DIVISION S-4—SOIL FERTILITY & PLANT NUTRITION

State-Space Approach to Spatial Variability of Crop Yield

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ABSTRACT

Spatial crop yield variability complicates interpretation of field experiments if there is no information available about the spatial variability structure of the soil. Our objective was to determine, using a state-space approach, the underlying process in a soil that caused spatial yield variability of a N_2-fixing crop and a nonfixing crop. On a heterogeneous soil, ryegrass (*Lolium multiflorum* L.) and alfalfa (*Medicago sativa* L.) were cropped on neighboring transects. Dinitrogen fixation, calculated with either the difference method or the ^{15}N isotope dilution method and averaged across the transects, did not differ. But, as we examined locations along the transect, differences in amount of fixed N calculated by each method became apparent. Yields of both crops showed different variability structures along the transects. Local effective soil N content was related to local N uptake from soil and to soil symbiotic N_2 fixation of alfalfa. In order to conclude this, the spatial distribution of the soil volume taken by stones in this partially rocky soil had to be considered. In stochastic (state-space) models based on spatial dependence between observations, crop yield, effective soil N, and N_2 fixation were identified as first-order autoregressive processes moving through the transect. In other cases, state-space models were useful tools for spatial interpolation of plant yield, except for large yield alterations between neighboring plots along a transect. This study showed that the spatial variability structure of yields could be explained from located field observations combined with state-space models.

Causal connections between field soil parameters and plant response can be detected effectively if space or time coordinates of observations are included in the analysis. In the past two decades, attention paid to soil spatial variability has allowed a better understanding of processes in field soils that influence the variability of crop yield (Bresler et al., 1981). It is now known that observations within and between treatment plots may not be independent of each other and, hence, a block design of a field experiment becomes inadequate (Nielsen and Alemi, 1989).

Symbiotic N_2 fixation, which has been shown to be an effective N source for legume crops, requires quantification for understanding the N budget of crop rotations, selecting effective legume crops, and estimating the potential for NO_3^- contamination of groundwater.

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Two methods (difference method [D] and ^{15}N isotope dilution method [ID]) have been developed to estimate quantities of atmospheric N_2 fixed in the field. Both methods, described and discussed by Weaver (1986), have been used in field experiments that have neglected sampling locations in space. An exception is the experiment, reported by Reichardt et al. (1987) and Kirda et al. (1988), at the FAO International Atomic Energy Agency Agricultural Laboratory experimental field in Seibersdorf, Austria. They observed alfalfa as a N_2-fixing legume crop and ryegrass as a nonfixing reference crop planted along two parallel transects. In view of the high variability of calculated N_2 fixation along the transect, Reichardt et al. (1987) concluded that estimations of N_2 fixation by either method may not be valid for highly variable soils and that such studies, even with ID, should be restricted to fairly homogeneous soils.

In many cases, there is a lack of information for a complete deterministic explanation of situations in the field. Our objective was to show that, in the Austrian field soil, a stochastic approach including simply observable parameters and their spatial distributions is useful in identifying the underlying process that caused different spatial yield variability of ryegrass and alfalfa. Therefore, we first had to determine whether ID was sensitive enough in defining different sources for N uptake of both crops to be an adequate method for field experiments in such a heterogeneous soil. Second, simply observable parameters causing crop yield variability had to be identified. Finally, we wanted to estimate local crop yields using the state-space approach (Shumway, 1988) based on spatial dependence between yield-determining factors.

METHODS

The data analyzed here were part of a field study carried out at the FAO International Atomic Energy Agency Agricultural Laboratory experimental field in Seibersdorf, Austria. The soil was classified as a Typic Eutrocrept with a coarse clay loam texture. Two transects, 96 m long by 1.8 m wide and separated by 0.5 m, were planted on 20 June 1984 with ryegrass as the reference crop and alfalfa as the N_2-fixing test crop. After germination 20 kgN/ha was uniformly applied to both transects as ^{15}N-labeled urea fertilizer with 4.8% ^{15}N atom excess. During the growing season, both transects were irrigated to avoid crop water stress. On 8 Aug. 1984, 63 plots (0.8 by 0.9 m) were harvested at 1.5-m intervals. Dry-matter yields were determined and subsamples of the plant material were analyzed for total N content using the Kjeldahl procedure and for

Abbreviations: D, difference method, ID, isotope dilution method; Ndfa, N derived from the atmosphere; N(fc), total amount of N in the shoot of the fixing crop; N(nfc), total amount of N in the shoot of the nonfixing crop; Neff, effective N content of soil.