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Grapevine Growth and Berry Development under the Agrivoltaic Solar Panels in the Vineyards

Comparison of changes in vine growth and fruit characteristics due to installation of farming-type photovoltaic facilities

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ABSTRACT

Farming-type photovoltaic power generation is a system that produces crops on agricultural land and at the same time produces electricity using light above the light saturation point required by plants. In order to develop a new source of income for farmers, solar panels were installed in vineyards and the growth and fruit development characteristics of water bodies were evaluated to explore the utilization of farming-type photovoltaics and to provide information necessary for developing future cultivation technologies. 152 × 68 × 3.5 cm in size were arranged with farming-type 150Wp (36cell) modules according to the row of vine replanting, and the environment and plant growth of the orchard were analyzed. In the untreated area, the winter wind speed reached 0.4-0.6 m·s-1, but in the facility installation zone, it remained at 0.01-0.02 m·$^{s-1}$. The carbohydrate content of the scoop bark was 183-184m·g-1 in the facility installation zone, which was not much different than that of the untreated gu (181-198mg·$^{g-1}$), and the germination rate of the scoop was not significantly different. The content of chlorophyll in the leaves was high in the treatment zone. As for the characteristics of the fruit after harvest, there was no difference in granules, fruit discharge, sugar content, and pericarp color. However, the dormitory was delayed by 5-7 days in the facility, and there was a slight difference in the coloring of the discoloring machine. In the orchard where farming-type solar panels were installed, the development of vines and fruits was not significantly different, and the coloring was delayed at the installation hole. These results can be used as information for the development of technologies to produce grapes by installing farming-type photovoltaic facilities in vineyards in the future.

keyword

> fruit development Fruit characteristics Farming-type photovoltaic viticulture

Agrivoltaic systems, also called solar sharing, stated from an idea that utilizes sunlight above the light saturation point of crops for power generation using solar panels. The agrivoltaic systems are expected to reduce the incident solar radiation, the consequent surface cooling effect, and evapotranspiration, and bring additional income to farms through solar power generation by combining crops with solar photovoltaics. In this study, to evaluate if agrivoltaic systems are suitable for viticulture, we investigated the microclimatic change, the growth of vines and the characteristics of grape grown under solar panels set by planting lines compared with ones in open vineyards. There was high reduction of wind speed during over-wintering season, and low soil temperature under solar panel compared to those in the open field. There was not significant difference in total carbohydrates and bud burst in bearing mother branches between plots. Despite high content of chlorophyll in vines grown under panels, there is no significant difference in shoot growth of vines, berry weight, cluster weight, total soluble solid content and acidity of berries, and anthocyanin content of berry skins in harvested grapes in vineyards under panels and open vineyards. It was observed that harvesting season was delayed by 7 - 10 days due to late skin coloration in grapes grown in vineyards under panels compared to ones grown in open vineyards. The results from this study would be used as data required in development of viticulture system under panel in the future

and further study for evaluating the influence of agrivoltaic system on production of crops including grapes.

Keywords

agrivoltaic system   berry characteristics   grape development   viticulture

MAIN

Preface

Farming-type photovoltaic power generation is a system that can simultaneously carry out farming and power generation, and was first introduced as a solar sharing concept in Japan and is used around the world (Jung et al., 2020; Parkinson and Hunt, 2020; Sohn et al., 2019). Farming-type photovoltaic installations are currently increasing in many countries around the world, and governments are supporting them in Japan, China, France, the United States, and South Korea (Schindele et al., 2020; Trommsdorff et al., 2021; Vitisphere, 2020; Vollprecht et al., 2021). In the West, crops that can be grown in farming-type photovoltaic facilities are selected through shading experiments and evaluated on various criteria (Abdel-Mawgoud et al., 1996; Hernández et al., 2015; Israeli et al., 1995; Marrou et al., 2013a; Ghosh et al., 2018; Zanon et al., 2016).

The domestic grape industry is worth 693 billion, and grapes have a large content of functional ingredients such as resveratrol and stilbene compounds, which is increasing consumer demand compared to other fruits (MAFRA, 2021). In addition, with the improvement of the economic level of the people, the demand for various grape varieties is increasing, increasing the consumption of 'Shine Musket' varieties from 'Campbell Early' or 'Giant Bong' varieties (KREI, 2021).

In foreign countries such as Europe and Japan, research on the development of production technology using farming-type photovoltaic facilities is actively carried out (Feistel et al., 2018; Jahanfara et al., 2018; Jones et al., 2022), and in Korea, research is being conducted to evaluate the impact on agricultural production by installing photovoltaic facilities in the production of rice, field crops, fruit trees, etc., and to improve productivity (An et al., 2021; Cho et al., 2021; Jung, 2019; Kang et al., 2021; Kim et al. 2019; Kim et al., 2020; Kim, 2020; Kim et al., 2021; Ko et al., 2021; Shin et al., 2021; Yoon et al., 2019).

Compared with other fruit varieties, grapes have a lower light saturation point required for fruit development and maturation, and certain varieties require scattered light, so it is believed that it will be advantageous for installing farming-type solar panels and producing fruits. Therefore, in this study, the growth characteristics of the vine tree body and the development characteristics of the fruit were evaluated in the grape orchard where the farming-type solar panels were installed and compared with the characteristics in the open field.

Materials and methods

1. Vine and vineyard

The vine variety used in this test is Campbell Early (*Vitis labruscana*L.) Solar panels have been installed in a grape orchard (planting distance 2.6 × 3 m, 4,000 m^2), where 6-7 year old trees are grown in a wakeman-style tree type, and the vineyards are located in Yeungnam University Affiliated Farm in Gyeongsan-si, Gyeongsangbuk-do, and Yeongheung-myeon, Ongjin County, Incheon, South Korea. The trials were conducted over 2021 and 2022.

2. Solar panel installation

The farming-type photovoltaic power generation system for vine fruit trees was installed in the same direction as the replanting direction of the vine in consideration of the replanting heat of the vine, and the farming-type solar panels (150Wp, 48 sheets of 36cell modules) were placed in the structure with a shading rate of less than 30% (Fig. 1).

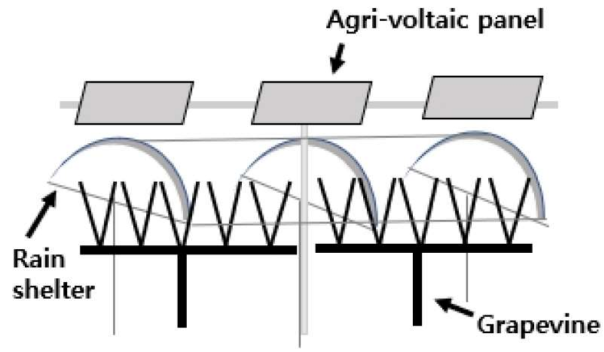

Fig. 1. Installation diagram of agri-voltaic panels in vineyard.

3. Vine water body growth survey

The vine water body growth survey examined the blind age, the leaf area, the leaf middle, the new grass field, the internode field, and the internode scope. The growth characteristics of new herbs were investigated from 3 weeks to 10 new plants per treatment, and the leaf area measurement was measured using a leaf area meter (LI-3000, LI-COR, Inc, Lincoln, NE, USA) from 3 new plants on the fruit harvest day for each treatment.

4. Investigation of microenvironment changes in the lower part of the facility

Changes in light intensity, temperature, and wind speed in the lower part of the facility were investigated. The data was used by connecting an environmental observation sensor to a data collection device (STL-T/RH/A4/D2, STA, Anyang, Korea). The temperature sensor (STL-T/ RH, STA, ANYANG, Korea) is placed in a white solar shading container to protect it from direct sunlight or rainwater, the temperature measurement range is –40°C to +120°C, the measurement error is +/\u20120.3°C, the measurement range of wind direction in the wind direction/wind speed sensor (Davis, USA) is 0-360 degrees, the measurement error is within 5 degrees, the measurement range of wind speed is 0-50m/s, and the measurement error is +/\u20121m/s or less. The light intensity (PPFD) of the light source was measured at the height of the water pipe (average height of 75 cm from the ground) using a spectroradiometer (PAR-200, J&C Tech Co., Ltd., Hwaseong, Korea).

5. Vine cold resistance test

In order to compare the cold resistance of the vines, the blindness rate of snow in the greenhouse was examined the following year, and 5-8 branches were collected from the base of the dormant result moji on December 21 and January 24 of the following year to measure the carbohydrate content of the bark. The carbohydrate content of the collected eggplant was crushed by drying the bark at 60 ° C. for 48 hours, then 0.5 g of the sample was added to 20 mL of 0.7N HCl solution, decomposed in a constant temperature bath maintained at 99.9 ° C. for 2 hours and 30 minutes, 5 mL of dinitrosalicylic (DNS) acid was added to 3 mL of the decomposition solution, boiled again for 5 minutes, and the absorbance ($A_{550\ nm}$) was measured using a colorimeter (Model S-3130, Scinco Co., Ltd, Seoul, Korea) (Winkler and Howel, 1986).

6. Analysis of chlorophyll content

After extracting chlorophyll by immersing the vine leaves in 80% acetone solution, the spectrum was measured at wavelengths 663 nm and 645 nm using a spectrophotometer (UV/Visible Diode Array, Walden Precision Apparatus Ltd., UK) and converted to the following equation (Arnon, 1949).

Chlorophyll a = $12.7\ A_{663} - 2.69\ A_{645}$

Chlorophyll b = $22.9\ A_{645} - 4.68\ A_{663}$

Total Chlorophyll (a + b) = $20.29\ A_{645} + 8.02\ A_{663}$

7. Investigation of the nature of the error

Five randomly selected fruit chambers per test treatment ball were analyzed according to the Agricultural Test Research Standard (RDA, 1995), over-discharge, granule weight, anthocyanin content, sugar content, and titration acidity. The soluble solids content was measured with a digital refractometer PAL-1, Atago, Japan, and the acidity was measured using a fruit acidity meter (GMK-835N, G-WON HITECH, Korea), and 10 granules were randomly selected and performed in 3 repetitions. Anthocyanin content was measured using a multimode microplate reader (PARK, TECAN) (Kwon et al., 2019).

8. Soil analysis and investigation of toxic components

The soil sample was dried and crushed, and then passed through a standard (10mesh) to be used for general analysis, and the soil was ground again and a sieve (100mesh) was used for heavy metal analysis. The physical and chemical analysis of soil was carried out according to the Soil Chemical Analysis Method (NIAST, 1988) of the Academy of Agricultural Sciences of the Ministry of Agriculture and Rural Development, and the pH meter for soil acidity, the EC meter for electrical conductivity, the Tyurin method for organic matter, the Lancaster method for effective phosphate, and the hydrometer for Saturn analysis. Analysis of soluble heavy metals in soil measured elements according to the Ministry of Environment Soil Pollution Process Test Method (KSTM ES 07552) (Kim et al., 2021).

9. Statistical analysis

Statistical processing was performed by performing a T-test using SPSS statistic 18 (IBM, US) to analyze significance.

Results

1. Growth characteristics of new plants and leaves of the vine

In order to analyze whether the installed solar panels affect the growth of the vine water body, the growth of vine new plants was investigated in the treatment zone where the solar panel was installed and the untreated hole where the solar panel was installed in two packages. The number of new seconds per week in the photovoltaic treatment zone was 17-18 or 23-29, which was no different from the number of new seconds per week (25-26) in the untreated zone (Table 1). The ultra-long length of the treatment ball was 154 cm, which was no different from the untreated bulb (146 cm), and the number of leaves per new second in the treatment ball was 13-14 sheets, which was no different from the untreated bulb (13 sheets). The average internode of the treated plant new herb was 12 cm, the average internode of the untreated plant was 11.0 cm, and the internode diameter of the new herb was 8 mm, similar to the internode diameter of the untreated bulb of 8.3 mm.

Table 1. The growth of shoots in vines under agrivoltaic panels in the vineyards.

Treatment		Budding date	No. of shoots per vine	Shoot length (cm)	No. of leaves per shoot	Internode diameter (mm)	Internode length (mm)
Gyeongsan	Control	4.17	18.1	91	11	5.1	8.0
	Agrivoltaic	4.19	16.9	99	12	5.3	9.0
Significance		NS[z]	NS	NS	NS	NS	NS
Incheon	Control	4.17	26.7	146	13	8.3	11.0
	Agrivoltaic	4.19	25.3	154	13	8.0	12.0

Significance		NS	NS	NS	NS	NS	NS

^{Z}NS: Nonsignificant, *significant at 5% level by t-test.

포도나무 신초당 3개의 잎(기부로부터 7, 8, 9번째)을 채취하여 엽중과 엽면적, 갈색무늬병의 발생을 조사하였다(Table 2). 두 개 포장에서 태양광 처리구에서 신초 잎의 엽중은 5.2 - 7.0g으로서 무처리구의 엽중(5.6 - 8.7g)과 유의차가 없었으며 태양광 처리구의 신초 잎의 엽면적이 226 - 265mm^2로서 무처리구의 엽면적(222 - 273mm^2)에 비해 유의차가 없었다. 태양광 패널 설치에 따른 병해 발생을 비교하고자 갈색무늬병 병반면적률을 조사하였다. 태양광 설치 처리구의 포도나무의 잎에 발생하는 갈색무늬병 발병면적률은 0.2 - 1.1%로서 무처리구의 잎에 발생한 병반면적률(0.1 - 4.8%)보다 현저히 낮아 태양광 처리구에서 발생이 적은 경향이었다.

Table 2. The growth and leaf spot development of vine leaves grown under agrivoltaic panels in the vineyards.

Region	Treatment	Leaf weight (g)	Leaf area (mm^2)	Lesion area of leaf spot in leaves (%)
Gyeongsan	Control	5.6	222.0	0.1
	Agrivoltaic	5.2	226.9	0.2
	Significance	NS^{Z}	NS	NS
Incheon	Control	8.7	273.5	4.8
	Agrivoltaic	7.0	265.6	1.1
	Significance	NS	NS	*

^{Z}NS: Nonsignificant, *significant at 5% level by t-test.

2. 포도나무 잎의 엽록소 함량 및 색택 특성 비교

포도나무 잎의 엽록소 함량은 처리구와 무처리구 간에 유의차가 없었지만 태양광 설치 처리구에서 23 - 50μg·g로서 무처리구의 19 - 41μg·g보다 높게 나타났다(Table 3). 이는 태양광 패널 설치로 인해 수체의 생육이 늦게까지 유지되었기 때문일 것으로 여겨진다(Table 3). 태양광 설치구에서 신초 잎의 색택을 비교한 결과, 처리구에서는 색도(Hunter value)는 각각 L = 37 - 41, b^* = 11.65 - 17.59이었으며, 무처리구의 포도나무 잎의 색도는 L = 38 - 40, b = 14 - 15로서 처리 간의 유의차가 인정되지 않았다.

Table 3. Contents of chlorophyll in the leaves of vines under agrivoltaic panels in the vineyards.

Region	Treatment	Content of chlorophyll (μg/g)				Hunter's value		
		chl a	chl b	a/b ratio	total	L	a	b
Gyeongsan	Control	14.06	4.97	2.83	19.02	40.27	–8.55	15.79
	Agrivoltaic	17.47	5.89	2.96	23.36	41.89	–7.54	17.59
	Significance	NS^{Z}	NS	-	NS	NS	NS	NS
Incheon	Control	27.52	13.71	2.01	41.21	38.07	\u2.51	14.08

	Agrivoltaic	31.41	18.99	1.65	50.39	37.18	\u0.94	11.65
	Significance	NS	NS	-	NS	NS	NS	NS

[Z] NS: Nonsignificant, *significant at 5% level by t-test.

3. Vine cold resistance test

In order to compare the difference in cold resistance of vine water bodies, branches were collected before and after wintering, and the carbohydrate content of the bark was analyzed, and the germination rate of wintering scoops was investigated. The carbohydrate content of the treated eggplant was 183-184 mg·g-1, similar to 181-198 mg·$^{g-1}$ of the untreated plant, but the germination rate of the collected scoop was high in the treatment zone (Table 4). In addition, the wind speed of the orchard due to the installation of photovoltaics has decreased in the treatment zone (Fig. 2), but when the winter cryogenic temperature due to the abnormal climate arrives, it is believed that the occurrence of East Sea and damage caused by drying of the overwintering vine will decrease as the wind speed decreases in the treatment zone.

Table 4. Carbohydrate content of stem bark from grapevines over-wintered under an agrivoltaics and open field of vineyards located in Incheon.

Cutting harvesting date	Treatment	Carbohydrate content (mg·g^{-1})	Bud burst (%)
Dec. 21, 2021	Control	181.3	54.2
	Agrivoltaic	184.3	50.0
	Significance	NS[z]	NS
Jan. 24, 2022	Control	198.9	66.5
	Agrivoltaic	183.4	75.0
	Significance	NS	*

[Z] NS: Nonsignificant, *significant at 5% level by t-test.

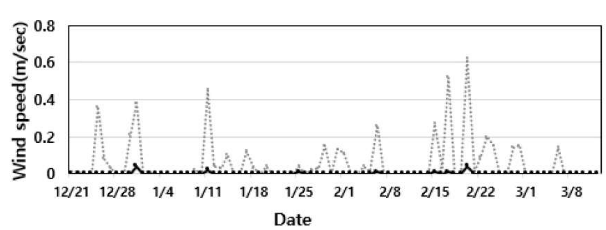

Fig. 2. Change of wind speed by agrivoltaic panels in the vineyards during winter season. —, agrivoltaics; ---, open field.

4. Comparison of vineyard grape fruit growth and characteristics

Changes in the growth characteristics and quality of grape fruits in the solar panel treatment pit were compared, and all surveys were performed in three repetitions. The over-discharge weight of grape fruit in the treatment zone was 253-327 g, and the over-discharge weight of the untreated bulb was 257-340 g (Table 5). The over-shielding and over-shielding diameters were 162-165.6 mm and 80.5-94.4 mm, which were no different from the over-shielding (144.2-183.2 mm) and over-shielding (76.7-93.4 mm) of the untreated sphere. The granule weight was 5.6-5.7 g, and there was no significant difference from the untreated granule weight (5.9-6.1 g) (Table 5).

Table 5. Growth of grapes harvested from vines under an agrivoltaics and in open field of vineyards.

Region	Treatment	Cluster weight (g)	Length of cluster (mm)	Cluster diameter (mm)	Berry weight (g)
Gyeongsan	Control	257.2	160.0	86	6.1
	Agrivoltaic	253.2	163.3	89	5.6
	Significance	NS[z]	NS	NS	NS
Incheon	Control	340.1	163.4	88	5.9
	Agrivoltaic	327.9	164.4	95	5.7
	Significance	NS	NS	NS	NS

[z] NS: Nonsignificant, *significant at 5% level by t-test.

The sugar content of grape fruits harvested after maturation in the treatment pit where the solar panel was installed was 14.0-15.5%, and the sugar content of the untreated bulb was 14.9-15.2% and there was no significant difference (Table 6). The titration of fruit was also not significantly different between treatment zones, but it remained high compared to the untreated acid content (0.51-0.63%) of grape fruit in the treatment pit (Table 6). It is believed that this is due to the decrease in the amount of light in the treatment zone by the photovoltaic facility (Fig. 3), which delays the maturation of the fruit.

Table 6. Characteristics of grapes harvested from vines under an agrivoltaics and in open field of vineyards.

Region	Treatment	Hunter value			Total soluble solid (°Bx)	Titrable acidity (%)	Harveting date
		L	a	b			
Gyeongsan	Control	25.1	\u20123.0	\u20120.1	14.9	0.55	8.7
	Agrivoltaic	26.6	\u20122.0	0.0	15.5	0.54	8.12
	Significance	NS[z]	NS	NS	NS	NS	*
Incheon	Control			0.2	15.2	0.60	8.31

		28.2	\u20123.7				
	Agrivoltaic	28.0	\u20123.1	\u20120.3	14.6	0.56	9.10
	Significance	NS	NS	NS	NS	NS	*

Z NS: Nonsignificant, *significant at 5% level by t-test.

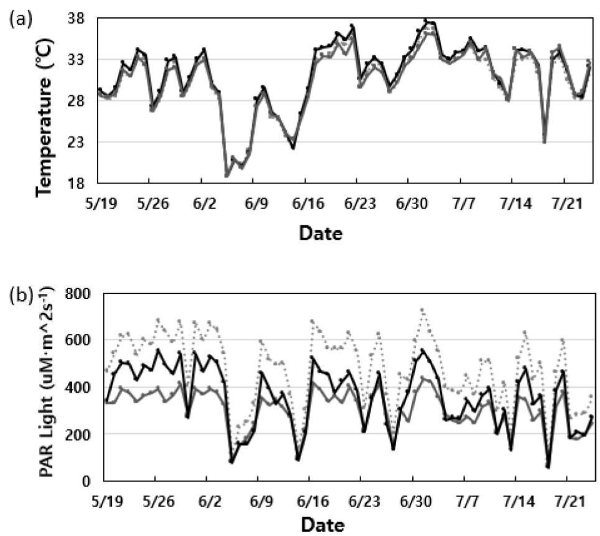

Fig. 3. Change of air temperature and soil temperature by agrivoltaic panels in the vineyards during grapevine growing season. (a) Air temperature and (b) PAR light under agrovoltaics (— and —) and in open vineyards.

The anthocyanin content of the pericarp of harvested grape fruits was 0.7-0.9% in both treated and untreated bulbs (Fig. 4). The appropriate harvest season in the treatment zone was around August 12 in the Gyeongsan area and September 4-10 in the Incheon area, which was delayed by 7-10 days compared to August 12 and August 26-31 in the untreated area (Table 6).

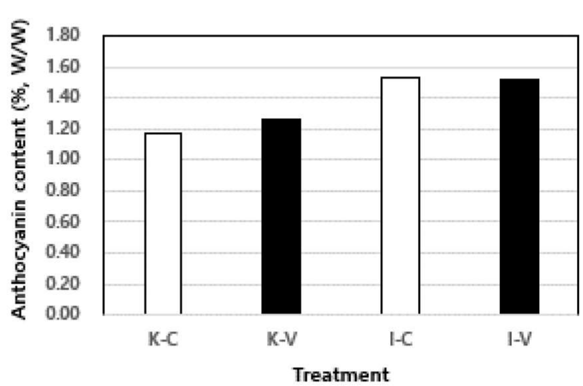

Fig. 4. Content of anthocyanin in grape skins harvested from vines under an agrovotaics and in open field of vineyards. K, Kyeongsan; I, Incheon; C, control; V, agrovoltaics.

5. Investigation of vineyard soil properties and toxicity

In order to investigate the change in the physical and chemical properties of the soil due to the installation of solar panels and the occurrence of toxic substances due to the installation of the structure, a total of 8 soil samples were collected by randomly separating the upper and lower soils by dividing them into treatment and untreated holes. Soil composition related to plant growth showed no significant correlation between acidity, organic matter content, effective phosphate, calcium content, magnesium content, and electrical conductivity between facility and no treatment (Table 7). The potassium content varies between treatment and facility, but analysis of more samples is required in the future. In addition, heavy metals such as mercury, lead, arsenic, and cadmium were detected at levels lower than the soil contamination concern standards, and there was no difference between the facility and no treatment (Table 8).

Table 7. Chemical properties of soil in vineyards in Incheon.

Soil depth		Soil pH	Organic matters ($g \cdot kg^{-1}$)	Phosphate ($mg \cdot kg^{-1}$)	Potassium ($cmol \cdot kg^{-1}$)	Calcium ($cmol \cdot kg^{-1}$)	Magnecium ($cmol \cdot kg^{-1}$)	Cation exchange capacity ($dS \cdot m^{-1}$)
Top soil	C	5.2 - 5.7	31 - 43	404 - 648	0.47 - 0.69	4.7 - 8.2	2.0 - 3.4	0.5 - 5.2
	V	5.5 - 5.7	32 - 37	458 - 693	0.69 - 1.33	6.5 - 8.8	2.6 - 2.9	1.0 - 2.5
Deep soil	C	5.8 - 5.8	31 - 33	521 - 732	0.65 - 1.07	6.6 - 8.9	2.2 - 4.1	0.5 - 5.4
	V	5.1 - 5.5	33 - 38	375 - 784	0.54 - 0.63	5.2 - 6.1	1.7 - 2.5	0.5 - 1.2
Optimal range		6.0 - 6.5	25 - 35	350 - 450	0.65 - 0.8	5.0 - 6.0	1.5 - 2.0	≤ 2.0

[z]C, control; V, agrivoltaics

Table 8. Content of toxic chemicals in the soil of vineyards.

Treatment		Hg ($mg \cdot kg^{-1}$)	Pb ($mg \cdot kg^{-1}$)	As ($mg \cdot kg^{-1}$)	Cd ($mg \cdot kg^{-1}$)
Top soil	C[z]	0.032 - 0.0041	14.37 - 15.84	1.62 - 1.85	ND[y]
	V	0.028 - 0.038	12.49 - 16.76	1.25 - 3.09	ND
Deep soil	C	0.034 - 0.044	14.79 - 15.94	1.69 - 2.20	ND
	V	0.037 - 0.039	13.30 - 14.79	2.03 - 2.60	ND
Risk level in Soil Quality Standard		4	200	25	4

[z] C, control; V, agrovoltaics.

[y] ND: Not detected.

Discussion

Farming-type photovoltaics are systems that can simultaneously produce plants and energy on the land (Parkinson and Hunt, 2020), and farming-type photovoltaics produce electricity using light above the light saturation point available to plants. However, since the amount of light is reduced by shading under farming-type photovoltaic facilities (Cossu et al., 2020), a decrease in the amount of light essential for plant growth can lead to a decrease in crop yield and a decrease in quality (Cossu et al., 2020; Loik et al., 2017). Therefore, since the response to light varies greatly depending on the crop, research is being conducted on the selection of appropriate crops that can be grown under farming-type photovoltaic facilities and the development of cultivation techniques (Aroca-Delgado et al., 2018; Cossu et al., 2017; Gonocruz et al., 2021; Marrou et al., 2013b; Murchie, 2002; Touil et al., 2021).

In the production of grape fruits, the photosaturation point and the photosaturation point are very important, and the photosaturation point shows different characteristics depending on the type of crop, and the light saturation point of the vine is 40-6klux, which requires light for the growth and maturation of the fruit (Lim, 2015). Because insufficient light hinders the growth and fruit development of the vine (Keller et al., 1998; Koyama et al., 2012) It is important to improve light transmittance by improving the tree shape of the vine (Reynold and Vanden Heuvel, 2009). However, when subjected to light above the light saturation point, a photoinhibitory phenomenon appears that inhibits its own growth in the plant body, resulting in a decrease in plant growth and productivity (Cheng et al., 2016; Takahashi and Badger, 2011).

Shading delayed fruit development of grapes but did not affect sugar content, and it was reported that granule hypertrophy increased (Abeysinghe et al., 2019; Caravia et al., 2016; Greer and Weedon 2012). However, high photon flux densities (PFDs) and the resulting high temperatures during the summer grape growing season hinder the normal growth of grapes (Webb et al., 2009). In France, photovoltaic installations have been installed in wine-producing viticulture, which has recently minimized the stress on grape fruit trees caused by record high temperatures and high solar radiation, promoting granule hypertrophy, improving sugar levels, and increasing anthocyanin and acid content (Reasoners and Ghosh, 2022; Vitisphere, 2020), and their effects on vine water growth, photosynthetic efficiency, and phenolic compound accumulation should also be examined in the future (Abeysinghe et al., 2019; Iland et al., 2011). In India, it is reported that installing solar power in grape orchards has an economic effect of more than 15 times that of the profits from grape production (Malu et al., 2017).

Less incidence of vine galvanosis was observed in photovoltaic treatment plants. It has been reported that under farming-type photovoltaic facilities, it promotes the growth of water bodies by helping to reduce the temperature of the above-ground part, inhibit the temperature rise of the soil, and retain moisture during the growing season (Adeh et al., 2018; Marrou et al., 2013a). Therefore, it is believed that the installation of the facility provided weather conditions suitable for the growth of the plant body, and the growth of the plant body was maintained vigorously, and it is believed that the occurrence of diseases has also decreased due to this. In addition, in terms of agricultural environment, soil characteristics may change depending on the type of farming, or heavy metal contamination of agricultural land may occur due to agricultural materials (Jung et al., 2004), and heavy metal contamination is affected by soil chemistry such as soil acidity and cation substitution capacity compared to non-polluted sites (McGrath, 1996). However, in this study, no change in the physical and chemical properties was seen in the soil of the treatment zone, and no toxic components or toxic components of the soil that may occur due to the installation of the structure did not occur, so it is believed that it does not affect the soil environment of the photovoltaic facility.

본 실험에서는 태양광 패널을 설치한 처리구에서 포도나무 수체의 생육과 발육은 무처리구에 비해 큰 차이가 나타나지 않았으나 숙기가 7일 정도 지연되었다. 이는 영농형 태양광을 도입하려면 성숙을 지연하는 질소질 비료의 시비를 줄이고 칼륨, 인산 등의 시비량을 늘리는 재배법의 개발이 필요하다는 것을 의미한다. 그러나 완숙이 된 포도 과실의 특성과 발육은 무처리구에 비해 큰 차이가 없었으며, 잎의 생육이 약간 촉진되고 병해 발생이 억제되었는데 이는 태양광 패널 시설의 설치에 따라 광과 복사열로 인한 식물체의 스트레스가 감소하였기 때문으로 여겨진다. 태양광 패널을 설치함에 따라 햇빛의 복사열로 인한 여름철 기온 및 지온 상승의 방지와 토양의 수분 증발 억제를 통해 열과 방지 등의 포도 생육에 유리한 효과를 기대할 수 있다. 영농형 태양광은 지속적인 수요 증가와 농가의 새로운 소득사업으로 중요한 의미를 지닌다. 따라서 향후 태양광 패널 시설 하부 경지에서 농작물 수량 및 품질 감소를 최소화하면서 포도를 비롯한 농작물을 안정적으로 생산할 수 있는 재배기술의 개발이 요구된다.

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