Sunflower yield response to crop density under climatic uncertainty: coupling an experimental and a simulation approach.

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(6061) SUNFLOWER YIELD RESPONSE TO CROP DENSITY UNDER CLIMATIC UNCERTAINTY: COUPLING AN EXPERIMENTAL AND A SIMULATION APPROACH.

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ABSTRACT

Crop establishment is a critical step for optimal agronomic and economic crop performances. In sunflower, average emergence rate stands between 70-85% in France, with a tendency to decrease because of increasing bird predation. Consequently, farmers have to sow again the crop in about 8% of the situations.
But obtaining a successful plant stand depends not only on the crop emergence rate but also on the initial sowing density.
Currently, the practical recommendation for sowing density is between 65-70k seeds per ha (target of 50-60k plants/ha) which should be increased (70-75k seeds/ha) in case of minimum tillage, because of lower crop emergence risk.
Ideally sowing density should also be adapted to expected soil water resources, pathogen pressure in the growing area, and cultivar.

Our study aims to refine the current sowing recommendations from *Terres Innovia* by providing site-specific decisions based on climate, soil, and cultivar.
We used field experiments (multi-environment trials) to assess yield and oil concentration response to plant density, soil type, and cultivar in French growing conditions.
We then extended this dataset with numerical experiments (simulations from *SUNFLO* crop model) to evaluate how climatic uncertainty and crop management were impacting or not current sowing recommendations. Datasets were analyzed with linear and quantile regressions both globally and for subsets of the studied population of crops.

We found that crop yield variance was mainly explained by farm location (soil and soil x climate interactions), with a weak average impact of plant density (<= 5%); the hierarchy of factors was similar with field or simulated dataset.
When refining practical recommendations to account for available soil water content (AWC), adjustment of plant density had a greater impact on crop performance.
In deep (AWC > 200 mm) and intermediate (100mm < AWC < 200mm) soils, optimal density range was around 50-60k plants/ha, with important yield loss (10-30%) below this level in deep soils and above it for intermediate soils. In shallow soils (AWC < 100 mm), sparse plant stands were more adequate, given low water available for growth.
From the exploration of unexperienced climatic conditions with simulation, we concluded that sowing density recommendations should be adapted to climatic conditions, to better account for soil x climate interactions.
Finally, our method coupling field and simulation experiments contributed to adapt more efficiently the crop water demand (through plant population) to available soil water ressources, hence refining the scope of technical support.

Key Words : crop density, simulation, crop model, yield, sunflower

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Context

Crop establishment is a critical step for optimal agronomic and economic crop performances.
In sunflower, average emergence rate stands between 70-85% in France, with a tendency to decrease because of increasing bird predation. Consequently, farmers have to sow again the crop in about 8% of the situations. But obtaining a successful plant stand depends not only on the crop emergence rate but also on the initial sowing density.

Currently, the practical recommendation for sowing density is between 65-70k seeds per ha (target of 50-60k plants ha^{-1}) which should be increased (70-75k seeds ha^{-1}) in case of minimum tillage, because of lower crop emergence risk.
Our study aims to refine the current sowing recommendations in France by providing site-specific decisions based on climate, soil, and cultivar.

Questions

- Does the adaptation of plant stand density to environmental context leads to sufficient crop performance improvement to support technical recommendations ?
- How are these recommendations affected by climate uncertainty ?

Methods

We used 38 field experiments from Terres Inovia to assess yield and oil concentration response to plant density, soil type, and cultivar in French growing conditions (256 locations × cultivars × years) [1].
We then extended this dataset with numerical experiments combining 4 locations, 3 soil types, 35 years, 16 genotypes, 3 sowing dates and 7 density levels (141120 combinations), using the SUNFLO crop model [2].
Both datasets were analyzed with linear and quantile regressions both globally and for subsets of the studied population of crops.

Results

In field and numerical experiments, yield variance was mainly explained by farm location (soil and soil x climate interactions), with a weak average impact of plant density (<= 1%); the hierarchy of factors was similar with both dataset.

Field experiments

The adaptation of plant density to the cropping context allowed to raise raw margin by 30€ ha-1 when considering all conditions and caused up to 5 fold margin variations depending on soil water capacity. Consequently, actual recommendations were updated to account for climate and soil, particularly in zones prone to water deficit (figure 1).

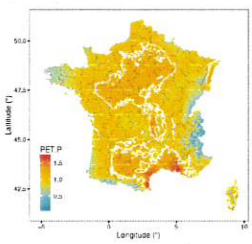

Figure 1. Map for climatic water deficit.
Climatic water deficit was computed as the mean potential evapotranspiration:precipitation ratio over 50 years (1950-2000) [3]. The white coutour line delimitates zone prone to water deficit (PET:P > 1.2).

Numerical experiments

Numerical experiments confirmed that defining practical recommendations according to available soil water content (AWC) led to greater impact on crop performance (figure 2):
- In deep (AWC > 200 mm) and intermediate (100mm < AWC < 200mm) soils, optimal density range was around 50-60k plants ha^{-1}, with important yield loss (10-30%) below this level in deep soils and above it for intermediate soils.
- In shallow soils (AWC < 100 mm), sparse plant stands were more adequate, given low water available for growth.

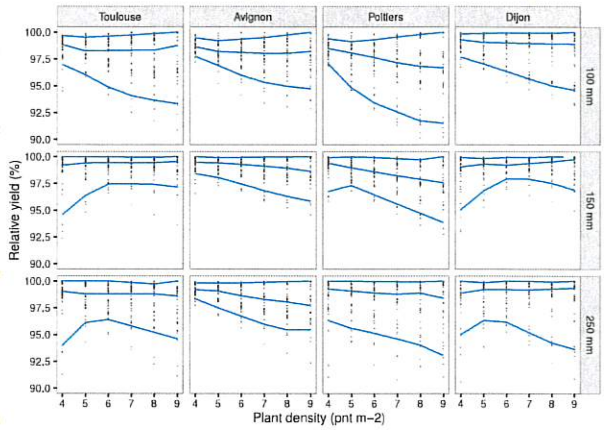

Figure 2. Simulated crop yield response curve to plant density at sowing
Points represents relative yield for each of the 35 years tested (1977-2011). Relative yield was defined as the ratio of yield at the density level to best yield for the trial. Lines are linear regression on quantiles (10%, median, 90%).

However, the exploration of unexperienced climatic conditions with simulation revealed strong soil × year interactions and illustrated that there was no location × soil combination where a modification of plant density would lead to significant yield increase in more than 20% of years (figure 3).

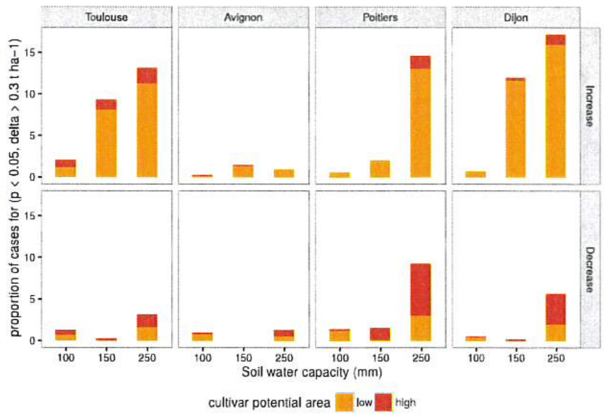

Figure 3. Decisions for plant density adjustment to pedo-climatic conditions under climatic uncertainty. Bars represent the proportion of conditions where density adjustement (increase or decrease) led to significant impact on yield. Colors indicate the cultivar potential leaf area development.

Conclusions and perspectives

Finally, coupling field and simulation experiments contributed to adapt more efficiently the crop water demand (through plant population) to available soil water ressources, hence refining the scope of technical support.
However, optimizing this factor alone had an overall small impact on performance because of trade-offs and environmental variations.
Systems approaches, accounting for different factors and constraints between them have the potential to further increase crop performance and stability.

References and contact

Corresponding author email : pierre.casadebaig@toulouse.inra.fr - Grants were provided by the French Ministry of Research (ANR SUNRISE ANR-11-BTBR-0005), the French Ministry of Agriculture (AAP CTPS 2007 & 2010) and by PROMOSOL association.

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