Flame Photometry in Testing Methods for Industrial Waste Water, JIS K 0102: p. 199, Tokyo (2013) (Japanese)
23) Japanese Standards Association, ICP Emission Spectroscopy in Testing Methods for Industrial Waste Water, JIS K 0102: pp. 204-205, Tokyo (2013) (Japanese)
24) Japanese Standards Association, ICP Emission Spectroscopy in Testing Methods for Industrial Waste Water, JIS K 0102: pp. 214-218, Tokyo (2013) (Japanese)
25) Ministry of the Environment, Neutralization Titration in Sediment Monitoring Methods: pp. 51-55, Tokyo (2012) (Japanese)
26) Japanese Standards Association, Molybdenum Blue Absorptiometry in Testing Methods for Industrial Waste Water, JIS K 0102: pp. 180-182, Tokyo (2013) (Japanese)
27) The Chemical Society of Japan, Kagaku Binran, 3rd Ed., p. II-177, Maruzen, Tokyo (1984) (Japanese)
28) K. Maeda, K. Iimura, H. Kuramochi and K. Fukui, Solubility of phosphoric salts in aqueous solutions and its applications, *Bull. Soc. Sea Water Sci. Jpn.*, **66**, 314-318 (2012)
29) Y. Ogawa, K. Roppongi, I. Goto, Tsuchi to Sehi no Shin-chishiki-Kankyo·Shigen·Kenko wo Kangaeta, pp. 178-180, Nosan Gyoson Bunka Kyokai, Tokyo (2012) (Japanese)
30) Abstracts of 75th Analytical Chemistry Symposium, 2015, Kofu, JAPAN, p. 144 (2015)

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クラゲ上澄み液を用いたミニトマト及びトマトの栽培

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要　旨

ミニトマト（*Lycopersicon esculentum Mill*）及びトマト（*Solanum lycopersicum*）栽培におけるクラゲ（*Aurelia aurita*）上澄み液の有用性について検討した．すなわち，ミニトマト及びトマト栽培において，ミズクラゲ上澄み液を定期的に栽培土壌に加えた．対象区には，クラゲ上澄み液の代わりに同量の水を加えた．また，トマト栽培では，比較のために海水処理区も設けた．ミニトマト，トマトを収穫後，果実重量，糖度，アスコルビン酸（AsA）濃度（トマトの場合は酸度）を測定した．その結果，ミニトマトの糖度及び AsA 濃度は，クラゲ処理区では，対象区よりそれぞれ 13，18 %高かった．ただし，果実重量はクラゲ処理区のミニトマトは，対象区のものより 23 %軽かった．また，トマトの糖度及び酸度は，クラゲ処理区では，海水処理区よりそれぞれ 16，15 %高かった．ただし，果実重量はクラゲ処理区のミニトマトは，海水処理区のものより 19 %軽かった．ミズクラゲ上澄み液は，ミニトマト及びトマトの品質向上に有用であることがわかった．

キーワード：酸度，有機廃棄物，リサイクル，土耕栽培，糖度

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