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**Multivariate evaluation of plant and soil variables in field grown cauliflower (Brassica oleracea v. botrytis).**

**Introduction.**
The soil - plant relationship is very complex. Studying one or just a few nutrient elements can not give reliable information about the situation in the field. In an attempt to identify nutrient factors limiting vegetable production in field a combination of soil and plant analyses has been practised at the agricultural research centre at Röbäcksdalen, (Magnusson 1995). The aim has been to include all known essential nutrient elements to get a broad picture of the nutrient balances in both crop and soil. To handle the large amount of variables in this kind of study a multivariate method for statistical evaluation has been applied. In this paper some examples of the applications to one of the field experiments are presented.

**Field experiment.**
Cauliflower cv ´Siria´ was grown at Röbäcksdalen during the summer 1990. Planting date was 14/6 and the harvest period 7/8 - 20/8. The experiment had 3 replicates which makes 30 plots.

<table>
<thead>
<tr>
<th>Fertilizer application</th>
<th>Treatments:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>before planting:</strong></td>
<td>1 Flat surface, no cover.</td>
</tr>
<tr>
<td>1 NPK 11.5.18 - micro</td>
<td>2 Bed, ca 15 cm high, no cover.</td>
</tr>
<tr>
<td>800 kg per ha.</td>
<td>3 Bed. Black agrylic cover on the soil.</td>
</tr>
<tr>
<td>2 Cattle manure</td>
<td>4 Bed. Green mulch 5 kg/sq.m. at planting.</td>
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<tr>
<td>35 ton per ha.</td>
<td>5 Bed. Green mulch 5 kg/sq.m. applied July 4 th.</td>
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**Plant samples** were taken in each plot at peak harvest. 10 representative plants from each plot were divided into yield (head) and residues (the rest of the plant above ground). The dried plant material was analysed for the total concentrations in dry matter of N, K, S, P, Ca, Mg, Na, Fe, Zn, B, Mn, Cu, Mo and Al.

**Soil samples** were taken in the depth of 0-30 cm in each plot 4 times during the season (each 14:th day, starting 2/7). The soil analyses included pH, electrical conductivity and the easily available amounts of NO3-N, NH4-N, K, S, P, Ca, Mg, Na, Fe, Zn, B, Mn, Cu, Al, Mo and Cl. (modified Spurway-Lawton method, and EDTA extraction). A parallel analysis of nitrogen was also made by the KCl-method.

**Evaluation by a multivariate statistical method.**
In this paper the program SIMCA-S 6.0 has been used for the statistical evaluation. This method makes it possible to relate one or several dependent variables to several independent variables at the same time. For description of the method see Wold et al (1983, 1984). As dependent Y-variable the fresh weight of the heads in the plant samples was chosen, and called **YIELD**.
Plant variables.

In model 1 (M1) the dependent variable *YIELD* is related to all plant variables (28). This model gives two significant components which together have a R² (the degree of explanation of the dependent variable Y) = 0.709 and a Q² (a measure of the degree of significance) = 0.525. The object plot, figure1, shows that there is no clear separation between the two different ground fertilizers although more objects receiving fertilizer 1 are located in the upper part of the plot, associated with higher yield. In figure 2 the same object plot is shown but here the objects are marked by treatment. Here we see a tendency for treatment 1 and 2 to aggregate in the lower part of the plot which is associated with low yield. Treatments 3, 4 and 5 tend to aggregate in the upper part of the plot and are associated with higher yield. The variable plots

![Scores M1.t[1] / M1.u[1]](image1)

Figure 1. Object plot of model 1 (M1). The numbers 1 - 2 mark the two different ground fertilizers.

![Scores M1.t[1] / M1.u[1]](image2)

Figure 2. Object plot of model 1 (M1). The numbers 1 - 5 mark the five different treatments.
of M1, figures 3 and 4, are two different ways to show the correlations between the dependent variable \textit{YIELD} and all the independent variables. In the scatter plot, figure 3, the variables located near the dependent variable \textit{YIELD} have a strong positive correlation to the yield. Variables located on the opposite side of the x or y axis have a negative correlation to the yield, and variables near origo have had little influence on the yield. In the column plot, figure 4, columns above the zero line have a positive correlation to the yield, and columns below zero a negative correlation to the yield. The height of the columns are proportional to the strength of correlation. In this field experiment the concentration of manganese, nitrogen and magnesium in the residues, (MN-R, N-R, MG-R, ) have the strongest positive correlation to the yield. Aluminium in the head (AL-H) shows the strongest negative correlation to the yield.

Figure 3. Variable plot of model 1 (M1). The letter H and R after the chemical name of the elements mark the concentrations in the heads and residues respectively.

Figure 4. Variable plot of model 1 (M1). The letter H and R after the chemical name of the elements mark the concentrations in the heads and residues respectively.
Soil variables.
In model 2 (M2) the dependent variable \textit{YIELD} is related to all soil variables (79). This model gives two significant components which together have a $R^2_Y = 0.798$ and a $Q^2 = 0.565$. In the object plot, figure 5, where the objects are marked by the two different ground fertilizers, there is no clear separation between the fertilizers. The object in the upper right corner of the plot may be an "outlier". In the object plot, figure 6, where the objects are marked by the five different treatments, treatment 1 is concentrated in the lower left part, which means that those objects besides having the lowest yield also have about the same conditions in the soil, which can explain much of the effects on the yield. The variable plot, figure 7, is somewhat crowded but shows which soil variables are located near the dependent

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig5.png}
\caption{Object plot of model 2 (M2). The numbers 1 - 2 mark the two different ground fertilizers.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig6.png}
\caption{Object plot of model 2 (M2). The numbers 1 - 5 mark the five different treatments.}
\end{figure}
Figure 7. Variable plot of model 2 (M2). The numbers 1 - 4 after the chemical names of the elements refer to the four sampling times. NO means nitrate nitrogen and NH means ammonium nitrogen. The letters S and K refers to the Spurway and KCl - methods respectively.
variable \textit{YIELD}, and thus have a positive correlation to the yield. Nitrogen and iron concentrations in the soil seems to have had a consistent positive influence on the yield during the season. The only element that has a consistent negative correlation to the yield is aluminium.

Concerning the different methods of nitrogen analysis in the soil, the Spurway method shows a somewhat stronger correlation to the yield for nitrate nitrogen than the KCl method. With ammonium nitrogen the situation is opposite, the KCl method shows a consistent strong positive correlation to the yield while the Spurway method alternates between positive and negative correlation to the yield.

\textbf{Discussion}

To be able to increase the knowledge about nutrient uptake in the complex situation that exists in the field, tools for handling a large amount of variables are needed. The aim of this paper was to demonstrate one method for statistical evaluation. The correlations found in a statistical evaluation like this are of course not to be equalled to casual relationships but have to be interpreted with care.

This field experiment is part of a series of nutrient studies, and later evaluations of a larger material might show which correlations are just occasional, and which show a reliable relationship between the nutrient balances and the yield potential of the plants. A comparison of the nutrient concentrations in the plants found in these experiments with critical concentrations reported in the literature is also an important part of the evaluation.

\textbf{References.}

