設施蘆筍溫室小型害蟲監測與爆發機制通報系統

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Date: 2020.11.5

CONTENTS

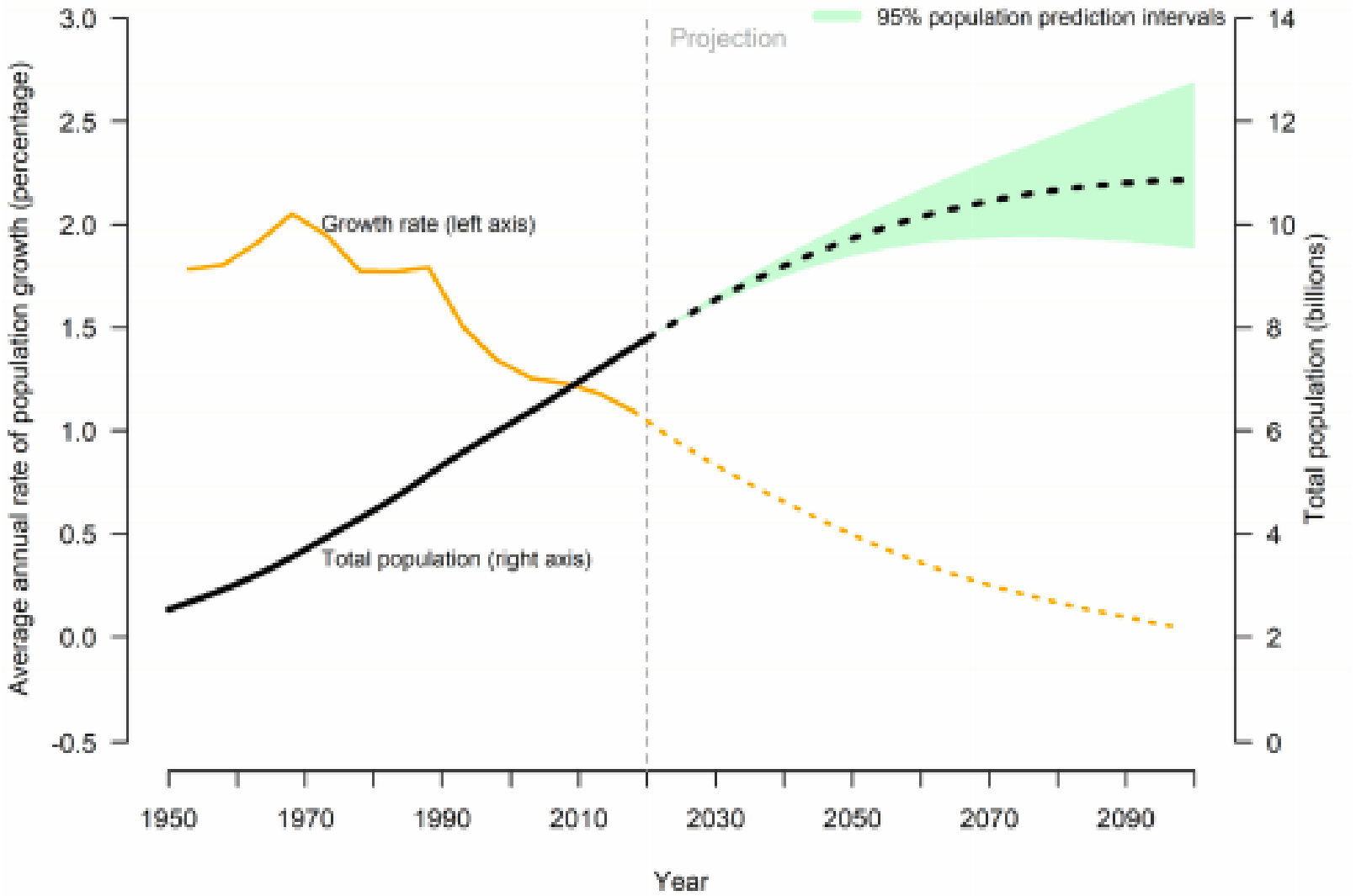
Chapter 1

Introduction

Why greenhouse?

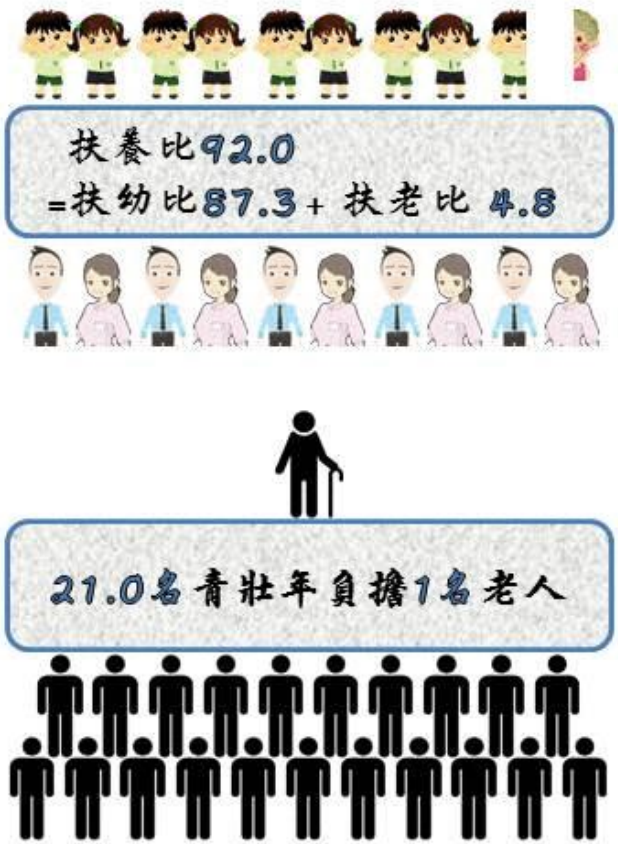
Source pictures：news

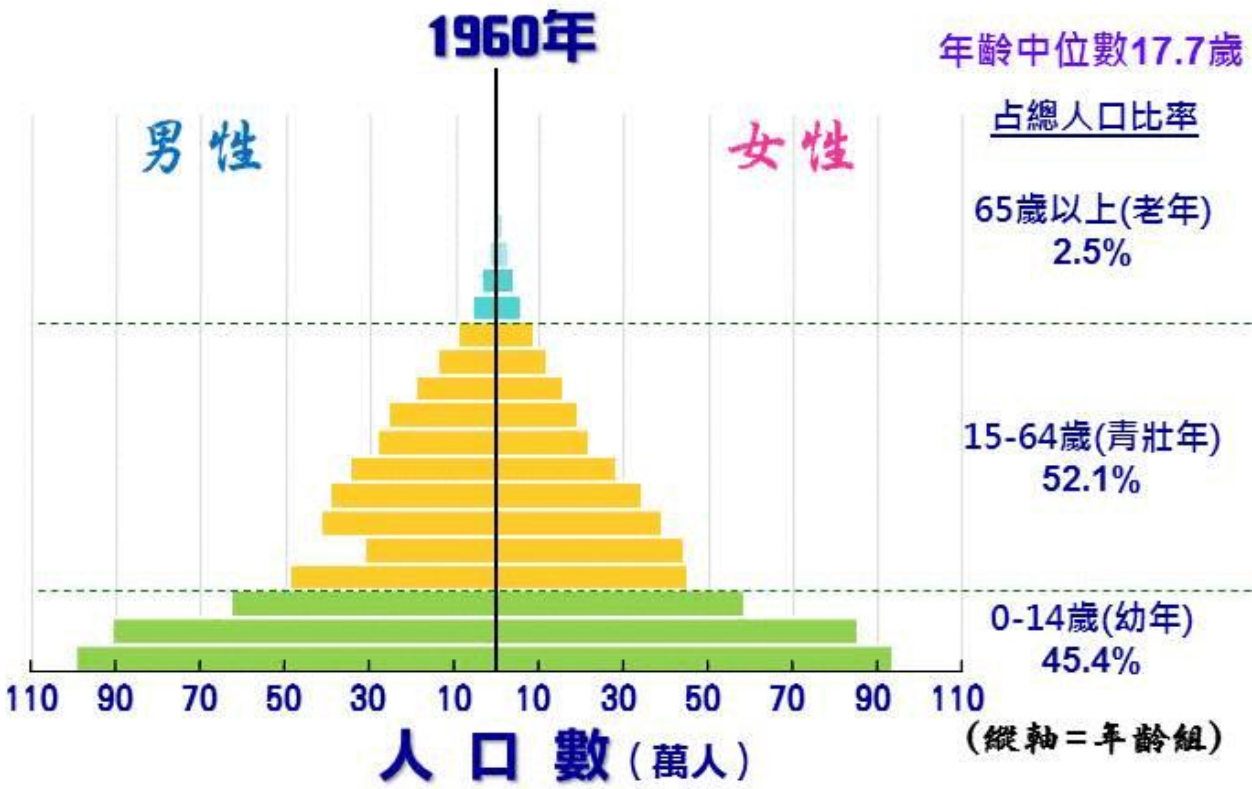
World population change



Source：《世界人口展望 2019》

Aging of structure

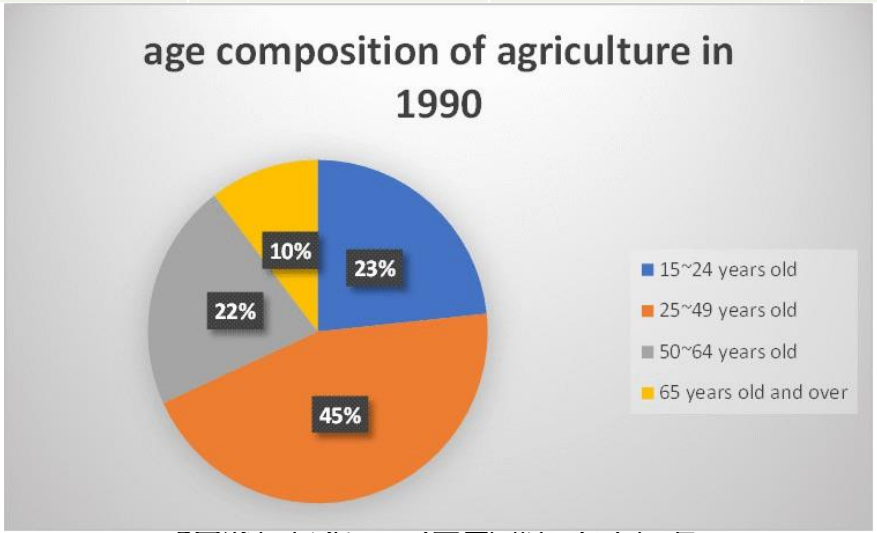




資料來源：國家發展委員會「中華民國人口推估（2018至2065年）」報告中推估結果，更新日期：107年8月30日（下次更新日期：109年8月底前）

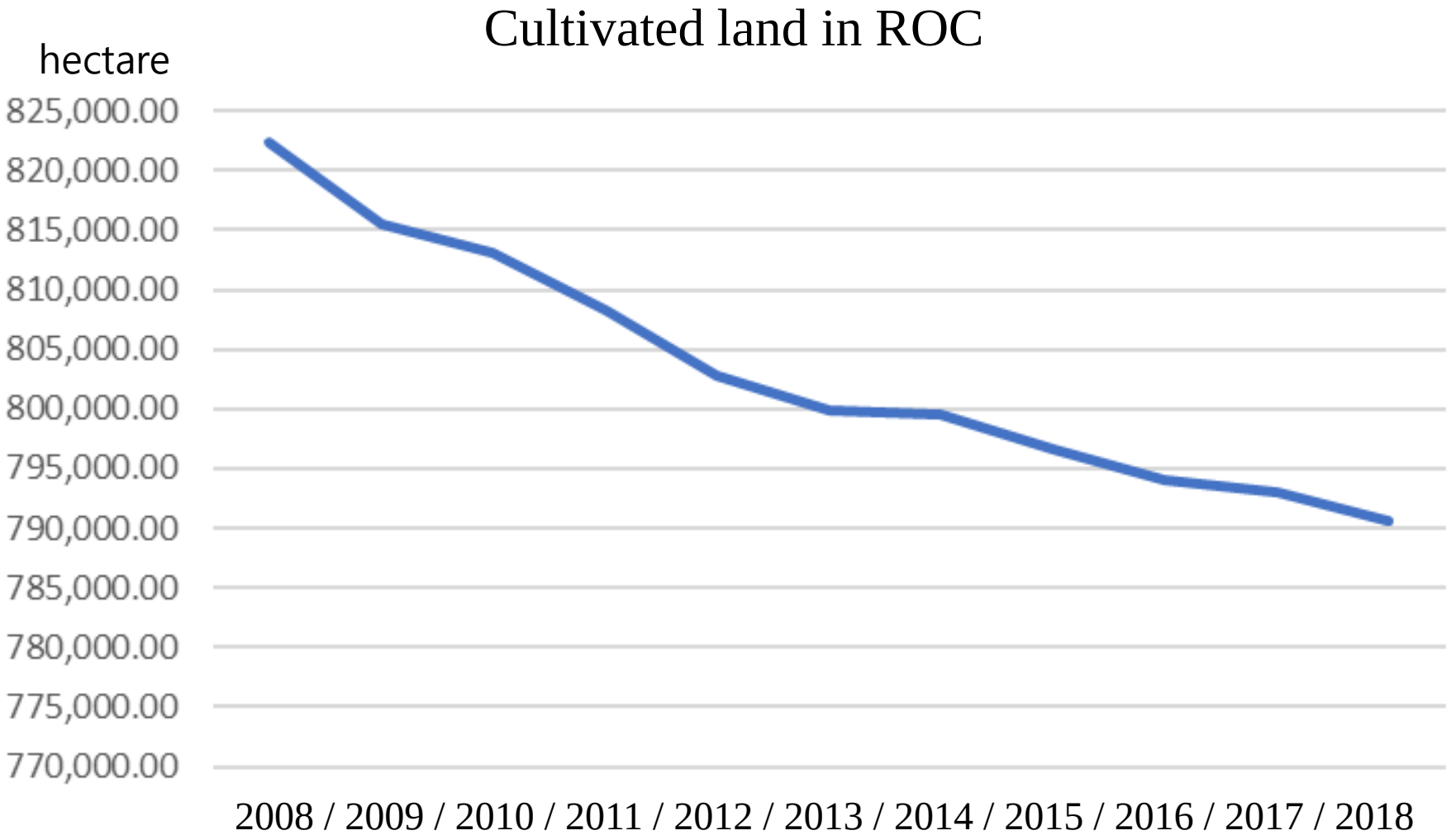
Farming population in ROC

Year	Total family	Farming family	Percentage (%)	Total population	Farming population	Percentage (%)
1990	5,093,098	859,772	16.88	20,352,966	4,309,787	21.18
1995	5,805,286	792,120	13.64	21,304,181	3,947,686	18.45
2000	6,662,192	724,645	10.88	22,216,107	3,688,885	16.60
2005	7,263,739	771,579	10.62	22,689,774	3,417,572	15.06
2010	7,902,440	780,388	9.88	23,054,815	2,975,523	12.91
2015	8,427,842	778,930	9.24	23,346,728	2,710,680	11.61



資料來源：行政院主計處

Reduction of cultivated land

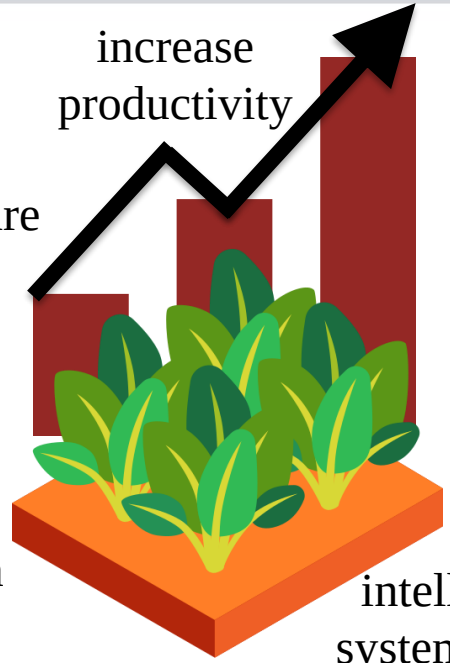


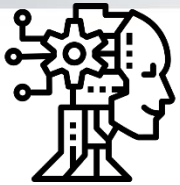
資料來源：行政院農業委員會

The agricultural situation nowadays

aging of structure

increase productivity





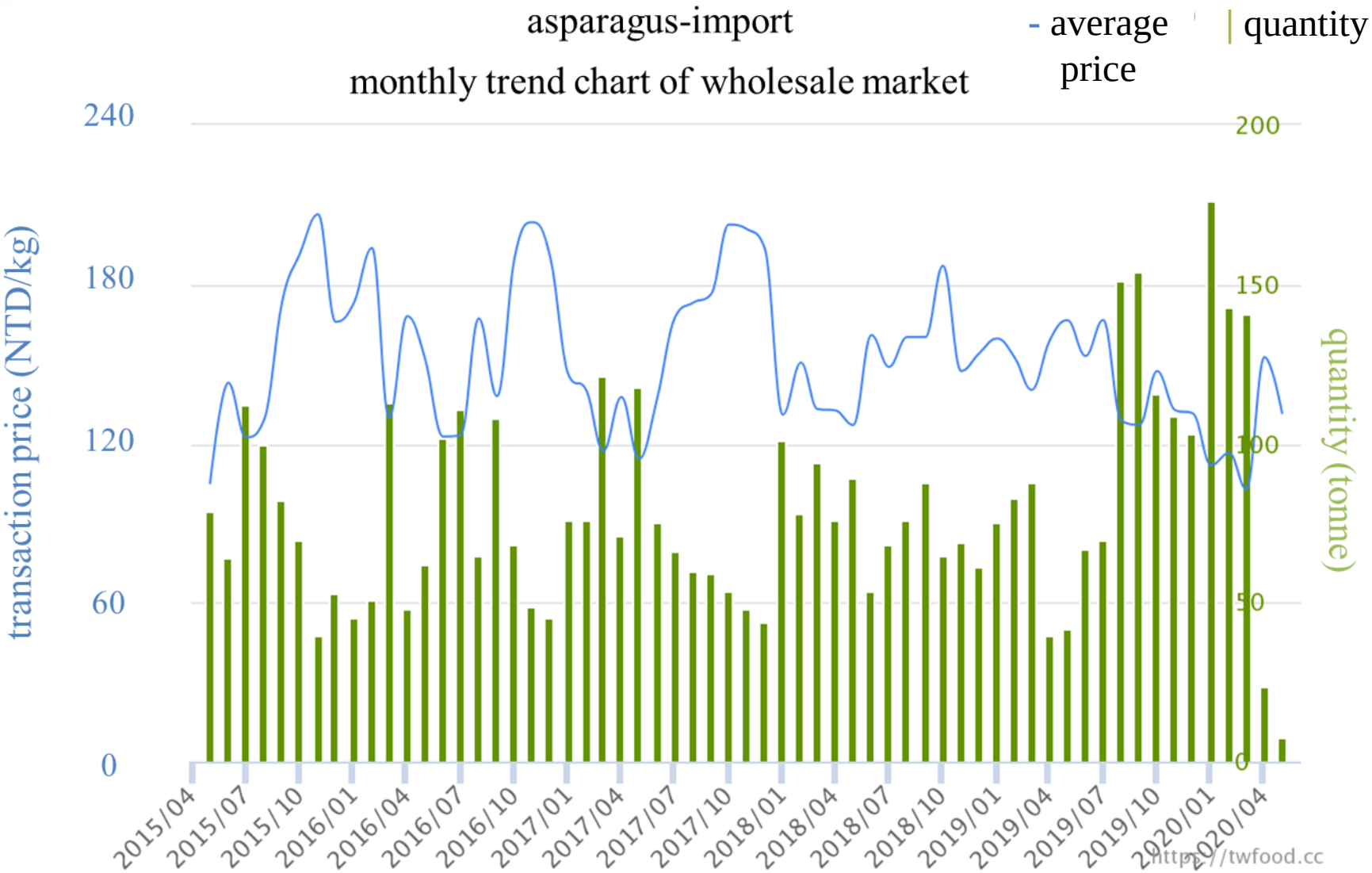
overpopulation

intelligent management system for the greenhouse

pest control

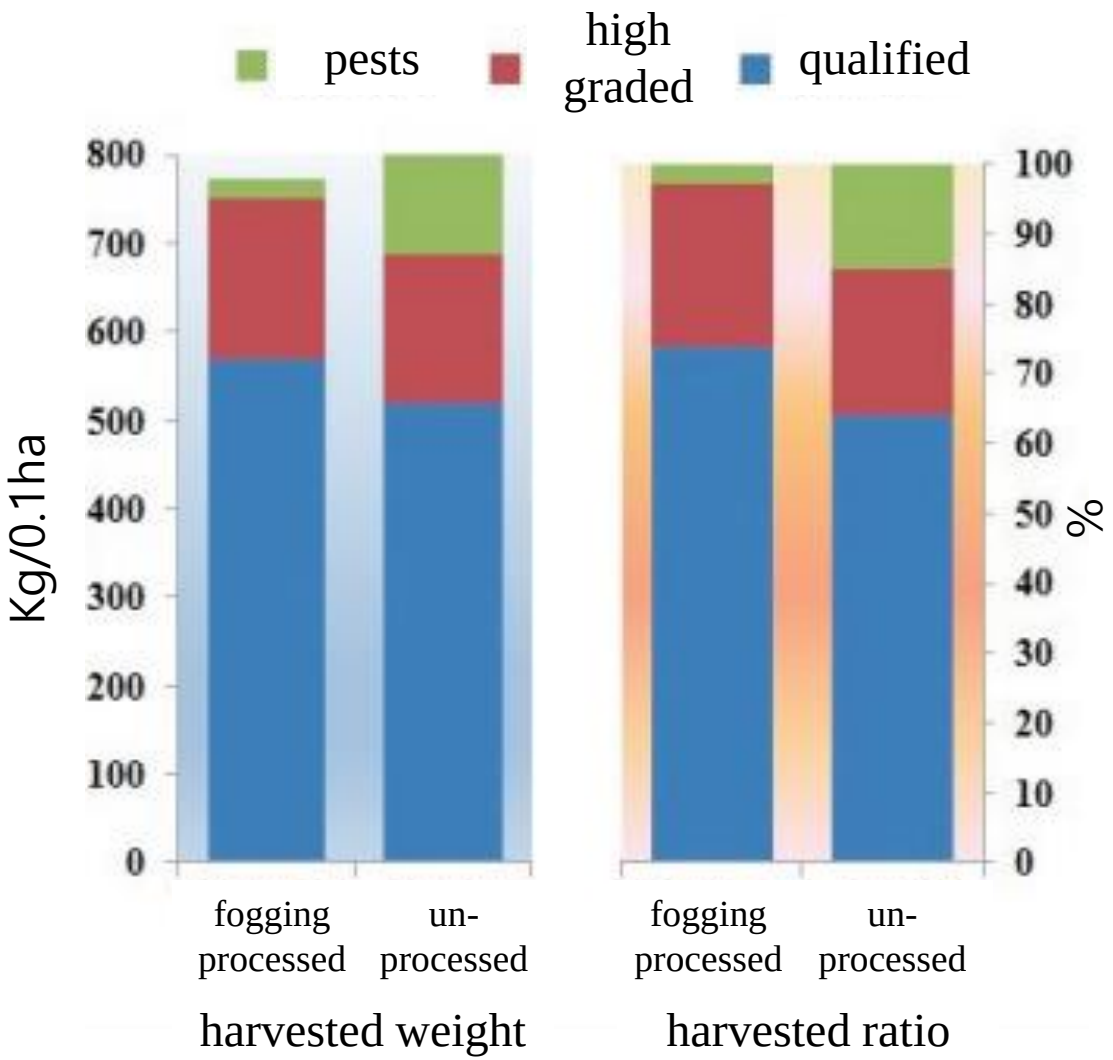
reduction of cultivated land

Why asparagus?



資料來源：當季好蔬果

Background



- economic loss caused by the pest (compared to the same period last year)
- limited by the spatial and temporal scale of data sources (installed widely)

What are the objects of this study?

- This study is a crop-based environmental research.
- Discussion object: pests in the greenhouse
- Pests are spatially heterogeneous and distributed throughout the world.

- Problem to be solved:
  - Develop an appropriate pest prevention method for crops to reduce the economic loss caused by the pest.

  - Pest trend prediction is an important method in pest control strategy, and it is also the basis of pest early warning system. It is limited by the spatial and temporal scale of data sources. Most of the research is medium and long-term prediction, and there are still insufficient representation problems. Therefore, this study focuses on Applications for short-term forecasting, such as automatic paper change timing, pest prevention method recommendations, etc.

Chapter 2

Literature

Literature

Author & Year	Insect trap	Classification hardware	Algorithm	Calculation time	Target insect	Accuracy
Lai, 2011	Attractant	Infrared/ camera	Image processing	3 min on average	Flies	80~90%
Silva *et al.*, 2013	Attractant	Laser sensor	SVM RBF	Real-time	4 species of mosquitoes 3 species of flies	Best accuracy: 87.33%
Li, 2016	Sticky paper	camera	SVM	N/A	Whitefly/ thrips	83.7/ 89.3%
Yeh, 2016	Rotary sticky paper	camera	Image processing	N/A	Gnat	†95.09%
Rustia *et al.*, 2019	Sticky paper	camera	Tiny YOLO v3	22 min	Fly/ gnat/ mothfly/ thrips/ whitefly	Average F_1-score: 0.926

†The accuracy is focus on gnat which is bigger than whitefly. Furthermore, the deployment of sticky paper is not proper.

Literature

- Asparagus
  - Perennial herb
- Growth environment
  - Seed germination: 25-30 °C
  - Vegetative growth: 20-30 °C
  - Grow slowly below 15°C
  - The shoot tip spreads above 30 °C
  - Stop growing above 35 °C
  - Not resistant to high temperature and humidity
- Light-loving crop
  - Strong light → Lush branches (photosynthesis is closely related to temperature)
- Deep-rooted crop
  - Soil moisture: around 50%
- White asparagus: harvested before protruding from the ground
- Green/ purple asparagus : irradiated by sunlight after protruding from the ground
- Green asparagus (King of vegetables) :valuable high-grade vegetable and health food
- Challenge in Taiwan
  - Dependent on import

Literature

- What Is Integrated Pest Management (IPM)?
  - an ecosystem-based strategy
  - a long-term prevention of pests or their damage
  - a combination of techniques

  - Biological control is the use of natural enemies.
  - Cultural controls are practices that reduce pest establishment, reproduction, dispersal, and survival.
  - Mechanical and physical controls kill a pest directly, block pests out, or make the environment unsuitable for it.
  - Chemical control is the use of pesticides. In IPM, pesticides are used only when needed and in combination with other approaches for more effective, long-term control.

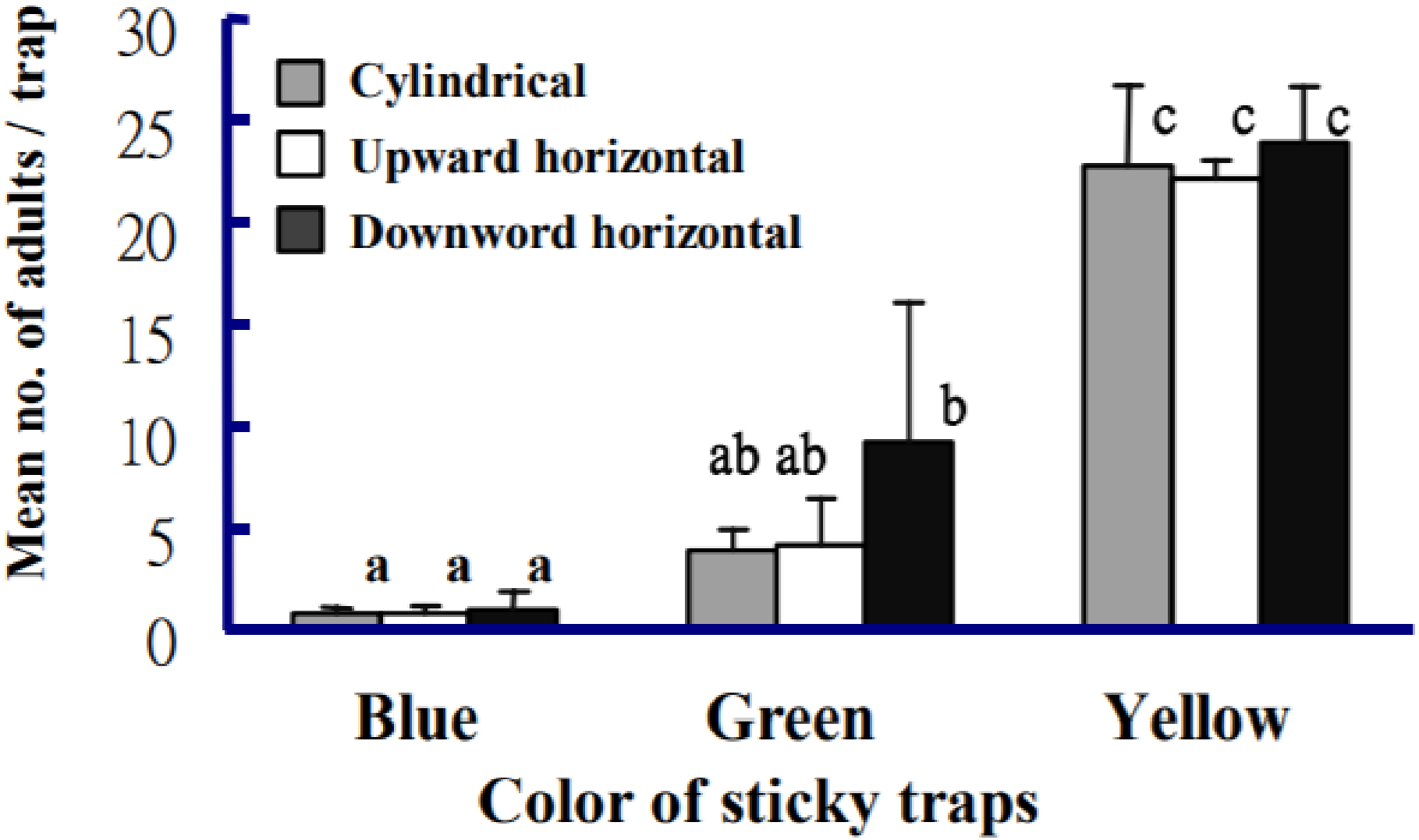
Literature

- IPM Programs
  - Pest identification
  - Monitoring and assessing pest numbers and damage
  - Guidelines for when management action is needed
  - Preventing pest problems
  - Using a combination of biological, cultural, physical/mechanical and chemical management tools
  - After action is taken, assessing the effect of pest management
- Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment.

Literature

English name	Silverleaf whitefly	Oriental fruit fly	Flower thrips
Scientific name	*Bemisia argentifolii*	*Bactrocera dorsalis*	*Frankliniella intonsa*
Body length	0.8-1.3 mm	5-6mm	female:1.3-1.7 mm male:1-1.2 mm
Trapping color	500~600nm (yellow)		around 500nm (blue)
High-risk site	leaf	fruit	young and mother stems
Influences	Sooty mold of litchi	none	bending tip and browning scale
Prevention methods	sticky paper/ water tray	sticky paper/ male annihilation	sticky paper
Control strategy	spray water	spray insecticidal baits	ultrasonic fogging
Height of sticky paper	close to the top of the crop		20 cm below the crop
Active environment	poor ventilation/ dry and high temperature	warm	dry and warm/ cloudy day and before sunrise
Peak period	late spring and early autumn	none	spring and autumn(25℃)
Change paper	7-10 days		7-21 days

The attractiveness of whitefly to different colors



資料來源：行政院農業委員會

YUV color space conversion

YUV (Y: Luminance, U: Chrominance, V: Chroma)

Y = 0.3 * R + 0.59 * G + 0.11 * B

U = 0.493 (B – Y)

V = 0.877 (R – Y)

Where R is red, G is green, and B is blue

Do X-axis and Y-axis operations on the input image first (Prewitt edge)

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

Then put the calculated G_x and G_y into

$$G = \sqrt{{G_x}^2 + {G_y}^2}$$

Then take the YUV values of the individual areas as features, the Euclidean distance formula is as follow

$$\mathrm{D} = \sqrt{{E_Y}^2 + (0.5E_U)^2 + (0.5E_V)^2}$$

Morphological processing

A is eroded by B is defined as

$$A \Theta B = \{z | (B)_z \subseteq A\}$$

The definition of A expands through B is as follow

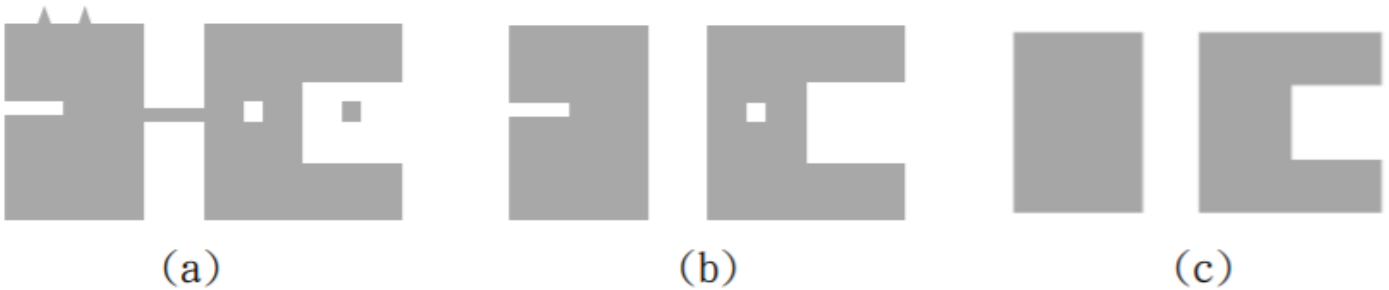
$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \varnothing\}$$

Opening is the dilation of the erosion of a set A by a structuring element B:

$$A \circ B = (A \Theta B) \oplus B$$

Closing is the erosion of the dilation of a set A by a structuring element B:

$$A \bullet B = (A \oplus B) \Theta B$$



(a) original image (b) the result of opening (c) the result of closing

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Author & Year	Insect trap	Classification hardware	Algorithm	Calculation time	Target insect	Accuracy
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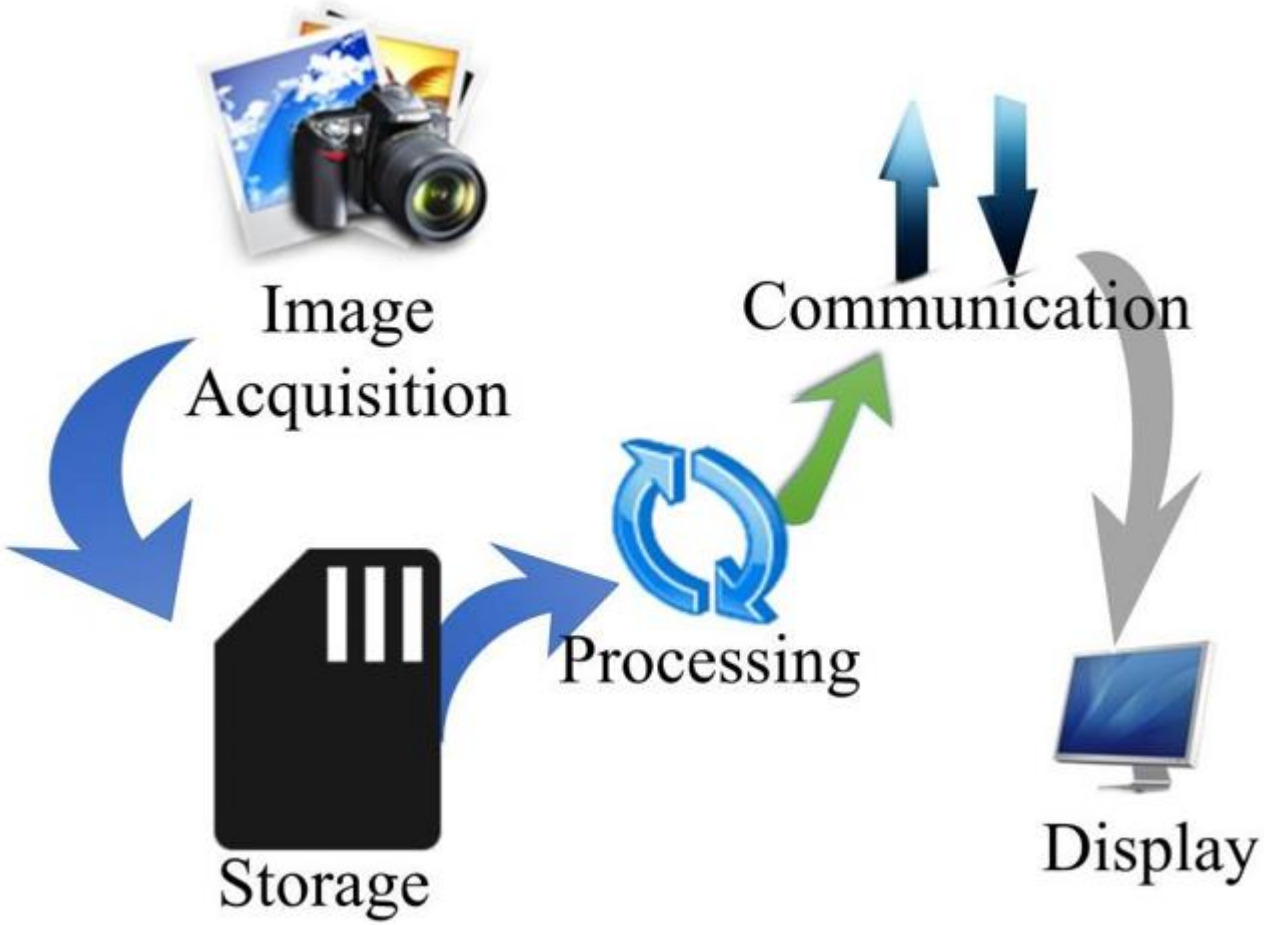
Rustia *et al.*, 2019	Sticky paper	camera	Tiny YOLO v3	22 min	Fly/ gnat/ mothfly/ thrips/ whitefly	Average F_1-score: 0.926
This study, 2020	Rotary sticky paper	camera	Image processing	25.78 sec	Whitefly/ fly	92.81%

Chapter 3

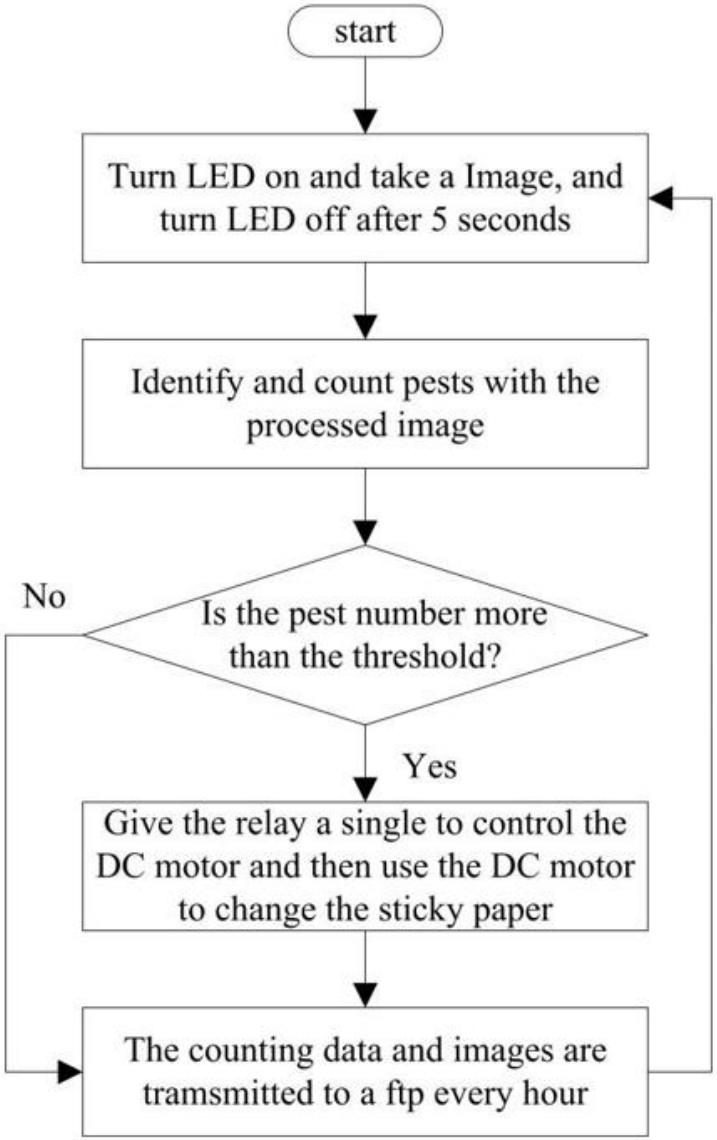
Method

The basic of digital image processing technology

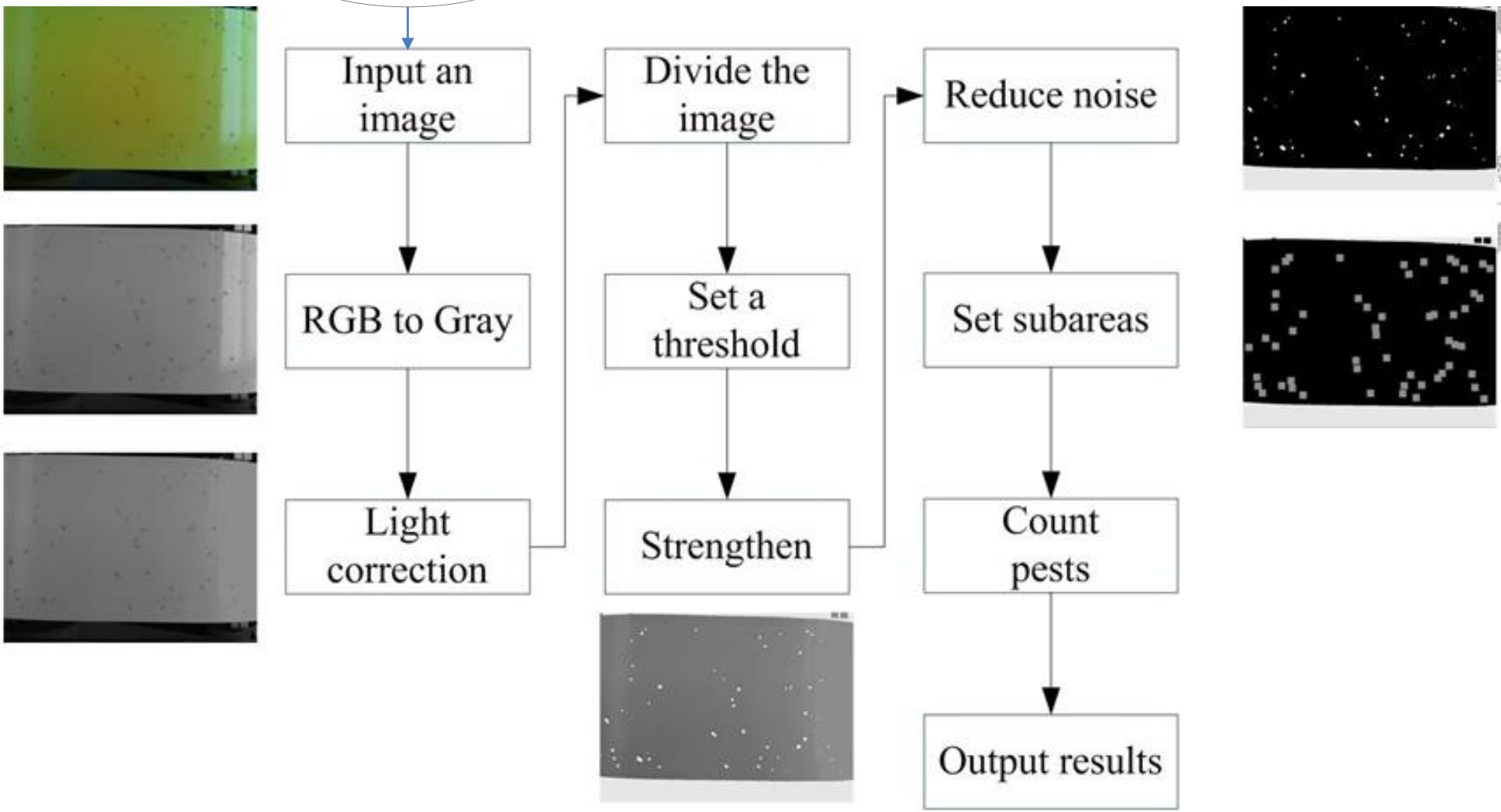


System architecture

The flowchart of the pest population monitoring mechanism



The flowchart for the pest monitoring algorithms

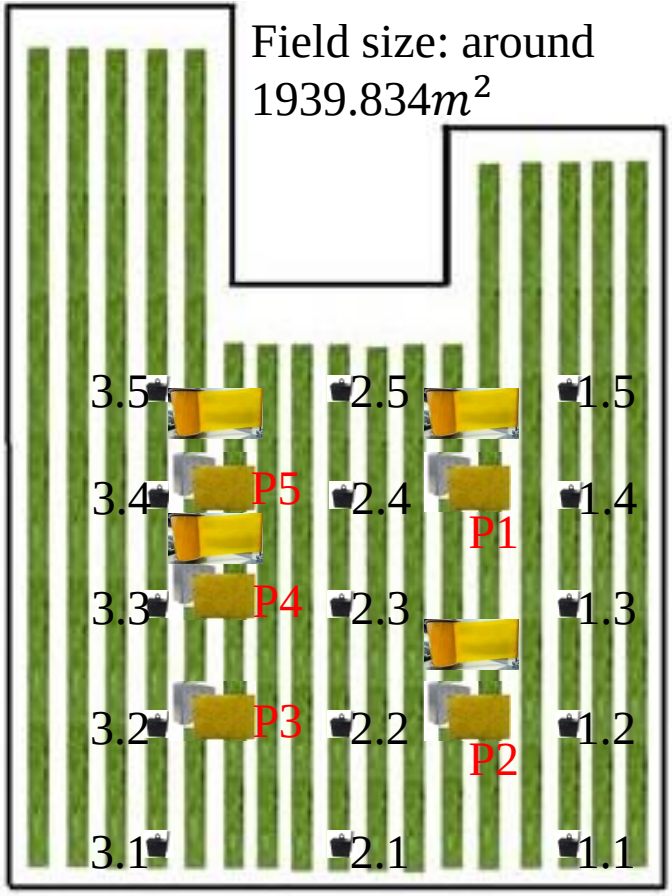


Chapter 4

Results

The deployment locations

Asparagus Greenhouse in Jiangjun District of Tainan City belongs to Joe-Ying Huang

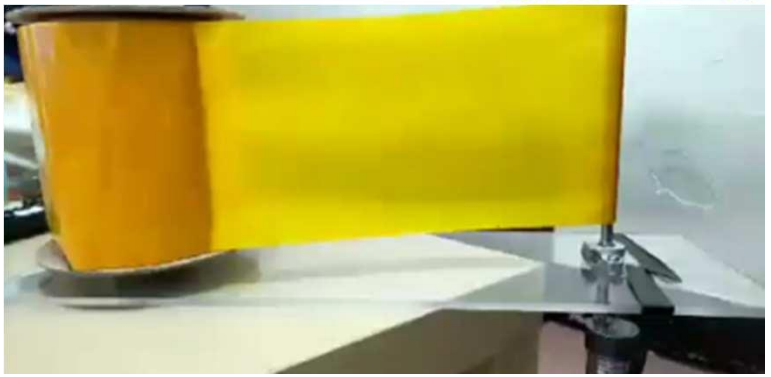


Cooperative experts: Dr. Ming-Hsien Hsieh and Research Assistant Ming-Chi Kuo at Yichu Work Station, Tainan District Agricultural Research and Extension Station, COA.

Pest monitoring device

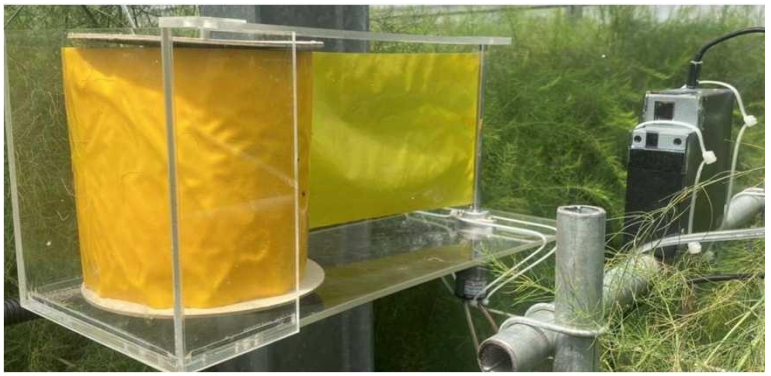
- First version

Since it is often necessary to ask the farmer to help replace the sticky paper, the farmer also reacted to the trouble of replacing the sticky insect paper. Therefore, the first version of the pest monitoring device was developed to solve the need for people to change the sticky paper.



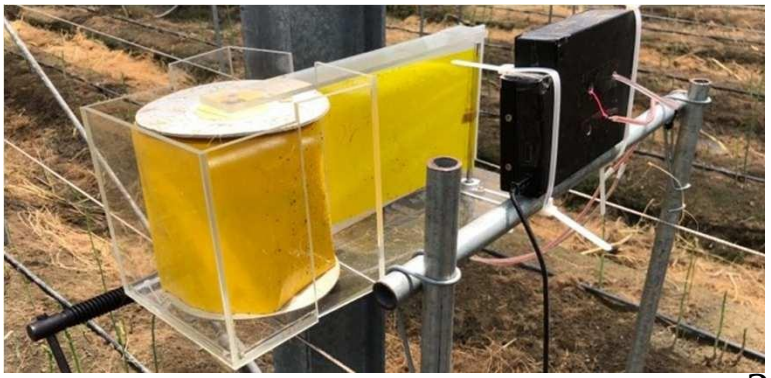
- Second version

Add an acrylic board next to the sticky paper.

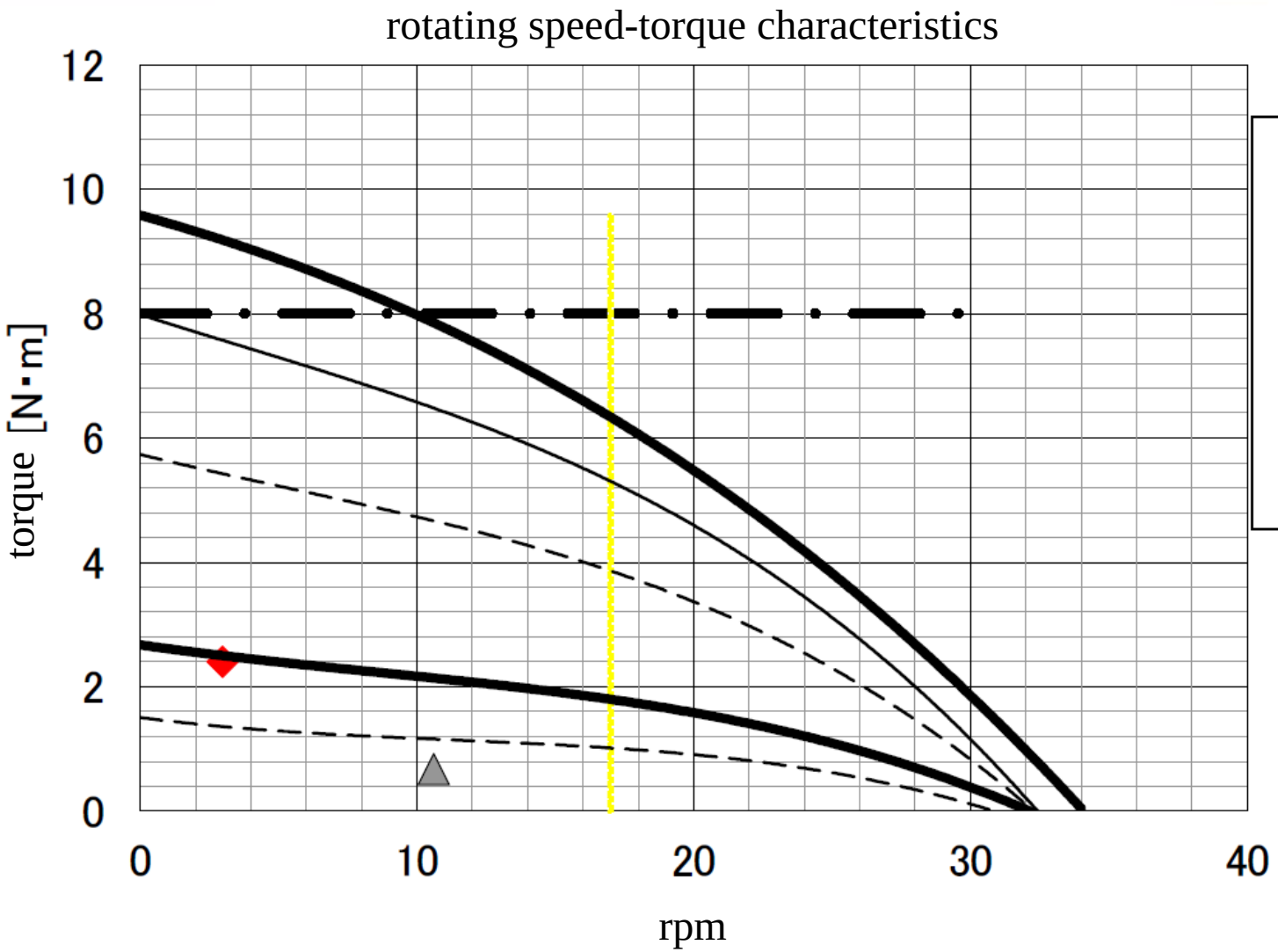


- Current version

Installing an acrylic sheet around the sticky paper roll.



Motor analysis



If it is not in the curve, it will not be able to drive, even when the allowable torque is exceeded.

Motor analysis

Tension F:	**30.0[N]**
Rotating speed V:	**1.5[m/min]**
D_{min}	**45[mm]**
W_{min}	**2[kg]**
D_{max}	**160[mm]**
W_{max}	**2.0[kg]**
Other inertia J_e:	**0.0001[kg*m^2]**
External reduction ratio I:	**1**
External reduction ratio efficiency η:	**1**
voltage	**AC110V**
frequency	**60Hz**
output	**10W**
reduction ratio i:	**50**
Torque setting voltage	**DC1.7V**

When the diameter is min

necessary torque $T = F*(D_{min}/1000)/(2*I*\eta) = 0.68$ [N*m]

rotating speed $N = V*I/(\pi* D_{min}/1000) =$ 10.6 [rpm]

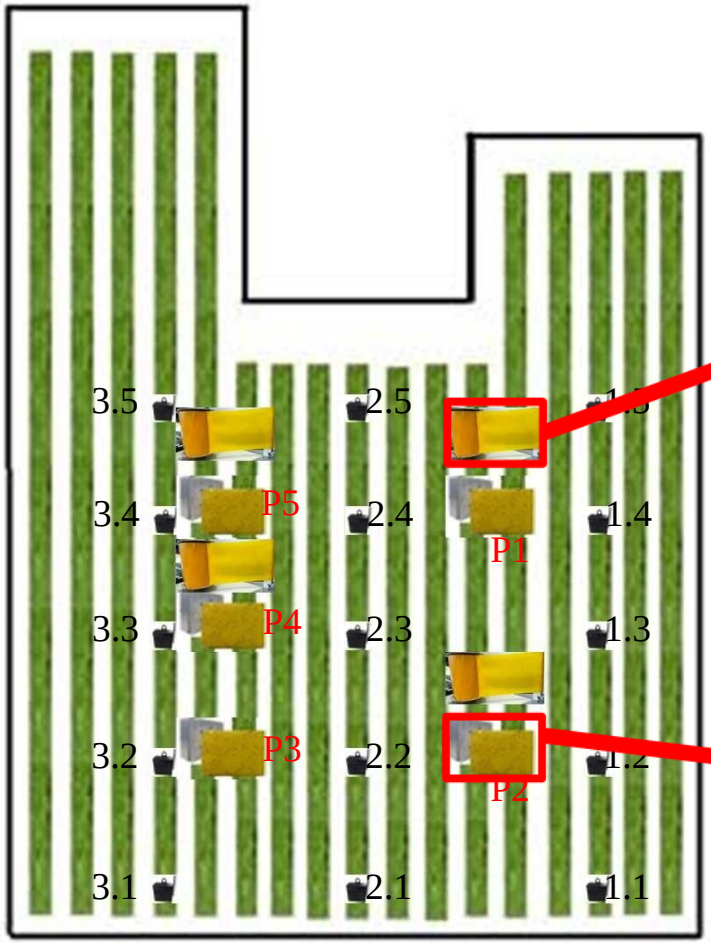
When the diameter is max

necessary torque $T = F*(D_{max}/1000)/(2*I*\eta) = 2.4$ [N*m]

rotating speed $N = V*I/(\pi* D_{max}/1000) =$ 3.0 [rpm]

Pest monitoring device based on IoT

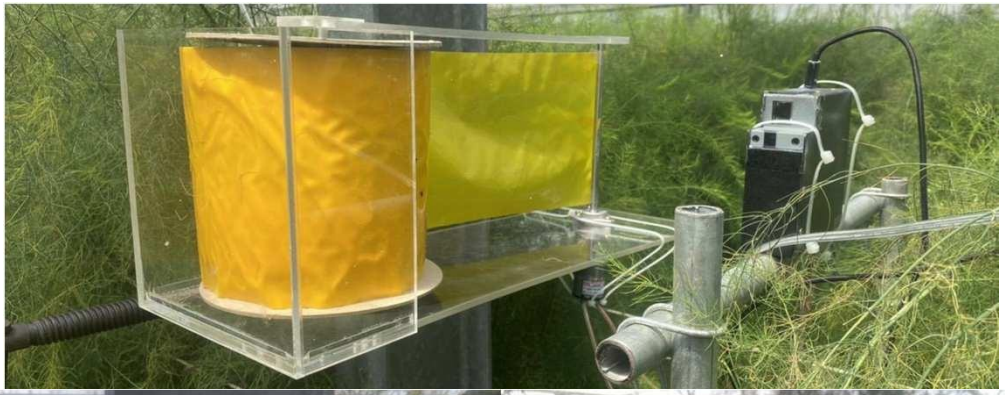
The main pests of asparagus are whiteflies and thrips.



2020.05.18 Complete the construction of new pest monitoring system

2019.06.25 Complete the construction of pest monitoring system

Pest monitoring device based on IoT



2020.7.23 A total of 218,005 pest images have been collected.

2020.7.23 A total of 14,762 pest images have been collected.

2020.7.23 A total of 5,339 pest images have been collected.

Pest identification

- Pest types: whitefly / drosophila / large insect

Distinguishing method: Distinguish pest types by pixel size

- Assisted identification technology:

Whitefly → High boost filter for feature highlighting (edge enhancement, sharpening features)

Drosophila → morphological erosion treatment

Identification process

Image pre-processing: grayscale → remove background

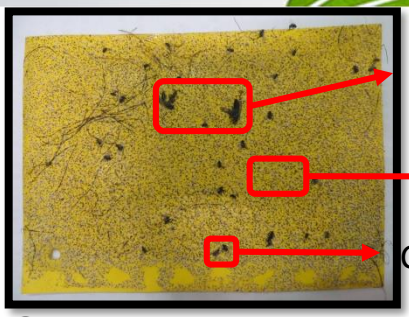
- Local dichotomy: cut the photo into 15 * 15 sub-images
- Area judgment (length): length filters branches and leaves

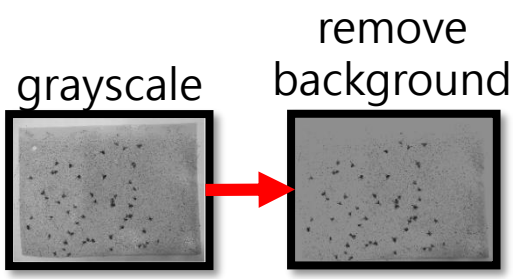
Whitefly <150 (pixel)

150 < drosophila <1000 (pixel)

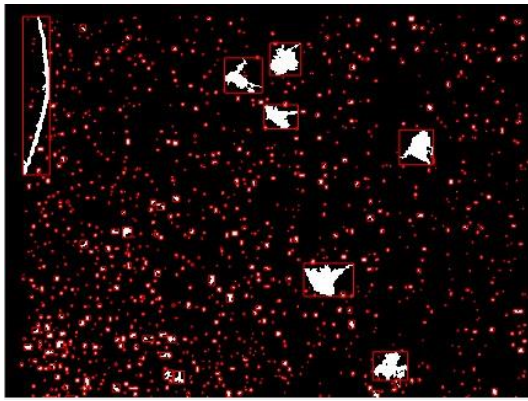
Large insect > 1500 (pixel)

Morphological treatment: eroding independent individuals

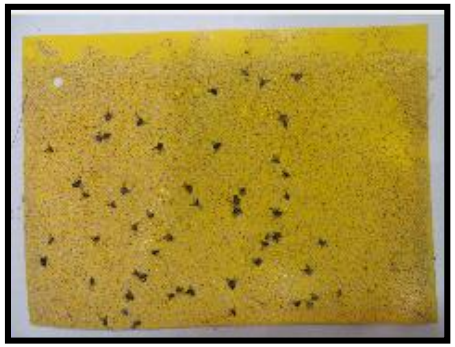


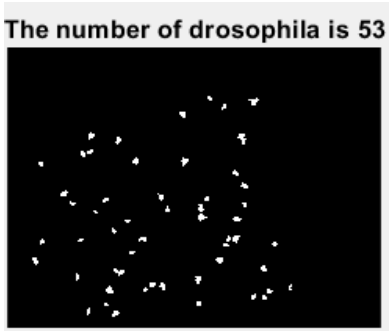


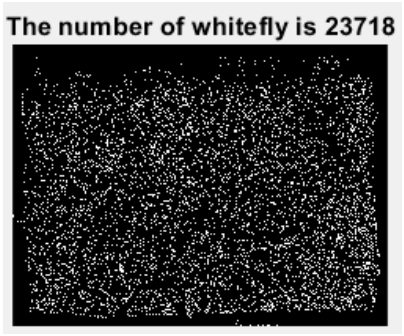
Outline selection (area judgement)

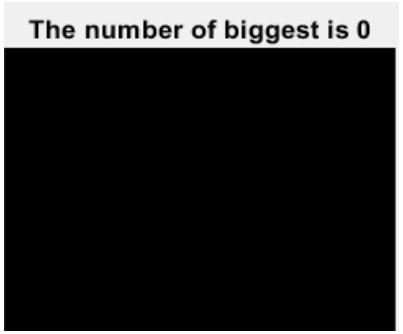


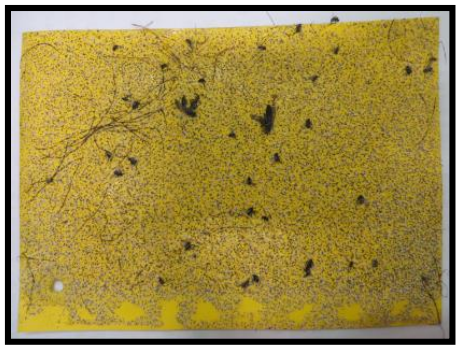
Pest identification

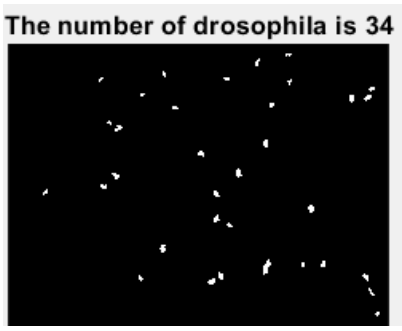


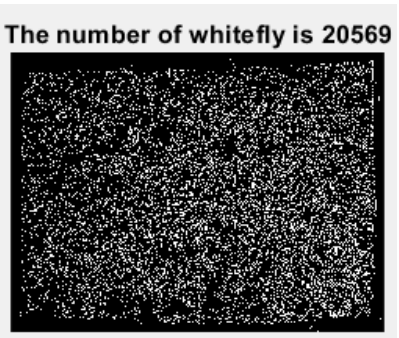


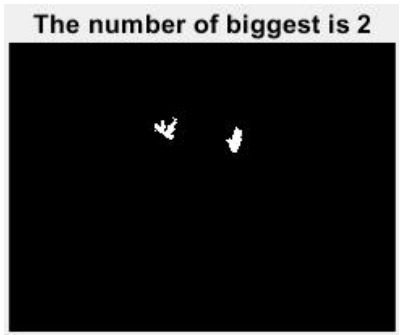


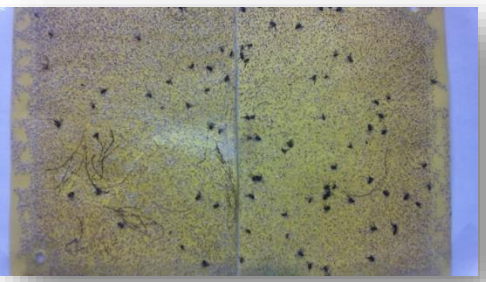


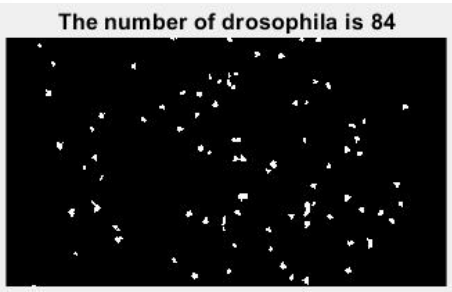


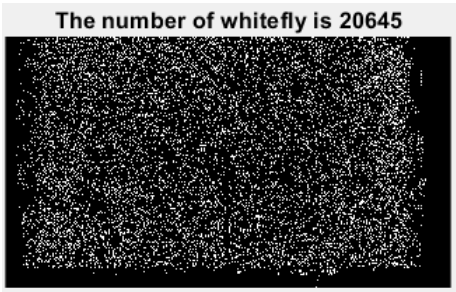






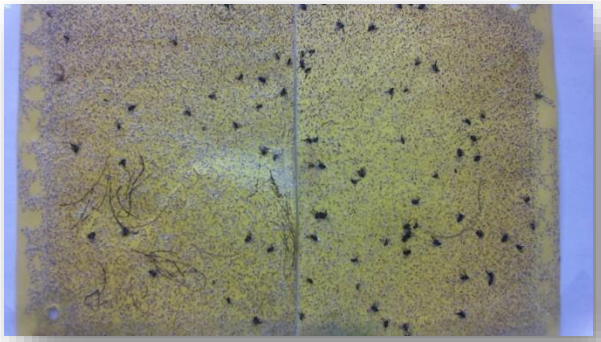






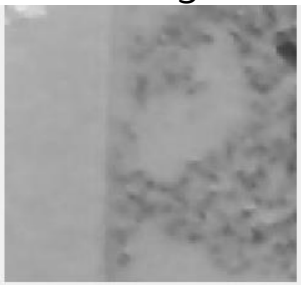
Validation

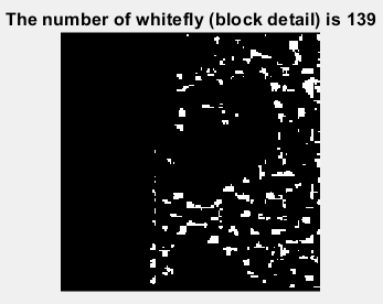
Original image



Validation: 129
Average error rate: 7.19%

Sub-image

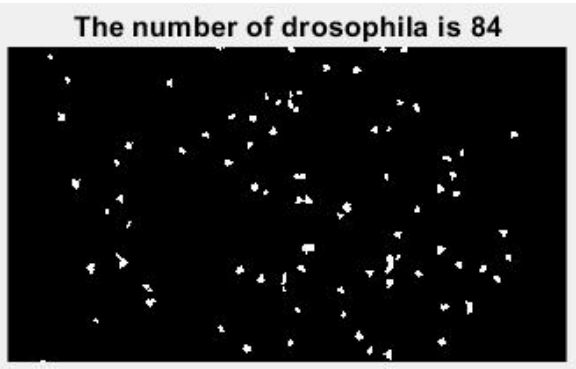




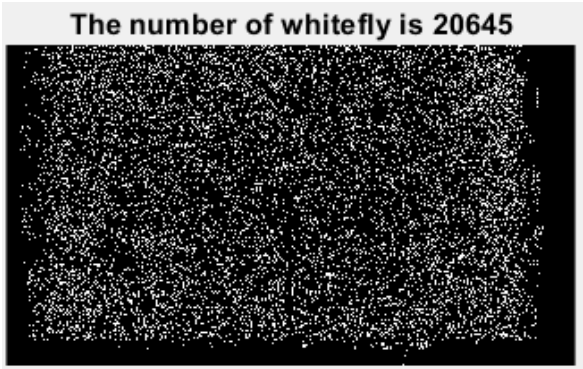
Pest count

input

output

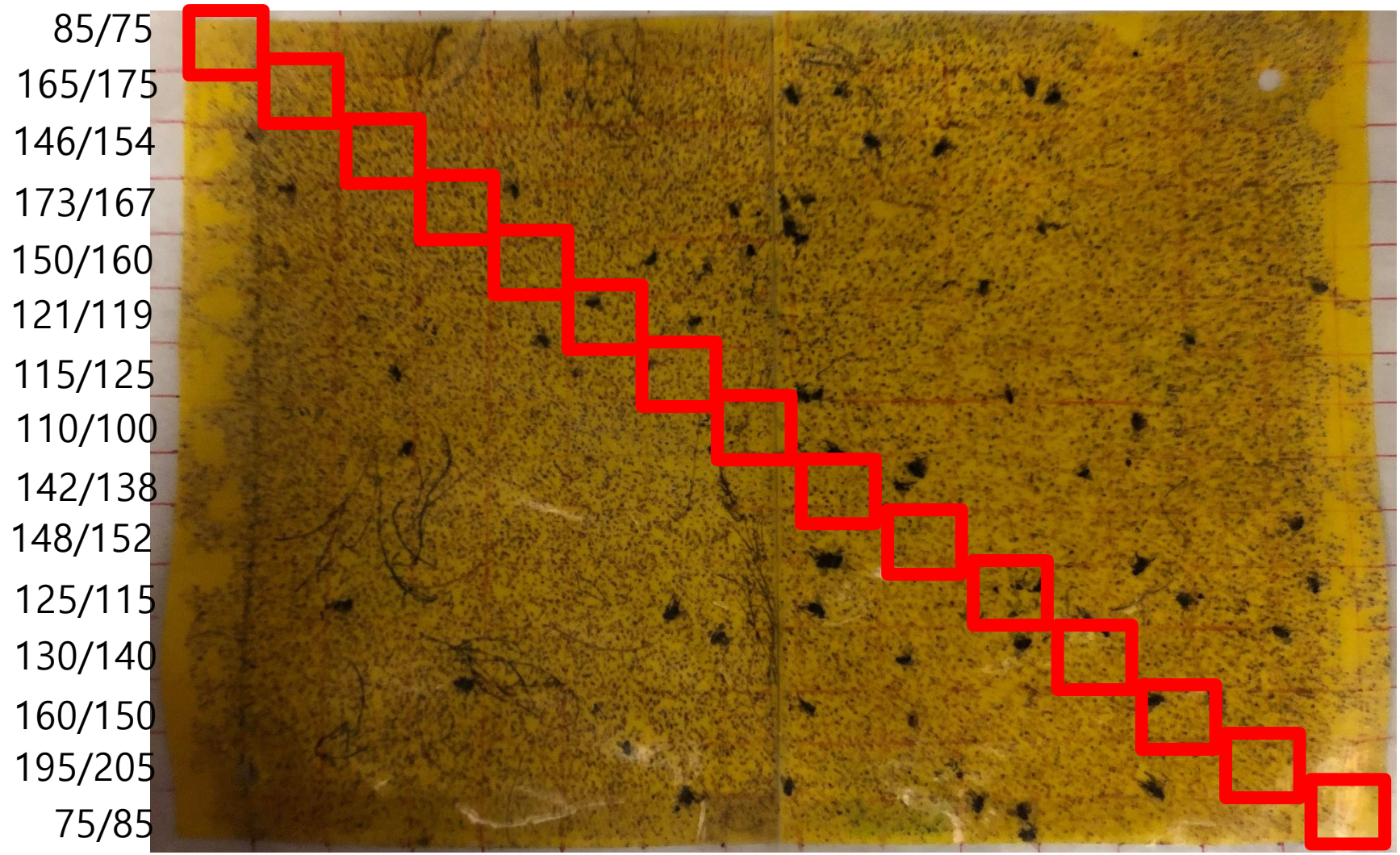


Validation: 87
Error rate: 3.45%



Validation: 18999
Error rate: 8.66%

Validation

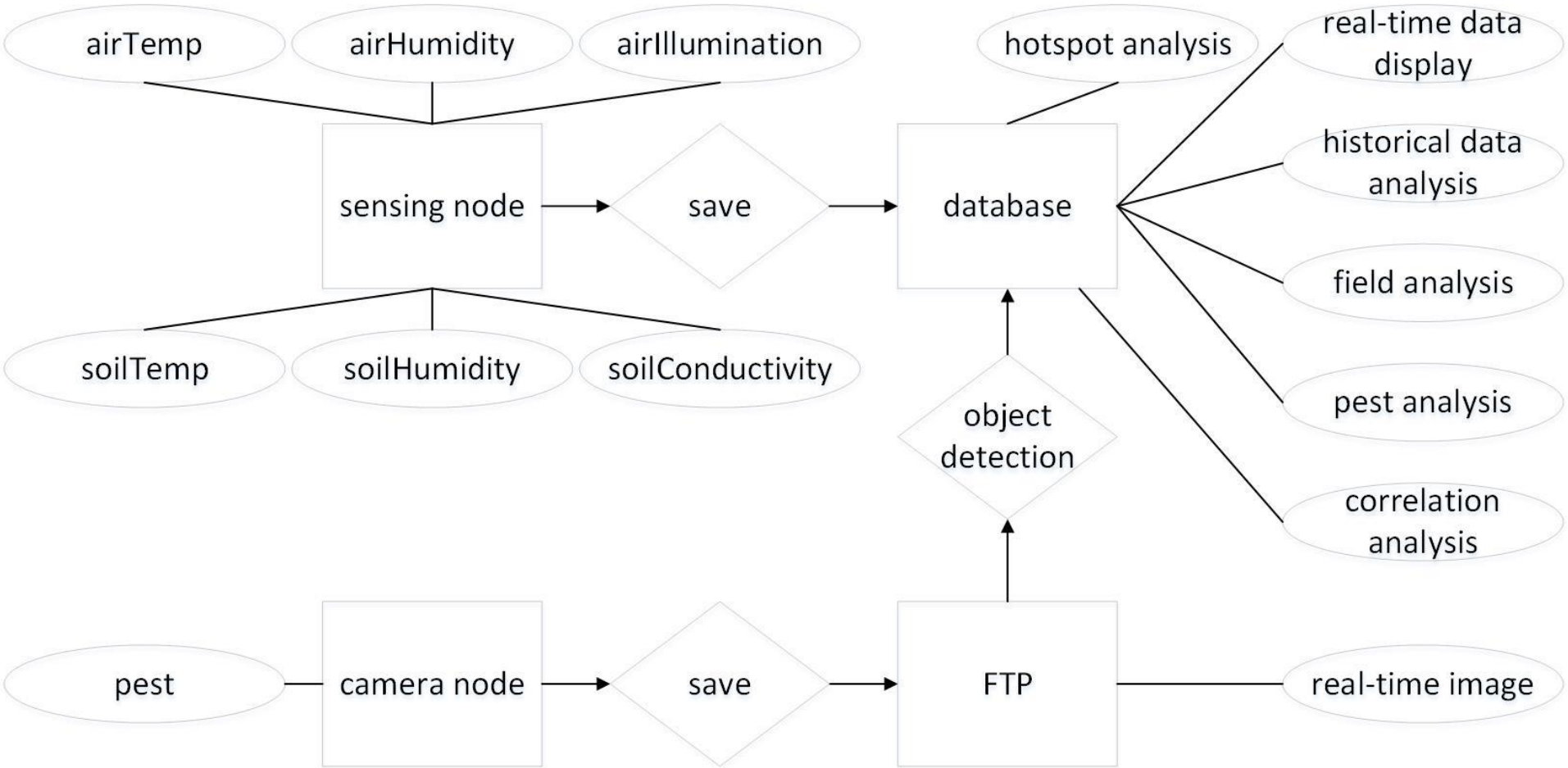

85/75
165/175
146/154
173/167
150/160
121/119
115/125
110/100
142/138
148/152
125/115
130/140
160/150
195/205
75/85

Validation

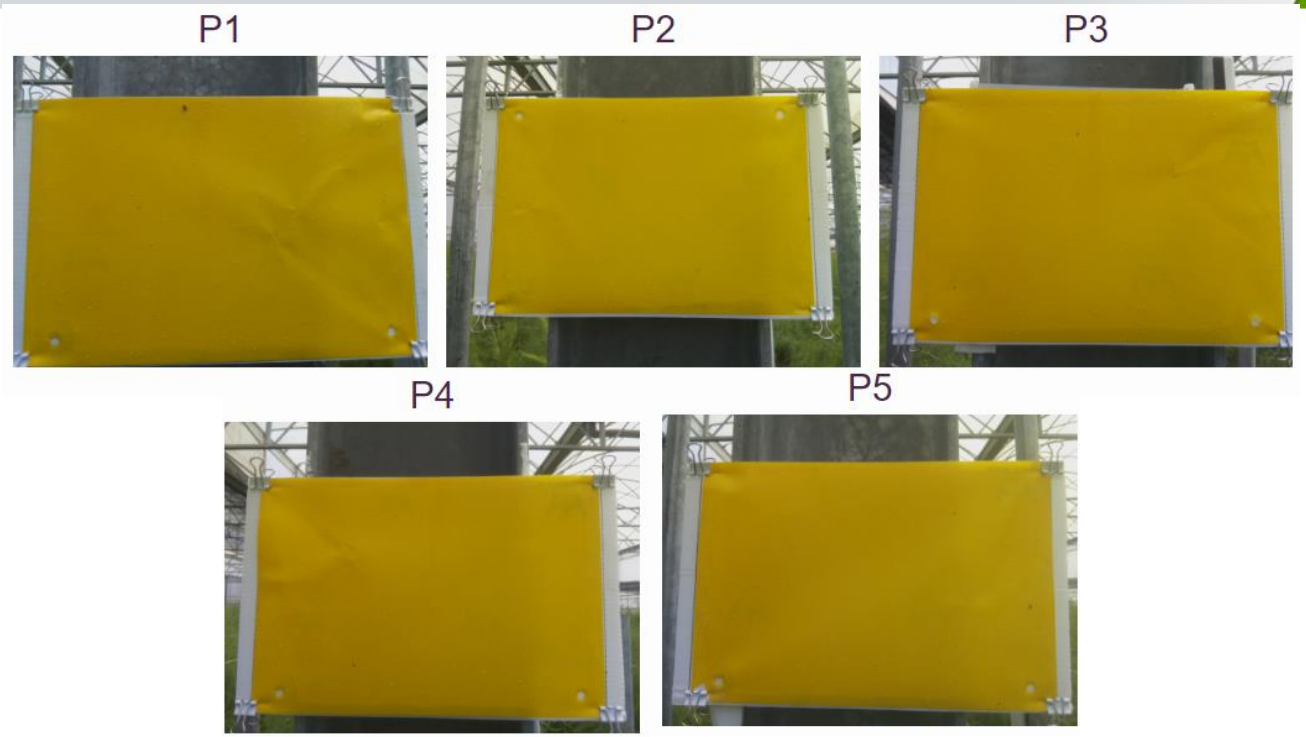
	(1,1)	(2,2)	(3,3)	(4,4)	(5,5)	(6,6)	(7,7)	(8,8)	(9,9)	(10,10)	(11,11)	(12,12)	(13,13)	(14,14)	(15,15)
N_c	87	165	146	173	150	121	115	110	142	148	125	130	160	195	75
N_p	75	175	154	167	160	119	125	100	138	152	115	140	150	205	85
E_r	16%	5.7%	5.2%	3.6%	6.3%	1.7%	8%	10%	2.9%	2.6%	8.7%	7.1%	6.7%	4.9%	11.76%

The average error rate above is 5.68%.
The total average error rate is 7.19%.
The total average accuracy is 92.81%.

Entity-relation diagram

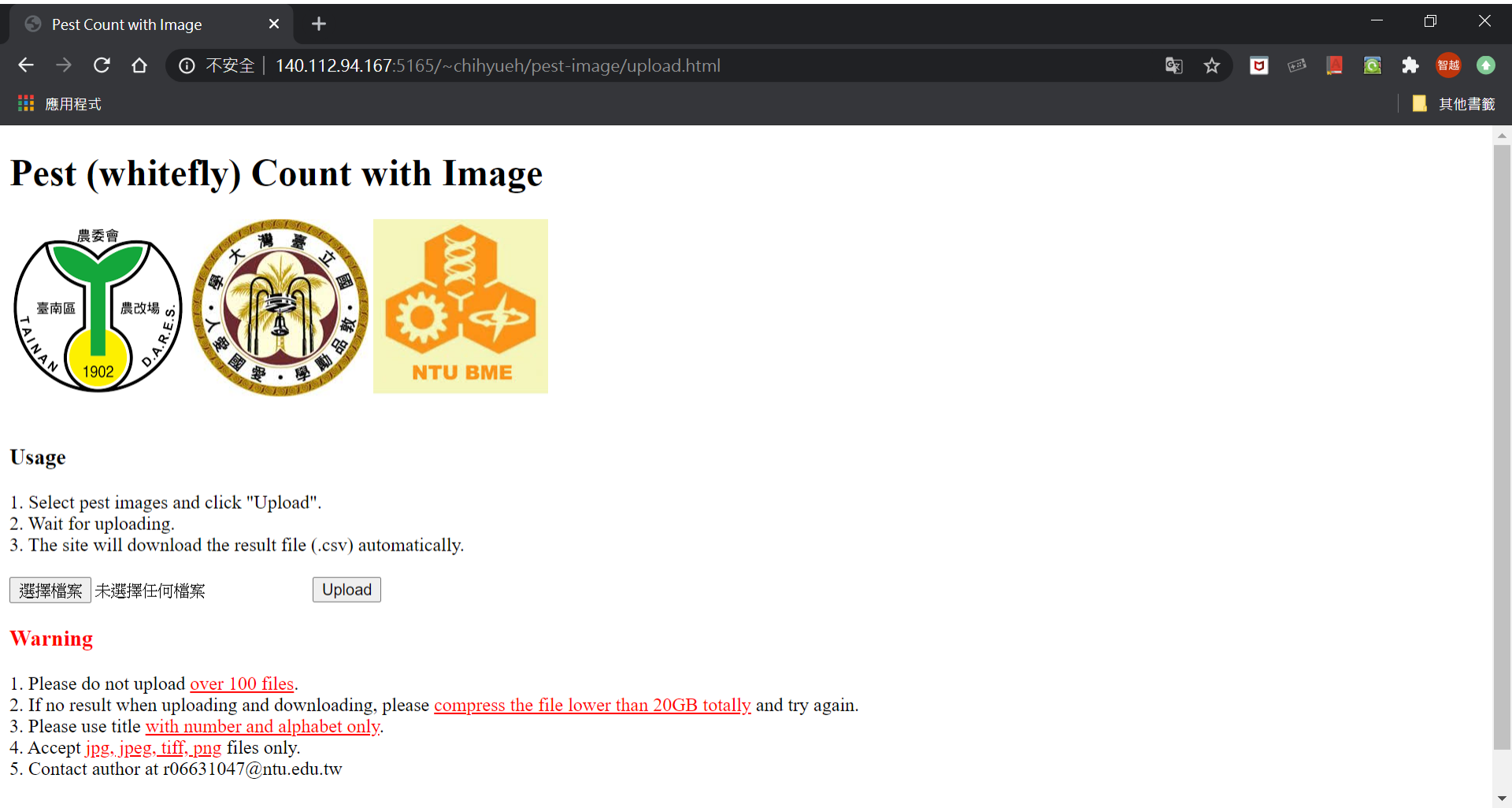


Real-time pest monitoring

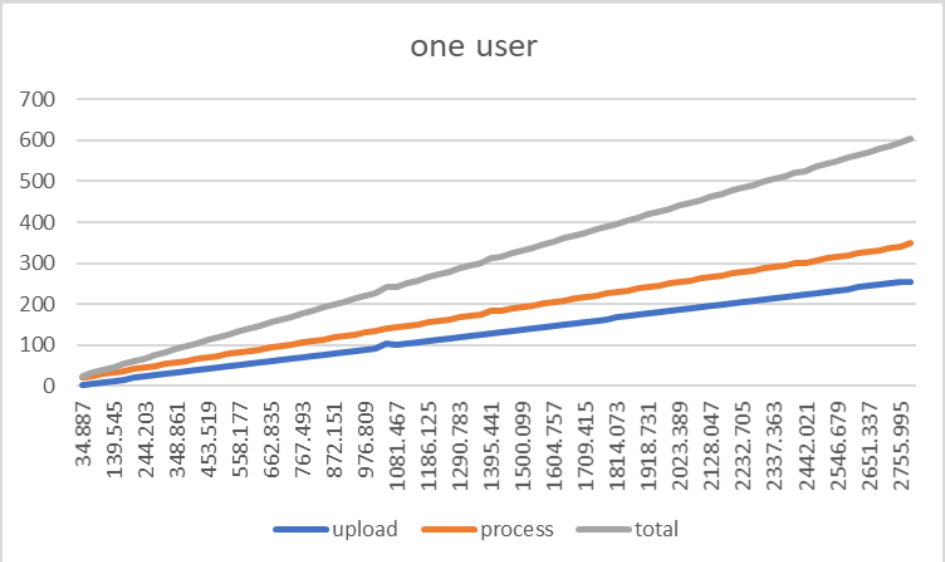


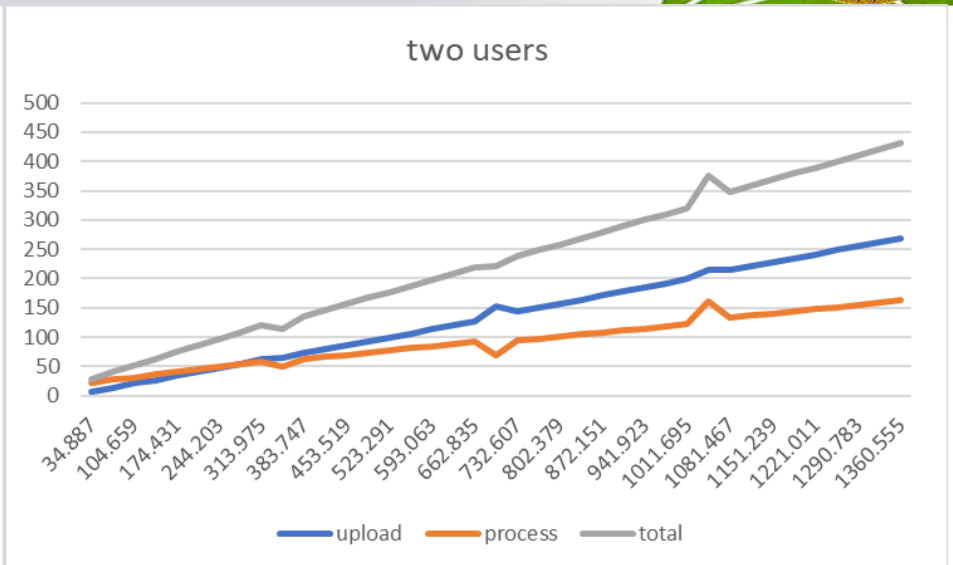
Location	Time	Silverleaf whitefly	Spodoptera litura	Phoridae	Others
P1	2020-05-30 18:30:00	10117	0	306	2
P2	2020-05-30 18:35:00	8398	0	263	1
P3	2020-05-30 17:30:00	9609	0	312	0
P4	2020-05-30 19:00:00	8318	0	2	0
P5	2020-05-30 18:55:00	2158	0	60	0

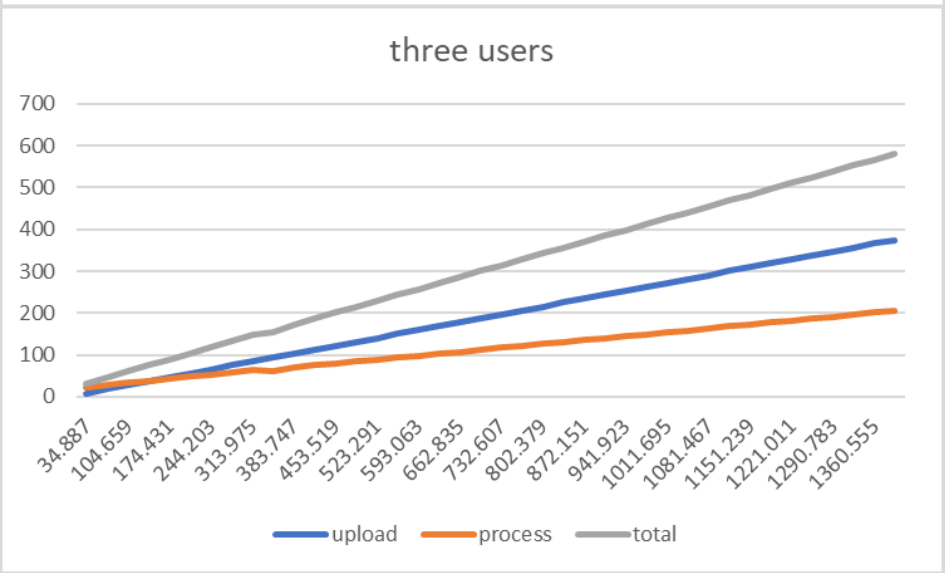
Web for pest count with image

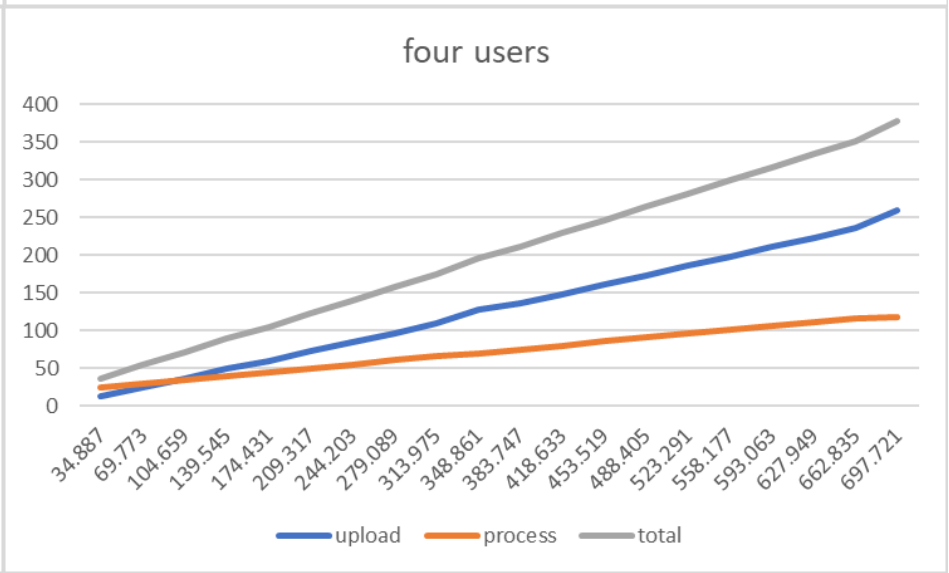


Loading test

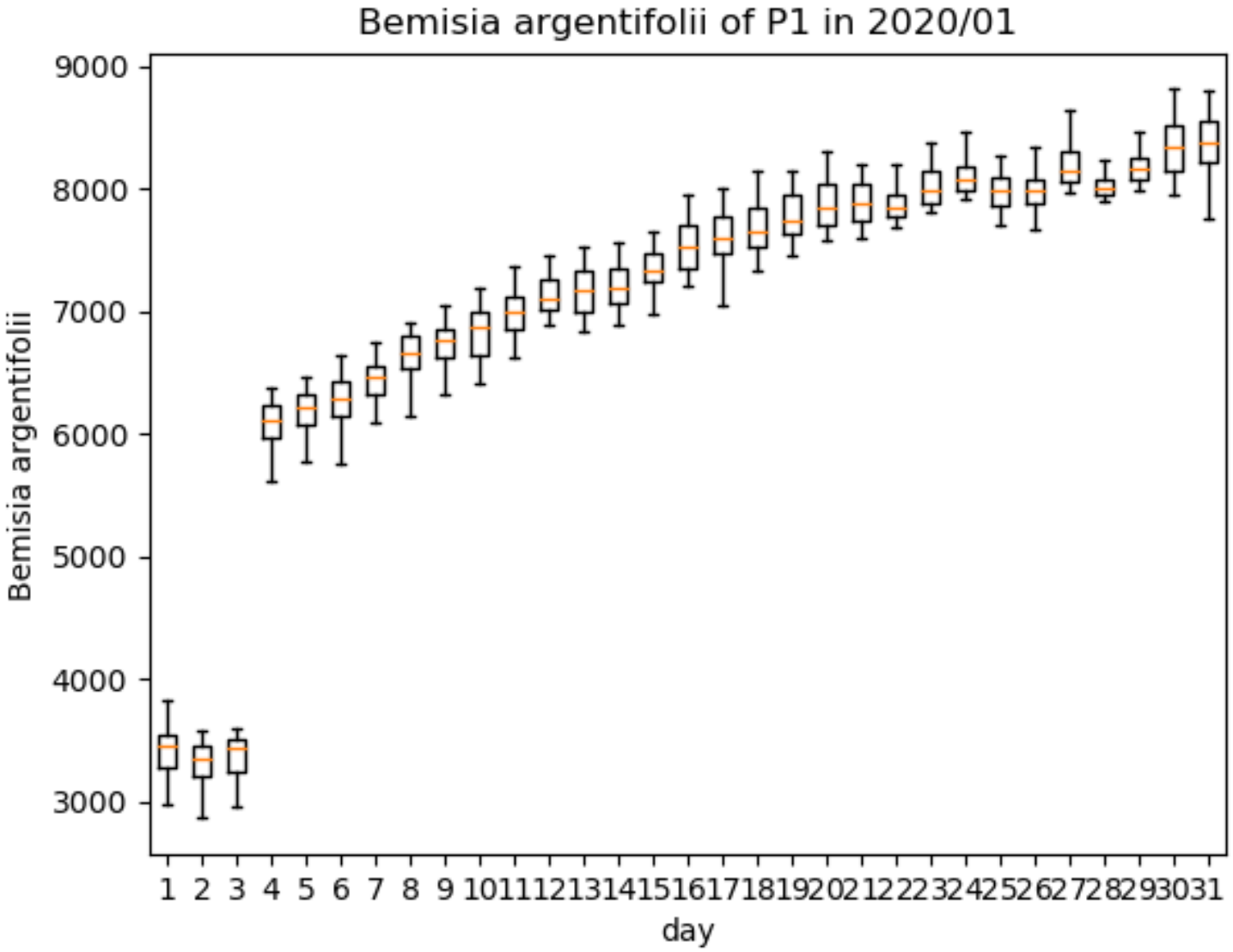




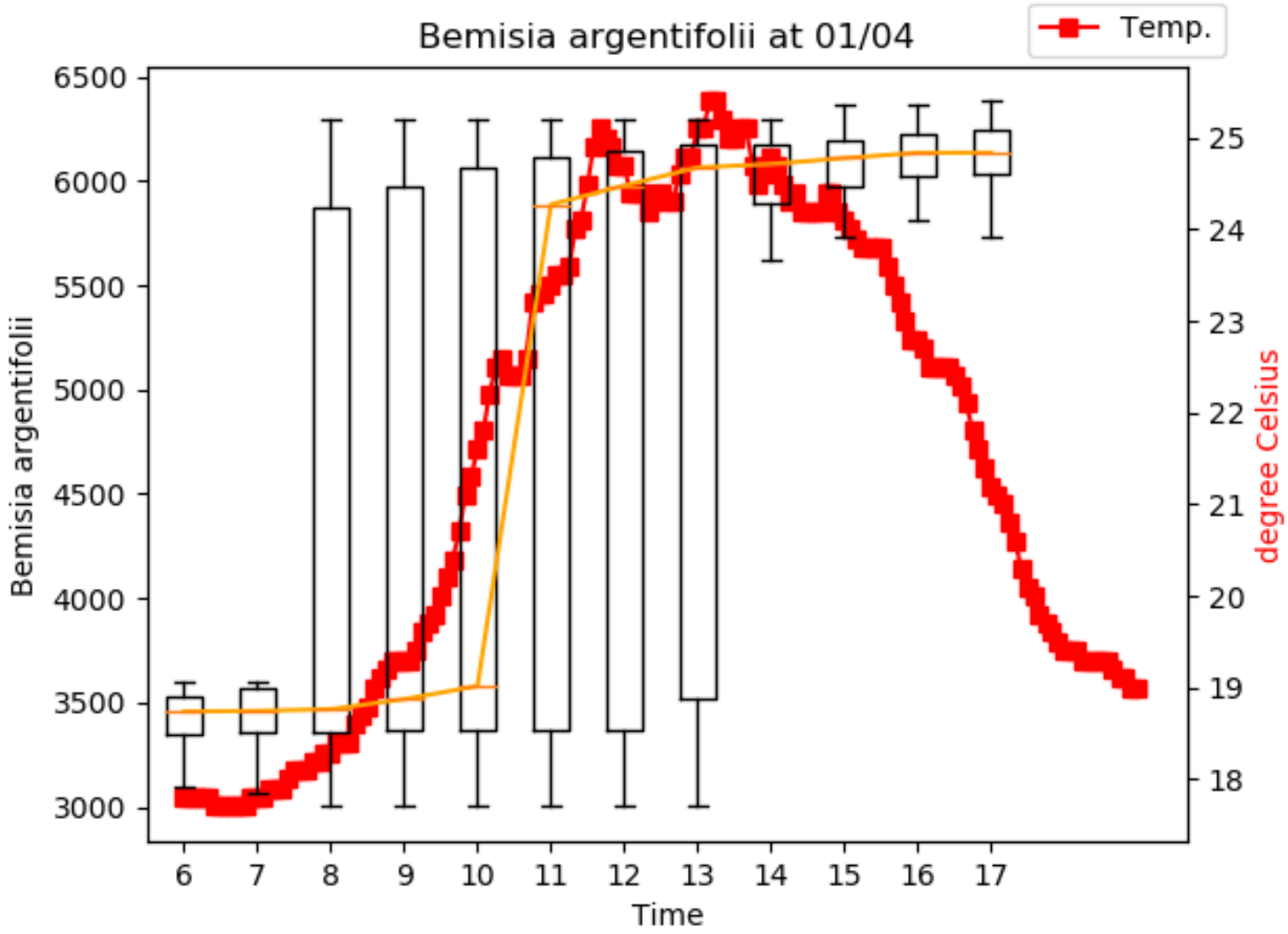




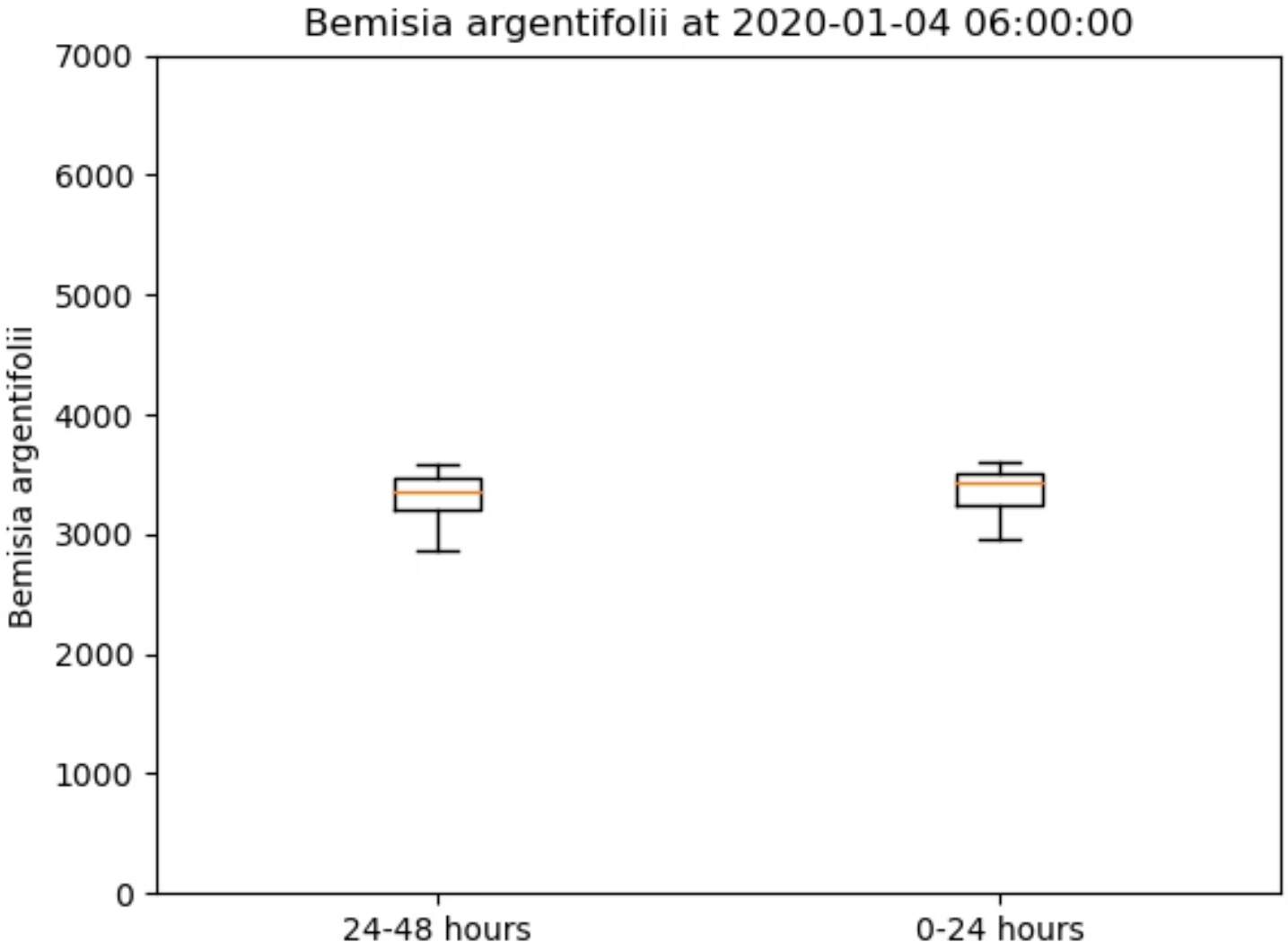
Boxplot


Bemisia argentifolii of P1 in 2020/01
Bemisia argentifolii
9000
8000
7000
6000
5000
4000
3000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
day

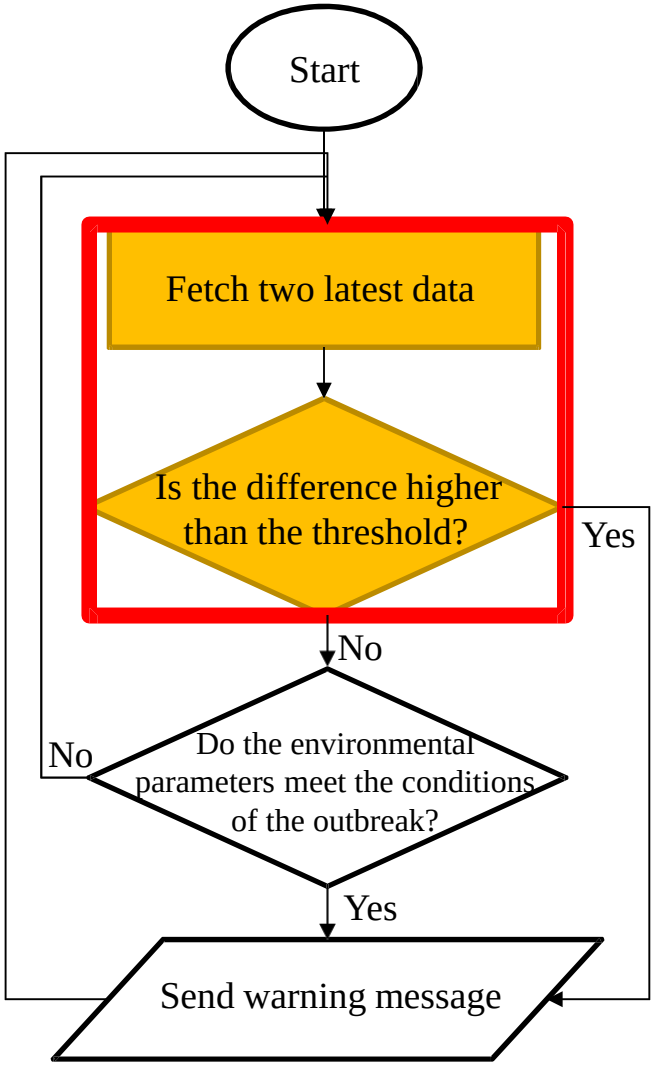
Boxplot

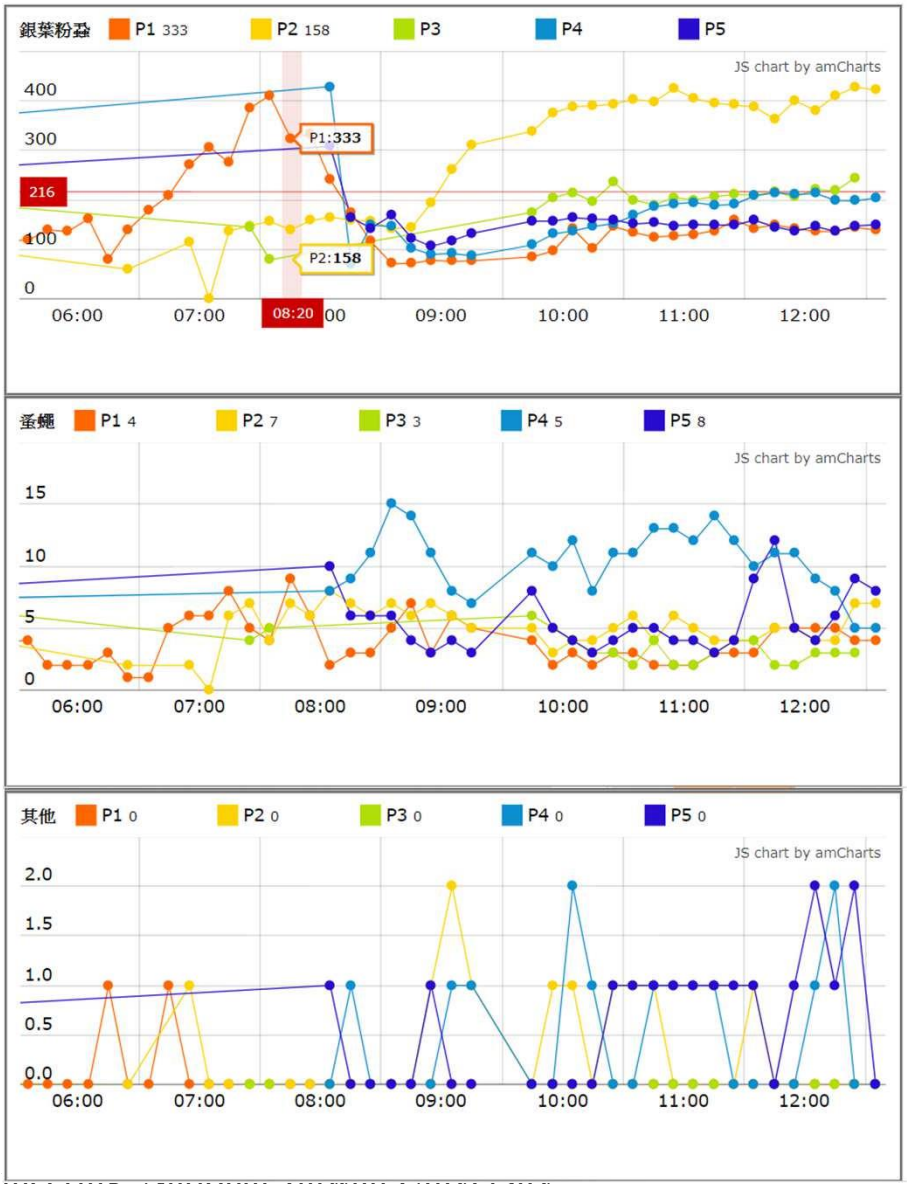

Bemisia argentifolii at 01/04
Temp.
Bemisia argentifolii
degree Celsius
Time
6500
6000
5500
5000
4500
4000
3500
3000
25
24
23
22
21
20
19
18
6
7
8
9
10
11
12
13
14
15
16
17

Boxplot

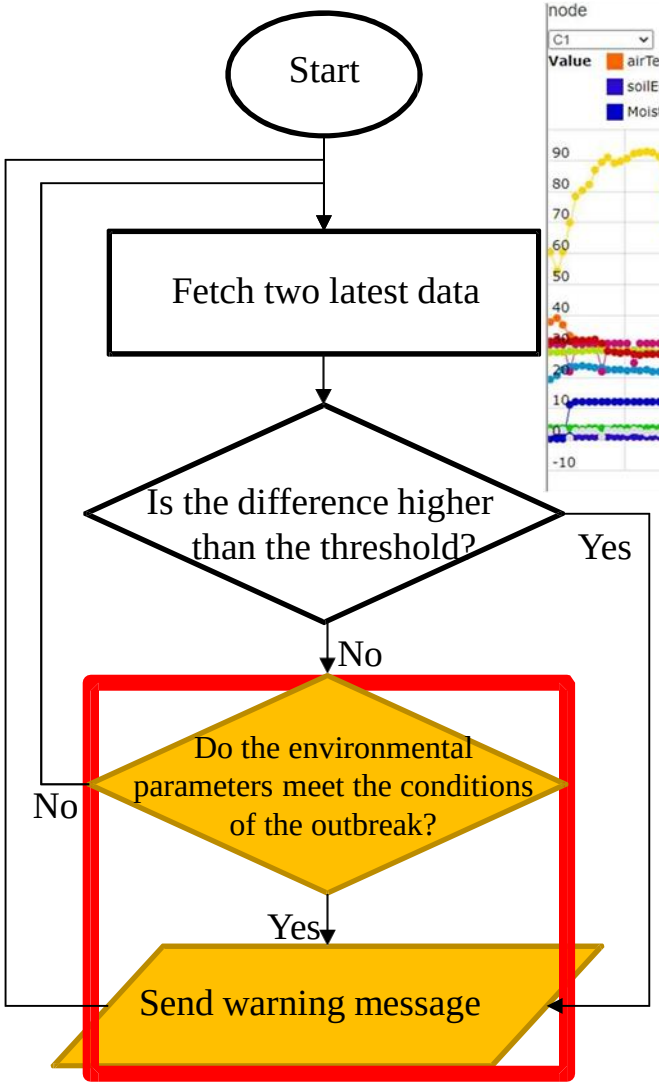

Bemisia argentifolii at 2020-01-04 06:00:00
Bemisia argentifolii
7000
6000
5000
4000
3000
2000
1000
0
24-48 hours
0-24 hours

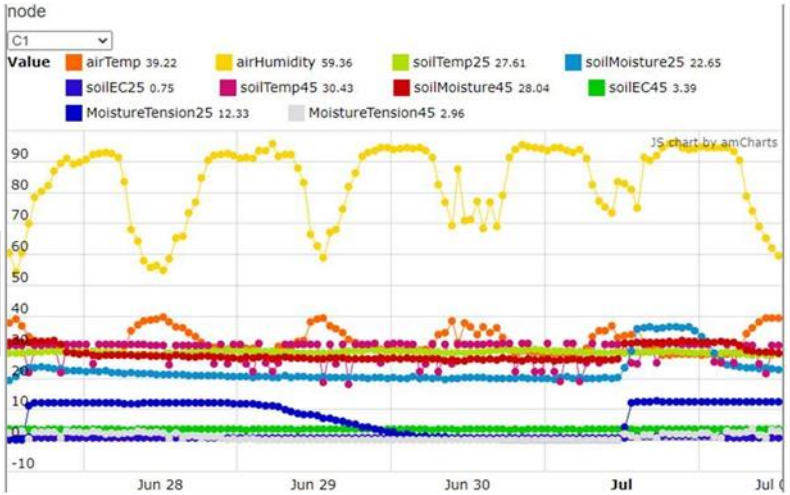
Pest outbreak mechanism

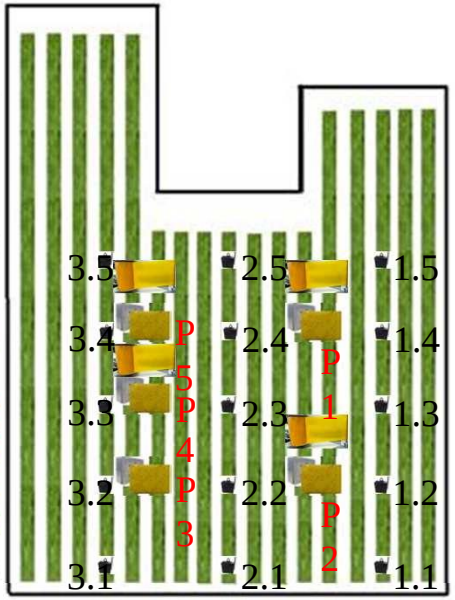




Warning notification system







Evaluation of stability of system

Daily report of pest and sensing data

r06631047 9 — 收件匣 Daily report (All) of Pest Image - This is the Daily report of Pest Image — 上午4:37

0200507-3.csv | 0200507-5.csv | 0200506-3.csv | +6

r06631047 — 收件匣 Daily report (05/05) of Pest Image - This is the Daily report of Pest Image — 5月5日

20200505.xlsx

r06631047 — 收件匣 Daily report (05/03) of Pest Image - This is the Daily report of Pest Image — 5月3日

20200503.xlsx

r06631 — 5月2日

	Image	Bemisia arge	others	Drosophila
2	2019_P1_P1_0430_0600.jpg	10338	1	284
3	2019_P1_P1_0430_0605.jpg	10216	2	287
4	2019_P1_P1_0430_0610.jpg	10258	2	310
5	2019_P1_P1_0430_0615.jpg	10277	2	302
6	2019_P1_P1_0430_0620.jpg	10201	1	297
7	2019_P1_P1_0430_0625.jpg	10137	2	311
8	2019_P1_P1_0430_0630.jpg	9935	0	315
9	2019_P1_P1_0430_0635.jpg	9896	3	290
10	2019_P1_P1_0430_0640.jpg	9916	5	313
11	2019_P1_P1_0430_0645.jpg	9766	4	316
12	2019_P1_P1_0430_0650.jpg	9923	2	310
13	2019_P1_P1_0430_0655.jpg	9817	0	283
14	2019_P1_P1_0430_0700.jpg	9485	1	333
15	2019_P1_P1_0430_0705.jpg	9485	2	327
16	2019_P1_P1_0430_0710.jpg	9423	4	336
17	2019_P1_P1_0430_0715.jpg	9603	2	337
18	2019_P1_P1_0430_0720.jpg	9675	2	313
19	2019_P1_P1_0430_0725.jpg	9691	3	309
20	2019_P1_P1_0430_0730.jpg	9864	2	327
21	2019_P1_P1_0430_0735.jpg	9999	4	276
22	2019_P1_P1_0430_0740.jpg	10238	3	300

Pest Image | Environment | Sheet

就緒

	nodeID	Time	airTemp	airIlluminati	airHumidity
2	6c513e	2020-04-30 5:59:47	21.9		99.9
3	6c513e	2020-04-30 6:04:50	21.9		99.9
4	6c513e	2020-04-30 6:09:53	22		99.9
5	6c513e	2020-04-30 6:14:55	22.1		99.9
6	6c513e	2020-04-30 6:19:58	22.2		99.9
7	6c513e	2020-04-30 6:25:01	22.4		99.9
8	6c513e	2020-04-30 6:30:04	22.6		99.9
9	6c513e	2020-04-30 6:35:07	22.8		99.9
10	6c513e	2020-04-30 6:40:09	22.9		99.9
11	6c513e	2020-04-30 6:45:12	23.1		99.9
12	6c513e	2020-04-30 6:50:15	23.3		99.9
13	6c513e	2020-04-30 6:54:47	23.4		99.9
14	6c513e	2020-04-30 6:59:50	23.5		99.9
15	6c513e	2020-04-30 7:04:53	23.6		99.9
16	6c513e	2020-04-30 7:09:55	23.7		99.9
17	6c513e	2020-04-30 7:14:58	23.9		99.9
18	6c513e	2020-04-30 7:20:01	24.1		99.9
19	6c513e	2020-04-30 7:25:04	24.2		99.9
20	6c513e	2020-04-30 7:30:06	24.4		99.9
21	6c513e	2020-04-30 7:35:09	24.7		99.9
22	6c513e	2020-04-30 7:40:12	24.9		99.9

Pest Image | Environment | Sheet

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Chapter 5

Conclusions

Conclusions

- This study proposes a pest monitoring system which combines the self-changed sticky paper mechanism.
- The proposed method average accuracy is 92.81%.
- Warn and provide corresponding preventive measures for agricultural workers before pest outbreaks.
- Real-time analysis, remote control and automatically update the pest numbers makes the system user-friendly.
- The current focus on whiteflies, flies and other pests is an asparagus problem that can be quantified. Future expectations can be studied against more asparagus problems.

Thank you