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# **Agronomic strategies in response to changes in agricultural and cropping systems**

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# The earlier the better: sowing date drives cover crop performance - A regional modeling study

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The cultivation of cover crops is gaining increasing importance in cropping systems due to their numerous agronomic and environmental benefits, including soil protection, nitrate leaching reduction, and weed suppression. Mechanistic cropping system models may help in quantifying these effects over different spatial and temporal scales. For this purpose, specific processes that are important for cover crops need to be implemented in models. First, since autumn cover crops are typically sown after summer cash crops, the sowing window ranges from late August to late October, during which soil temperature and moisture conditions can vary considerably; in particular, besides temperature, also soil water content can limit crop emergence, which therefore needs to be simulated using the hydrothermal time concept. Second, cover crop termination may occur chemically, mechanically or by frost. To simulate frost winterkill termination, models need to predict crop resistance to cold, quantify frost damage, and simulate the subsequent mineralisation of damaged biomass. This study aimed to implement and enhance the CropSystVB model (Bechini and Stöckle, 2007) to simulate cover crop growth under varying conditions and to evaluate their long-term agronomic effects in the Lombardy region. After improving the model with the hydrothermal time to simulate emergence and with a frost damage module, CropSystVB was calibrated and validated for white mustard and black oat using experimental data collected from 2019 to 2025 at several sites across Lombardia, encompassing diverse sowing dates, nitrogen rates, and residue management strategies. The region was divided into 12 agrometeorological zones, within which representative soils were selected based on texture, SOC, skeleton content, and root distribution. For each climate-soil combination, a maize-cover crop rotation was simulated under three slurry-

nitrogen fertilization levels (N0, N75, N150), two residue management options (incorporated or removed), and two seedbed preparation methods, resulting in 7,632 scenarios over 14 years. Sowing date significantly affected biomass production and nitrogen uptake. Sowing by early September ensured biomass exceeding 3 t/ha for both species, with peak biomass occurring 89–102 days after sowing for white mustard and 94–135 days for black oat—coinciding with the onset of frost damage. Later sowings reduced biomass, but improved frost tolerance, especially in black oat, supporting spring regrowth. Biomass production significantly varied among sites, largely due to rainfall patterns. Also, early sowings achieved a fraction of intercepted radiation >80% more rapidly, ensuring effective soil cover and improved weed suppression. Sowing date also had a marked impact on nitrogen uptake and the associated reduction in nitrate leaching compared to bare soil. White mustard sown at the earliest date showed a nitrogen uptake of 136 kg/ha, which decreased by 63% by the latest sowing date. Black oat followed a similar trend, with initial uptake of 112 kg/ha, decreasing by 67%. Notably, by the third sowing date, nitrogen uptake had already declined by 28% for white mustard and 35% for black oat. Overall, early September was identified as the optimal sowing date for maximizing biomass, nitrogen uptake, and weed control, supporting cover crops as a sustainable management strategy in Lombardia's cropping systems.