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RESEARCH ARTICLE

# POSITIVE EFFECTS OF THE VICTIM BY THE GROWING OF PLANTS AFTER GREAT EAST JAPAN EARTHQUAKE

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**ABSTRACT**

The growing of plants are said to improve individuals' physical and mental states. The growing of plants is a process through which the people are stimulated to positively change. Actually, the growing of plants has been used as a method of the psychological care of the person of the PTSD. For this reason, the growing of plants could be assumed to reflect plastic change in the brain. However, the neural basis of the growing of plants for PTSD is uncertain. This study sought to verify PTSD reaction reduction and changes in brain morphology and stress hormones by growing of plants in women with earthquake stress. Fifty-four right-handed women with mild PTSD in a disaster area participated in this randomized, permuted block method, controlled, crossover trial. Participants were randomly assigned to a horticultural therapy (HT) intervention or stress education (SE) intervention group. Within the 8-week study period, magnetic resonance imaging, psychological index for intervention evaluations, and saliva tests were performed before and after interventions. The HT group showed significantly increased regional gray matter volume (rGMV) of the left subgenual anterior cingulate cortex and left superior frontal gyrus compared with the SE group. The HT group also showed significant improvement in PTSD reactions, posttraumatic growth, and positive affect compared with the SE group. The HT group showed greatly improved salivary cortisol and alpha amylase levels compared with the SE group. These results demonstrate that the growing of plants restore people with PTSD reactions to good condition. Additionally, the growing of plants reduced stress levels in people with PTSD reactions for an earthquake disaster. The growing of plants increased the rGMV of brain areas known to be reduced in PTSD patients. Neural plasticity may underlie the psychological and physiological effects of the growing of plants.

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## INTRODUCTION

The coastal regions of the Tohoku area suffered significantly from the Great East Japan Earthquake on March 11, 2011. One year after the earthquake, intermittent aftershocks continue to occur in the region. The mental health problems of victims are most evident a certain amount of time after a disaster (1-3). There is growing concern that people from disaster-affected areas may develop post-traumatic stress disorder (PTSD). Previous neuroimaging studies of patients with PTSD symptoms revealed morphological changes in brain areas such as the amygdala (4), the medial prefrontal cortex (MPFC), including the anterior cingulate cortex (ACC) (4, 7, 8) and medial frontal gyrus (5); the hippocampus (4-6); and the orbitofrontal cortex (OFC) (9). Our longitudinal magnetic resonance imaging (MRI) study suggested that young healthy subjects with smaller regional gray matter volume (rGMV) in the right ventral ACC before the earthquake, and subjects with decreased rGMV in the left OFC through the Great East Japan Earthquake disaster area were likely to have PTSD symptom (10). The ACC is involved in processing fear and anxiety, and have been suggested to be related to vulnerability to development of PTSD symptoms (10). Additionally, decreased OFC volume was induced by falling to extinct conditioned fear soon after traumatic event (10). Furthermore, our study suggested that salivary cortisol levels of young healthy subjects in the disaster area were significantly increased after the earthquake compared with levels before the earthquake (11). Cortisol is considered to be an indicator of psychological and physiological stress, and salivary cortisol levels increase in people with PTSD symptoms (72).

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The growing of plants are said to improve individuals' physical and mental states. The growing of plants is a process through which the people are stimulated to positively change. Actually, the growing of plants has been used as a method of the psychological care of the person of the PTSD. It is referred to as a horticultural therapy (HT). HT is an intervention method for PTSD that was developed in the USA for psychological care and social rehabilitation of disabled soldiers and war veterans with PTSD symptoms after World War II (12). HT is usually led by a professional trained to tailor the use of plants to fit the therapy and rehabilitation needs of those individuals with whom they are working. HT is a process through which the people are stimulated to positively change. Process of HT such as seeding and growing plants itself improves people's mood and attentiveness. Besides, therapy in a group setting improves people's communication skill through collaborative horticultural activity. The people identify him or herself with plant growth, regains health and motivation, and has a chance to be happy. Through such the experiences, people are certainly improved through association with nature (21).

MRI study of horticulture exist only one so far. In a functional MRI study in patients with cerebrovascular disease, the fusiform, and supramarginal gyri, left cerebellum, and visual, inferior temporal, right motor, left supplementary motor, and right sensory areas were activated during recognition tasks using emotional photograph (pleasant or unpleasant) after HT (22).

Previous studies suggested that HT and exposure to nature can have cognitive (14, 15), psychological (12, 13, 16-18), social (19, 20), and physical benefits (16, 18). Additionally, HT has a positive effect on physiological measures, such as heart rate and salivary cortisol level (23). The change in cognitive function of elderly people or patients with PTSD or cancer after HT could be assumed to be the result of clinical efficacy and plastic change in the brain. However, the neural basis of HT as a treatment for people with PTSD is uncertain. We hypothesized that HT possibly improves a decline in brain volume in people with PTSD.

The purpose of this study was to verify the reduction in PTSD symptoms in disaster victims with earthquake stress by HT intervention, and to reveal changes in brain morphology and stress hormones produced by HT intervention.

## MATERIALS AND METHODS

### Participants

Figure 1 presents a flowchart of this study. This study was a randomized, permuted block method, controlled, crossover trial. Participants were randomly assigned to an HT intervention or stress education (SE) intervention group. A total of 106 participants were recruited through a leaflet in the local newspaper, which is circulated exclusively in the disaster area, and screened using a questionnaire before inclusion. Fifty-two participants were excluded from a clinical trial. Fifty-four right-handed women with mild PTSD participated in this study. These women (age range: 23–55 years) were victims of the Great East Japan Earthquake of March 11, 2011, and were still living in the disaster area. They lived in cities that were devastated, such as Ishinomaki city, Onagawa town, and Higashi-Matsushima city, all in Miyagi Prefecture. To assess whether the volunteers had mild PTSD, we used the Clinician-Administered PTSD Scale (CAPS) (24-26). CAPS scores are divided into the following categories: 0–19 (asymptomatic/few symptoms), 20–39 (mild PTSD/subthreshold), 40–59 (moderate PTSD/above threshold), 60–79 (severe PTSD symptoms), and >80 (extreme PTSD symptoms). All participants were verified to have no neuropsychiatric disorder *via* the Mini-International Neuropsychiatric Interview (M.I.N.I.) (27, 28). Trained psychologists (A.O., N.A., M.S., N.S., S.T., and Y.W.) administered the Japanese version of the CAPS (26) to all subjects in structured psychiatric diagnostic interviews to screen for post-traumatic stress symptoms. All participants were diagnosed with PTSD *via* the M.I.N.I., and each had symptoms of all three PTSD symptom clusters, including re-experiencing the event, avoidance, and hyperarousal. The CAPS and M.I.N.I. were administered before and after intervention. Written informed consent was obtained from each subject in accordance with the Declaration of Helsinki (1991). This study was approved by the Ethics Committee of Tohoku University School of Medicine.

### Randomized controlled trial design

This randomized, double-blind, controlled, crossover trial was registered in the University Hospital Medical Information Network Clinical Trials Registry (UMIN000006170). The trial was conducted between September 2011 and March 2012 for people who lived in the coastal areas of Miyagi Prefecture (see Supplementary Information for more details about trial design and study limitations).

### HT intervention sessions

The HT intervention was designed in consultation with a horticultural therapist. The intervention comprised a total of eight weekly sessions (60 min each) at a university lab and at participants' homes. The lab sessions comprised interactive lectures and practical training. In the first two sessions, a teaching aid showed participants videos containing introductory psychology and stress management lessons. The participants then attended six horticultural lessons, including topics such as designing a garden planter, seeding, watering, weeding, and picking flowers. Participants filled out an HT intervention session checklist after each session as a self-assessment. Participants took care of plants for 15 min per day at their convenience with horticulture kits provided by the experimenters, and recorded the completion of this task daily on forms provided by the experimenters at the intervention sessions. The participants submitted these forms to the experimenters at the HT intervention session each week.

### The stress education session (SE intervention session)

The SE intervention session was a 60-minute session consisting of a video lecture regarding stress education, and it was managed by teaching aids who served as psychological testers. The participants in the control group attended the SE intervention sessions once each week (a total of eight lessons). The video series used in the SE intervention sessions educated participants about the human body, such as stress mechanisms, psychology, stress management Participants filled out an SE intervention session checklist after each session. The 2nd session and the 6th session of the HT intervention session and the SE intervention session used the same teaching aid.

### Psychological measures

For pre- and post-intervention evaluation, a questionnaire with the following content was administered: (a) a health interview checklist regarding drinking, smoking, and sleeping in daily life before and after the earthquake; (b) the World Health Organization Quality of Life 26 instrument (29); (c) the World Health Organization Subjective Well-Being Inventory (30, 31); (d) the Center for Epidemiologic Studies Depression Scale, which measures the respondent's level of depressive symptoms within the past week (32, 33); (e) the Cornell Medical Index, which measures the subject's physical and mental state (34, 35); (e) the General Health Questionnaire 30, which measures psychological distress (36, 37); (f) the Positive and Negative Affect Schedule (PANAS), which measures positive affects (PAs) and negative affects as states and traits (38, 39); (g) the Profile of Mood States Scale, which measures aspects of mood (40, 41); and (h) the Posttraumatic Growth Inventory (PTGI), which measures positive outcomes of people who have experienced traumatic events (42, 43), such as post-traumatic growth (PTG). Overcoming trauma and achieving human growth to recover quality of life involve (1) strengthened consideration of or kindness to others, (2) discovery of new possibilities, (3) becoming humanly strong, (4) appreciation of life and human life, and (5) a deeper understanding of something beyond human knowledge, such as religion and nature (42).

### Saliva sampling

We collected saliva samples from participants to measure salivary cortisol and salivary alpha amylase (SAA) levels. Distressing psychological stimuli are associated with an increased cortisol level (44). The SAA level increases during stress and decreases during relaxation (23) (see Supplementary Information for more details about collection dates, times, and assay method).

### Image acquisition

All MRI data were acquired with a 3-T Phillips Achieva scanner. Using a magnetization prepared rapid gradient echo sequence, high-resolution T1-weighted structural images (240 × 240 matrix, repetition time = 6.5 ms, echo time = 3 ms, field of view = 24 cm, 162 slices, 1.0-mm slice thickness) were collected.

### Voxel-based morphometry analysis

Voxel-based morphometry (VBM) was used to investigate morphological changes in the brains of women with mild PTSD after HT intervention. All morphological data were processed as in previous studies (45, 46). All images were subsequently subjected to 12-mm Gaussian smoothing. The change in rGMV between pre- and post-intervention images was computed at each voxel for each participant. We included only voxels with GMV probabilities > 0.10 on pre- and post-intervention images in these computations to avoid possible partial-volume effects at the borders between the GM and white matter, as well as between the GM and cerebrospinal fluid. The resultant maps representing the rGMV before intervention and the rGMV change between the pre- and post-intervention scans (pre-post) were then used in the group-level analysis described below (see Supplementary Information for more details).

### Statistical analyses

Psychological and salivary data were analyzed using the PASW statistical software package (ver. 18 for Windows; SPSS Inc., Chicago, IL, USA). Demographic and clinical data were subjected to one-way analyses of variance. One-way analyses of covariance were conducted with the difference between pre- and post-intervention scores included as dependent variables and pretest scores as covariates of each psychological measure. Because our primary endpoint of interest was the beneficial effect of intervention training, test-retest changes were compared between the HT and control groups using one-tailed tests ($p < 0.05$), as in previous studies (47).

In the group-level analysis of rGMV, we examined groupwise differences in rGMV changes using the factorial design option in SPM5. The effect of the intervention was estimated by comparing changes between pre- and post-intervention measures as described above, and then comparing between groups at each voxel with age, total GMV before intervention, and daily smoking reported in the health interview as covariates. The data were corrected for multiple comparisons across the whole brain at the nonisotropic adjusted cluster level (48), with an underlying voxel-level threshold of $p < 0.0025$. Nonisotropic adjusted cluster-size tests should be applied when data are known to be nonstationary (i.e., not uniformly smooth), as are VBM data (48). We did not perform region-of-interest analyses in this study.

## RESULTS

### Psychological measures

Demographic and clinical data are given in Table 1. Age, CAPS scores, amount of smoking per day, and amount of alcohol consumed per day did not differ significantly between the HT and SE groups. Comparisons between each group's psychological changes before and after intervention are given in Table 2. The HT group showed a significantly larger decrease between pre- and post-intervention CAPS scores [$F(1,51) = 13.526$, $p < 0.001$]. The CAPS score was significantly lower and PTSD symptoms were reduced more in the HT group than in the SE group. The HT group also showed a significantly larger increase between pre- and post-intervention PTGI-J total scores [$F(1,51) = 4.315$, $p < 0.05$]. The PTGI-J total score was significantly higher in the HT group than in the SE group, and PTG was improved by HT in comparison with SE. Moreover, the HT group showed a significantly larger pre- to post-intervention increase in PANAS-PA scores [$F(1,51) = 5.66$, $p < 0.05$]. The PANAS-PA score was significantly higher in the HT group than in the SE group, and PA was increased by HT in comparison with SE.

### Salivary stress marker

Comparisons between each group's salivary cortisol and SAA levels before and after intervention are given in Figure 2. The HT group showed a significantly larger pre- to post-intervention decrease in salivary cortisol [$F(1,51) = 14.077$, $p = 0.001$] and SAA [$F(1,51) = 16.978$, $p = 0.001$] levels, indicating that stress was reduced by HT in comparison with SE.

**Table 1** Demographic and clinical data

| | HT group | | SE group | | |
|---|---|---|---|---|---|
| Measure | Mean | SD | Mean | SD | $p^a$ |
| Age (years) | 42.48 | 9.72 | 44.22 | 7.78 | 0.884 |
| CAPS score | 31.52 | 6.5 | 31.25 | 6.47 | 0.471 |
| Amount of smoking per day (numbers of cigarette) | 1.81 | 3.55 | 3.26 | 6.16 | 0.354 |
| Amount of drinking per day (ml) | 111.11 | 133.97 | 155.56 | 207.24 | 0.296 |

[a]One-way analysis of variance.
HT, horticultural therapy; SE, stress education; SD, standard deviation; CAPS, Clinician-Administered Post-Traumatic Stress Disorder Scale.

**Table 2** Results of psychological measures before and after intervention

| | HT group | | | | SE group | | | | Planned contrast | $p^a$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre | | Post | | Pre | | Post | | | |
| Measures | Mean | SD | Mean | SD | Mean | SD | Mean | SD | | |
| CAPS score | 31.52 | 6.5 | 10.0 | 7.05 | 31.25 | 6.47 | 16.11 | 9.32 | HT < SE | **<0.001** |
| WHO-QOL26 total score | 52.52 | 5.8 | 53.89 | 6.45 | 52.34 | 6.3 | 51.0 | 5.85 | HT < SE | 0.297 |
| WHO-SUBI positive score | 37.11 | 6.47 | 38.44 | 6.82 | 37.3 | 6.34 | 38.04 | 5.94 | HT > SE | 0.277 |
| WHO-SUBI negative score | 49.67 | 7.13 | 50.41 | 5.97 | 50.33 | 6.52 | 51.04 | 5.67 | HT > SE | 0.861 |
| CES-D score | 13.44 | 7.11 | 11.81 | 7.39 | 14.56 | 6.87 | 12.52 | 5.18 | HT < SE | 0.934 |
| CMI somatic status score | 191.89 | 16.13 | 151.81 | 54.33 | 189.63 | 13.45 | 153.63 | 47.62 | HT < SE | 0.385 |
| CMI emotion status score | 49.96 | 7.88 | 38.52 | 14.63 | 50.63 | 6.97 | 38.63 | 14.12 | HT < SE | 0.949 |
| GHQ score | 7.07 | 5.09 | 4.37 | 4.16 | 6.78 | 5.72 | 5.0 | 4.71 | HT < SE | 0.248 |
| PANAS positive affect | 20.52 | 6.36 | 23.33 | 7.42 | 23.56 | 7.8 | 20.96 | 7.18 | HT > SE | **0.011** |
| PANAS negative affect | 18.93 | 7.69 | 15.11 | 5.96 | 21.78 | 7.12 | 18.52 | 6.36 | HT < SE | 0.071 |
| POMS Tension-Anxiety score | 10.0 | 5.08 | 8.26 | 4.12 | 10.19 | 5.43 | 10.0 | 4.77 | HT < SE | 0.057 |
| POMS Depression-Dejection score | 13.3 | 8.35 | 9.63 | 6.62 | 12.63 | 10.05 | 10.63 | 7.84 | HT < SE | 0.191 |
| POMS Anger-Hostility score | 12.0 | 8.72 | 9.89 | 7.8 | 11.04 | 9.05 | 8.22 | 5.61 | HT < SE | 0.420 |
| POMS Vigor-Activity score | 8.74 | 6.23 | 10.74 | 6.37 | 8.0 | 5.2 | 8.52 | 6.1 | HT > SE | 0.104 |
| POMS Fatigue-Inertia score | 10.59 | 6.6 | 8.59 | 5.92 | 9.44 | 6.44 | 7.63 | 4.97 | HT < SE | 0.366 |
| POMS Confusion score | 8.93 | 3.83 | 7.22 | 3.18 | 7.89 | 3.7 | 7.0 | 3.23 | HT < SE | 0.357 |
| POMS Total Mood Disturbance score | 46.26 | 28.03 | 34.59 | 26.15 | 43.0 | 30.05 | 33.22 | 21.97 | HT < SE | 0.957 |
| PTGI total score | 66.56 | 18.05 | 72.33 | 15.66 | 68.41 | 18.29 | 66.48 | 17.85 | HT > SE | **0.022** |

aOne-way analyses of covariance with pre–post differences in psychological measures as dependent variables and pre-intervention scores as covariates (one-tailed).
HT, horticultural therapy; SE, stress education; SD, standard deviation; CAPS, Clinician-Administered Post-Traumatic Stress Disorder Scale; WHO-QOL26, World Health Organization Quality of Life 26; WHO-SUBI, World Health Organization Subjective Well-Being Inventory; CES-D, Center for Epidemiologic Studies Depression Scale; CMI, Cornell Medical Index; GHQ, General Health Questionnaire; PANAS, Positive and Negative Affect Schedule; POMS, Profile of Mood States; PTGI, Posttraumatic Growth Inventory.

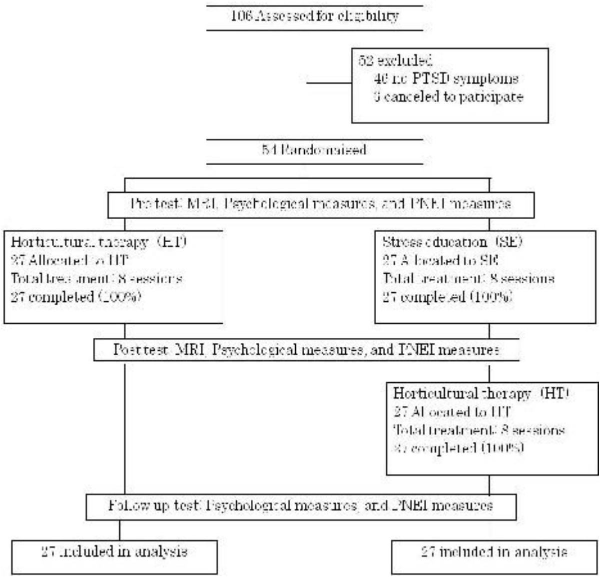


**Figure 1** Flowchart of the study

### Effects of HT intervention on gray matter structures

Compared with the SE group, the HT group showed a significant increase in the rGMV of the left subgenual ACC (sgACC; MNI coordinates: $x = –10$, $y = 22$, $z = –5$; $t = 3.81$; $p < 0.05$, corrected for multiple comparisons at the nonisotropic adjusted cluster level with an uncorrected cluster-determining threshold of $p < 0.0025$) and posterior and medial parts of the left superior frontal gyrus [SFG (BA8)]/MPFC ($x = –15$, $y = 16$, $z = 66$; $t = 3.90$; $p < 0.05$, corrected for multiple comparisons at the nonisotropic adjusted cluster level with an uncorrected cluster-determining threshold of $p < 0.0025$; Figure 3). The SPM contrast employed was SE group ($rGMV_{pre} – rGMV_{post}$) – HT group ($rGMV_{pre} – rGMV_{post}$). No other significant result was found in this analysis.

## DISCUSSION

Our objective was to reveal a reduction in PTSD symptoms and changes in brain morphology and stress hormones in disaster victims with earthquake stress by growing of plants The present study revealed the effect of the growing of plants on rGMV, psychological scale scores, and salivary cortisol markers in women with mild PTSD in the Great East Japan Earthquake disaster area. The results are consistent with our hypothesis that the growing of plants might reduce PTSD symptoms in disaster victims with earthquake stress and change the brain structure and stress marker levels, as discussed in detail below.

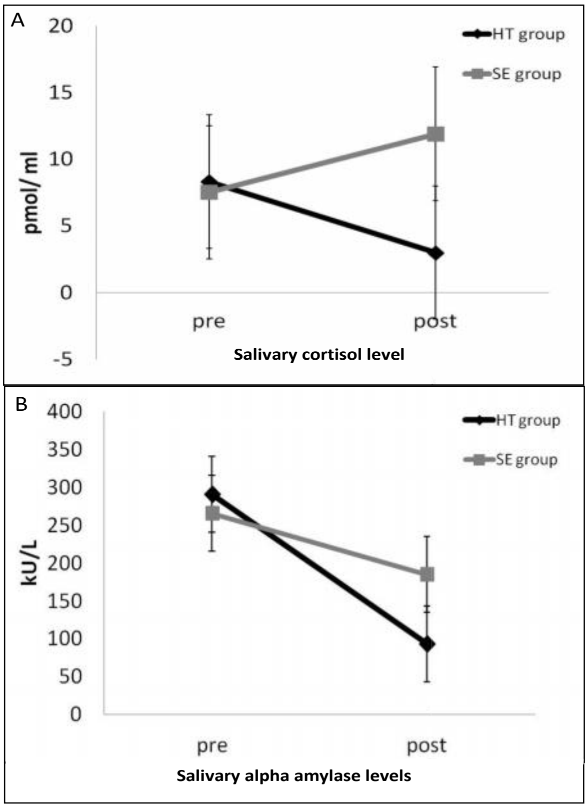


**Figure 2** Pre- and post-intervention salivary cortisol levels and salivary alpha amylase levels in the horticultural therapy (HT) and stress education (SE) groups. (A) Salivary cortisol levels decreased in the HT group and increased in the SE group, showing a significant interaction with group: (HT group, SE group) × salivary cortisol level ($p < 0.01$). (B) Salivary amylase levels were significantly lower in the HT group than in the SE group, showing a significant interaction with group: (HT group, SE group) × salivary alpha amylase level ($p < 0.05$).

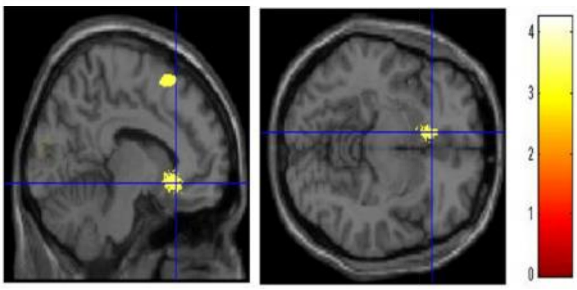

**Figure 3** Regional gray matter volume increased in the horticultural therapy (HT) group compared with the stress education (SE) group in the left subgenual anterior cingulate cortex and posterior and medial parts of the left superior frontal gyrus/medial prefrontal cortex. Results are shown at a significance level of $p < 0.05$, corrected for multiple comparisons at the cluster level with an underlying voxel level of $p < 0.0025$. The color density represents the T score.

t sgACC and the left SFG (BA8)/MPFC, which are considered to be the neural substrates of PTSD, as described below. VBM analysis revealed rGMV increases in the left sgACC and left SFG (BA8). Previous studies suggested that the ACC has important roles in responding to states of extreme stress, such as PTSD (7, 8). These studies have shown that stress affects brain structure, and function and VBM studies revealed structural changes in the ACC of people with PTSD (10, 49, 50). In particular, our findings show that the sgACC is involved in fundamental mental operations, such as affective processing and inhibitory control of negative affection (51). Structural studies suggested that sgACC volume is significantly reduced in people with symptoms such as anxiety, mood disorders, and PTSD (52, 53). This area is also involved in the modulation of sympathetic and neuroendocrine responses (54).

Our findings also suggest that the weak sgACC field may be enhanced initially in people who readily develop PTSD. The structure of the sgACC field was related to PTSD following the Great Earthquake in this study, as in the preceding study, and the growing of plants may have affected this structure because this area is associated with vulnerability to PTSD (10).

On the other hand, another study suggested that people with bipolar disorder have a smaller volume of this brain area compared with healthy people (56), and this may be associated with vulnerability to depression. The structure of the sgACC may be affected by acquired and vulnerability factors (10, 55). Previous studies of the connection between the posterior and medial part of the SFG (BA8)/MPFC and PTSD suggested that less activation of the SFG/MPFC is associated with downregulation of the fear response (5, 56). The PTSD subjects showed clusters of decreased SFG volumes compared with healthy subjects (57). Another study suggest that the MPFC plays an important role in modulating hypothalamo-pituitary-adrenal responses to emotional stress (58). For the aforementioned reasons, our findings reflect increases in the volumes of these PTSD-related brain areas after the growing of plants and show that structural changes involving reduction of the left sgACC volume and left SFG (BA8)/MPFC volume may be reversed with the growing of plants.

Based on the present intervention results, the growing of plants may have increased the volumes of the sgACC and SFG/MPFC, which play important roles in emotional control functions and are associated with PTSD. This effect may also have fortified relevant functions, such as suppression of cortisol secretion (59), which is the result of suppression of the stress reaction derived from sympathetic nerves (60, 61) as well as improvement in positive emotion (62).

These results are also consistent with our hypothesis that the growing of plants may recover the mental and physical functions of PTSD-afflicted women, which were probably weakened due to the traumatic experience; the HT group showed improved CAPS scores compared with the SE group, indicating that the growing of plants reduced PTSD symptoms. This finding extends the previous findings of the effect of the growing of plants on severe PTSD in men to that on mild PTSD in women. Furthermore, the HT group showed improved PTGI-J total scores and PANAS-PA scores after intervention compared with the SE group. Thus, HT may induce a positive psychological state. The HT group showed reduced salivary cortisol and SAA levels compared with the SE group, indicating that the growing of plants reduced the stress level. These salivary stress marker findings are similar to those of previous studies (23, 63).

Previous studies suggested that HT intervention for patients with depression improves mental health indices, including PANAS scores (64). Few studies have used CAPS scores to evaluate the effect of the growing of plants, however, we believe that the HT group showed decreased CAPS scores because their PTSD symptoms decreased, suggesting positive effects of the growing of plants such as mood improvement and stress reduction (16-18). Few previous studies have investigated the relationship between PTGI-J results and the growing of plants, however, a study of the PTG process reported that people suffer emotional pain due to trauma to their personal growth resulting from the traumatic experience. As described below, people struggle with or feel conflicted about prior trauma. However, they use PTG to react in diverse ways, such as remembering their status before the event, referring to their own personality characteristics, relying on the support of others, and self-disclosing their own experiences with the negative event (65, 66). Victims of the Great East Japan Earthquake had varying experiences, such as coping with the effects of the tsunami or living as refugees or evacuees in the days following the earthquake. Victims in coastal areas encountered especially serious situations. However, support groups from nearby and outside of the disaster areas began to offer various types of assistance shortly after the disaster. Through support activities, victims and those who provided support developed compassion, respect, and humanity toward others. After experiencing the earthquake as a very negative event, victims who participated in our study seemed able to attain peace of mind and compassion by remaining in their own homes for 2 months and by attending gardening sessions in a university laboratory once per week for 2 months. It can be considered that horticultural activity changed victims' confused recognition behaviors caused by the earthquake to controllable behaviors within themselves, changed the process of understanding the series of events related to the earthquake, and helped them to find possible meanings for the traumatic occurrence in association with PTG (67).

Salivary cortisol and SAA levels decreased after the growing of plants. Although the growing of plants is related more weakly to SAA levels than to salivary cortisol levels, SAA levels notably respond more rapidly to stress (68). Previous studies suggested that PTSD is associated with behavioral and physiological pathologies, including disruption of the hypothalamic–pituitary–adrenal axis (69), which is involved in the mediation of physiological responses to stress and secretion of the stress hormone cortisol (70). Cortisol is considered to be an indicator of psychological and physiological stress and can be used to examine the pathophysiology of PTSD (71). People with severe PTSD due to the Hanshin-Awaji earthquake had significantly higher cortisol levels (72). A previous study showed increased SAA levels in unpleasant conditions and decreased SAA levels in pleasant conditions (73). The sgACC is associated with the modulation of sympathetic and neuroendocrine responses, such as cortisol and amylase secretion (54). A previous study suggested that impaired sgACC function in mood disorders may contribute to cortisol hypersecretion in depression (74). In addition, depressive subtypes showing regional reductions in GMV (e.g., bipolar disorder, familial pure depressive disease) also show evidence of increased cortisol secretion during stress (75). Our findings suggest that salivary cortisol and SAA level changes might be influenced by sgACC function. In addition, a previous study suggested that salivary cortisol levels were significantly decreased and PANAS-PA scores were fully restored after horticultural activity (23). We consider that the change in psychological measures and cortisol levels could be influenced by the sgACC.

## CONCLUSION

The purpose of this study was to reveal the neural basis of the growing of plants for PTSD reactions. Our research has demonstrated that the growing of plants improves PTSD reactions and feelings, promotes PTG, and decreases physiological stress in women with mild PTSD. In terms of a neural basis, the growing of plants can also increase GMV in known brain areas. These results support the hypothesis that the growing of plants is effective for women with mild PTSD and can change the neural basis of PTSD. In the future, we would like to examine whether the same effect can be confirmed in other diseases and healthy groups. Although 4 year has passed since the Great East Japan Earthquake, we would like to continue examining time-dependent changes in the affected areas while simultaneously supporting disaster victims.

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