SINCE
1998

UCD Lamp for Plant Cultivation

Kaixen Co., Ltd.

V1410

KAIXEN
UCD Light System

V1505-K

1. Background of Study and Experiment

- **Request from well reputed Bio company**
  * To check UCD Lamp application for overseas vegetable factory project
    → Vinyl house operation for vegetable cultivation
    → To provide extra lighting after sunset during winter
    → To provide extra lighting during continuous cloudy days
  * Looking for a lamp having suitable spectrum and energy-saving feature

- **To check the possibility of contribution to vegetable cultivation industry**
  * Near sunlight feature of UCD Lamp
  * Economical merit of energy-saving with UCD Lamp

- **To prove an opinion in the industry by short-term experiment**
  (Opinion; Near sunlight, white colored lighting is the best for plant cultivation.)
  * Start experiment by transplanting lettuce seedlings on nutrient culture beds
  * Provide 100% artificial lightings in dark space
  * Compare UCD Lamp and Hi-pressure Sodium Lamp (HPS)
  (HPS has been the most popular for greenhouse lighting in the world.)

2. Lighting Requirement for Vegetable Factory

- **Technical Viewpoint;**

  * Suitable light spectrum for Photosynthesis and Growth Stages

  * Optimized light intensity (Lux, **μ**Mol/m²/sec)

- **Economical Viewpoint;**

  * Minimize initial investment for depreciation cost

  * Minimize running energy cost

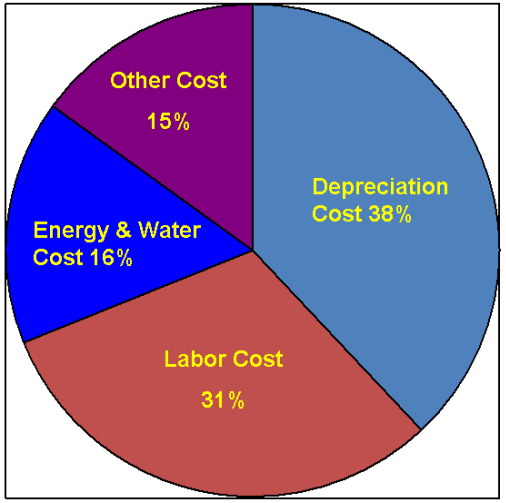
- **Operational Viewpoint;**

  * 100% Artificial lighting (Urban Vegetable Factory)

  * Sunlight & Artificial light for extra lighting

    (Greenhouse Vegetable Production)

- **Cost Factors for Vegetable Factory →**



3. Lighting Methods for Plant Cultivation

Urban Vegetable Factory with mixed Discharge Lamps

Greenhouse with Discharge Lamp

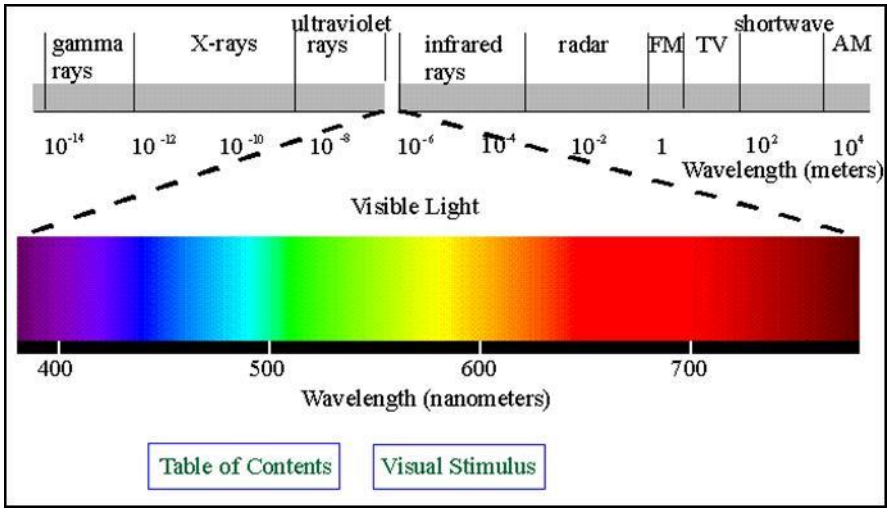
Urban Vegetable Factory with HEFL

Urban Vegetable Factory with LED Lamps

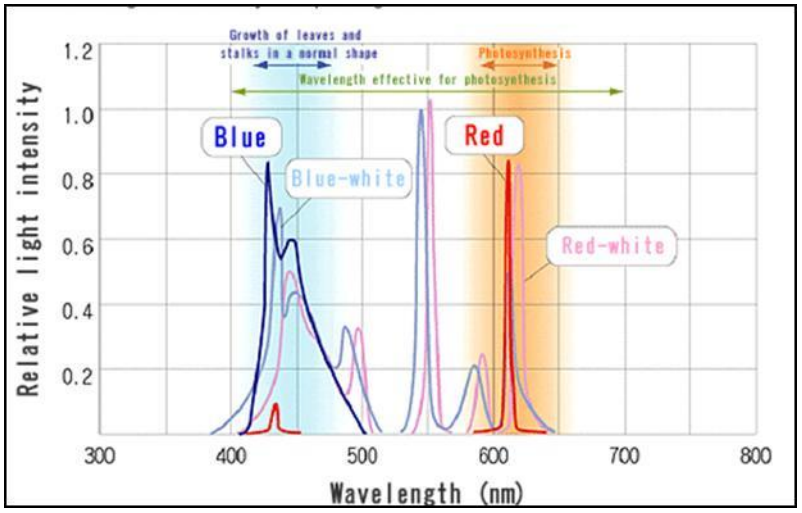
4. Lighting Principles for Plant Cultivation

- Basically plants require whole visible light spectrum.
- Depending on the color of light, the effect of plant growth differs.
- Photosynthesis requires mainly Orange-red ray, 640~690 nm.
- Proper growth and formation of leaves require Indigo-blue ray, 420~470 nm.
- In case of 100% artificial light application, in order to save energy cost, Red and Blue parts of light spectrum are used by mixing with specific ration.

*** Light Spectrum Overview**



*** Major Spectrum for Plant Growth**



5. Lamp selection Guide-line for Vegetable Cultivation

For both vegetable factory (100% artificial lighting) and greenhouse (extra lighting), it is necessary to check characteristics and performances of lamp to be installed. Basic points to be checked are as follows.

- Spectrum Characteristic of Lamp

No plant grows properly only with one type of wave-length. For example, if you cultivate vegetable only with red light, the vegetable still grows but it never grows properly as a commercially acceptable vegetable. It is same with blue light only.

Even though it looks growing well but it is a succulent growth resulting in straggly, weak and thin-stemmed status.

As a result of various experiments, it becomes obvious that the light spectrum for plant cultivation must be wide enough having all the visible light wavelengths.

The most suitable light for plant cultivation must be sunlight-like white ray which contains all visible colors evenly.

- Light Intensity

In case of 100% artificial light for plant cultivation, the light intensity must be 30~150 μmol/m²/sec.

In case of extra lighting after sun-set, the light intensity should be 2~15μmol/m²/sec. But for the purpose of growing leaves only by delaying flower stalk, lower intensity of light can be effective.

6.Required Illuminance for Photosynthesis

*** Reference; Sunlight on sunny day is 20,000 ~ 100,000 Lux, Sunlight on cloudy day is 10,000 Lux**

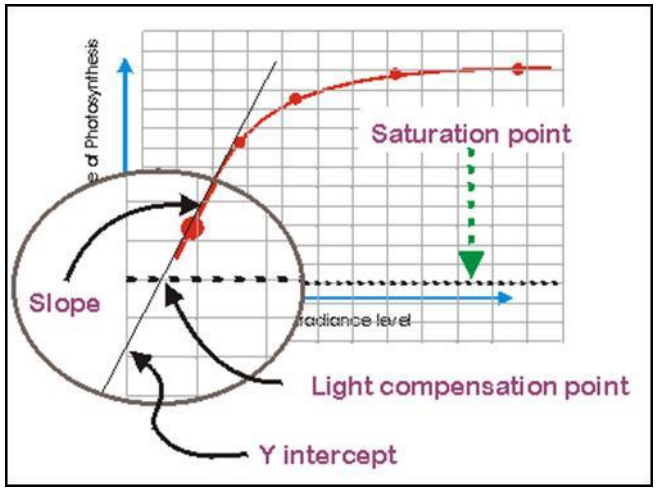
Plant	Light Saturation Point	Light Compensation Point
Tomato, Water melon	70,000 Lux (847 μmol/m²/sec)	3,000 Lux (36 μmol/m²/sec)
Cucumber	55,000 Lux (665 μmol/m²/sec)	2,000 Lux (24 μmol/m²/sec)
Lettuce, Paprika	25,000 Lux (302 μmol/m²/sec)	1,500 Lux (18 μmol/m²/sec)
Ginseng	12,000 Lux (145 μmol/m²/sec)	500 Lux (6 μmol/m²/sec)

*** Light Saturation Point;**

As light intensity continues to rise, the rate of photosynthesis rises until a plateau is reached. Any further increase in light intensity has no effect on the rate of photosynthesis. The light intensity at which the plateau is reached is called the light saturation point.

*** Light compensation point;**

The point is the amount of light intensity on the light curve where the rate of photosynthesis exactly matches the rate of respiration of the plant. At this point, we can say that the plant can not grow further by photosynthesis.



재배작물	광포화점lx(PPFD)	광보상점lx(PPFD)
토마토, 수박	70,000 lx (847)	3,000 lx (36)
오이	55,000 lx (665)	2,000 lx (24)
완두콩	40,000 lx (484)	2,000 lx (24)
양상추, 피망	25,000 lx (302)	1,500 lx (18)
포도	40,000 lx (484)	400 lx (5)
귤	40,000 lx (484)	200 lx (2.5)
배	40,000 lx (484)	300 lx (3.6)
복숭아	40,000 lx (484)	400 lx (5)
무화과	40,000 lx (484)	1,000 lx (12)
세인트폴리어	5,000 lx(60)	500 lx (6)
난종류	10,000 lx (121)	300 lx (3.6)
시클라멘	15,000 lx (181)	300 lx (3.6)
인삼	12,000lx (145)	500 lx (6)

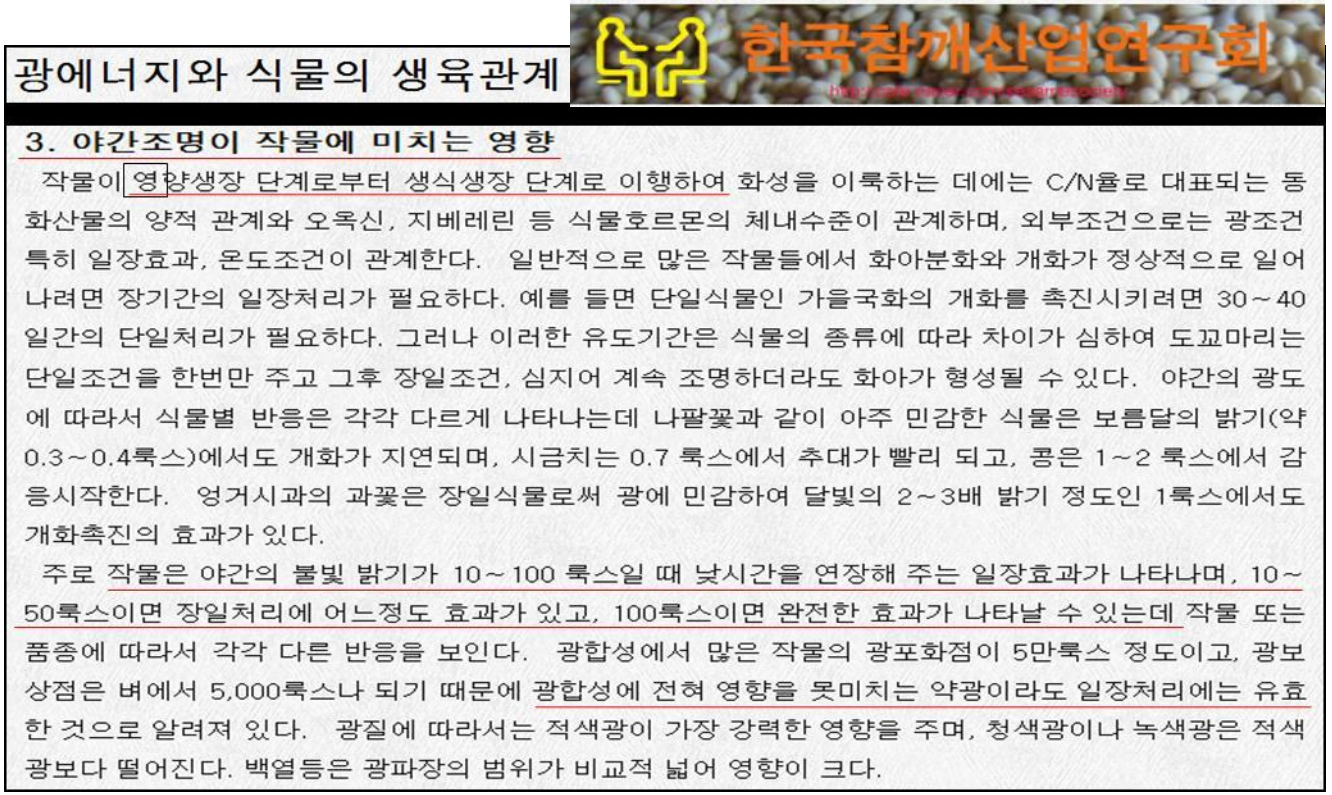
7. Required Illuminance for Extra Lighting after Sunset

- Reference from Sesame Industry Association
- Required illuminance to extend daylight;

  * 10 ~ 100 Lux; Effective range

  * 10 ~ 50 Lux; Starting range

  * Higher than 100 Lux; Completely effective



광에너지와 식물의 생육관계

한국참깨산업연구회

3. 야간조명이 작물에 미치는 영향

작물이 영양생장 단계로부터 생식생장 단계로 이행하여 화성을 이룩하는 데에는 C/N율로 대표되는 동화산물의 양적 관계와 오옥신, 지베레린 등 식물호르몬의 체내수준이 관계하며, 외부조건으로는 광조건 특히 일장효과, 온도조건이 관계한다. 일반적으로 많은 작물들에서 화아분화와 개화가 정상적으로 일어나려면 장기간의 일장처리가 필요하다. 예를 들면 단일식물인 가을국화의 개화를 촉진시키려면 30~40일간의 단일처리가 필요하다. 그러나 이러한 유도기간은 식물의 종류에 따라 차이가 심하여 도꼬마리는 단일조건을 한번만 주고 그후 장일조건, 심지어 계속 조명하더라도 화아가 형성될 수 있다. 야간의 광도에 따라서 식물별 반응은 각각 다르게 나타나는데 나팔꽃과 같이 아주 민감한 식물은 보름달의 밝기(약 0.3~0.4룩스)에서도 개화가 지연되며, 시금치는 0.7 룩스에서 추대가 빨리 되고, 콩은 1~2 룩스에서 감응시작한다. 엉거시과의 과꽃은 장일식물로써 광에 민감하여 달빛의 2~3배 밝기 정도인 1룩스에서도 개화촉진의 효과가 있다.

주로 작물은 야간의 불빛 밝기가 10~100 룩스일 때 낮시간을 연장해 주는 일장효과가 나타나며, 10~50룩스이면 장일처리에 어느정도 효과가 있고, 100룩스이면 완전한 효과가 나타날 수 있는데 작물 또는 품종에 따라서 각각 다른 반응을 보인다. 광합성에서 많은 작물의 광포화점이 5만룩스 정도이고, 광보상점은 벼에서 5,000룩스나 되기 때문에 광합성에 전혀 영향을 못미치는 약광이라도 일장처리에는 유효한 것으로 알려져 있다. 광질에 따라서는 적색광이 가장 강력한 영향을 주며, 청색광이나 녹색광은 적색광보다 떨어진다. 백열등은 광파장의 범위가 비교적 넓어 영향이 크다.

8. Features of UCD for Plant Cultivation

- Equating with natural sunlight (Color Rendering Index; 94 Ra)
- Wider light spectrum to cover whole visible light wavelength; 360 ~ 700 nm
- Supreme Energy-saving (Efficiency 110 Lm/W)
  - → Doubled efficiency comparing to LED Lamp
  - → Metal-halide Lamp 250W can be retrofit with UCD Lamp 150W.
- Instant ON and instant re-strike for easy management
  - → Hi-pressure Sodium Lamp takes 7 minutes to get stabilized and needs 10 minutes for re-strike.
- Best light source in cold weather conditions (Instant ON at -50° C)

9. Available Light Sources Comparison

Light Source	Incandescent Bulb	Fluorescent Lamp	Hi-pressure Sodium Lamp	LED Lamp	UCD Lamp
Efficiency (Lumen/W)	15	37	68	70	110
Lifetime (Hrs)	1,000	3,000	8,000	20,000	36,000
Color Rendering (Ra)	100	60	65	70	94
Merit	• Low cost	• Low cost	• Easy procurement • Low cost	•Various Color	• High efficiency • Near Sunlight effect
Demerit	• Extremely low efficiency •Extremely short lifetime	• Low efficiency	•Low efficiency • No instant On • No instant re-strike	• High cost • Weak against moisture • Whole module replacement for service	• No reference for plant cultivation

10. Applicable Luminaires for Greenhouse & Warehouse

1. Flood

FDA-70W

Casing Dimension
420 x 300 x 130 (mm)
Weight : 3.8 kg IP65

2. Flood

FDC-100/150W

Casing Dimension
435 x 410 x 145 (mm)
Weight : 5.2 kg IP65

3. High bay

SPDA-70/100/150W

Casing Dimension
350 x 370 (mm)
Weight : 3.5 kg

4. Double Flood

FDE-300/500W

Casing Dimension
435 x 555 x 170 (mm)
Weight : 11kg

5. Xen-8(SR)

X8WL-*45/650W*

Casing Dimension
255 x 80 (mm)
Weight : 600g

6. Xen-8(CR)

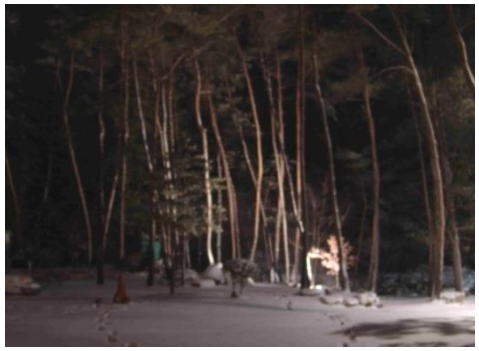
X8WL-*45/650W*

Casing Dimension
255 x 80 (mm)
Weight : 600g

7. Xen-8(IR8)

X8WL-*45/650W*

Casing Dimension
255 x 80 (mm)
Weight : 600g



11. Applicable Street Light & Security Light

- Replacement with UCD street lights on a bridge road with 11 lanes (72% saved)

Before : Natrium 250W(Road)+150W(Sidewalk)=400W

After replaced with UCD 120W

12. Installation cases with UCD for plant cultivation

- Comparison of light in a greenhouse (3 wavelength lamps vs. UCD)

Model	W	Q'ty	Power Consumption	Remarks
3 Wavelength Lamp	18W	50EA	900W	1. Waste of electric power 2. Lack of amount of light 3. Decrease of yield

Model	W	Q'ty	Power Consumption	Remarks
Xen-8 Wavelength Lamp	65W	10EA	650W	1. High efficiency 2. Twice the brightness 3. 8 wavelength with solar light 4. Increase of yield

13. Installation cases with UCD for plant cultivation

- Comparison of lights in a strawberry greenhouse (Incandescent lamps vs. Xen-8 lamps)

Model	W	Q'ty	Power Consumption	Remarks
Incandescent Lamp	60W	40EA	2,400W	1. Waste of electric power 2. Suspension of use 3. Low efficiency 4. Decrease of yield

Model	W	Q'ty	Power Consumption	Remarks
Xen-8 Wavelength Lamp	65W	6EA	390W	1. High efficiency 2. Twice the brightness 3. 8 wavelength with solar light 4. Increase of yield

14. Cultivation Experiment

- Technical support from Jeonju Biomaterial Institute who is running Vegetable Factory
  * Support to advise cultivation procedures
  * To provide further supports in the future

- Experiment Method
  * Vegetable; Lettuce
  * Starting; Seedlings transplanted
  * Farming beds; Hydroponics
  * Location; Dark space in a warehouse
  * Lighting type; 100% Artificial lighting
  * Method; Comparison between UCD 120W and Hi-pressure Sodium (HPS) 150W

- Comparison Conditions; 2 Beds for same distance and 2 beds for same light intensity

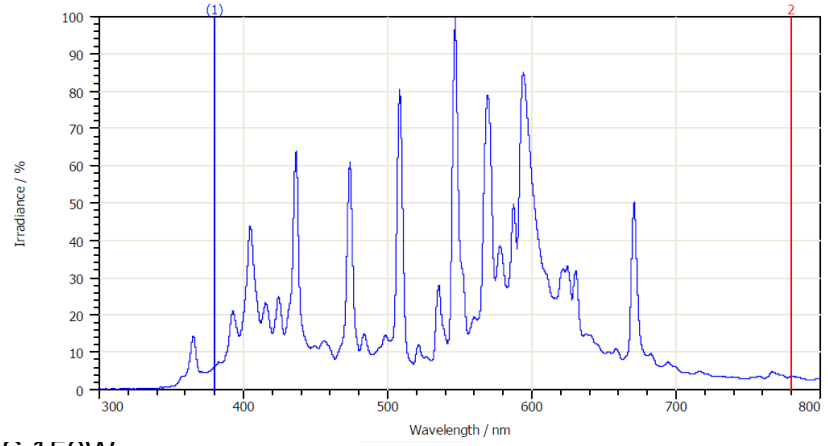
  * Daily checking made for the growing status monitoring.

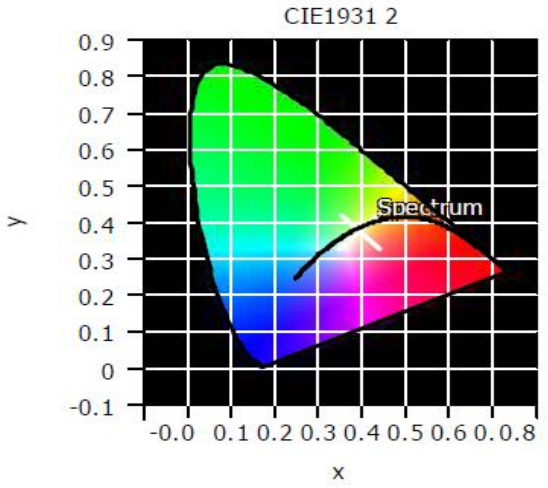
Condition	Same Distance		Same Light Intensity	
Lamp	UCD 120W	HPS (Natrium) 150W	UCD 120W	HPS (Natrium) 150W
PPF	191μmol/m²/sec	337μmol/m²/sec	524μmol/m²/sec	560μmol/m²/sec
Lux	872 Lux	1124 Lux	1925 Lux	1655 Lux
Bed No.	1	2	3	4

15. Lamp Spectrum Measurement for Experiment Application

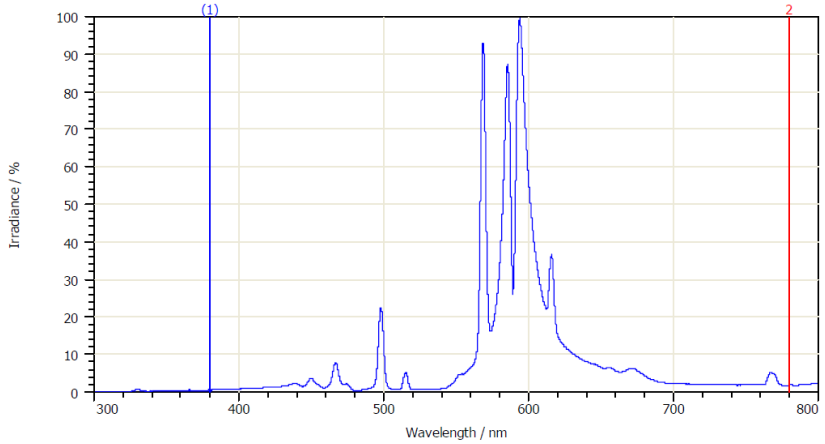
- Test Lab; Jeonbuk Techno-park
- Test Result Comparison; Spectrum and Color Coordinate

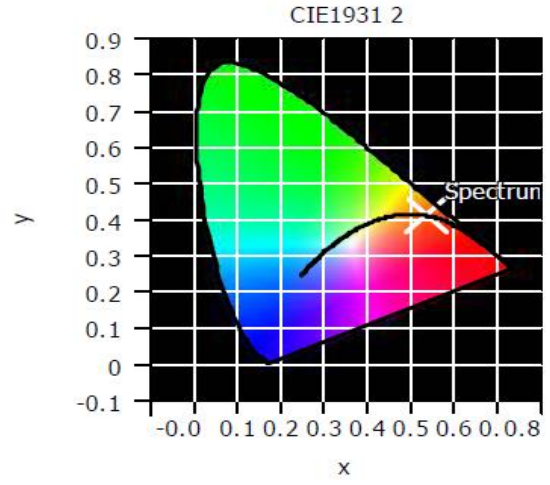
* UCD Lamp 120W





* HPS 150W





1st Day (Aug. 6, 2010 / PM 6:20, Seedlings transplanted)

Same Distance (1m)

UCD 120W, 191μmol/m²/sec

HPS 150W, 337μmol/m²/sec

Same Light Intensity

UCD 120W, 524μmol/m²/sec

HPS 150W, 560μmol/m²/sec

2nd Day (Aug. 7, 2010 / PM 10:10, 28 Hrs after transplant)









Enlarged Photos on following pages →

2nd Day (Aug. 7, 2010 / PM 10:10, 28 Hrs after transplant)

Same Distance (1m)

UCD 120W, 191μmol/m²/sec

HPS 150W, 337μmol/m²/sec

2nd Day (Aug. 7, 2010 / PM 10:10, 28 Hrs after transplant)

Same Light Intensity

UCD 120W, 524μmol/m²/sec

HPS 150W, 560μmol/m²/sec

3rd Day Morning (Aug. 8, 2010 / AM 08:20, 38 Hrs after transplant)

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Same Distance (1m)

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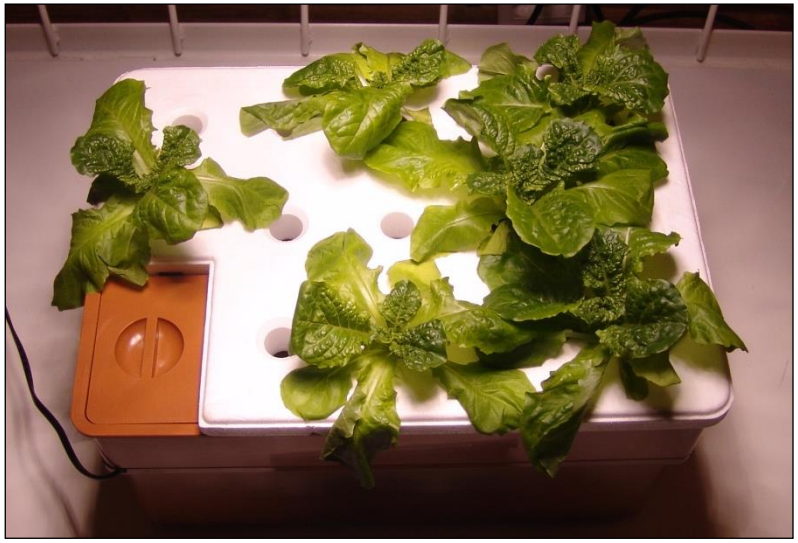

HPS 150W, 560µmol/m²/sec

3rd Day Evening (Aug. 8, 2010 / PM 10:00, 52 Hrs after transplant)

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3rd Day Evening (Aug. 8, 2010 / PM 10:00, 52 Hrs after transplant)

Same Distance (1m)

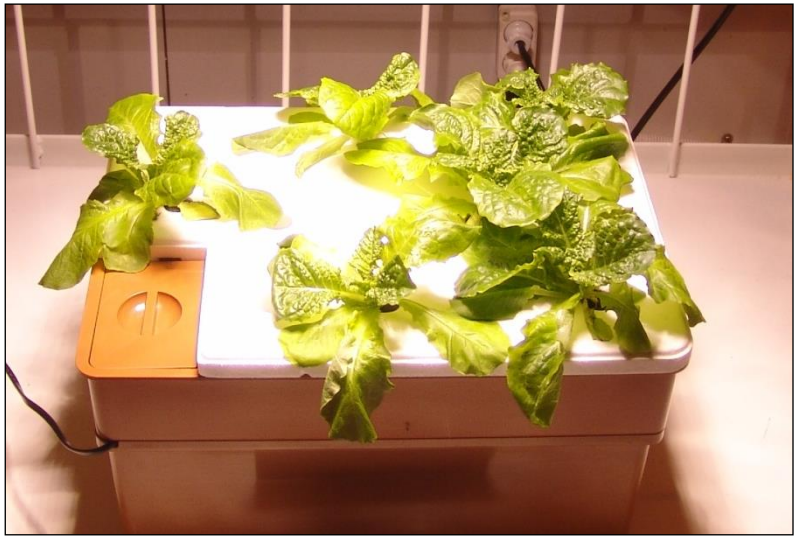
UCD 120W, 191μmol/m²/sec

HPS 150W, 337μmol/m²/sec

3rd Day Evening (Aug. 8, 2010 / PM 10:00, 52 Hrs after transplant)

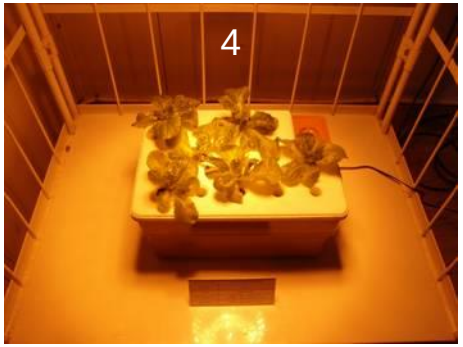
Same Light Intensity

UCD 120W, 524μmol/m²/sec



HPS 150W, 560μmol/m²/sec

4th Day (Aug. 9, 2010 / PM 04:00, 70 Hrs after transplant)






UCD and HPS turned off and photos taken under Fluorescent Lamp

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4th Day (Aug. 9, 2010 / PM 04:00, 70 Hrs after transplant)

Same Distance (1m)

UCD 120W, 191μmol/m²/sec

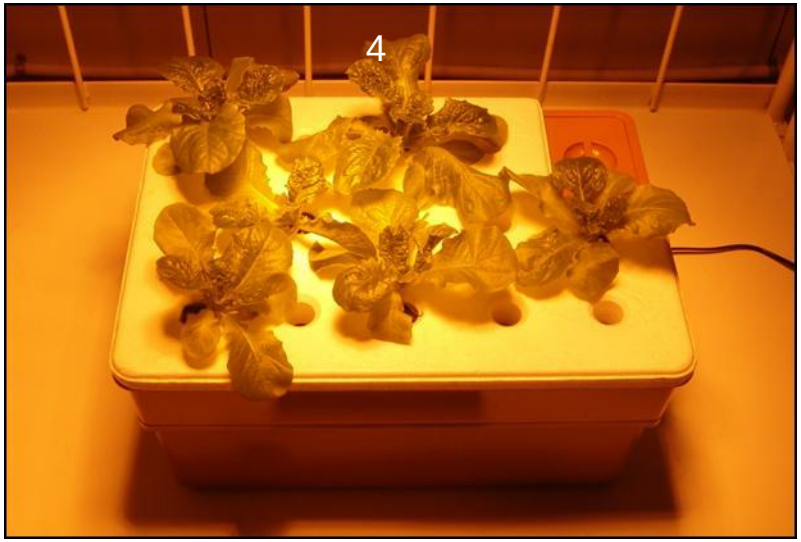
HPS 150W, 337μmol/m²/sec

4th Day (Aug. 9, 2010 / PM 04:00, 70 Hrs after transplant)

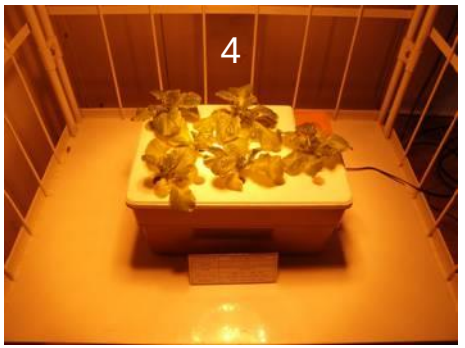
Same Light Intensity

UCD 120W, 524μmol/m²/sec

HPS 150W, 560μmol/m²/sec

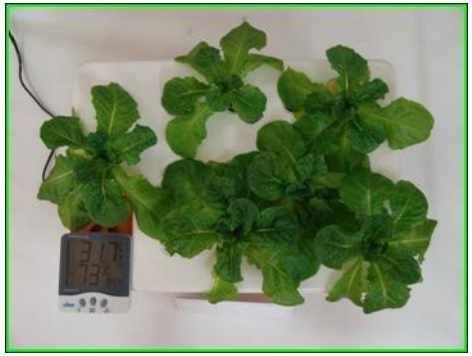


5th Day (Aug. 10, 2010 / PM 10:30, 100 Hrs after transplant)






UCD and HPS turned off and photos taken under Fluorescent Lamp




Enlarged Photos on following pages →

5th Day (Aug. 10, 2010 / PM 10:30, 100 Hrs after transplant)

Same Distance (1m)

UCD 120W, 191μmol/m²/sec

HPS 150W, 337μmol/m²/sec

5th Day (Aug. 10, 2010 / PM 10:30, 100 Hrs after transplant)

Same Light Intensity

UCD 120W, 524μmol/m²/sec

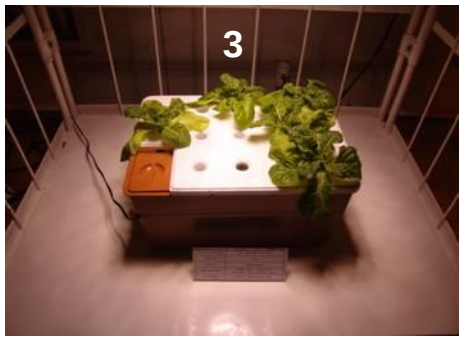
Due to high humidity and no ventilation, fungal infection occurred.

HPS 150W, 560μmol/m²/sec

6th Day (Aug. 11, 2010 / PM 10:30, 124 Hrs after transplant)

One lettuce removed due to fungal infection.

7th Day (Aug. 12, 2010 / PM 10:30, 148 Hrs after transplant)










8th Day (Aug. 13, 2010 / PM 9:00, 171 Hrs after transplant)





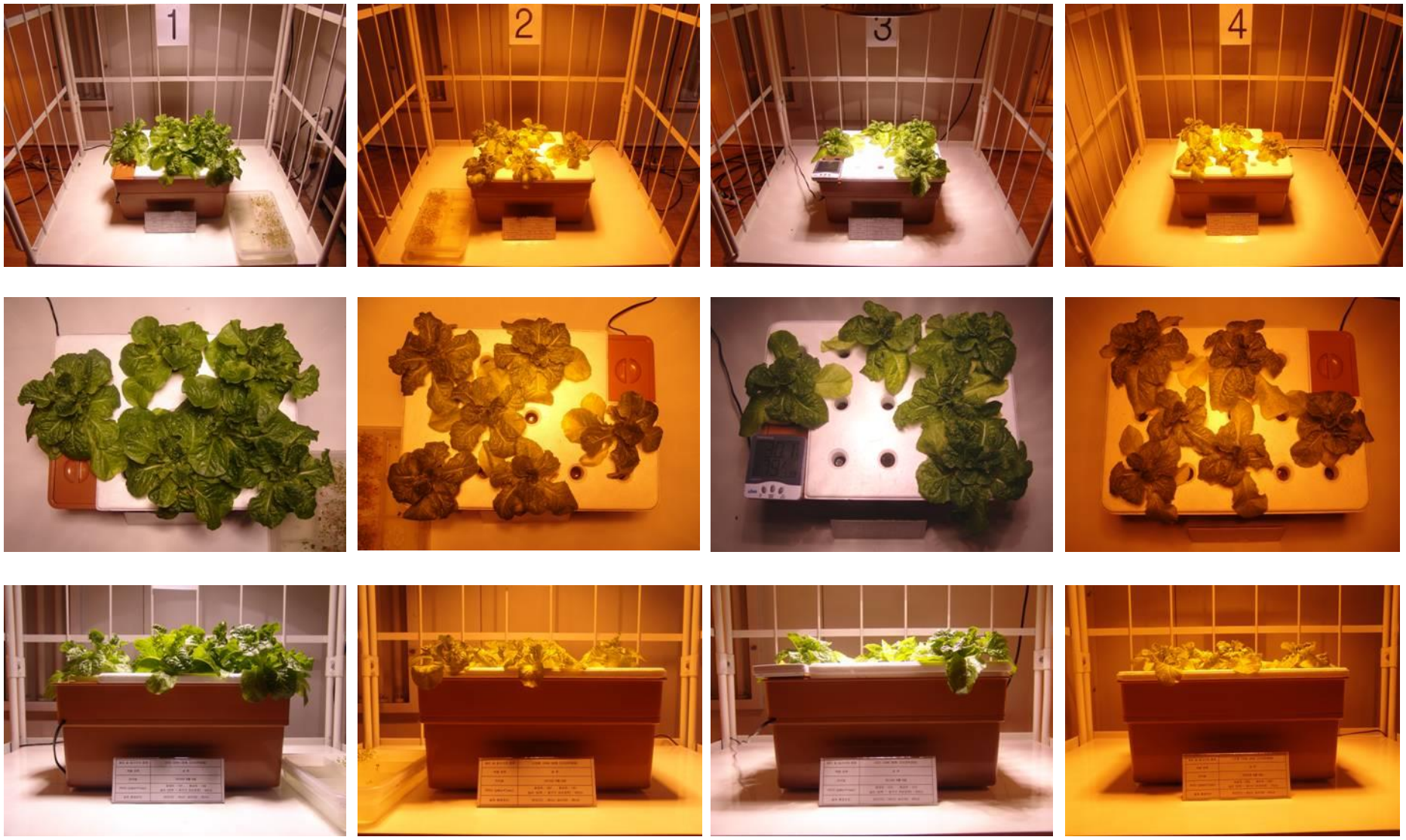



9th Day (Aug. 14, 2010 / PM 9:00, 195 Hrs after transplant)

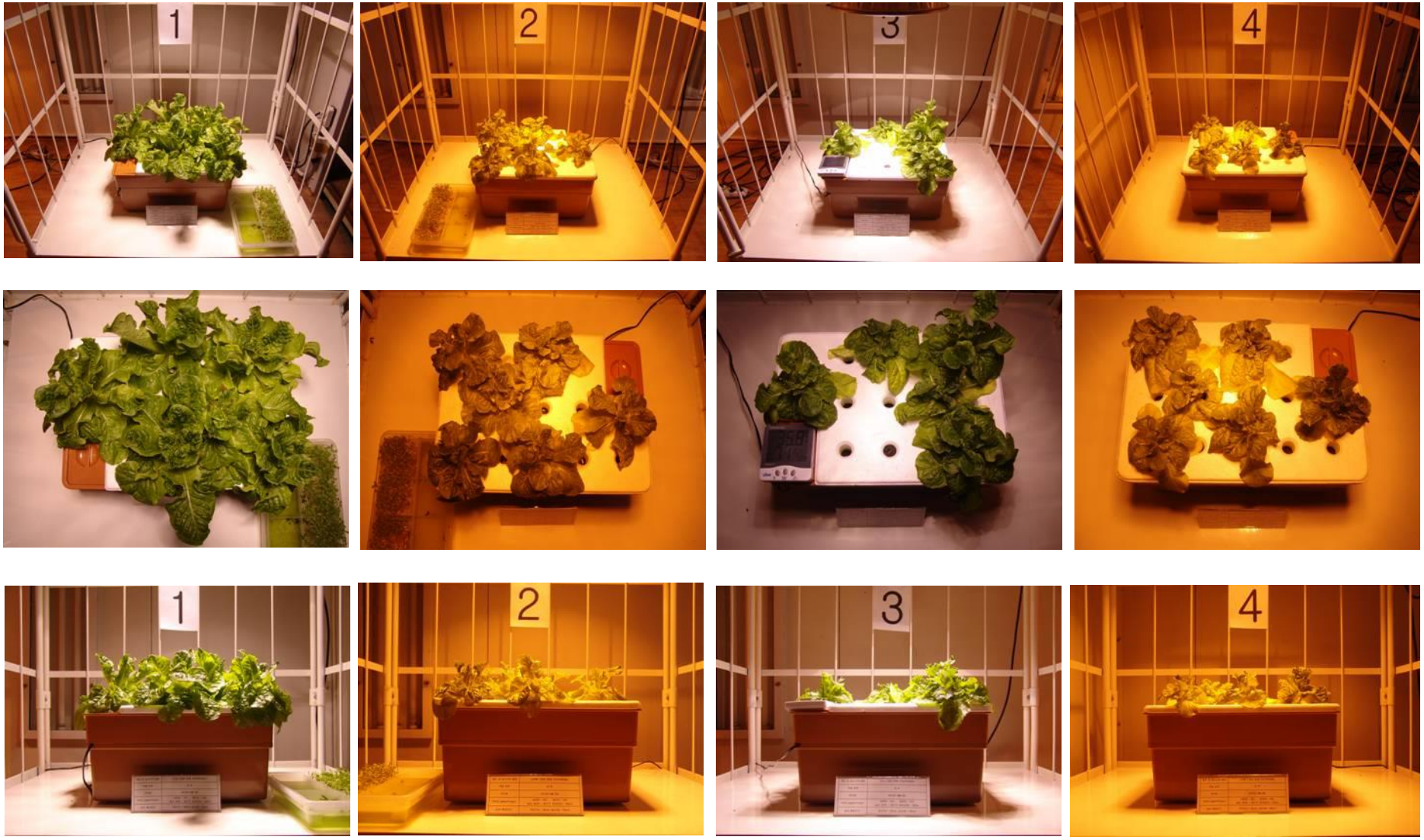
*** UCD Lamp down-graded from 120W to 60W to reduce the heat.**

10th Day (Aug. 15, 2010 / AM 11:00, 209 Hrs after transplant)

11th Day (Aug. 16, 2010 / PM 11:00, 245 Hrs after transplant)



15th Day (Aug. 20, 2010 / PM 7:00, 337 Hrs after transplant)



Daily checking History

Date	Time	Temp. (°C)	Humi. (%)	Event	Remark
Aug. 6 (Fri)	PM 06:20	28~27	85	Transplanted seedlings	After 12 hours lighting in the night, lettuces under UCD lamp start to lead in the growth.
Aug. 7 (Sat)	PM 10:10	34~28	75	Leaves withered due to extremely high temperature.	Turned off all the lamps to cool down.
Aug. 8 (Sun)	PM 10:00	32~29	55	Gets OK after Lamp turn-off. During day time, temperature rises too high.	Due to high temperature, turned off all the lamps during day time, from PM 12:00 till PM 7:00. (31°C)
Aug. 9 (Mon)	PM 10:00	33~30	67	Temperature rises too high.	Due to high temperature, turned off all the lamps during day time, from AM 7:00 till PM 9:00. (31°C)
Aug. 10 (Tue)	PM 10:30	32~29	85	Temperature rises too high.	One lettuce on bed No. 3 withered due to water shortage.
Aug. 11 (Wed)	PM 11:30	31~29	68	Additional water supplied.	One lettuce on bed No. 3 was removed due to fungal infection
Aug. 12 (Thu)	PM 10:10	32~29	79	Growth becomes slow.	Experiment continued.
Aug. 13 (Fri)	PM 09:00	32~30	79	UCD Lamp for bed No3 down-graded from 120W to 60W to reduce heat.	Due to high temperature, turned off all the lamps during day time, from AM 8:00 till PM 9:00. (32°C)
Aug. 14 (Sat)	PM 08:30	32~31	80	Growth becomes slow.	Found moss on some roots.
Aug. 15 (Sun)	AM 10:00	30~28	94	Found water temperature reaches 32°C .	Replaced all the water and supplied nutrient.
Aug. 16 (Mon)	PM 10:30	28~26	95	Lettuces under UCD grows faster.	Low temperature helps to make growth faster.
Aug. 17 (Tue)	PM 10:00	31~30	80	Make air circulation for the space.	Experiment continued.
Aug. 18 (Wed)	PM 11:00	32~30	87	Leaves withered under HPS lamp.	Withered leaves under HPS lamp became yellowish.
Aug. 19 (Thu)	PM 10:00	33~32	73	Leaves under UCD lamp are OK.	Leaves under UCD are OK in high temperature condition.
Aug. 20 (Fri)	PM 07:00	34~33	68	Completed experiment and checked crops.	Crops under UCD are weighed double of the ones under HPS.

Photos for Quick-view

UCD 120W, 1M distance	HPS 150W, 1M distance	UCD 60W, Same intensity	HPS 150W, Same intensity
			
Starting stage			
			
After 10 days			

On the final day of experiment

			
Finishing stage			

Final Check & Crop Measurement

Roots status

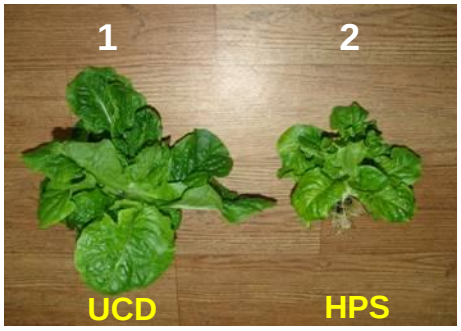
Crops measurement


Biggest under UCD; 53g


Biggest under HPS; 25g


Biggest under UCD; 34g


Biggest under HPS; 23g



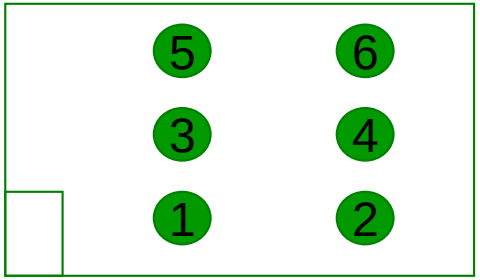
16. Crops Data Comparison

- Weight measurement after completion of 14 days experiment.

Unit; Gram

Conditions	Bed Number	Lettuce Head Number on the Bed						Total Weight	No of Head	Average Weight
		1	2	3	4	5	6			
Same Distance (1M)	1 (UCD 120W)	53	34	44	39	33	47	250	6	41.7
	2 (HPS 150W)	22	20	19	25	22	17	125	6	20.8
Same Light Intensity (500μmol/m²/sec)	3 (UCD 60W)	Fungal infection	28	26	25	23	34	136	5	27.2
	4 (HPS 150W)	24	23	16	19	21	18	121	6	20.2

* Head Number



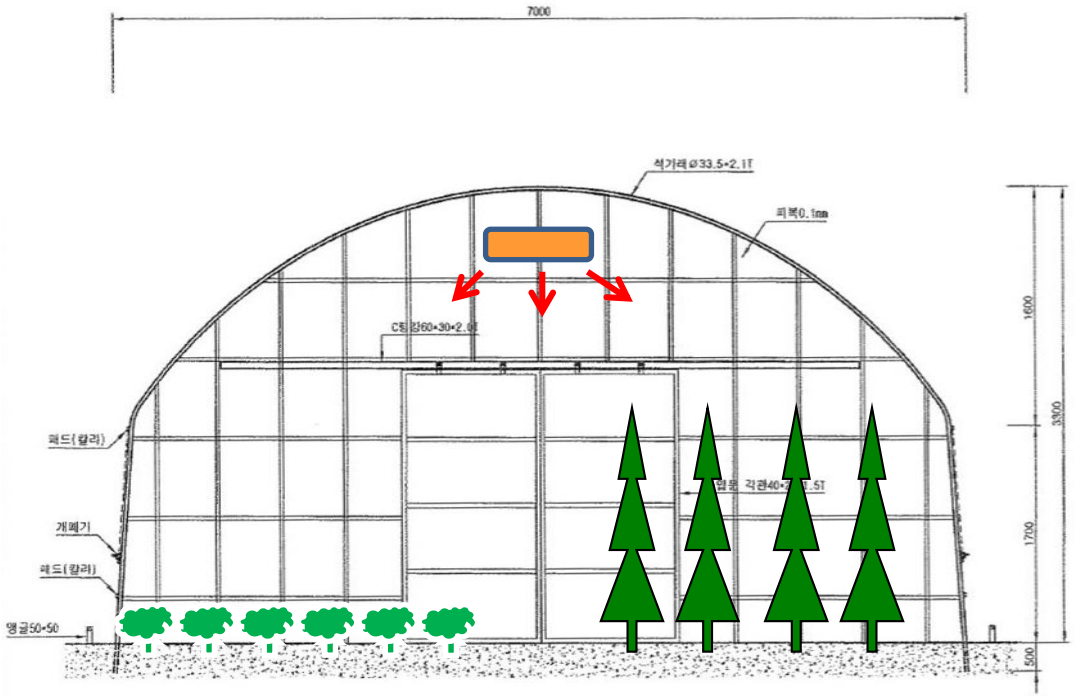
17. Greenhouse Lighting; 665 M² Type

- Greenhouse Dimension; Width 7m x Height 3.3m x Length 95m (665 M²)
- Illuminance Design;

  * Case 1) 100~200 Lux on the ground → For extra lighting after sun-set

  * Case 2) Evenly 200 Lux on the ground → For extra lighting after sun-set

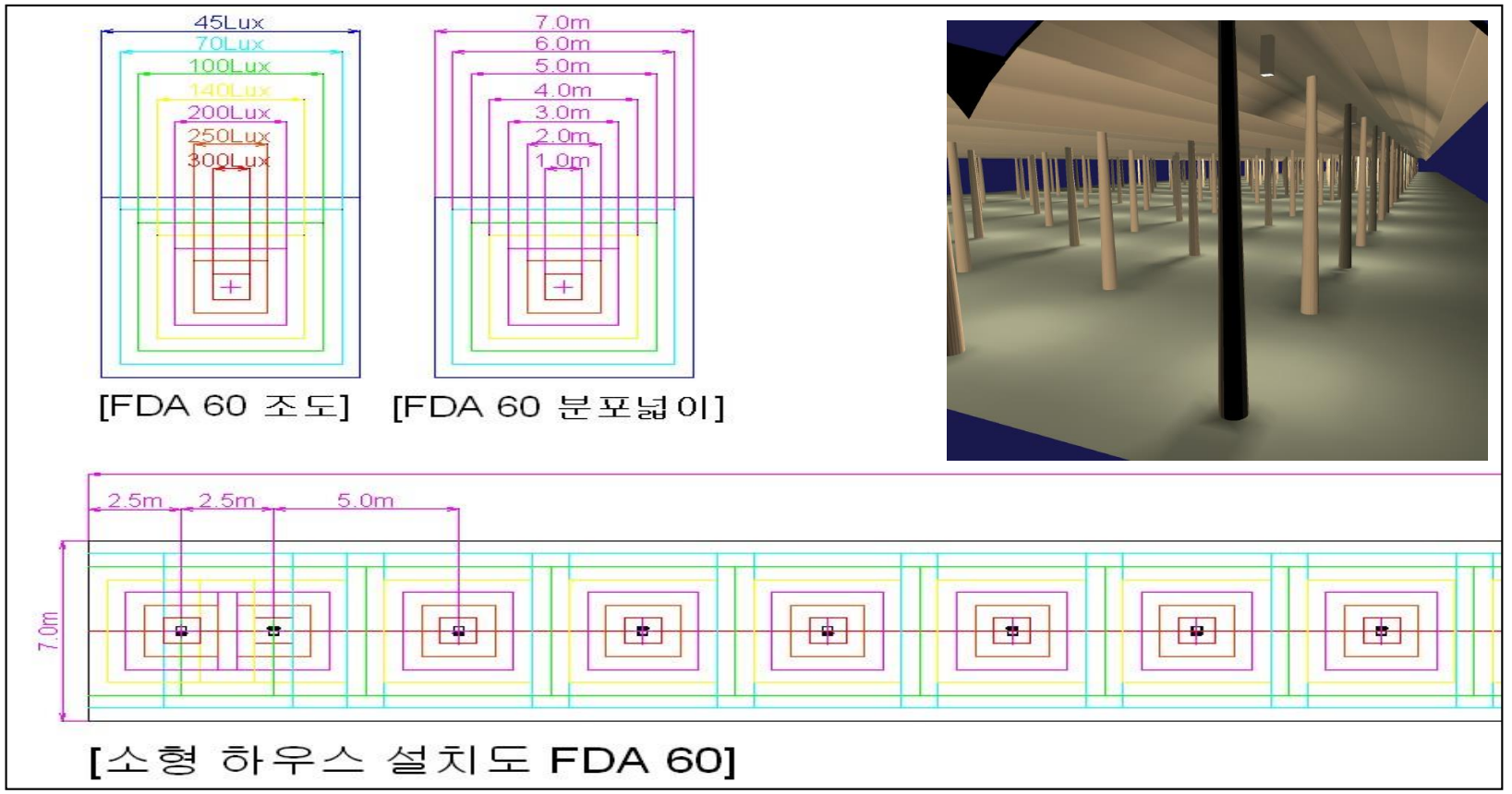
  * Case 3) Up to 500 Lux on the ground → Additional lighting during cloudy days



Greenhouse Lighting Design; Case 1

- Expected illuminance 120~250 Lux on the ground → For extra lighting after sun-set

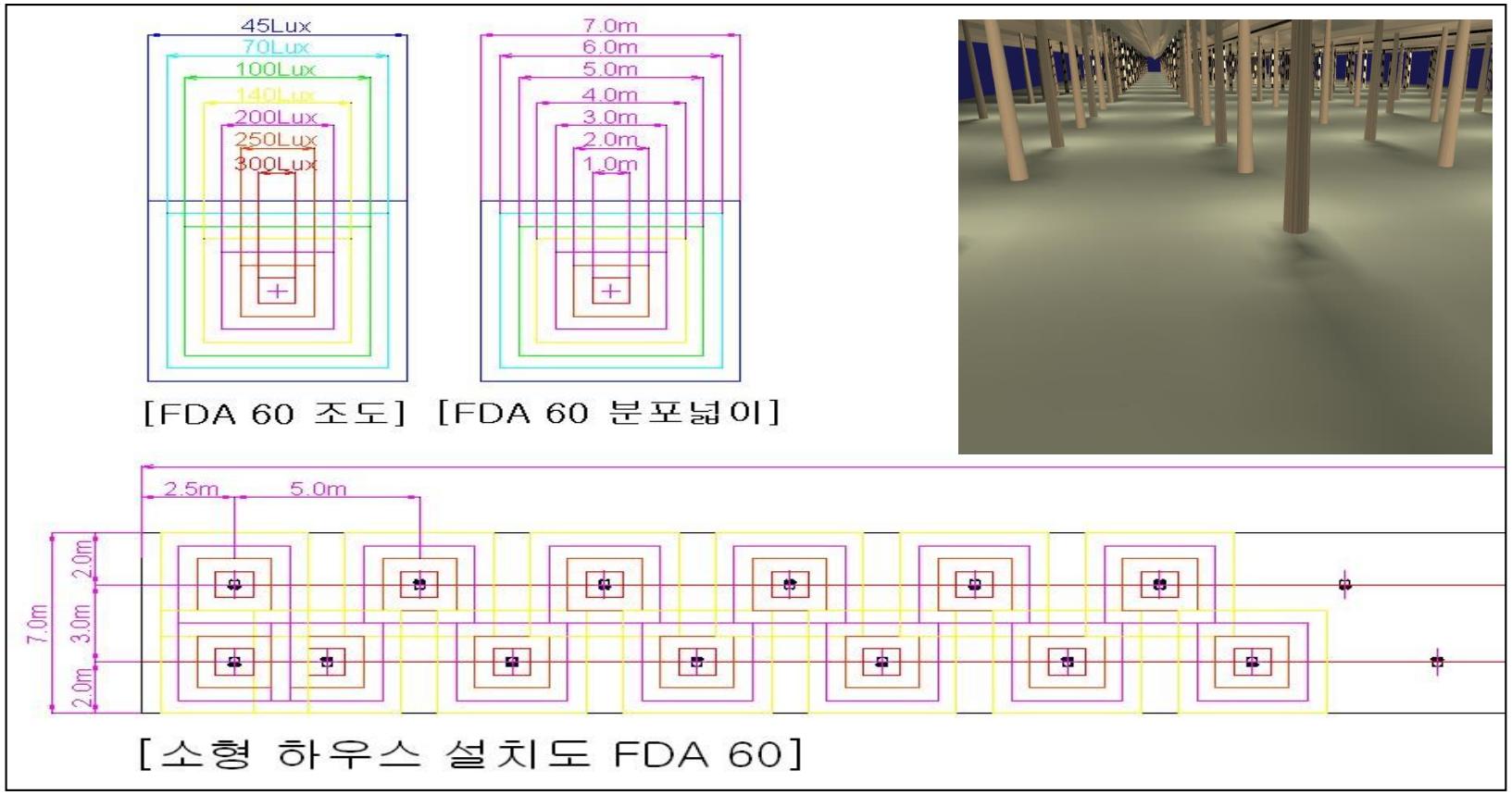
  * Lamp requirement; FDA 60W 20 sets



Greenhouse Lighting Design; Case 2

- Expected illuminance 200~250 Lux on the ground → For extra lighting after sun-set

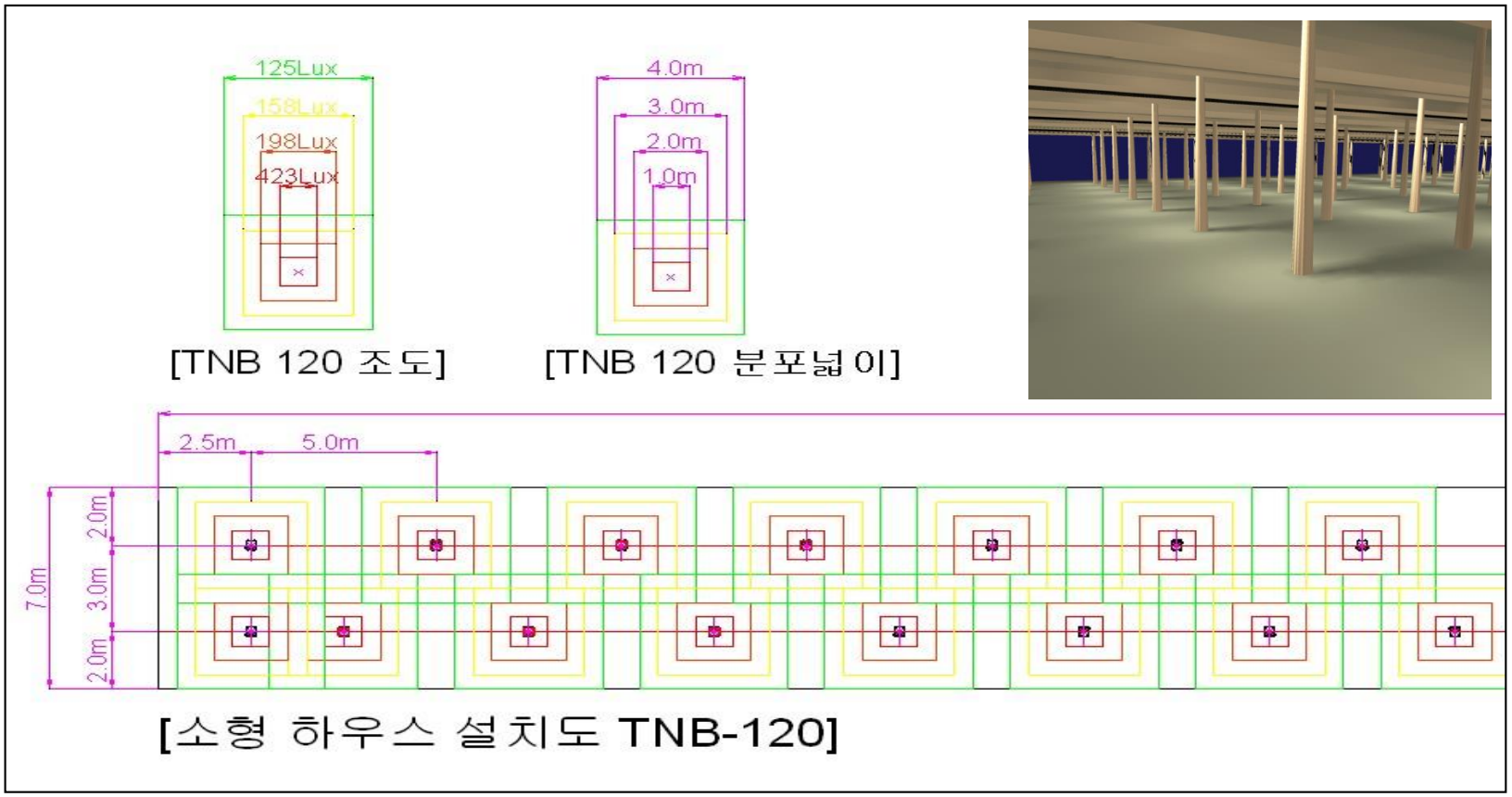
  * Lamp requirement; FDA 60W 40 sets



Greenhouse Lighting Design; Case 3

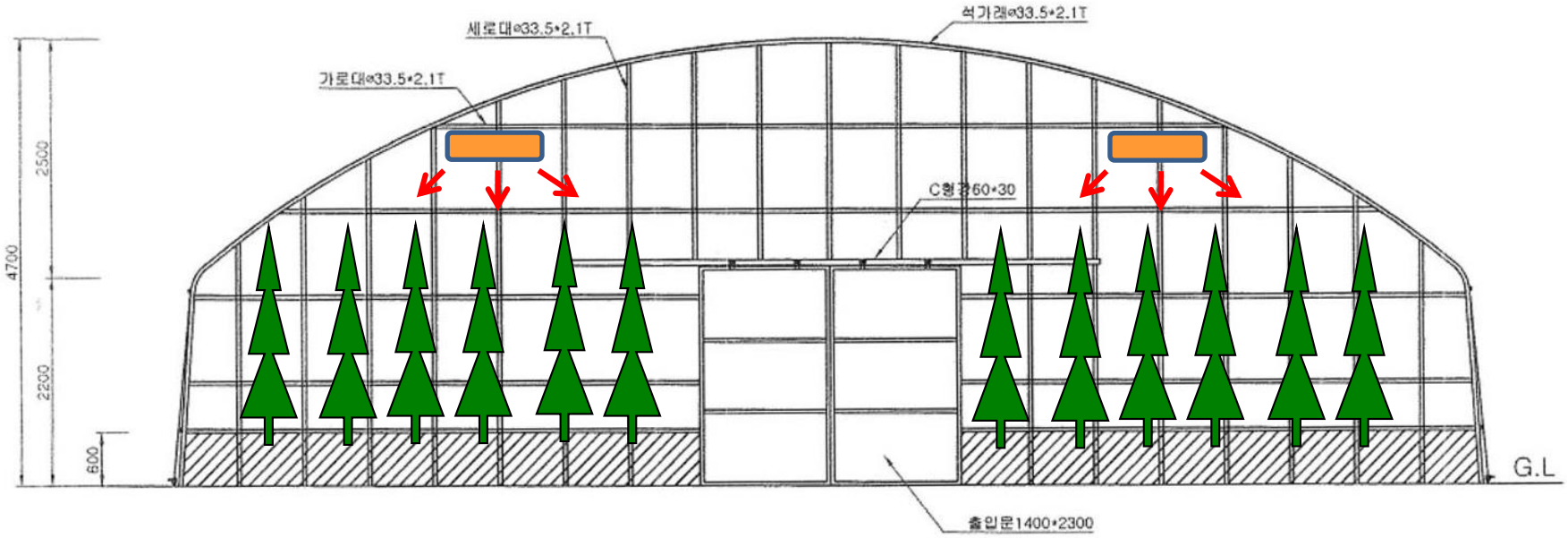
- Expected illuminance 250~430 Lux on the ground → For additional lighting during cloudy days

  * Lamp requirement; TNB 120W 40 sets



Greenhouse Lighting; 1235 M² Type

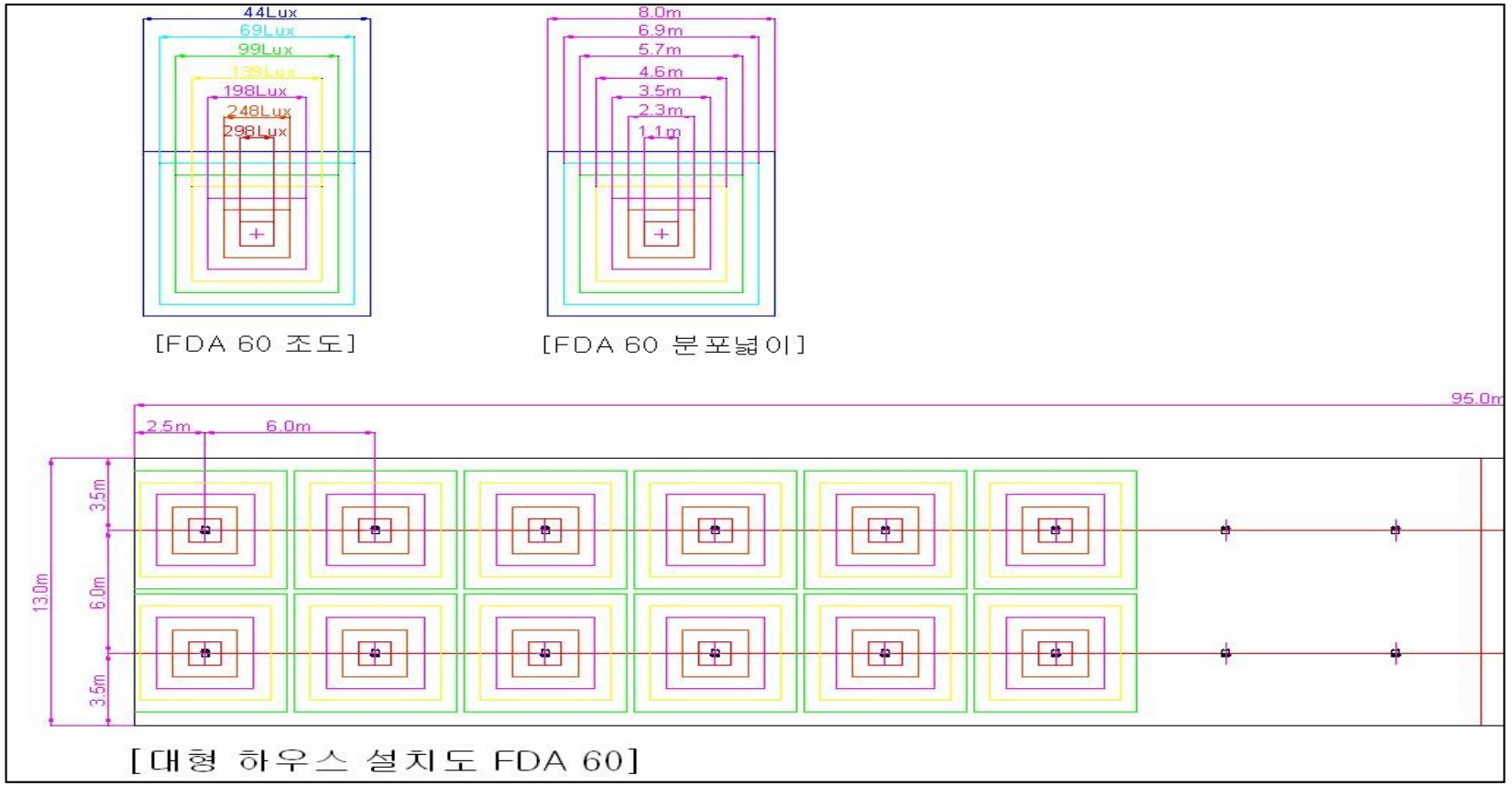
- Greenhouse Dimension; Width 13m x Height 4.7m x Length 95m (665 M²)
- Illuminance Design; 100~200 Lux on the ground → For extra lighting after sun-set



Greenhouse Lighting Design

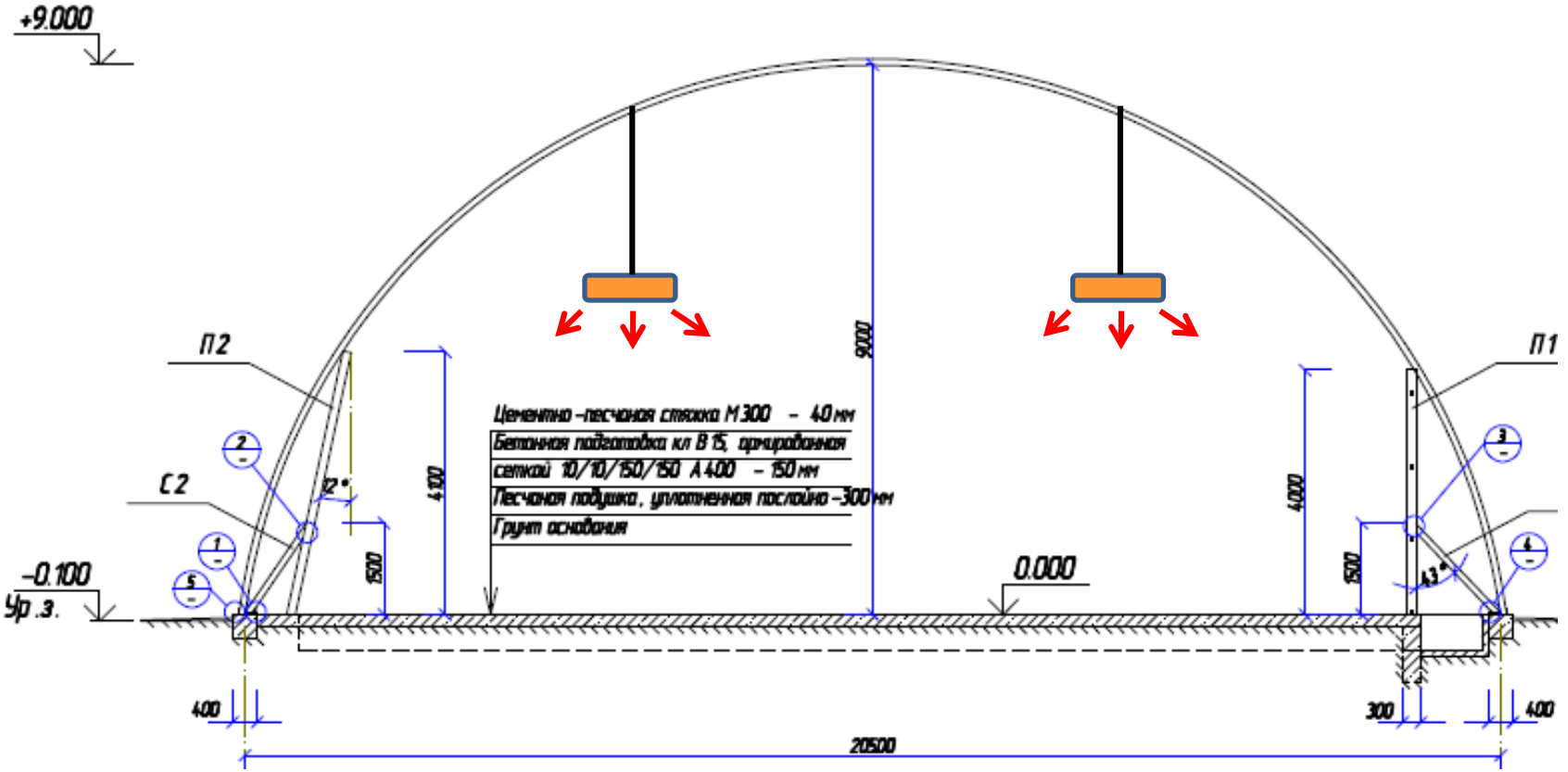
- Expected illuminance 90 ~ 248 Lux on the ground → For additional lighting during cloudy days

  * Lamp requirement; FDA 60W 32 sets



Warehouse Lighting; 1000 M² Type

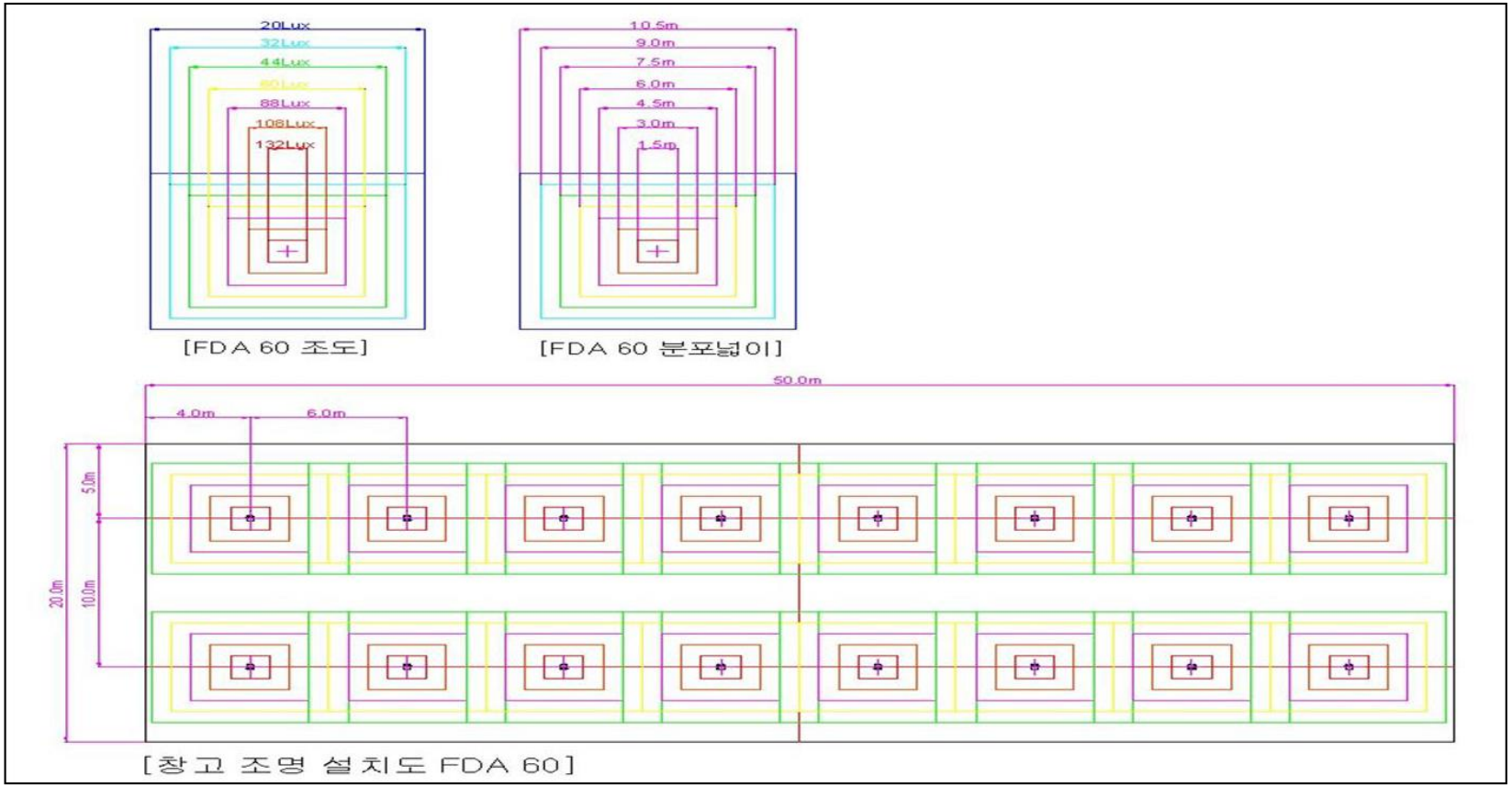
- Warehouse Dimension; Width 20m x Height 9m x Length 50m (1000 M²)
- Illuminance Design; More than 90 Lux on the floor → For storage management and inspection



Warehouse Lighting Design

- Lamp Installation Height; 4.5m
- Expected illuminance 90 ~ 130 Lux on the ground

  * Lamp requirement; FDA 60W 16 sets



Roadway Lighting Design

- Main Entrance Road; Width 6m x Length 60m
- In-site Road; Width 6m x Length 1,600m

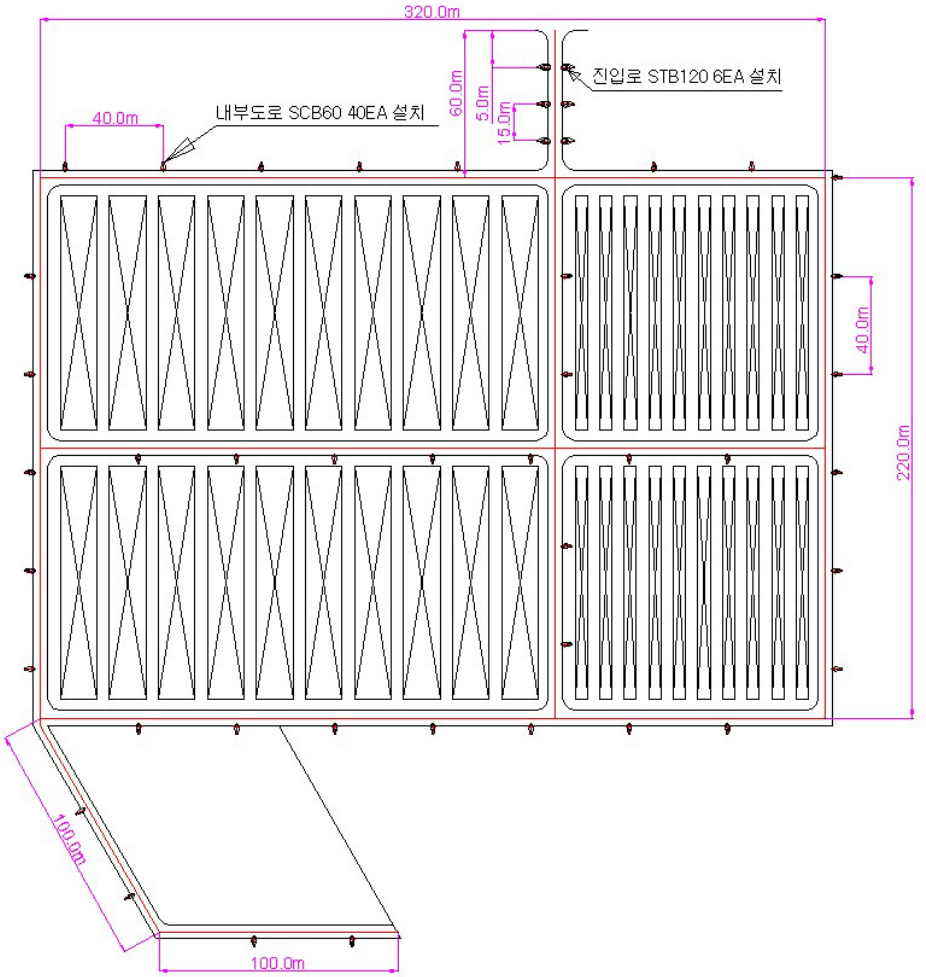
- Illuminance Design;

  * Main Entrance; Height 9m, Max 80 Lux

    → Street Light Type; STB 120W 6 sets

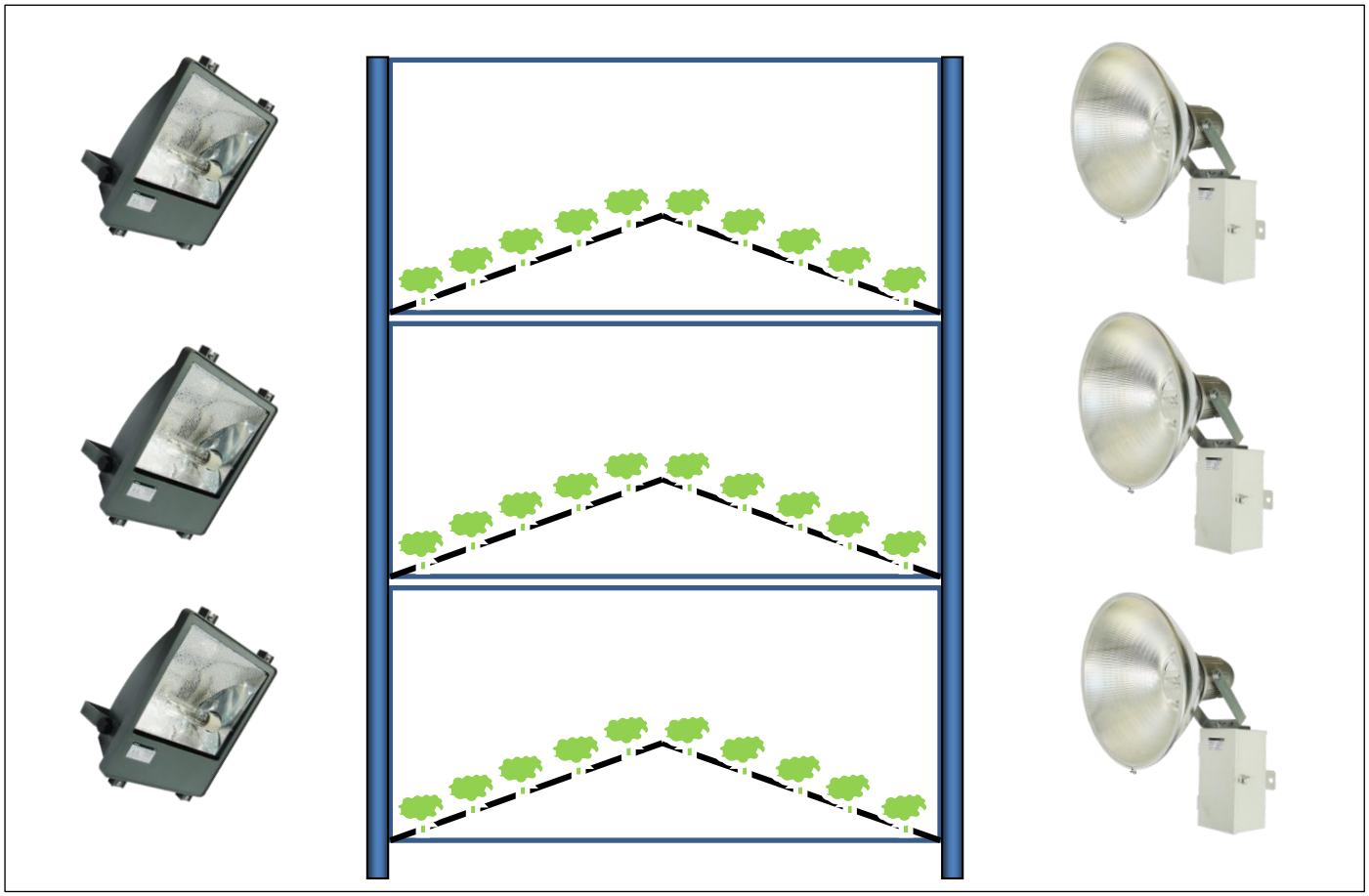
  * In-site Road; 40m span, Height 6m, Max 16 Lux

    → Security Light Type; SCB 60W 40 sets



18. Application: UCD Solution for Urban Vegetable Factory

- Layout & Features
  - * Multiple Shelf Type → Suitable for Urban Vegetable Factory with minimum space
  - * Inclined Farming Bed → Easy management on visible site / Labor-saving bed structure
  - * Side lighting UCD Lamp → Energy-saving with minimum number of lamp
- System Concept



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