Characterization of wheat plant density and sowing pattern from RGB images taken at the ground level

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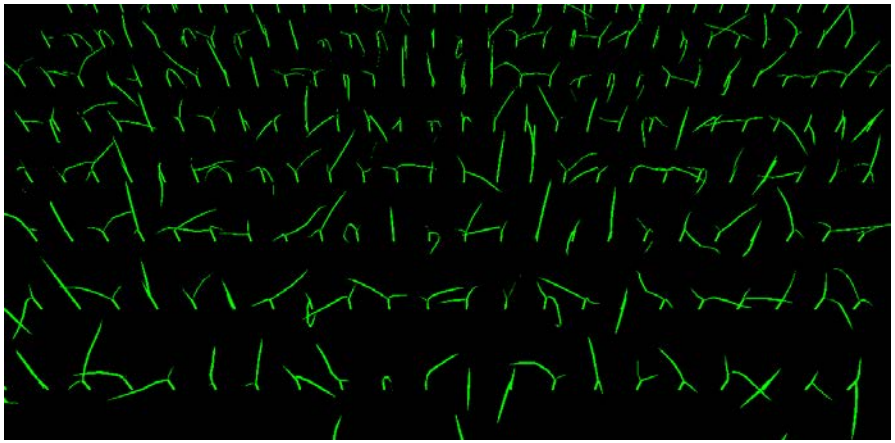
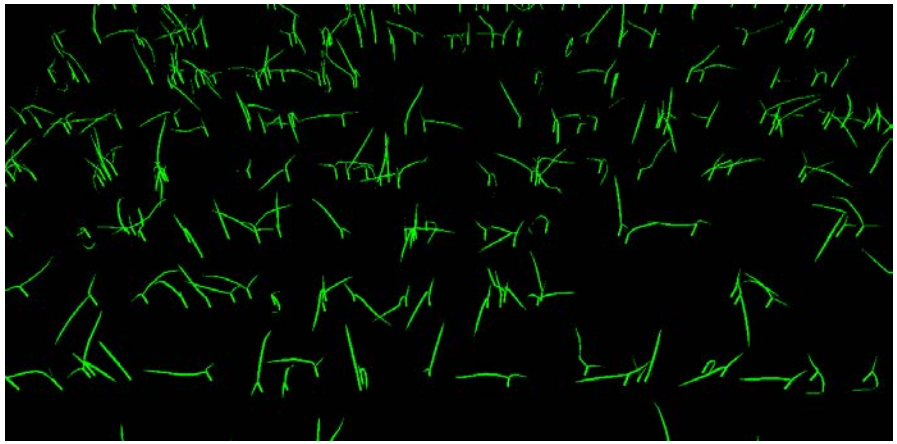
Why plant density and distribution?

- Field management parameter
- Scale-up factor: from plant to canopy scale
- Assessing the uniformity of plant distribution
- Precise canopy description





Experiment

Two types of data acquisition:

Experiment

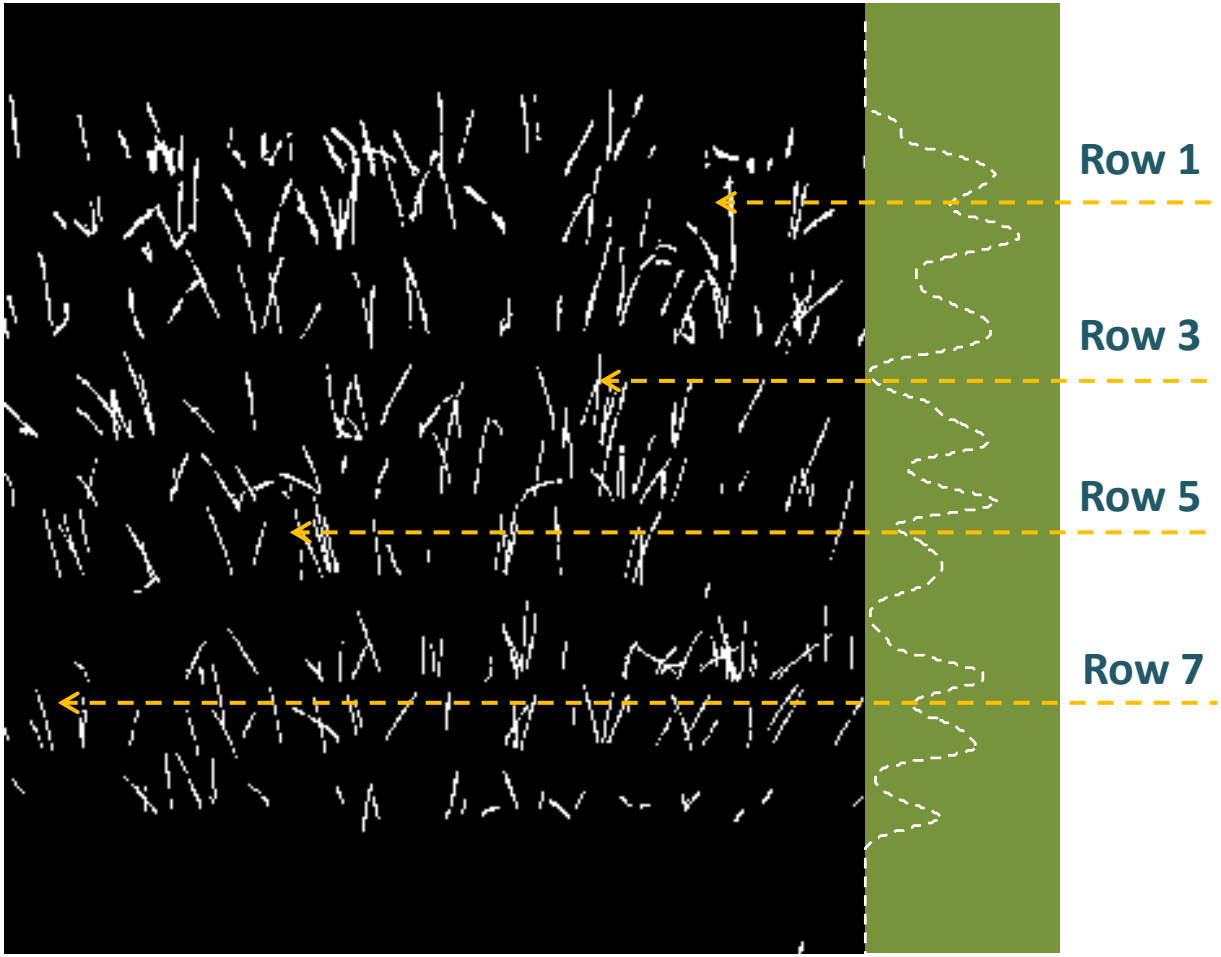
Factors needed to be taken into account:

- cultivar
- density
- sowing machine
- sowing and growth condition…

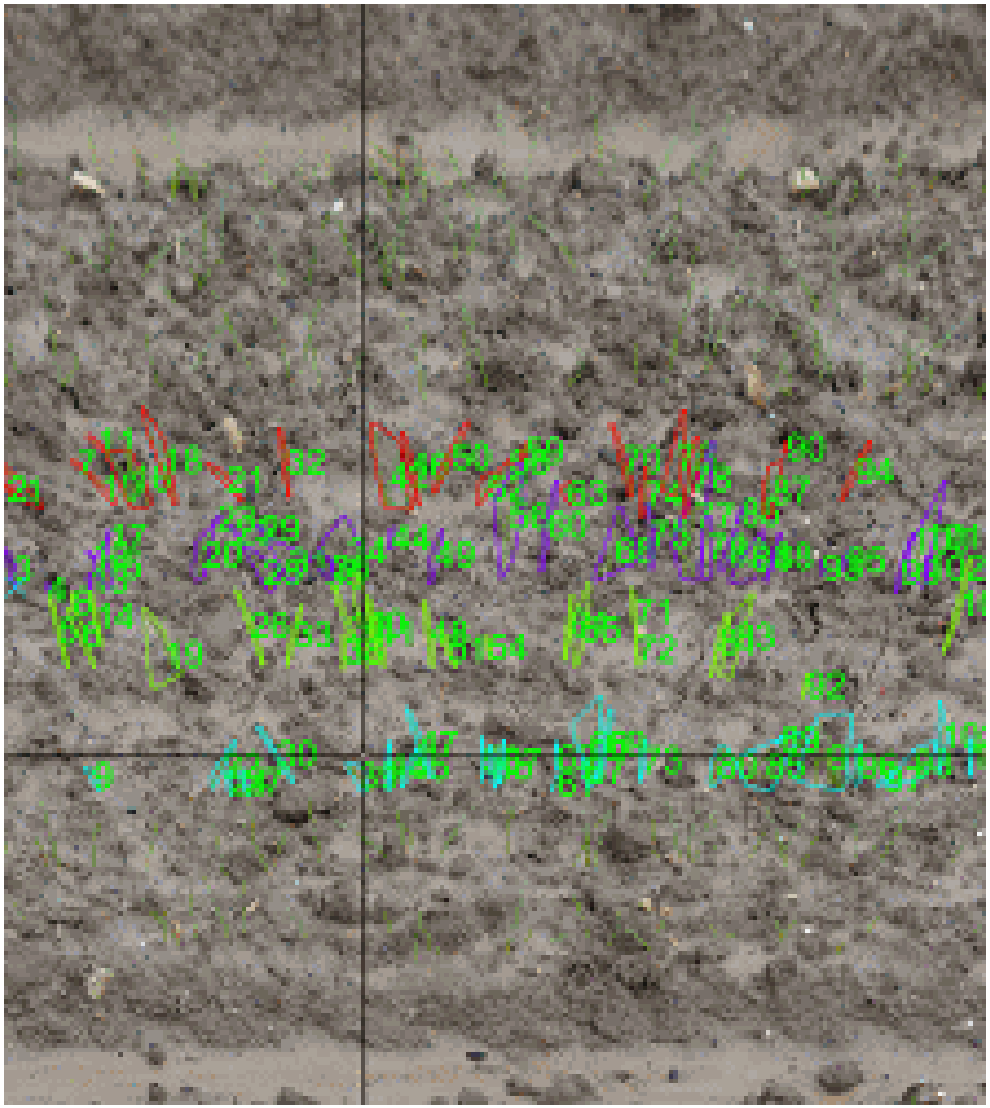
Experiment treatment:

- **Toulouse**: two cultivars x five densities
- **Avignon**: four densities (one cultivar)
- **Paris**: two densities x 60 cultivars

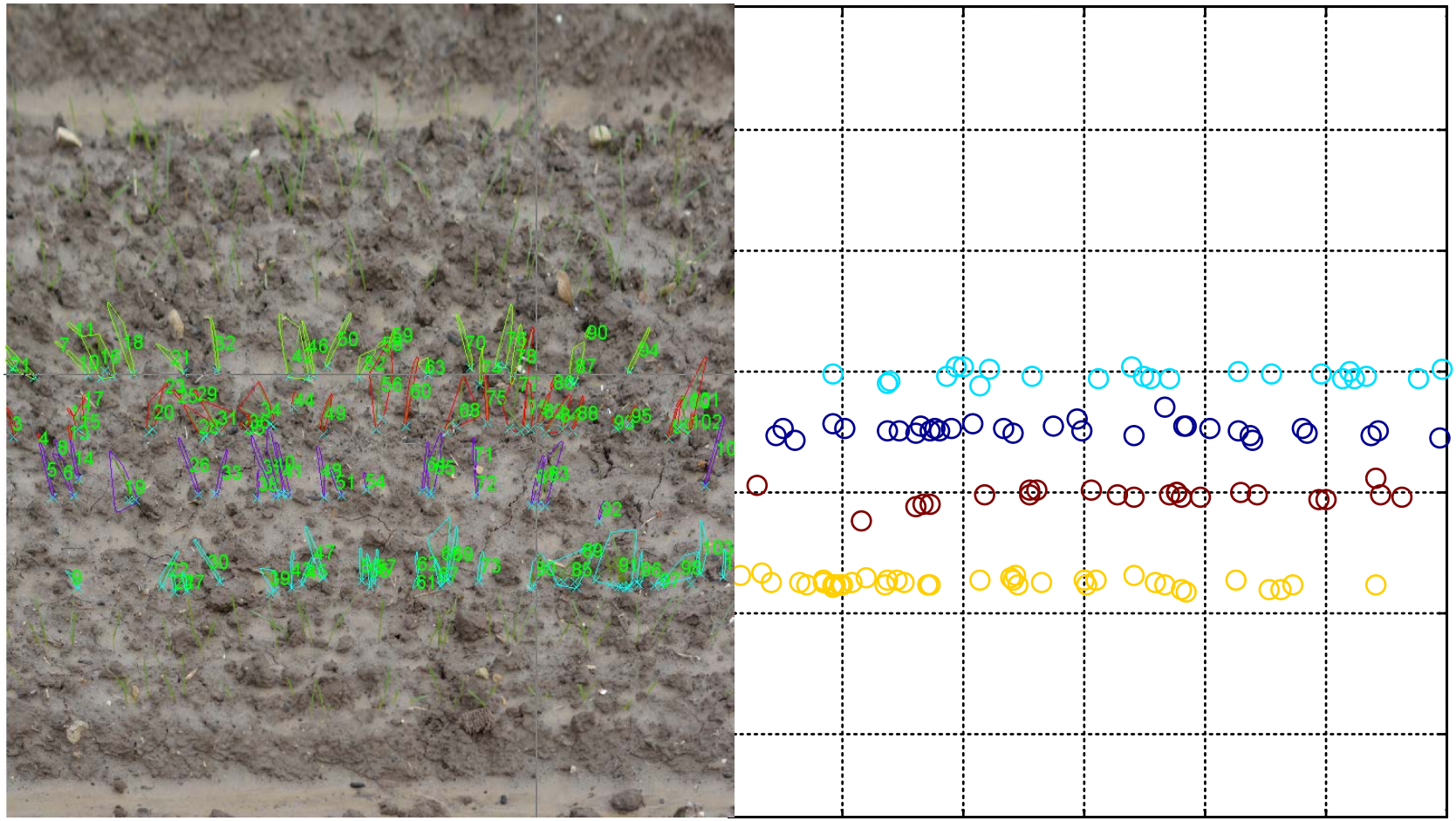
Row detection



Plant labeling



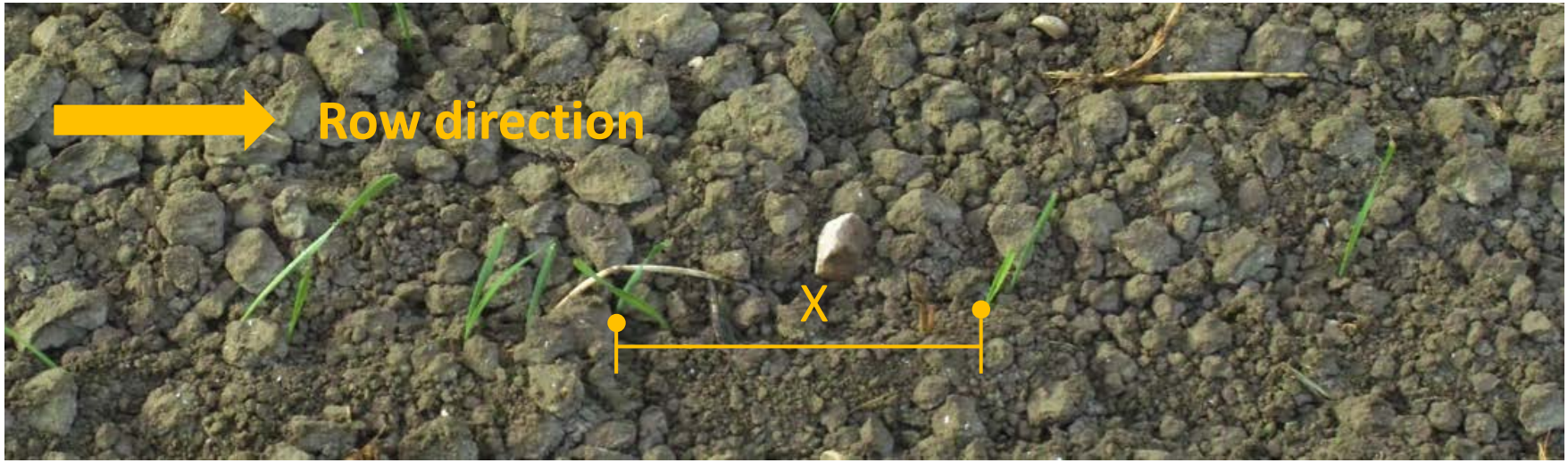
Plant position



Plants distribution pattern

- **Along the row direction:**

$$X \sim ?$$



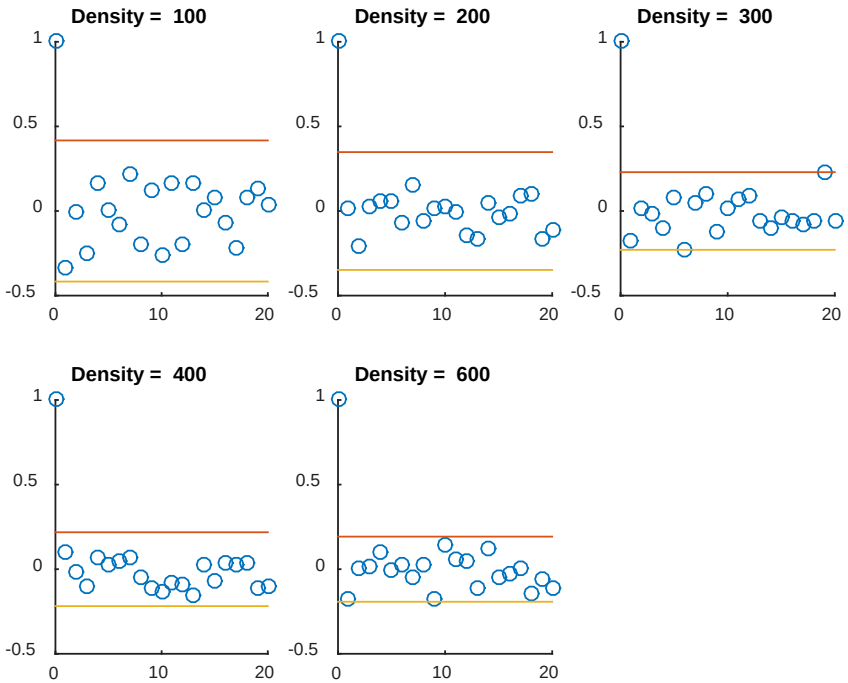
Plants distribution pattern

- **Across the row direction:**

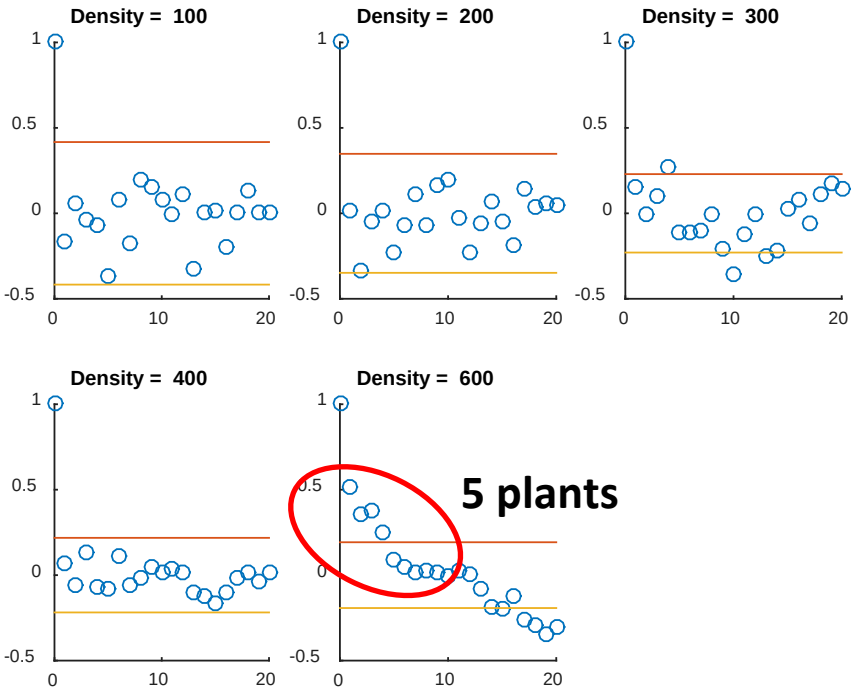
$$Y \sim ?$$

Independency

Along row direction



Across row direction

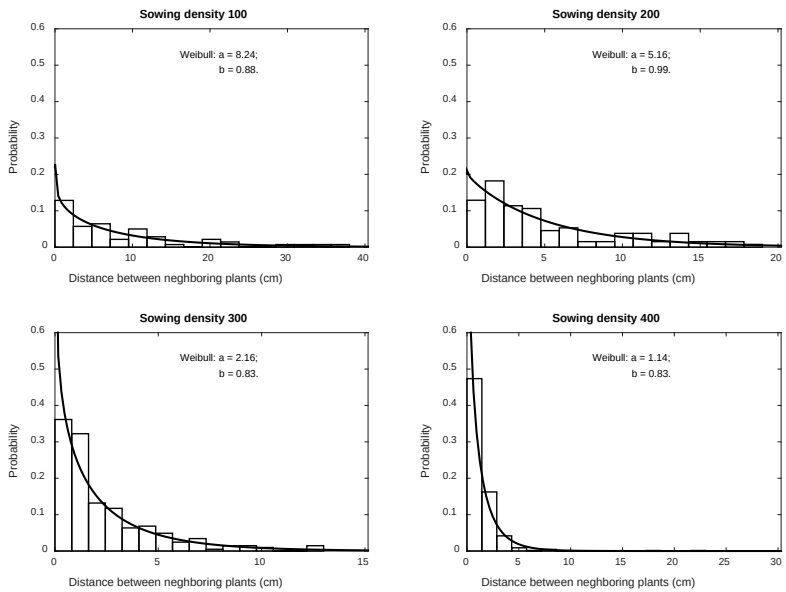


(Toulouse 2013)

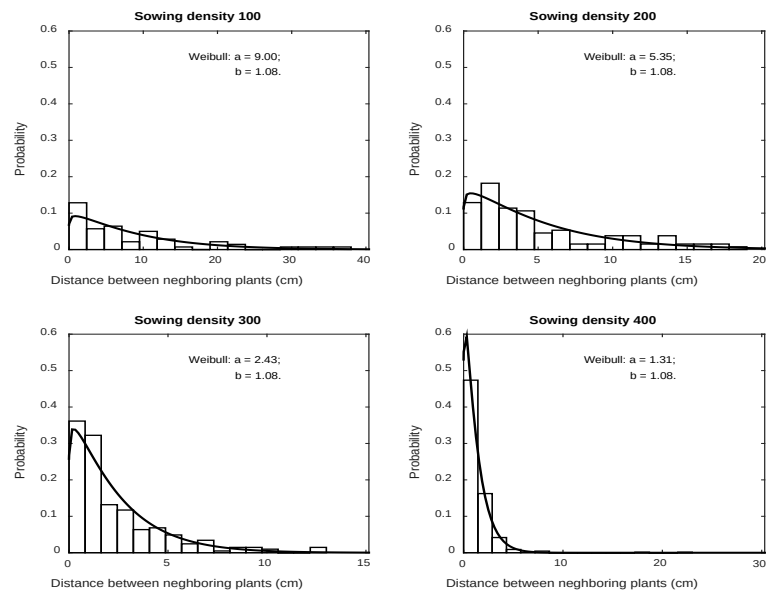
Field Measurement

$$X \sim Weibull(a, b)$$

Scale parameter a*; Shape parameter* b

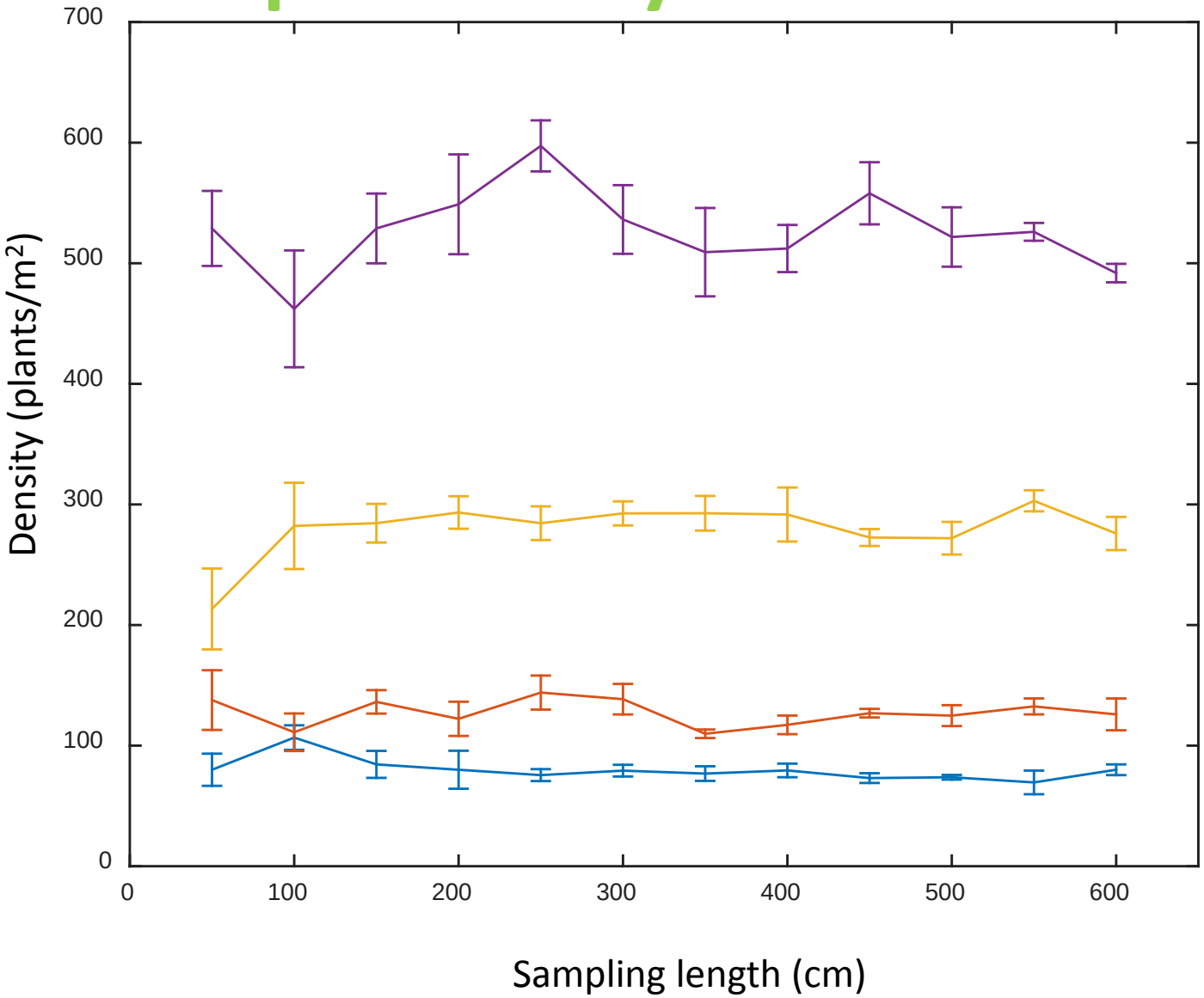


$$X \sim Weibull(a, b)$$



$$X \sim Weibull(a, constant)$$

Density estimation with the probability function

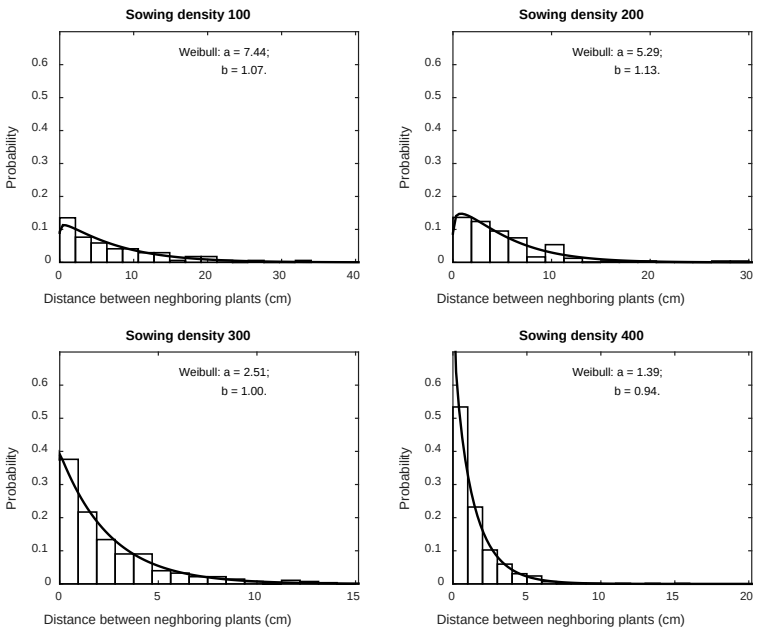


Sampling strategy:

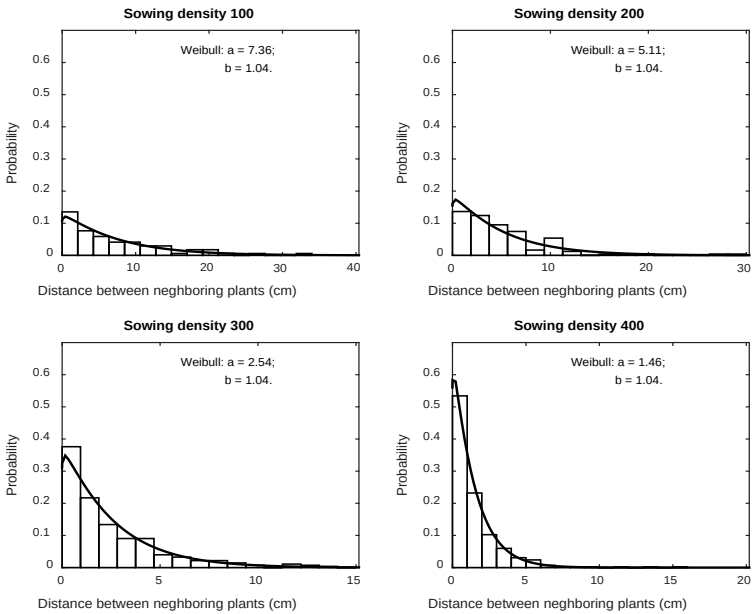
three rows $\times$ ***two meters each*** **row**

Density	Field measurement		Two parameters			One fixed		
	mean	std	mean	std	RE	mean	std	RE
100	68.89	13.92	80.00	15.75	16%	77.78	5.56	13%
200	126.67	10.18	122.22	14.19	**4%**	146.67	6.94	**16%**
300	283.33	27.15	293.33	13.47	**4%**	280.00	10.72	**1%**
400	522.22	12.37	548.89	41.38	**5%**	516.67	36.72	**1%**

Extracting from the pictures

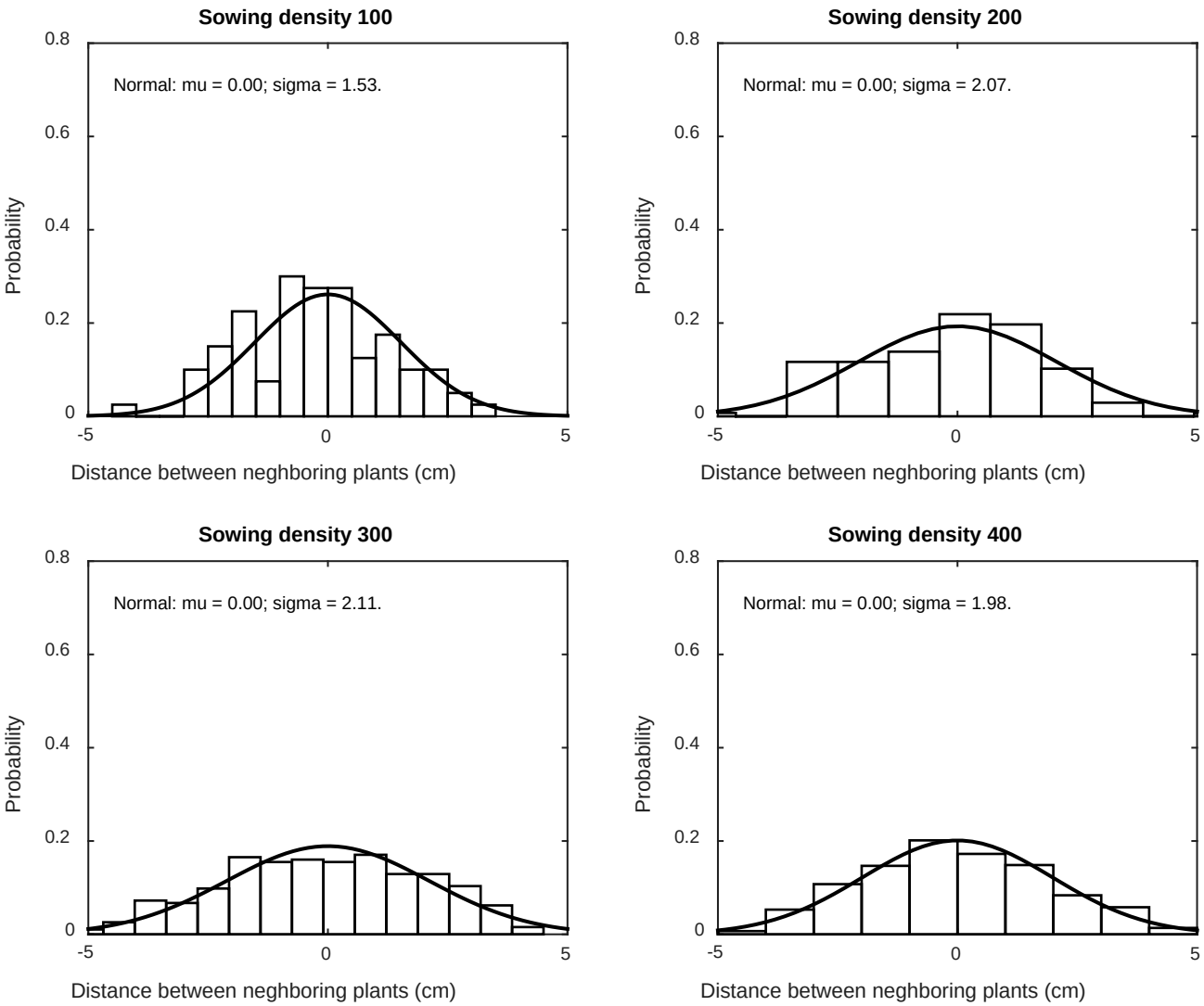


$X \sim Weibull(a, b)$



$X \sim Weibull(a, constant)$

$$Y \sim Normal(0, \sigma^2)$$



$\boldsymbol{Sampling\ strategy}$:

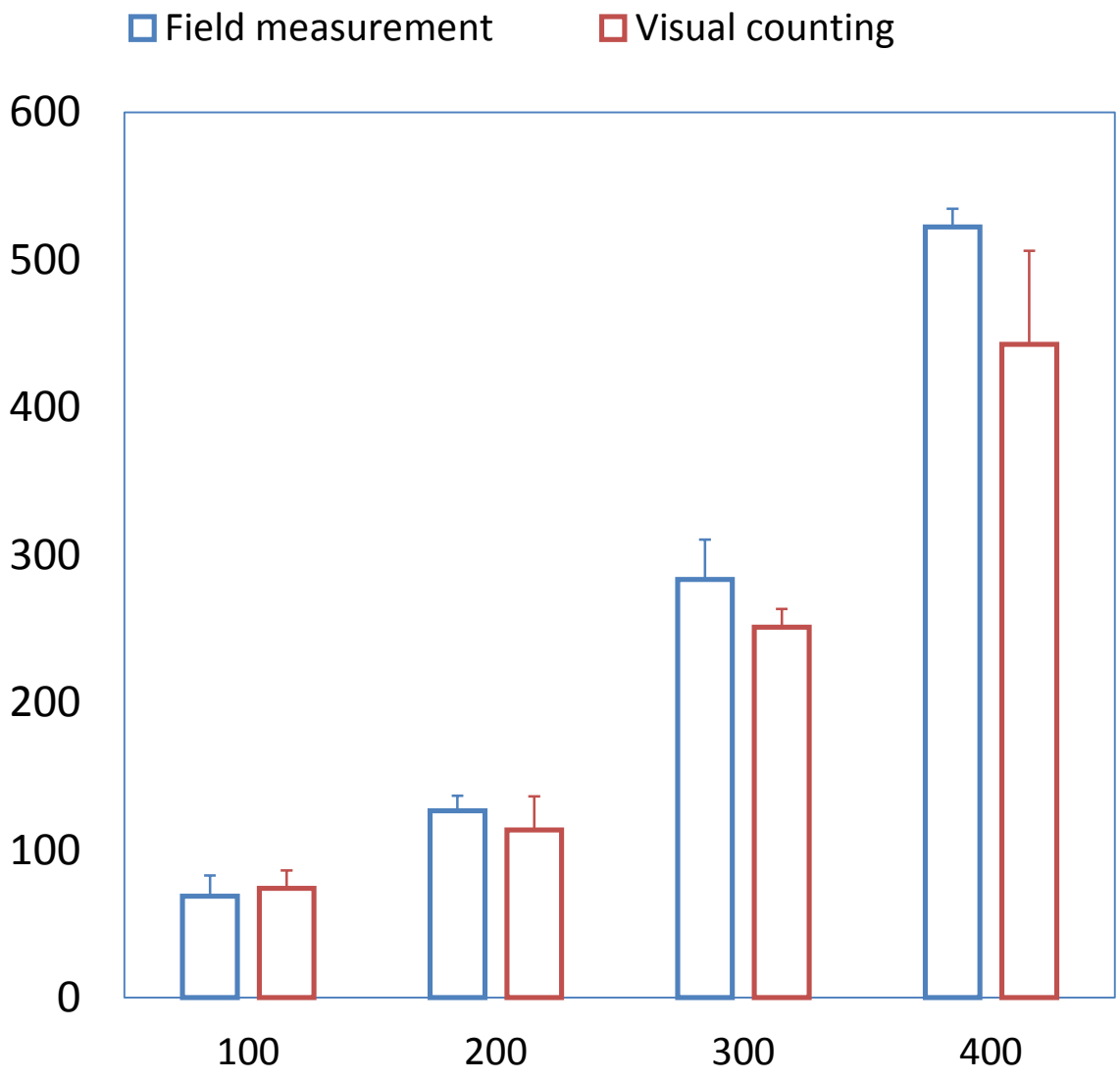
$\boldsymbol{ten\ rows \times 0.8\ m\ each}$ **(the length of the picture)**

Density	Field measurement		Two parameters			One fixed		
	mean	std	mean	std	RE	mean	std	RE
100	74.07	12.21	88.33	9.48	19%	90.00	6.78	22%
200	113.58	22.93	147.50	9.05	30%	135.00	9.53	19%
300	251.03	12.48	265.00	9.11	**6%**	276.67	19.12	**10%**
400	442.80	63.36	440.00	19.48	**1%**	479.17	18.39	**8%**

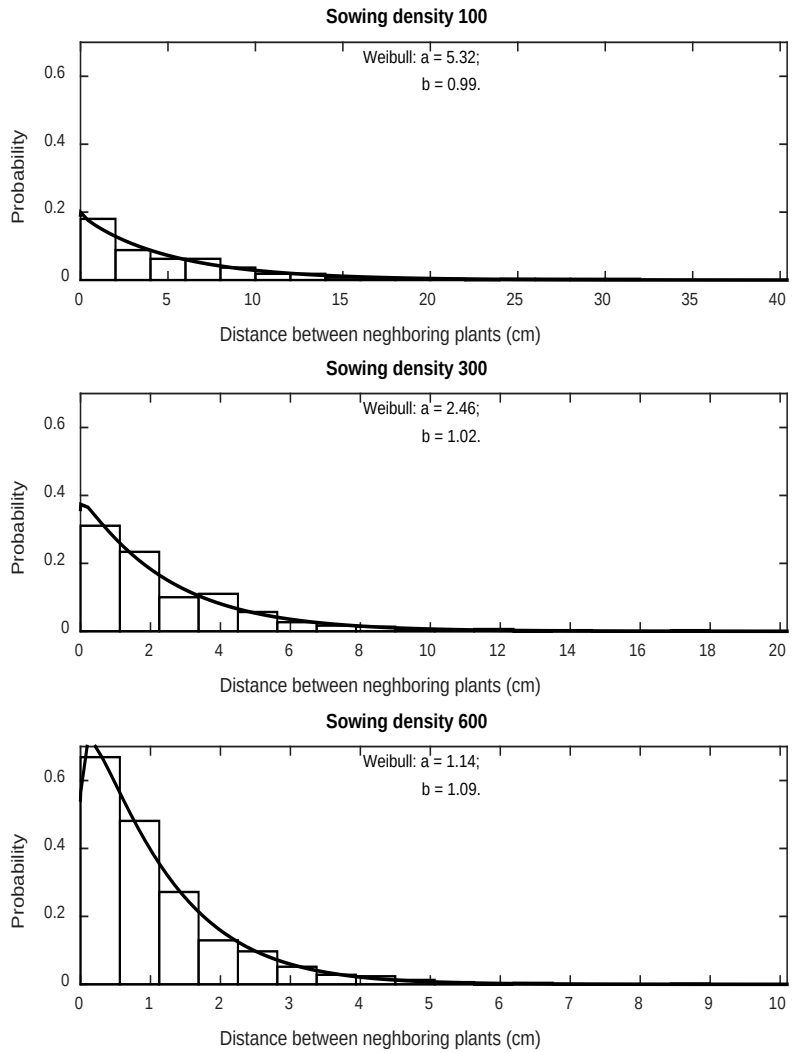
Field measurement vs Visual counting

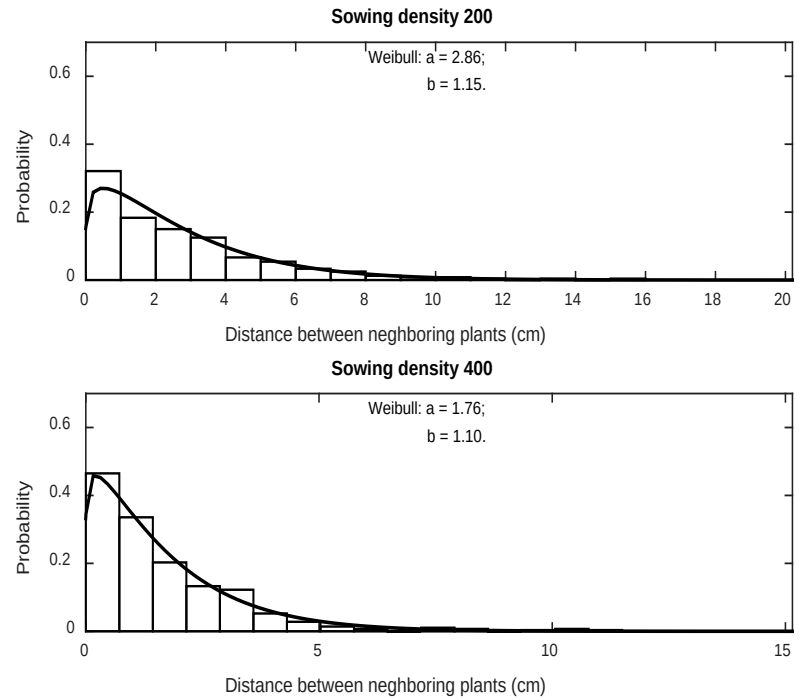
1) Easy to conduct (zoom)

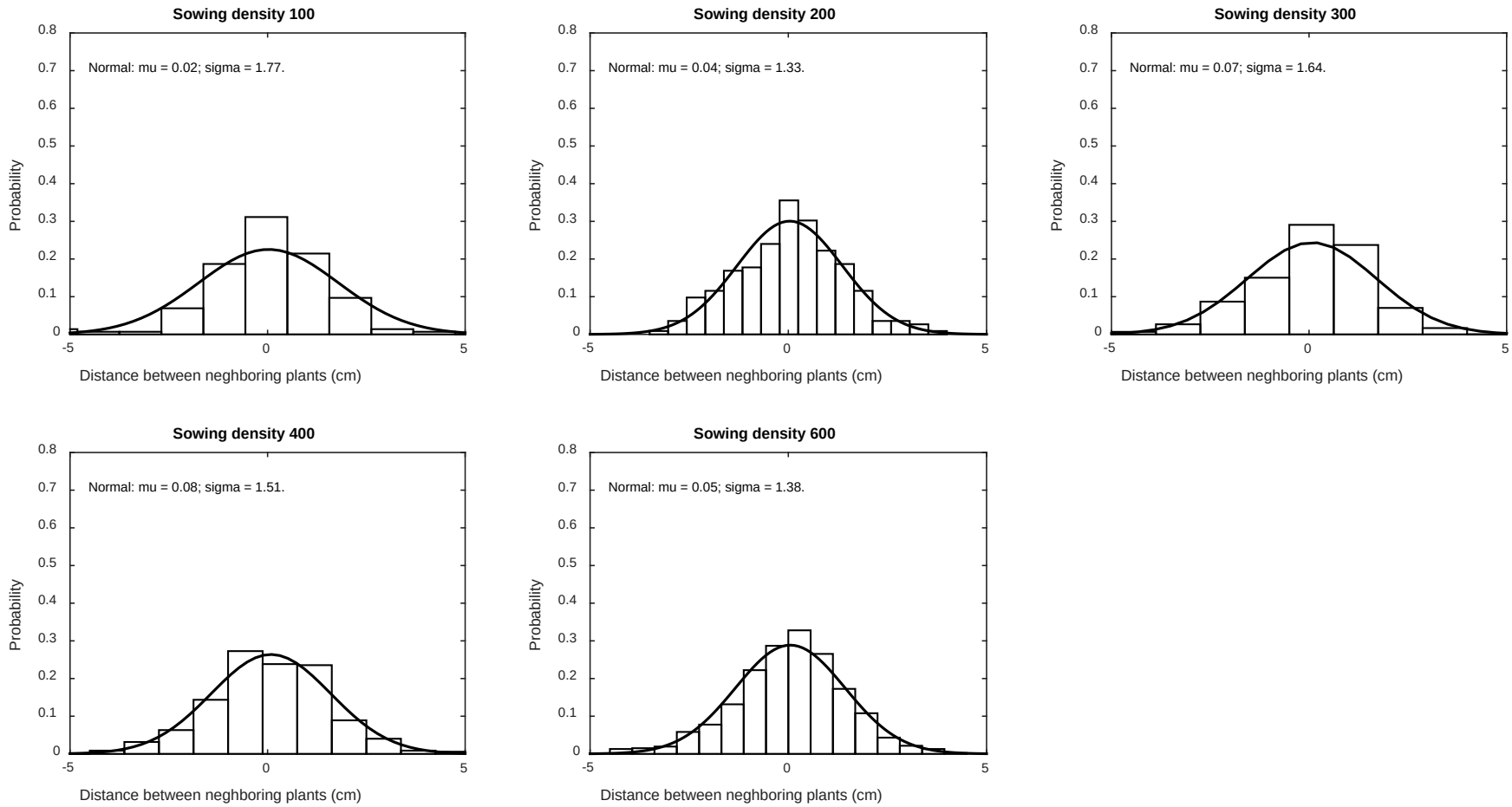
2) Sampling position (the central rows)



Further validate the distribution law



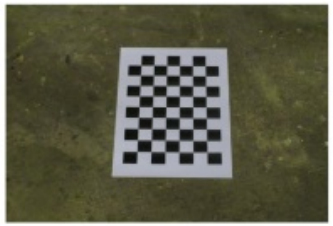


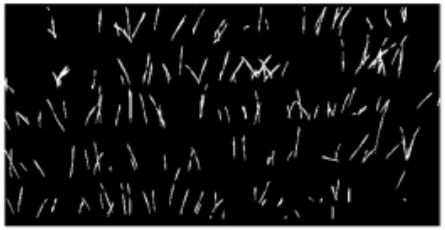

Sowing density 100
Normal: mu = 0.02; sigma = 1.77.
Sowing density 200
Normal: mu = 0.04; sigma = 1.33.
Sowing density 300
Normal: mu = 0.07; sigma = 1.64.
Sowing density 400
Normal: mu = 0.08; sigma = 1.51.
Sowing density 600
Normal: mu = 0.05; sigma = 1.38.
Probability
Distance between neghboring plants (cm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-5
0
5

Density estimation

Data acquisitions

Image processing





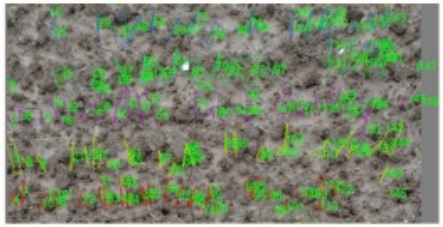


Image calibration → Image segmentation → Row identification and feature extraction

Modelling

Feature selection → Model training or fitting → Test and application

Modelling–
supervised and unsupervised method

- **Neural network**
  - The cost function:

$$MSE_{modified} = \frac{\sum_{i=1}^{n}(Target_i - round(Simulation_i))^2}{n}$$

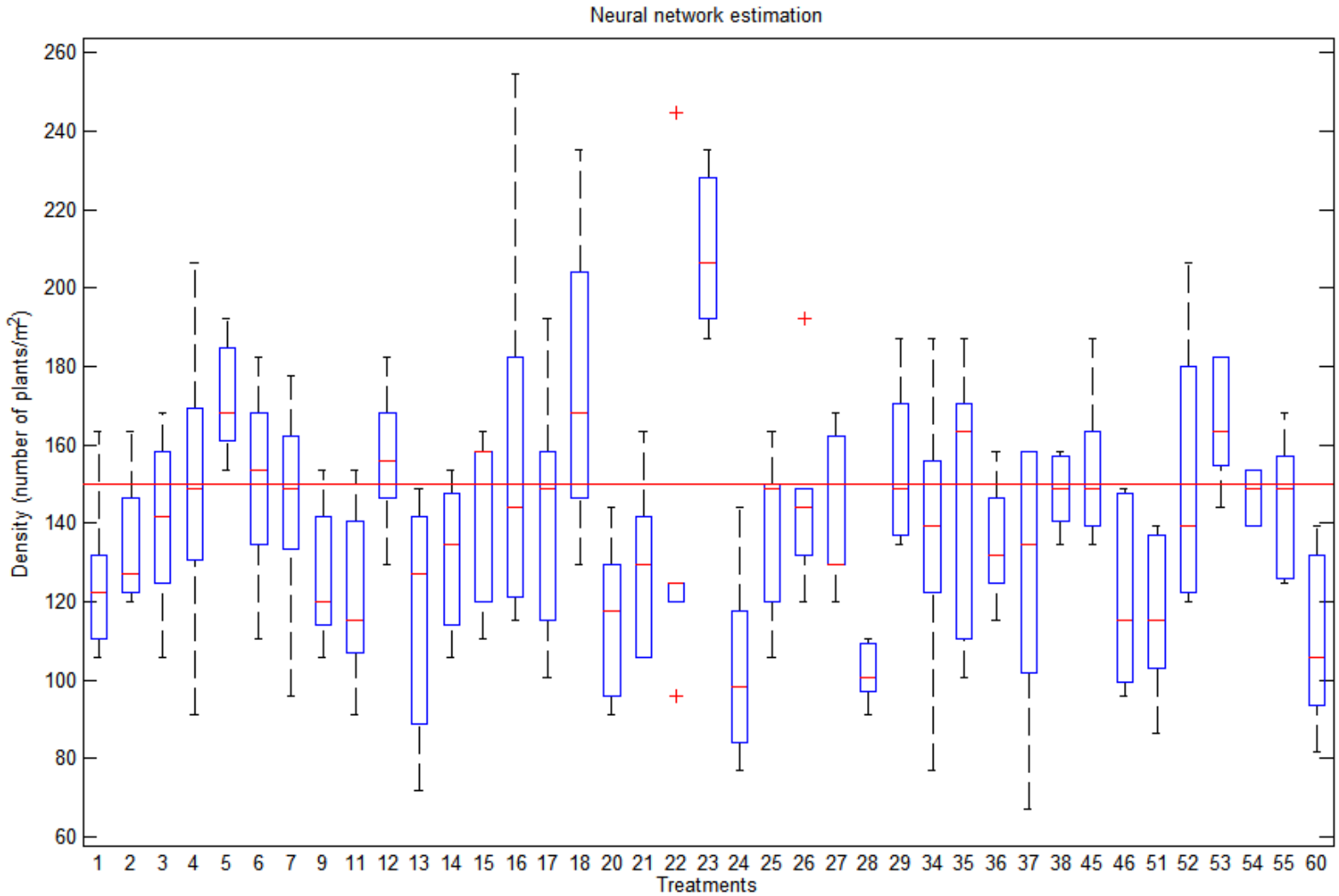
- **Multivariate linear regression**

Model training and evaluation

$$RRMSE = \frac{\sqrt{\sum_{i=1}^{i=n}(\hat{y}_i - y_i)^2}}{\bar{Y}}$$

Number of pictures	Number of isolated objects	RRMSE (%)	
		Neural	Linear
1	121	12.52	19.03
2	223	13.43	14.33
3	317	11.27	13.10
5	541	11.42	14.10

Model application



Conclusions

- Weibull distribution of plant location along the row and normal distribution across the row.

- Along the row direction, the plants are distributed independently. Conversely, significant spatial correlations were found across the row for the highest densities.

- Supervised approach provides reliable estimates of the plant density as compared with the reference method, i.e. visual counting.

Thanks for your attention!