

博士論文(要約)

The effects of companion planting with Crassulacean Acid
Metabolism (CAM) plants on the growth of nectar-producing
plants for green roofs

屋上緑化における CAM 植物の混植が
蜜源植物の生育に及ぼす効果の解明

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Introduction

Green roofs in urban areas have attracted a great deal of attention in recent years, primarily due to its range of ecosystem services, including cooling and pollination. Moreover, green roofing became widely popular since it requires lesser cost and maintenance, and due to their shallower substrate depths, it has relatively low weight and reduced requirements for watering. However, the shallow substrates often make the vegetation prone to drought, reducing the number of suitable plant species which can survive under water-stress condition. Many green roofs, therefore, rely on succulent plants such as *Sedum* species due to their superior drought tolerance. It is suggested that companion planting with *Sedums* can substitute for frequent watering on green roofs and can improve the health condition of the associated plants. The research hypothesized that companion planting with *Sedums* induce suppression of evapotranspiration due to their CAM photosynthesis and a mulching effect, which may lead to higher substrate water content. Hence, companion planting with CAM plants had positive effects on the growth conditions of nectar-producing plants on green roofs.

Previous studies, however, indicated that not all species combinations showed positive interactions in green roof system, and plant traits are important in determining the effects of companion planting with CAM plants. Particularly, physiological traits of plants, including photosynthetic type, could affect evapotranspiration and thus, impact substrate water condition. Additionally, morphological traits such as leaf shapes and growth forms would also affect the degree of inter-specific interaction. Thus, the objectives of this study is to elucidate the relationship between effects of companion planting with CAM plants on health condition of nectar plants and their physiological and morphological traits.

Effects of leaf traits of *Sedum* on evapotranspiration

To elucidate the growth characteristics of *Sedums* species which has low evapotranspiration, I investigated evapotranspiration of three *Sedum* species (*S. album*, *S. kamtschaticum* and *S. reflexum*), focusing on their morphological and physiological traits. Companion planting with *Sedum* would positively affect neighboring plants by the increase of substrate water availability. CAM induction status in *Sedum* has a possibility to affect evapotranspiration, and it would be affected by its leaf trait. Hence, I measured chlorophyll fluorescence to evaluate CAM induction status non-destructively, which enables to measure evapotranspiration by weight changes of modules simultaneously.

CAM induction status differed by *Sedum* species, and suppression of evapotranspiration was accompanied by CAM induction. *S. kamtschaticum* and *S. album* showed gradual CAM induction, and might withstand drought stress without photoinhibition, presumably due to their leaf succulence. Particularly, *S. album* showed rapid CAM induction and suppressed evapotranspiration significantly, and thus it would have strong drought tolerance.

The results indicated that when CAM plants were used as companion plants on green roofs, *Sedums* with leaf succulence such as *S. kamtschaticum* and *S. album* would be suitable for drought resistance on green roofs. Additionally, *Sedums* with rapid CAM induction such as *S. album* would suppress evapotranspiration and contribute to increasing substrate moisture content, which could improve health condition of neighboring plants.

Effects of companion planting with *Sedums* on health condition of nectar-producing plants depending on physiological and morphological traits of the *Sedums*

To elucidate the effects of differences in *Sedum* species as companion plants on health condition of neighboring nectar-producing plants, I cultivated *Sedums* and nectar-producing plants together in a greenhouse, and determined the optimal species combination. Companion planting with *Sedums*, which show low evapotranspiration, would affect positively on the growth of neighboring plants by increasing substrate water content. Thus, I tested two *Sedum* species that differ morphologically and physiologically as companion plants for nectar-producing plants in a greenhouse. I used two CAM species (*S. album* and *S. kamtschaticum*) and two species of nectar-producing plants (*Fagopyrum esculentum*, *Trifolium repens*), and cultivated them by changing species combination and planting rate.

Effects of growth forms of nectar-producing plants on their health condition when they were planted

Plant traits are important in determining the degree of competition for reproducing and space. Particularly, growth form seems to be crucial factors to determine the effects of companion planting. Therefore, to test the effects of inter-specific interactions due to companion planting with CAM plants in different growth forms, I cultivated each nectar-producing species with and without CAM plants.

I evaluated eight species of nectar-producing plant classified into three growth forms: prostrate ascending (*Mimosa pudica*, *Rosmarinus officinalis* 'Prostratus'), prostrate carpet (*Phyla canescens*, *Trifolium repens*, *Thymus serpyllum*) and erect (*Calamintha nepeta*, *Lavandula officinalis*, *Rosmarinus officinalis* 'Erectus'). In terms of neighboring CAM plants, I used *S. album* as companion CAM plants which showed significant positive effects on

neighboring plants.

Synthesis and outlook

Companion planting with CAM plants has positive effects on health condition of neighboring nectar-producing plants for green roofs. However, these positive effects are dependent on plant species and substrate water content. This study is imperative to understand the appropriate species selection of combination based on their growth characteristic, and can support cultivating nectar-producing plants on green roof without frequent watering through the aid of companion planting with CAM plants.