The new EU Directives requirements and the innovation in pesticide application techniques.

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The evolution of the spraying equipment for arboreal crops

1860 1900 1920 1940
2000 2010
The evolution of the spraying equipment over the last century

1860 - 1980
MAIN OBJECTIVE

APPLY NEW CHEMICAL PRODUCTS

IMPROVE SPRAYER FIELD CAPACITY

The evolution of the spraying equipment over the last century

<table>
<thead>
<tr>
<th>YEAR</th>
<th>VOLUME APPLIED (l/ha)</th>
<th>TIME REQUIRED (h manpower/ha)</th>
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<td>1500</td>
<td>14</td>
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<td>800</td>
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<td>1960*</td>
<td>100</td>
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* with helicopter
The evolution of the spraying equipment over the last century

1980 - 2010

MAIN OBJECTIVE

IMPROVE SPRAYER PERFORMANCE IN TERMS OF

- EFFICIENCY OF THE APPLICATION
- REDUCTION OF ENVIRONMENTAL DAMAGE
- OPERATOR SAFETY

THE PRESENT SITUATION IN EUROPEAN UNION COUNTRIES (EU)

SPRAY MASS BALANCE DURING APPLICATION IN VINEYARDS IN ITALY AND SPAIN

(Balsari et al., Pergher et al., Gil et al.)

Evaporation (4-6%)

Drift losses (10-15%)

Spray deposit on the target (20-55%)

Ground losses (30-60%)
WORLD PESTICIDES CONSUMPTION

Year 2004

Europe 28%
South America 18%
North America 25%
Asia 25%
Middle East / Africa 4%

Estimated amount of pesticides yearly sold in the world: >2.5 m tons
~ 50% lost??

Source: Crop Life International

WATER CONTAMINATION DUE TO PLANT PROTECTION PRODUCTS USED

POINT SOURCES

DIFFUSE SOURCES

POINT SOURCES

DIFFUSE SOURCES
WATER CONTAMINATION DUE TO POINT SOURCES

Transport

Storage

Filling

Cleaning

PPP waste disposal

EXAMPLE OF PPP POINT SOURCE POLLUTION (VITICULTURAL FARM)

Residual mixture = 260 l/year
Internal washing and hydraulic circuit washing water = 660 l/year
Water for external washing = 670 l/year

TOTAL WASTE TO DISPOSE ~ **1600 l/year**

PPP concentration = 0.1%,
**1.5 kg/year** of PPP dispose of in less than 10 m²
WHAT DO WE MEAN BY SPRAY DRIFT?

**Spray Drift**: “Quantity of plant protection product that is carried out of the sprayed (treated) area by the action of air currents during the application process” (ISO 22866)
SPRAY DRIFT VALUES ASSESSED IN ORCHARD

(Source: Ganzelmeier et al. 2000)

HOW TO PREVENT SPRAY DRIFT CONTAMINATION

Buffer zone

THE CONCEPT

(Source: Ganzelmeier et al. 2000)
## Example of Definition of Buffer Zones Widths in Orchards According to Sprayer Type and PPP Applied Dose (LERAP, UK)

<table>
<thead>
<tr>
<th>Sprayer type</th>
<th>Applied Dose</th>
<th>Full Rate</th>
<th>¾ Rate</th>
<th>½ Rate</th>
<th>¼ Rate</th>
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<tr>
<td>Standard</td>
<td>18m</td>
<td>15m</td>
<td>12m</td>
<td>7m</td>
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<tr>
<td>LERAP Low drift 1 star</td>
<td>15m</td>
<td>12m</td>
<td>9m</td>
<td>5m</td>
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<tr>
<td>LERAP Low drift 2 star</td>
<td>12m</td>
<td>9m</td>
<td>6m</td>
<td>5m</td>
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<tr>
<td>LERAP Low drift 3 star</td>
<td>9m</td>
<td>6m</td>
<td>5m</td>
<td>5m</td>
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THE PRESENT EU LEGISLATIVE OUTLINE CONCERNING PESTICIDES

EU Framework Directive on Wastes
EC/12/2006

PPP registration and introduction on the market
EU Directive 91/414 and successive revisions

Use of PPP
New EU Directive on the Sustainable Use of Pesticides (text approved by EU Council in September 2009)

PPP wastes
EU Regulation 396/2005

PPP residues

THE NEW EU DIRECTIVES RELATED TO PESTICIDE USE

NEW FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES
AMENDMENT OF EU MACHINERY DIRECTIVE 2006/42/EC
THE FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES
(COM 2006, 372 – FINAL TEXT APPROVED BY EU COUNCIL ON 24 SEPTEMBER 2009)

- Promote strategies to reduce and to optimise the use of PPP
- Limit the improper use of PPP
- Maximise treatment efficacy and limit environmental contamination risk
- Promote integrated pest management
- Train PPP end users
- Improve spraying equipment

THE FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES
MAIN ASPECTS RELATED TO SPRAYERS

Mandatory periodical inspection of sprayers in use

By 2016 all sprayers employed in EU for professional use shall be inspected at least once (over 2 million sprayers to be inspected)

2016-2021: Regular inspections every 5 years
MANDATORY PERIODICAL INSPECTION OF SPRAYERS IN USE – MAIN COMPONENTS TO BE INSPECTED

- Pressure gauge
- Boom cross flow distribution
- Pressure regulator
- Nozzles flow rate

THE FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES
MAIN ASPECTS RELATED TO SPRAYERS

FARMERS TRAINING CONCERNING CORRECT SPRAYER USE AND ADJUSTMENT
THE FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES

MAIN ASPECTS RELATED TO SPRAYERS

BAN OF AERIAL SPRAY APPLICATION (EXCEPTIONS CAN BE AUTHORISED IN PARTICULAR CASES)

MITIGATION OF ENVIRONMENTAL RISK LINKED TO PPP SPRAY APPLICATION

ADOPTION OF DEVICES ABLE TO REDUCE SPRAY DRIFT

ESTABLISHING OF ADEQUATE BUFFER ZONES
THE FRAMEWORK DIRECTIVE ON THE SUSTAINABLE USE OF PESTICIDES

MAIN ASPECTS RELATED TO SPRAYERS

ESTABLISHING PROPER MANAGEMENT OF PPP EMPTY CONTAINERS

AND OF PPP RESIDUAL AT THE END OF APPLICATION AND OF THE WATER USED FOR SPRAYER CLEANING

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PPP REMAINING AT THE END OF SPRAY APPLICATION

Spray mixture remaining in the tank is composed by two fractions

**Consequence of improper sprayer adjustment**

[Diagram showing parts A and B, with text: A: Amount not sucked by the pump]
Fraction A in new ENTAM certified sprayers may vary from an average value of 6 litres for air-assisted sprayers up to an average value of 12 litres for field crop sprayers, but in not certified sprayers or in the obsolete ones this spray mixture remaining value may reach some dozens litres.

MANAGEMENT OF WATER USED FOR SPRAYER CLEANING

INTERNAL CLEANING

Average water volume used: 60 litres

EXTERNAL CLEANING

Average spray deposit on the external sprayer surfaces: 0.5±2% of applied
AMENDMENT OF THE EU MACHINERY DIRECTIVE

IT MUST BE UNDERLINED THAT, FOR THE FIRST TIME, TO APPLY THE CE MARK ON CROP PROTECTION MACHINERY, THE MANUFACTURER HAS TO FULFIL REQUIREMENTS NOT ONLY RELATED TO OPERATOR SAFETY BUT ALSO THOSE RELATED TO ENVIRONMENTAL SAFETY
AMENDMENT OF THE EU MACHINERY DIRECTIVE

a) Sprayers and their components shall be reliable and so designed that they can be used properly in accordance with their intended use, without harming the environment unnecessarily. They shall be designed so that they can be safely operated, supervised and switched off immediately from the operator's position.

AMENDMENT OF THE EU MACHINERY DIRECTIVE

b) Easy and safe filling and complete emptying of the sprayer tank shall be possible. This includes that filling levels and limits shall be determined easily. Unintentional dispersal of liquid shall be avoided.
c) Sprayers shall be equipped with devices enabling the adjustment of the volume application rate in an easy, accurate, and repeatable way.

Source: www.hardi-international.com

d) Sprayers shall be designed so that an even distribution and an adequate deposition can be achieved. When the application system is off, any dispersal of PPP shall be avoided.
e) Easy, safe, and complete emptying and cleaning of the sprayer shall be possible, especially regarding the main tank.

f) Changing worn parts shall be possible. For checking the sprayer and verifying its correct functioning, it shall be possible to connect measuring instruments to the sprayer components.

Source: www.aams.be

Source: www.hardi-international.com
g) Nozzles shall be marked in such a way that they can be identified directly or from information given in the instruction handbook. At least, type and size shall be indicated.

ISO 10625

<table>
<thead>
<tr>
<th>Portata (toleranza ± 5%) l/min</th>
<th>Dimensione Ugetto</th>
<th>Colore</th>
<th>Codice RAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0050</td>
<td>Pearl violet</td>
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<td>0.6</td>
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<td>025</td>
<td>Signal yellow</td>
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</table>

Portata (toleranza ± 5%) l/min | Dimensione Ugetto | Colore | Codice RAL |
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
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<td>6.0</td>
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h) Filters shall be marked in such a way that they can be identified directly or from information given in the instruction handbook. At least, type and mesh size shall be indicated.

ISO 19732

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</table>
AMENDMENT OF THE EU MACHINERY DIRECTIVE

i) in the instructions handbook the following indications shall be reported:
   1) filling and precautions to be taken to avoid contamination of the environment,
   2) conditions of use (for example maximum driving speed) and the corresponding adjustment of the sprayer enabling an even spray distribution on the target without dispersals,
   3) type and size of nozzles and type and mesh size of filters,
   4) time frequency for checking nozzles and filters,
   5) any restriction of use for certain type of pesticides,
   6) additional equipment or attachments for the sprayer according to the intended use, and
   7) inspections to be made on the sprayer, according to the rules of the pertinent EU Directives.

SPRAYER INNOVATION PERSPECTIVES

SPRAYER INNOVATION PERSPECTIVES

DEVELOPING COUNTRIES

DEVELOPED COUNTRIES

GREENHOUSES
SPRAYER INNOVATION PERSPECTIVES IN DEVELOPED COUNTRIES

MAIN GOALS:
Environmental protection – Operator and consumer safety

LESS PPP LOSSES
LESS PPP USE
MORE PRECISE AND UNIFORM PPP DEPOSIT ON THE TARGET

IMPROVEMENT OF THE USE OF ELECTRONIC DEVICES

LES PPP LOSSES

ENVIRONMENTAL FRIENDLY SPRAYER

Control panel:
- Speed
- Flow rate
- Cleaning system
- Pressure

Antidrip nozzles
Internal cleaning device
Clean water tank
External cleaning device
Proper agitation system
Minimum PPP mixture remaining
Induction hopper
Fan air outlet adjustable and closing independently on each side
LESS PPP USE
PATCH WEED CONTROL

BY WEED OR SEEDS MAPPING

BY WEED SENSORS

LESS PPP USE

- Direct scouting
- Aerial photo
- Yield map
- Weeds seeds bank

PATCH WEED CONTROL
(by weed or seeds mapping)

WEEDS MAP

PATCH SPRAY
LESS PPP USE
PATCH WEED CONTROL BY WEED OR SEEDS MAPPING

- Aerial photo
- Weeds seeds bank
- Direct scouting
- Yield map

LESS PPP USE
SPRAYER WITH INJECTION SYSTEM FOR
PATCH WEED CONTROL BY WEED MAPPING

- regulation system
- mixing system
- dosing pump
- PPP tank
- control panel
- boom
- speed sensor
- main pump
- injection system
LESS PPP USE

PATCH WEED CONTROL BY WEED SENSOR

Control unit
herbicide

Forward direction

LESS PPP USE

THE GreenSeeker® SYSTEM

Boom forward direction

Solenoid valve
Spray nozzle
Sensor window
LED dual wavelength light source
Target plant
THE GreenSeeker® SYSTEM

Possible applications

Optimising PPP spray distribution

Weed control under vine rows

Spray application in vineyard in the early growth stages

UP TO 70% PPP SAVINGS

MORE PRECISE AND UNIFORM PPP DEPOSIT ON THE TARGET

Sprayer able to adjust distribution as a function of ground slope

PPP losses during spraying in high transverse slope vineyard
MORE PRECISE AND UNIFORM PPP DEPOSIT ON THE TARGET

- Control panel
- Pendulum
- Actuators
- Hydraulic cylinder on the helm
- Sonar sensor

MORE PRECISE AND UNIFORM PPP DEPOSIT ON THE TARGET

- Device able to modify nozzle position
- Electronic pendulum
- Electronic pendulum able to find row transverse slope
Sonar sensor able to determine the distance between sprayer and rows.

Hydraulic cylinder on the helm able to maintain the sprayer in the inter-row center.

Conventional situation

Innovative sprayer

PPP savings 15-20%
LESS PPP LOSSES

MORE PRECISE AND UNIFORM PPP DEPOSIT ON THE TARGET

LESS PPP USE

CASA
Crop Adapted Spray Application

• identification of PROBLEM
  CHS – Crop Health Sensor

• identification of TARGET
  CIS – Crop Identification System

• identification of ENVIRONMENTAL CIRCUMSTANCES
  EDAS – Environmentally Dependent Application System
**CASA**
*Crop Adapted Spray Application*

**Integrated System**
- CHS
- CIS
- EDAS

**Controller**

**CAN bus LINE**

**Crop Health Sensor**
*Spectral analysis for identification of object properties*

**Energy**
- Fluorometry
- Spectrometry
- Reflection

**Absorption**

**Transmission**

**Identifying plant stress**
*(Hyperspectral analysis)*

**Graph**
- Reflectance [%]
- Wavelength [nm]

- Data points for different wavelengths showing reflectance percentages.
Spectral analysis of Elstar leaves

Healthy Leaves

Infected Leaves

(ascospores of Venturia inaequalis)

Crop Health Sensor

Spectral analysis for identification of object properties

Crop Identification System

Identification of plant size and density

NDVI estimation based on reflectance wavelength groups:
- 675, 679, 680 nm
- 745, 750, 755 nm

Early detection of apple scab (reduced NDVI) – 2 days after infection
**Crop Identification System**

**Identification of plant size and density**

Ultrasonic sensors identifying canopy **WIDTH** and tree **DENSITY**

**Sensor I**
- Distance range: 60 ÷ 500 cm
- Ultrasound frequency: 45 kHz
- Ultrasonic impulse frequency: 10 Hz
- Precision of distance detected: < 1% of measured value

**Sensor II**
- Power supply: 9 ÷ 17 V
- Distance range: 60 ÷ 500 cm

**Sensor III**
- **LEVEL I**: 100 cm
- **LEVEL II**: 30°
- **LEVEL III**: 100 cm

**ACQUISITION OF SENSORS DATA IN THE FIELD WAS CARRIED OUT DURING THE WHOLE SEASON**

Comparison between figures from sensors and percentage of “gaps” in the vegetation wall assessed by image analysis.
RESULTS
Comparison between figures from sensors and percentage of “gaps” in the vegetation wall assessed by image analysis

![Graph showing the comparison between sensors data and percentage of gaps.](image)

\[ R^2 = 0.92 \]

Crop Identification System
Identification of plant size and density

CIS spray application system

4 nozzles per air spout individually controlled by on/off pneumatic valves

LEVEL I
LEVEL II
LEVEL III

4.0 m
2.8 m
1.6 m
0.4 m
Results – Volume (dose) applied

Orchard A – 2-year ‘Gala’  h = 2.2 m
Orchard B – 11-year ‘Red Chief’  h = 4.0 m
Orchard C – 13-year ‘Gala’  h = 4.0 m

Identification of plant size and density

Crop Identification System

Environmentally Dependent Application System

Concept

Sprayer position is based on DGPS SYSTEM.

Wind velocity and direction are measured with ULTRASONIC ANEMOMETER.

Application parameters are adjusted depending on sprayer position and wind situation, in order to minimise spray drift and protect sensitive areas from contamination:

- **SPRAY QUALITY** – by altering FINE/COARSE SPRAY nozzles
- **AIR FLOW** – independently for left and right sides
Environmentally Dependent Application System

Adjustment of SPRAY QUALITY

- Pneumatic valves
- Air-inclusion nozzle 90°
- Standard flat-fan nozzle 90°

Adjustment of AIR FLOW

- Air vane
  - directing air flow LEFT/RIGHT
- Diaphragm leaf shutter
  - restricting air flow on fan inlet
- Electric actuators
  - controlling shutter and vane
SPRAYS INNOVATION PERSPECTIVES IN DEVELOPING COUNTRIES

MORE DIFFUSE PPP APPLICATION SYSTEMS

PPP LOSSES > 70% OF APPLIED VOLUME
SPRAYERS INNOVATION PERSPECTIVES IN DEVELOPING COUNTRIES

THE EXAMPLE OF CHINA

SPRAYERS

PRODUCT QUALITY CERTIFICATION

CCC MARK

MANUFACTURER ADVISEMENT CERTIFICATION

MARKET ACCESS CERTIFICATION

MORE ATTENTION GIVEN TO ENVIRONMENTAL ASPECTS

AIR INDUCTION NOZZLES

BOOM SPRAYERS EQUIPPED WITH AIR SLEEVES

ELECTRONIC SENSORS

PRECISION AGRICULTURE
SPRAY INNOVATION PERSPECTIVES IN GREENHOUSES

About 400,000 hectares of protected crops only in the Mediterranean regions

PESTICIDE APPLICATION IN GREENHOUSES

MAIN PROBLEMS

- Extension of the growing season
- Elevated temperatures
- High humidity
- Different range of crops and of crop size and shape
- Potted and bedding growing

- Favourable environment for pests and disease
- High number of applications per year
PESTICIDE APPLICATION IN GREENHOUSES

Different range of crops and of crop size and shape

EXTREMELY REDUCED FREE SPACE

PESTICIDE APPLICATION IN GREENHOUSES

CLASSIFICATION

- High volume spraying (up to 6000 l/ha)
  - high pressure (up to 6 MPa) - *fine spray*
- Low volume spraying (50-100 l/ha)
  - *very fine spray*
- Fogging (less than 5 l/ha)
  - *fine aerosol*
PESTICIDE APPLICATION IN GREENHOUSES

High volume

Stationary or mobile sprayer with a long hose with a spray lance at the end for spot treatments

Stationary sprayer

PROS

- Low investment
- Low pesticide residues on harvested product

CONS

- High spray losses
- Low distribution uniformity
- Low concentration of active ingredient (low effectiveness against pests)
- High contamination risk for the user
- Low labour productivity
PESTICIDE APPLICATION IN GREENHOUSES

Average PPP operator contamination

Considering 70 applications per year

> 6 litres of PPP per year on the operator body

Flowers

Total = 89.7 ml/h

SPRAY INNOVATION PERSPECTIVES IN GREENHOUSES

Low volume spraying

Flying doctor (IMAG)

rotation nozzles
VMD 60-80 µm
working width 350 cm
controlled by a PLC
sprayer automatically rinsed in the home position
SPRAY INNOVATION PERSPECTIVES IN GREENHOUSES

Low volume spraying

Satellite sprayer travelling on rails

Air assisted sprayers
JKI (ex BBA) prototype

Ganzelmeier, 2001

SPRAY INNOVATION PERSPECTIVES IN GREENHOUSES

Automatic single pot pesticide application

Robot realized by DEIAFA - CNR - IMA
SPRAY INNOVATION PERSPECTIVES IN GREENHOUSES

USE OF ROBOTICS

IMPLEMENTATION OF REMOTE CONTROL SPRAYERS
CONCLUSIONS

The use of pesticides will remain essential in future (world population = 9 billions in 2050)

More food quantity, quality and profitability

New demands

Equipment operator safety  
Protection for the environment  
Consumers safety

Key roles of the sprayer and application techniques

New regulations

New market opportunity

Necessity to improve sprayer performances

CONCLUSIONS

Due to the necessity to pay more attention to the environmental aspects and due to the EU Directive, there will be a new improvement in spray application technology and an input for the sprayers and components market

New sprayers  
Repair of sprayers in use
### SPRAYERS IN USE IN EU (source: Spise)

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### SPRAYERS COMPONENTS TO BE REPLACED DUE TO THE INSPECTION
(average of inspection activity results in Belgium, Italy and Germany)

- Nozzles -15%
- Pressure regulator - 20%
- Pump membranes - 5%
- Pump - 5%
- Manometer - 5%
- Filters - 5%
- Antidrip - 5%
NUMBER OF PIECES REQUIRED AND EU MARKET VALUE IN THE FOLLOWING 7 YEARS

6,000,000

1,000,000

50,000

Average EU market ~1,000,000,000 €

NUMBER OF SPRAYERS TO BE REPLACED DUE TO THEIR INABILITY TO PASS THE INSPECTION

IN EU ~ 35,000 sprayers (1.5% of the inspected)

250 million of Euro

+ 33% of the present market value

(750 million of Euro)
CONCLUSION

Due to the EU Framework Directive, the EU field crop and orchard sprayers market will be improved about

1,3 billion Euro

within the next 7 years