Ponencia la aplicación de las TICs en la agricultura China

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Agenda

• 1 Introduction
• 2. Breeding
• 3. Production
• 4. Logistics and traceability
• 5. Application
• 6. Cooperation with Spain
Horticulture: rapid development

• The rapid rise of the middle class and rising per capita income in emerging economies are leading to increasing demand for healthy, safe and sustainably produced horticultural products. (China has about 300 million population with middle class level)
1.1 General view of China’s horticulture

<table>
<thead>
<tr>
<th>Year</th>
<th>Grain yield (10,000 tons)</th>
<th>Vegetable yield (10,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>54,006.98</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>62,891.98</td>
<td>67,334.48</td>
</tr>
<tr>
<td>2012</td>
<td>71,776.98</td>
<td>76,219.48</td>
</tr>
<tr>
<td>2013</td>
<td>76,219.48</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Horticultural yield in China

- **Tea yield**: (10000 tons)
- **Fruit yield**: (10000 tons)
- **Melon yield**: (10000 tons)
- **Strawberry yield**: (10000 tons)
Orchard area

Orchard area (1000 hectares)
Cucurbit crop area

- Cucurbit crops area (1000 hectares)
- Watermelon area (1000 hectares)
- Melon area (1000 hectares)
- Strawberry area (1000 hectares)
Per capital yield

![Bar chart showing per capita yield for grain, fruit, and vegetables from 2010 to 2014.]

- **Per capita grain yield**
- **Per capita fruit yield**
- **Per capita vegetable yield**
Higher demand for imported food

- 2015, China imported more than 4 million tons of fruits
Global importers

Exhibitors

137 International Exhibitors

270% Growth from 2013

90 Chinese Exhibitors

Nations & Regions

2014 Top 15 Imported Fruit

<table>
<thead>
<tr>
<th>Variety</th>
<th>Total (Tons)</th>
<th>Variety</th>
<th>Total (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longan</td>
<td>128,790.37</td>
<td>Kiwi</td>
<td>6,886.94</td>
</tr>
<tr>
<td>Banana</td>
<td>134,475.49</td>
<td>Citrus</td>
<td>6,758.73</td>
</tr>
<tr>
<td>Watermelon</td>
<td>72,423.74</td>
<td>Apple</td>
<td>2,513.74</td>
</tr>
<tr>
<td>Dragon Fruit</td>
<td>67,764.32</td>
<td>Pear</td>
<td>1,061.83</td>
</tr>
<tr>
<td>Grape</td>
<td>36,500.98</td>
<td>Mango</td>
<td>610.27</td>
</tr>
<tr>
<td>Durian</td>
<td>17,307.64</td>
<td>Papaya</td>
<td>107.09</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>11,000.95</td>
<td>Leechi</td>
<td>0.05</td>
</tr>
<tr>
<td>Pineapple</td>
<td>6,923.40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data from China World Fruit & Vegetable Trade Fair, 2015
S&T demand for horticulture

- Fresh, Frozen & Dehydrated Produce Products
- Nuts & Processed Produce Products
- Juice, Drinks & Winery
- Herbs & Spices
- Organic & Healthy Food
- Produce Packaging Machinery & Technology
- After Harvest Machinery & Technology
- Logistics & Cold Chain
- Breeding & Seedling Technology
- Marketing, Research, Consulting & Financial Solutions
2. Breeding

- Mining the variety resources
2. Breeding

- Establish the variety resource standard
2. Breeding

- Golden seed breeding platform
3. Production

- 3.1 Problem
- 3.2 Monitor
- 3.3 Model
- 3.4 Decision and conduction
Fast increase of horticultural production in China

Annual planting area and yield for vegetables in China

Li Baoju, 2013
3.1 Problem

China greenhouse Area (1000 ha)

- Solar greenhouses 950
- Big (standard) plastic tunnels 1700
- Small plastic tunnels 1050
- Multi-span greenhouses 1.3
Low cost, simple facilities in agriculture

- Solar greenhouses
- Big plastic tunnels
- Small plastic tunnels
- Multi-span greenhouse

Zhang Zhenhe, 2009
Solar greenhouse creation

- 1985, Farmers in Haicheng and Wafangdian, Liaoning province, China invented solar greenhouses to produce fruit vegetables, in the external weather of -20°C.
Solar greenhouse extension
Fig. 1. Models, structure parameters, and evolution of solar greenhouse structure in China. (A) The primary solar greenhouse (before 1985): spans = 5.5 to 6.5 m, wall thickness = 0.5 to 0.7 m, arch height = 2.1 to 2.4 m; steel frames and two to three pillars inside the greenhouse, no insulating blanket, the roof is glass. (B) Modified solar greenhouse (1986–95): spans = 6.0 to 8.0 m, arch height = 3.0 to 4.0 m; frames are bamboo, steel, or a mixture of both, with two to three pillars inside; soil wall thickness = 0.8 to 1.1 m with heterogeneous double layer; transparent coverage materials polyethylene (PE) or polyvinyl chloride (PVC) with insulating blanket on it. (C) Modern solar greenhouse (1996–present): spans = 8.0 to 14.0 m, arch height = 3.8 to 5.5 m, walls of air-entrained brick, polystyrene slates, and perlite at 0.8 m; non-pillar, zinc-coated steel frame. The rolling up and down of the insulation blanket and ventilation vents are all automatic. The east and west walls have a wet curtain cooling system. (D) Double-arch solar greenhouse (2007–present): structure parameters are the same as (C) except the double-arch frames; 1 m = 3.2808 ft.
Fig. 2. Photos of a single-slope solar greenhouse: (A) exterior, (B) interior, (C) upper side of the double-arch solar greenhouse, and (D) a group of solar greenhouses. (Photos A through C were provided by M. Qu and Z. Zhang, respectively; photo D is courtesy of Beijing Agricultural Bureau).
Greenhouses in different latitudes

Table 1. The main structural parameters of the solar greenhouse located at different degrees of latitude (Zhang, 2001).

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Greenhouse types&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Span (m)&lt;sup&gt;y&lt;/sup&gt;</th>
<th>Ridge ht (m)</th>
<th>Back wall ht (m)</th>
<th>Back roof horizontal shadow length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>43°N</td>
<td>1</td>
<td>7.0</td>
<td>3.5–3.8</td>
<td>2.3–2.5</td>
<td>1.5–1.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6.5</td>
<td>3.3–3.6</td>
<td>2.2–2.3</td>
<td>1.4–1.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.0</td>
<td>3.0–3.4</td>
<td>2.0–2.2</td>
<td>1.3–1.4</td>
</tr>
<tr>
<td>41°N–42°N</td>
<td>1</td>
<td>7.5</td>
<td>3.6–3.9</td>
<td>2.3–2.6</td>
<td>1.5–1.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.0</td>
<td>3.4–3.7</td>
<td>2.1–2.4</td>
<td>1.4–1.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.5</td>
<td>3.2–3.5</td>
<td>2.0–2.3</td>
<td>1.3–1.4</td>
</tr>
<tr>
<td>38°N–40°N</td>
<td>1</td>
<td>8.0</td>
<td>3.7–4.0</td>
<td>2.4–2.6</td>
<td>1.4–1.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.5</td>
<td>3.5–3.7</td>
<td>2.2–2.5</td>
<td>1.3–1.4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7.0</td>
<td>3.3–3.5</td>
<td>2.2–2.5</td>
<td>1.2–1.3</td>
</tr>
</tbody>
</table>

<sup>*</sup>Greenhouse types are divided by the span and the ridge height.

<sup>y</sup>1 m = 3.2808 ft.
### Table 2. Input and output of different styles of greenhouses for growing cucumber and tomato in Beijing, China.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Solar greenhouse</th>
<th>Gutter-connected heated greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modified bamboo-steel frame</td>
<td>Modern zinc-coated steel frame</td>
</tr>
<tr>
<td>Construction cost (yuan/m²)*</td>
<td>40–60</td>
<td>150–200</td>
</tr>
<tr>
<td>Depreciated value</td>
<td>5–10</td>
<td>15–20</td>
</tr>
<tr>
<td>Value/year (yuan/m²)</td>
<td>4–12</td>
<td>7.5–13.3</td>
</tr>
<tr>
<td>Annual production material input (yuan/m²)</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Labor input (yuan/m²)</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Heating energy input (yuan/m²)**</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wet-curtain cooling cost (yuan/m²)*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Production cost (yuan/m²)</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Vegetable productivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual vegetable income (yuan/m²)**</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Net income (yuan/m²)</td>
<td>21–29</td>
<td>19.5–25.5</td>
</tr>
<tr>
<td>Ratio of annual input/output</td>
<td>1:1.88</td>
<td>1:1.76</td>
</tr>
</tbody>
</table>

*1 yuan/m² = $0.1466/m² = $0.0136/ft².

**Heating cost was calculated by assuming that the gutter-connected greenhouse needs to be heated 100 d in winter, and needs burn 1.12 kg·m⁻² (0.229 lb/ft²) of coal per day at unit price of 0.80 yuan/kg ($0.1172/kg, $0.0532/lb).

**Cooling cost was calculated by assuming that the gutter-connected greenhouse needs to be cooled 100 d in summer, and needs consume 0.4 kW·m⁻² (0.007 kW/ft²) of electricity per day at unit price of 0.80 yuan/kW ($0.1172/kW).

**Annual vegetable income was calculated by assuming vegetable price is 2.0 yuan/kg ($0.2930/kg, $0.1329/lb) and annual average yield of solar greenhouse and gutter-connected greenhouse in 3 years was 22.5 and 30.0 kg·m⁻² (4.61 and 6.14 lb/ft²), respectively.
Some problems

• Lack of unified plan and strategy
• Less ability of environment control
• Heavy soil continuous cropping obstacles, and diseases and pests
• Lower efficiency of production
Diseases and insect pests are the major limitation for agricultural production

• The usual loss for horticultural crops is more than 20% due to pests, and the improper control may result in loss of 50-60%, especially no harvest when the heavy situation occurs.
The improper control for diseases and pests affect Agricultural product quality safety.
Traditional pathogen monitoring method

Spore traps

Collection by labor

Microscope testing

Spore analysis
Traditional pest monitoring method

Field sample

On site testing

Expert identify

Statistic analysis
Lower efficiency of usage on data

Weather station data has not been well used
Urgent need of Intelligent, automatic tools

Hyper spectrum

Voice

Infra red

Machine vision

IOT, Cloud computing, big data has great potential
Trends in Plant Protection Science

• Thousands years ago: Experiment
  – Field survey
  – Express the natural phenomenon

• A hundred years before: Theory
  – Disease epidemiology and insect ecology
  – Mathematical Model

• Last several decades: Computing
  – ICT application
  – Computer simulation

• Nowadays: Big Data
  – Data-intensive scientific discovery
  – Global pest forecast and control
Our goal

- Automatic monitoring
- Precision model
- Decision and control

(Yang et al., New Zealand Journal of Agricultural Research, 2007; Li et al.)
3.1 Monitoring the pest tetrahedron
Complex system of disease pyramid

Host phenotyping: Hyperspectral, High-throughput, online

Cultivation record: holistic, traceable, visible

Environment monitoring: integrated, dynamic and heterogeneous

Pest detection: from Molecular to Population

Plant disease and insect early warning model and system
(1) Pest monitoring equipment in fruits
Plant pathogen detection

Micro spores collection

Photograph by microscope

Patent: ZL201010178307.2
NERCITA has developed ten types of greenhouse sensors:

- **Technologies:** drift suppressing, nonlinearity compensation
- **Advantages:** precision, stable, consistent
- **Practical use:** information acquisition in greenhouse

(2) Monitoring inside and outside environment of the facilities
# Soil moisture monitoring

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil info</td>
<td>Four channel of soil temperature, soil moisture and eight channel for other sensors.</td>
</tr>
<tr>
<td>Weather parameters</td>
<td>Air temperature, relative humidity, wind velocity, wind direction, solar radiation, atmosphere, rainfall, ET</td>
</tr>
<tr>
<td>Display</td>
<td>LCD touch screen</td>
</tr>
<tr>
<td>Communication</td>
<td>GPRS, GSM, WAN</td>
</tr>
<tr>
<td>Protocol</td>
<td>Standard MODBUS</td>
</tr>
<tr>
<td>Data storage</td>
<td>20000 rows</td>
</tr>
<tr>
<td>Programming</td>
<td>Online programming</td>
</tr>
<tr>
<td>Transfer method</td>
<td>At different interval, called by cell phone</td>
</tr>
</tbody>
</table>

**Integrated station**
Web specific map and short message services

Agricultural soil moisture disclosure and service software
The system has got the funding of 800 million RMB from MOA since 2012.
Time-space distribution of greenhouse environment

Fig. 2-9 Temperature spatial and temporal distribution under different canopy height on different weather spring.
Environment monitoring combing remote sensing and meteorology information

- Vegetarian status variables:
  TVI, SAVI, DSWI, SIWSI

- Farm environment variables:
  Land surface temperature (LST)
  Temperature, rainfall, humidity, radiation
(3) Host phenotyping: Hyperspectral, High-throughput, online
The calibration method for leaf wetness sensors

(Li et al., Transaction of CSAE, 2010b)
The estimation model based on RH

RH ≥ 89% or 90%, the errors are about 1~2h

(Li et al., Transaction of CSAE, 2010c)
Crop disease spectrum characteristics and info abstraction

**Powdery mildew**

**Yellow rust**

**Canopy spectrum**

**Image spectrum**

**Analysis and process of image spectrum information**

**Spectrum abstraction**

**Disease intensity modeling**
Crop disease monitoring

\[
\text{Disease index} = \frac{R_{\text{Disease}} - R_{\text{Normal}}}{R_{\text{Normal}}} \times \frac{\text{NIR}_{\text{Normal}} - \text{NIR}_{\text{Disease}}}{\text{NIR}_{\text{Normal}}}
\]

PHI image spectrum based disease index monitoring in different stages

- More heavy diseases
- Heavy diseases
- Mid diseases
- Slight diseases
- No diseases
- Good growth
NERCITA has developed five crop information analysis systems
With machine vision and Hyperspectral technologies, we have realized non-damage detection for greenhouse crop nutrition, growth diagnosis, main agricultural parameters.
UAV in application
(4) Portable agricultural record keeping system
Production record keeping system

Field ID: 003605
Cultivar: Jingyan mini No.2
Primary inoculum: Yes
Transplanting date: 2008-02-05
The latest irrigation date: 2008-04-14
Sky in daytime: Overcast
Sky in nighttime: Overcast
Daily mean temp(℃): 13.5
Daily mean RH(%): 92
Daily range of temp(℃): 4

Warning
Cucumber downy mildew early warning!
The predicted infection date is 2008-4-14.

Warning obviation treatment:
The ventilation in time is required. The Chlorothalonil smoke could be used.

Pesticide Usage
Field ID: 003605
Damage Level: Low
Pesticide Type: Fungicide
Pesticide Name: Chlorothalonil
Usage Date: 08-4-16

OK
Quit
Field image monitoring
(5) Wireless Sensor Network application

- Research on characteristics of radio propagation through agricultural environment

Conclusions

The existed models fail in estimating the path loss in orchard. The path loss change greatly in different heights at the same time. Great change exists in path loss at different times in the same height. The new model can well estimate the path loss in different height and times.

Comparison between the measured data and some existed models
(5) Wireless Sensor Network application

- ZigBee-based wireless sensor network image transmission technology

<table>
<thead>
<tr>
<th>2Bytes</th>
<th>2Bytes</th>
<th>8Bytes</th>
<th>1Bytes</th>
<th>1Bytes</th>
<th>0-80Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xFF</td>
<td>0xD8</td>
<td>ZigBeeNetwork layer address</td>
<td>ZigBee MAC layer address</td>
<td>Serial number</td>
<td>Data payload Length</td>
</tr>
</tbody>
</table>

Acquire and process JPEG Image

Image data packet format

Image data compression and subpackage processing

Acquire JPEG Image

Greenhouse crop conditions

Image sensor module

Coordinator node

Single or multi-hop routing

Monitoring platform

UART

UART
(5) Wireless Sensor Network application

• H.264 video compression technology

The video records of the different stages of agricultural products

The acquisition of video information and Compression of the video information for video using H.264 algorithm

H.264 video compression module

Camera → HI3512 Chip → 3G Module

Production server

Production server for storing video record

PC → Video record

The PC to access the server to view the video resume

H.264 compression technology

Interframe prediction / intra prediction
CAVLC/CABAC
Sub-pixel interpolation
Based on Lagrangian bitrate control
Deblocking filtering

CIF(352X288) of picture size
145:1 of the compression rate
4-5 frame of the transmission rate

Compression result

Package format for transmission of video streams

Frame Head | IP Packet Head | UDP Head | RTP Head | Application Data NALU

Internet
3.3 Model establishment
Field experiment

Beijing Xiedao Co, Ltd
2005.10-2006.2, three greenhouses
2006.2-2006.7, (preliminary experiment)

Xiaotangshan base for precision agriculture
2006.10-2007.1, three greenhouses
2007.2-now, three greenhouses

Jingyan mini No.2
The substrate used was a 2:1 mixture of peat and vermiculite

Beijing academy of agricultural and forestry sciences (BAAFS)
2008.9-2009.1, one greenhouse
2009.3-2009.12, one greenhouse
Clarifying the meaning of warning

• These warnings would include disease occurrence (yes or no) and its probability.

Table 1
Categories and a summary of calculation results of the early warning model for primary infection of cucumber downy mildew in solar greenhouses (EWMPICDW) in each day.

<table>
<thead>
<tr>
<th>N</th>
<th>Estimated – Yes</th>
<th>Estimated – No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed – Yes</td>
<td>Hits ((X'))</td>
<td>Misses ((Y'))</td>
</tr>
<tr>
<td>Observed – No</td>
<td>False alarms ((S'))</td>
<td>Correct negatives ((Z'))</td>
</tr>
</tbody>
</table>
Forecasting the warning situation

• Infection condition early warning sub model
  – $\text{LWD} \times \text{TLWD} \geq 40 \text{ h \, °C}$ ($\text{LWD} \leq 2\text{h}$, $5\text{ °C} \leq \text{TLWD} \leq 30\text{ °C}$) (Cohen, 1977)

(Lindenthal et al., 2005)
Forecasting the warning situation

- Incubation period early warning sub model

(Fu and Yao, 1983)
Validation by 4-year data

<table>
<thead>
<tr>
<th>Year</th>
<th>Point</th>
<th>Predicted infection date</th>
<th>Predicted occurrence date</th>
<th>Observed occurrence date</th>
<th>Year</th>
<th>Point</th>
<th>Predicted infection date</th>
<th>Predicted occurrence date</th>
<th>Observed occurrence date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>31</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>32</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>33</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>34</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>5</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>35</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>36</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>7</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>37</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>2006</td>
<td>8</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>38</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>9</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>39</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>10</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>40</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>11</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>41</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>12</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>42</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>13</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2008</td>
<td>43</td>
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<td>26-October</td>
<td>2008</td>
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<td>2006</td>
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<td>2009</td>
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<td>2006</td>
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<td>26-October</td>
<td>2009</td>
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<td>2009</td>
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<td>25</td>
<td>21-October</td>
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<td>2009</td>
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<td>26-October</td>
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<td>2009</td>
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<td>N</td>
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<tr>
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<td>26-October</td>
<td>26-October</td>
<td>2009</td>
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<td>N</td>
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<tr>
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<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2009</td>
<td>58</td>
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<tr>
<td>2006</td>
<td>29</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2009</td>
<td>59</td>
<td>N</td>
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<td>N</td>
</tr>
<tr>
<td>2006</td>
<td>30</td>
<td>21-October</td>
<td>26-October</td>
<td>26-October</td>
<td>2009</td>
<td>60</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

† Predicted infection date or predicted occurrence date was earlier than the observed occurrence date.
‡ The cucumber downy mildew did not appear, and the model did not present early warning (true negative points, TNP).
§ The model did not present infection and occurrence early warning before the observed occurrence date.
∥ The predicted infection date was earlier than the observed occurrence date, but predicted occurrence date was later than the observed occurrence date.
|| N denoted no predicted infection, predicted disease occurrence or observed disease occurrence.
Model evaluation

### Table 4

<table>
<thead>
<tr>
<th></th>
<th>Estimated - Yes</th>
<th>Estimated - No</th>
<th>Total number</th>
<th>Prior probability</th>
<th>Posterior probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed - Yes</td>
<td>384 $P(A</td>
<td>b) = 0.68$</td>
<td>123</td>
<td>612</td>
<td>$P(A) = 0.68$</td>
</tr>
<tr>
<td>Observed - No</td>
<td>34 $P(A</td>
<td>b) = 0.06$</td>
<td>462</td>
<td>733</td>
<td>$P(A) = 0.32$</td>
</tr>
<tr>
<td>Total number</td>
<td>418</td>
<td></td>
<td>733</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Figure 5

Comparison of the occurrence date between observed values and estimated values under the early warning model for primary infection of cucumber downy mildew in solar greenhouses.

- **(a)**: $y = 0.995x + 0.3072$, $R^2 = 0.9969$
- **(b)**: $y = 0.9486x + 1.3667$, $R^2 = 0.8264$

Warning the disease by 95% probability

(Zhao et al., Computers and Electronics in Agriculture 2011)
3.4 Decision and conducting
Early warning system application
黄瓜霜霉病预警模型

（1）菌源条件
如果温室前茬种植过黄瓜或发生过黄瓜霜霉病，或者附近温室或露地发生黄瓜霜霉病，就具备菌源条件。

（2）初侵染预警
计算每天的叶片湿度时间，叶片湿度时间的获得，采用每天超过93%的相对湿度的小时数作为估计。计算叶片湿度时间内的平均温度。

$LWT \times TLWT \geq 40 \left( LWT \geq 2, 5 \leq TLWT \leq 30 \right)$

式中：$LWT$——叶片湿度时间，$h$；$TLWT$——叶片湿度时间内的平均温度，℃。满足上述条件，霜霉病病菌就可能侵染。

（3）潜育期/发病日期预警
此后开始启动每小时平均温度$t$与潜育期贡献率$y$的模型公式。当$y$累计达到1时，潜育期结束。式中：$y$——潜育期贡献率，无量纲；$t$——每小时的平均温度，℃。

$$y = \frac{0.0165}{1 + 10^{3.892 \cdot \exp(-0.5743 \cdot t)}}$$

（4）发病概率预警

<table>
<thead>
<tr>
<th>级别</th>
<th>绿</th>
<th>蓝</th>
<th>黄</th>
<th>橙</th>
<th>红</th>
</tr>
</thead>
<tbody>
<tr>
<td>初侵染发生分级</td>
<td>无警</td>
<td>轻警</td>
<td>中警</td>
<td>重警</td>
<td>巨警</td>
</tr>
<tr>
<td>奠基病初侵染发生概率$\alpha$（%）</td>
<td>$\alpha = 0$低</td>
<td>$0 &lt; \alpha \leq 40$较低</td>
<td>$40 &lt; \alpha \leq 60$中等</td>
<td>$60 &lt; \alpha \leq 80$较高</td>
<td>$80 &lt; \alpha \leq 100$很高</td>
</tr>
</tbody>
</table>
Visual simulating appearance of plant leaves infected by disease and insect pests

Fig. 7 Actual plant disease images.

Fig. 8 Appearance of powdery mildew of cucumber of different disease indexes

Miao et al, 2014
New systems
Potato late blight warning system
Spraying machine
Robot platform for multi-span greenhouses

Remote Spay robot for solar greenhouses
Variable rate spraying system based on machine vision

This kind of sensor-based variable rate sprayer can find weeds on-line in the field automatically, so where is weeds where is spraying.
4. Logistics

Wireless Sensor Network plus the Three Networks Integration (telecom, radio, and TV, and Internet networks)
Auto packaging line for agricultural products

- Package, weight, 1D barcode
- LED
- Scanning equipment
- Package equipment
- 2D barcode generation and printing
Logistics management system
Logistics loading and 3D display

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Product</th>
<th>3D loading</th>
<th>Prior grade</th>
</tr>
</thead>
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<tr>
<td><img src="image1.png" alt="Vehicle Image" /></td>
<td><img src="image2.png" alt="Product Image" /></td>
<td><img src="image3.png" alt="3D Loading Image" /></td>
<td><img src="image4.png" alt="Prior Grade Image" /></td>
</tr>
</tbody>
</table>
Temperature dynamic modeling in cold chain
Transaction management

- Electronic scale for traceability using barcode

<table>
<thead>
<tr>
<th>Type</th>
<th>Portable</th>
<th>Pillar base</th>
<th>weigh-bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max scope</td>
<td>30Kg</td>
<td>300Kg</td>
<td>1t or individual size</td>
</tr>
<tr>
<td>Division value</td>
<td>10g</td>
<td>20g</td>
<td>0.1kg</td>
</tr>
<tr>
<td>Main functions</td>
<td>Weighting, location, 2D barcode printing and data wireless transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>RFID identification</td>
<td>Multi-form of barcode printing</td>
<td>IPC control and touch screen</td>
</tr>
<tr>
<td>Applied scene</td>
<td>High-level agri-product, cooperative with direct package in field</td>
<td>Cooperatives or whole sale market with mid-amount</td>
<td>Cooperatives or whole sale market with big amount</td>
</tr>
</tbody>
</table>
Transaction management

- Transaction management system
Quality traceability-website
Quality traceability-cell phone

- Support Android, IOS with 1D and 2D barcode
Quality traceability-touch screen
Government supervision

- Environment evaluation systems for agricultural production field
Government supervision

- Supervision platform for agricultural product quality safety
5. Application

- Applied in more than 10 provinces with 254 bases
Application-typical cases

• Vegetable quality safety management and traceability in Tianjin
Cooperated with Tianjin Pollution-Free Agri-Products (Crop Planting) Management Center

2012-2015: 30000 ha non-pollution vegetable bases (total vegetable area is 90000 ha in Tianjin, with 70000 ha in greenhouses, 7.5 billion RMB);
260 million tons, 57% of total vegetable supply for Tianjin;
Establish the supervision system from Municipal, county, town to enterprise;
More than 5 million production record in the platform, to support the reduction of 19 million RMB
Application-typical cases

• Digital orchard management and DSS in Shandong province
Application-typical cases

• The sturgeon caviar processing traceability for the first class food of *lufthansa*
Beef traceability in Binzhou, Shandong province
Application-typical cases

• Agri-product traceability for the whole supply chain of field to community model
6. Cooperation with Spain
INTRODUCTION of TEAP (PIRSES-GA-2013-612659)

- A Traceability and Early warning system for supply chain of Agricultural Product: complementarities between EU and China” (TEAP)

- Marie Curie Actions ➔ Mobility

- IRSES ➔ International Research Staff Exchange Scheme

- Objectives of the program:
  - Exchange/sharing of “actual” knowledge
  - Foster collaboration between institutions
  - Analyzing possible collaborations
  - Preparing further research projects.

It is a Mobility action!! ➔ Sharing/Improving actual knowledge.
1) INTRODUCTION

PARTICIPANTS

UAU - University of Almeria
AUA - Agricultural University of Athens
UB - University of Bonn
UNIPI - University of Pisa
UPM - Polytechnic University of Madrid
NERCITA - Beijing Research Center for Information Technology In Agri.
CAU - China Agricultural University
SDAU - Shandong Agricultural University
TJCC - Tianjin Climate Center
TMMCNAP - Tianjin Pollution-Free Agri-Products Management Center
GZNCP - Guangzhou Agricultural Products Quality & Safety Supervisory Institute
2) OBJECTIVES

Specific – Thematic Objectives

- Share knowledge about four main lines:
  1. Good Agricultural Practices and Quality Standards in application;
  2. Alert programs in the production and disease warning models;
  3. HACCP software in the logistics;
  4. Traceability systems for the supply chain of agricultural products “seed-to-plate”.
2) OBJECTIVES

General – Final Objectives

- Improve future collaboration between partners:
  A. Preparing new research common projects, such as Horizon 2020 Work Programme
  B. Developing thematic networks with the participation of both sides;
  C. Supporting long time expertise exchange.
### 3) STRUCTURE

- **Work Packages:**

<table>
<thead>
<tr>
<th>Work package n°</th>
<th>Work package title</th>
<th>Coordinators</th>
<th>Start month</th>
<th>End month</th>
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<tbody>
<tr>
<td>1</td>
<td>Agricultural Products Quality and Safety Standards in application.</td>
<td>NERCITA / AUA+UAL</td>
<td>11-2013</td>
<td>09-2014</td>
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<td>2</td>
<td>The optimum techniques of environment, fertilizer, water management for horticulture</td>
<td>AUA+UNIPI / CAU + SDAU</td>
<td>11-2013</td>
<td>07-2014</td>
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<td>3</td>
<td>Early detection of pathogens and pests: molecular, serological and conventional techniques.</td>
<td>UB / NERCITA + CAU</td>
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<td>02-2015</td>
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<tr>
<td>5</td>
<td>HACCP system in the fresh agri-product logistics for quality safety control.</td>
<td>UPM+AUA/ NERCITA</td>
<td>02-2015</td>
<td>08-2015</td>
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<td>6</td>
<td>Traceability Systems in EU and China.</td>
<td>CAU+NERCITA/ AUA</td>
<td>06-2016</td>
<td>09-2016</td>
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<tr>
<td>7</td>
<td>Common challenges in AP quality. Proposal of joint research activities</td>
<td>NERCITA /UAL</td>
<td>09-2016</td>
<td>08-2017</td>
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</table>
TEAP kick-off meeting, 2013
Study on greenhouse environment modeling and disease warning

- Cooperation and write a paper “Development of Air Temperature Model for Chinese and Spanish Traditional Greenhouses” to IJABE.

- Prof. Xue and Li were invited for Jorge’s thesis defending meeting. Ms. Wang Hui has been enrolled as the PhD candidate of computer major in ARM group of UAL.
Study on cold chain logistics

• Cooperated with Prof. Luis Ruiz García, Departamento de Ingeniería Agroforestal, UPM, and write two papers:

• 1）Artificial Neural Networks and thermal image for temperature prediction in apples. Food and Bioprocess Technology

• 2）CFD simulation of airflow and heat transfer during forced-air precooling of individual apples. International Journal of Refrigeration
Study on agri-product supply chain

- Cooperated with Fernando Bienvenido of UAL, Cynthia Giagnocavo from Coexphal/UAL, Pedro Hoyos Echevarría of UPM
Some visits
National Engineering Research Center for Information Technology in Agriculture
The History of NERCITA

Laboratory for Information Technology in Agriculture (Crop Research Institute) 1991-98

Beijing Research Center for Information Technology in Agriculture (863 Project) 1999

Key Laboratory for Information Technology in Agriculture (The Ministry of Agriculture of China) 2001

National Engineering Research Center for Information Technology in Agriculture (NERCIITA) 2002

Beijing Research Center for Agri-food Testing and Farmland Monitoring 2005

National Engineering Research Center of Intelligent Equipment for Agriculture (NERCIEA) 2009

Beijing Research Center for Internet of Things in Agriculture 2012

International Cooperation Research Center for Agricultural Aviation with USDA ARS 2015

...is Developing

27 research platform

2000

2001

2002

2005

2009

2012

2015

27 research platform
Departments

15 Research Dept. and 6 Administration Dept.: 

- Software Engineering
- Information Engineering
- Cartoon and Animation Design
- Intelligent System
- Environment Resources
- Remote Sensing (RS)
- Logistic Information
- Intelligent Equipment
- Agricultural Automation
- Precision Agriculture
- Biological Equipment
- Strategy Research
- Digital Farming
- Intelligent Testing
- Agricultural Aviation

- Administration Division
- Program and finance Division
- Sci-Tech Management Division
- International Cooperation Division
- Achievement Transfer
- Experimental Station

One enterprise: Beijing Paid Weiye Science and Technology Co. ltd

One base: Xiaotangshan National Precision Agriculture Research and Demonstration Base

One Academic Society: Beijing Society of Agricultural Informatization
Development Strategies

- Technological Innovation
- Platform Construction
- Products Development

Technological Innovation According to Demand ->
Sustainable Development

Hi-Tech
Ease of Use
Participate

Technological Innovation
Fit Market Competition

Resources Integration, Advantage Development

National Demand Application Demand + Technological Innovation + Demonstration Extension + Industrial Development -> Competitive
Research Team: 408 in total, 119 regular staff, 161 employed by enterprise, 128 Master and Doctor students with Post-doctor

Titles: 16 investigators, 26 associate investigators, 5 senior engineers; 80% with Master and Doctor degree, 100 Doctors

Team: 硕/博导13人；863专家1人；千人计划1人；国务院津贴3人；国家百千万1人，农业部杰出人才及创新团队1人，北京百名领军人才1人，北京百千万5人；北京突贡2人，北京新星25人，北京优青4人，北京优秀人才22人，农科院青年基金14人。

Major: Computer/Electronics/Automation/Mechanical equipment: 40%, Agriculture: 30%, researchers combined with computer and agricultural sciences: 30%
Status

- Planning and design of ICT in agriculture for Ministry of Agriculture, Ministry of Science and Technology, Ministry of Industry and Information
- Team leader organization for agricultural application of national standard working group for internet of things
- National consulting expert for rural informatilization
- National high-tech program expert
Research achievement and effects

- More than 80 Invention patents, 137 practical models patents; more than 600 software registrations;
- Published more than 1203 papers indexed by SCI/EI;
- 22 S&T awards with more than provincial level, with 3 national awards;
- Extension to 30 provinces with economic benefit of 1 billion yuan.
3 national and 1 international awards
Infrastructure
Xiaotangshan base: window
National Experimental Station for Precision Agriculture

Laboratory with 1050M²
 Equipments

170 hp Tractor
Maize Harvester with Sensors
Disk Harrow
Combine Harvester
16 Greenhouses

Farm Machine Warehouse with 1130M²
Further work

• 1) Cooperation in the model and system in different area of ICT in agriculture.
• 2) Supply chain management of agri-products
• 3) Apply the research in the practices.
• 4) Future research project.
Thank you!