Schuffelen as reflected in the work of his doctoral students

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Since his appointment to the chair of Agricultural Chemistry at the University of Wageningen in 1949, it was particularly through his many doctoral students that Schuffelen put his imprint on the development of agricultural chemistry in the Netherlands. True to his nature to put his own interests second to the needs of others, he accepted the responsibility to guide and help more than thirty doctoral candidates to acquire their doctoral degree. This large number of doctoral students has been surpassed only by few of his colleagues.

In line with his believes that a doctoral degree is in the first place a proof of the ability to conduct research independently, Schuffelen was very broad-minded in accepting a wide variety of research topics. While always ready for advice, he never pressed his wishes upon his students, thus stimulating them to learn to solve their problems themselves. His active interference with the work of his students was thus purposely limited to a rigorous check on the validity of the method of investigations, the logics of the interpretation and the presentation of the results. Again in line with his believes in the necessity of absolute freedom of the individual scientist to select and develop his own way of approach to a problem, Schuffelen's meddling with the shaping of a doctoral thesis increased sharply towards the end, culminating in a meticulous reading-together, sentence by sentence, of the proposed manuscript.

Full freedom of his disciples to develop their own scientific personality having been preserved, the final confrontation of Schuffelen with his doctoral student at the promotion exercise often had a scent of originality foreign to a situation where the promotor has actively molded the thinking of his doctoral student.

Glancing over the roughly 4000 printed pages constituting the theses of Schuffelen's doctoral students one is struck by the fact that here are about thirty scientists speaking out over a middly varying range of subjects. The common denominator is not so much found in their carrying out a uniform school of thought, but in the method of approach. An analytical chemist himself, Schuffelen put great weight on the assessment of the validity of the experimental methods employed, requiring his doctoral students to do the same. Equally striking is the attempt to unambiguity of presentation, distinguishing carefully between established facts and speculation. It seems warranted to expect that Schuffelen's unbiassed and open-minded approach to the solution of problems in the field of soil fertility and plant nutrition will be propagated by his many disciples.

In the following pages a bird's eye view is given on the subjects of the doctoral theses prepared under guidance or supervision from Schuffelen, in some cases jointly with another promotor (see list of theses below).

As a follow-up of Schuffelen's own doctoral research, *Zeegers* (1959) studied the possibility of introducing spectrochemical analysis for minor elements in soil samples. Although this work gave promising results as to the accuracy of the method, the rapid development of less costly colorimetric and flame photometric methods stood in the way of a large-scale application of spectrophotometry in serial analyses.

The first study of the composition of the inorganic part of the soil adsorption complex (clay minerals), inspired by Schuffelen, was made by *Arens* (1951). By appli-

cation of the DTA (Differential Thermal Analysis) and standardization of the method, Arens was able to discern differences in the composition of lattices of illites, which did or did not show the phenomenon of potassium fixation. This method proved to be of value also for establishing differences between the degree of crystallization of the clay mineral (kaolinite) and the physical behaviour of different soil types containing this mineral.

The study of the organic part of the adsorption complex did not form a regular part of the research of Schuffelen's Department. Nevertheless a very interesting contribution on the understanding of the fate of organic matter when it is regularly applied to the soil, was given by *Kortleven* (1963). By the use of data from classic manuring experiments, some of which were laid out by Schuffelen's predecessor Hudig, Kortleven worked out mathematical formulae for the rise or fall of the humus content.

The study of the behaviour of the exchangeable cations, started in Wageningen already before World War II (Roborgh, van der Marel, Hauser), found its continuation in the studies of the effects of salt water inundations during the winter 1944/1945 and after the flood in 1953. In 1958 *van der Molen* published his thesis on this subject. Exchange reactions had been studied with special emphasis on poly-ionic systems, for which then current exchange equations proved inadequate. Applying the theory of collumn exchange chromatography as developed by Glueckauf, van der Molen was able to give a qualitative explanation of field soils with sea water as well as during the following reclamation period.

From this earlier period, before the institution at the Agricultural University of a separate chair of Soil Physics and Chemistry, stem the theses of Koenigs (1961) and Janse (1969). *Koenigs* conducted an extensive study on the aggregate stability in, and swelling behaviour of soils depending on the composition of the exchange complex and on prior treatment. It could be shown that flocculation phenomena as observed in dilute suspensions play a subordinate rôle in the creation of stable structures. Only drying, in the presence of polyvalent cations, may induce the formation of poly-place structures held together by modeling type forces, which are sufficiently irreversible to convey structural stability to soils.

The thesis of *Janse* explored the acoustical behaviour of the soil as a porous medium, by studying the reflection characteristics of a layer of soil in audible frequency ranges as a function of pore geometry. The method proved to be reproducible and sensitive, thus providing a non-destructable method of 'finger-printing' pore geometry. At the same time a back translation of an observed reflection characteristic into pore geometry or its ensuiing soil physical behaviour proved to be rather difficult.

More directly related to Schuffelen's personal field of interest, i.e. soil fertility and plant nutrition, are the remainder of the theses produced. Serving as co-promotor with the late van Wijk, Schuffelen became involved in *de Wit's* treatise of fertilizer placement (1953). Perhaps to be considered as a forerunner of his later specialization in developing mathematical models for processes occurring in soil and its plant cover, de Wit's work presented a clear example of how simple physical theories may be combined to yield an integral picture of the processes occurring simultaneously when fertilizer is added to soil.

A basic link in the process of plant nutrition is the absorption of ions by roots. As a follow-up on the work done by Schuffelen himself on the relation between the uptake of ions by roots and their activities in nutrient solutions, this subject was treated by Jacobs (1958) and Grobler (1959). *Jacobs* earned his Ph.D. degree at Illinois on a thesis worked out under supervision of Schuffelen, which was concerned

with optake in relation to root potentials. *Grobler* attempted to divide the uptake process into the fast primary adsorption stage followed by much slower metabolic accumulation process which is accompanied by the formation of organic acids in the root. Grobler's work may be considered a first attempt to unravel the total process of transfer of nutrient ions from the soil solution into the plant root. Further studies along this line are still in progress and will be reported on in the theses of *Breteler* and *Keltjens* at the moment still in preparation.

In the field of fertility studies the thesis of *Yoshida* was published in 1964. By means of extensive and accurately performed experiments in nutrient solution, a study was made of the interrelation between the K and the Mg uptake by oats. The mechanisms of absorption of both the ions could be studied and also the relation between the uptake of both ions in connection with the ratio in which they were present in the nutrient solution. Elsewhere in this issue this subject is reviewed by Prof. Schuffelen.

The interrelation between different ions and their mutual interaction in the process of uptake by crops formed the subject of the thesis by *El Kholi* (1961). His results gave an indication that the observed interactions were not directly caused by changes in the uptake mechanism, but had to be ascribed to differences in the physiological conditions of the plant, as affected by differences in the composition of the growth media.

Effects of excessive changes in the substratum on the uptake of nutrients by crops, were studied much earlier by *van den Berg* (1952) by making use of experiments on soils which were inundated with sea water. A study was made of the development of different crops grown on soils which previously had been inundated with sea water for shorter or longer periods. This study revealed great differences in the behaviour of crops. Some reacted strongly on the concentration of the substrate, while for others the percentage of Ca of the total quantity of adsorbed cations proved to act as a governor in the absorption process. The salt tolerance of crops was found to be related to the ratio between Ca and the other cations present in the plant. The effect of salinity on growth and on utilization of nitrogen by crops was also studied by *Arnold Bik* (1970).

Specific behaviour of plants as to the uptake of Na was studied by *Wybenga* (1957), who by use of the radioactive isotope ^{22}Na, opened the possibility of studying the transport and accumulation of this ion within plants of different species. *Roorda van Eysinga* (1974) studied the uptake of fluoride by the root and its effects on various crops, particularly freesias.

A further study on the fate of different ions after their uptake by plants was done by *van Tuil* (1965). Following the work previously published by Dijkshoorn et al., van Tuil studied the significance of the relation between dry matter yield of various plants and the (C-A) value (the difference between the totally absorbed amount of cations and the sum of anions present in the plants). His research showed that the (C-A) value practically corresponded with the total amount of organic acids which could be determined in the plants after their harvest. The value of (C-A) appeared to be rather specific for different plant species and so formed a valuable indication on the crop's state of health. The above line of approach is at present followed by *van Egmond*, who in his thesis (in press) shows that the (C-A) content in every part of the sugar-beet plant is a measure for the amount of reduced nitrate-nitrogen in that part of the plant.

Simultaneously with the above research, other doctoral students made studies to investigate the possibility of application of data, showing the chemical composition of crops as found by leaf analysis, for fertilizing recommendation. *Broeshart* (1959) elaborated a method of sampling and analysis of oil palm leaves. He confirmed the

correctness of Schuffelen's view that a diagnosis of shortages or deficiencies should be based on characteristic changes in leaf composition for all the elements and not on those of one element only. *De Waard* (1969), working with black pepper *(Piper nigrum* L.*)* in Serawak, arrived to a similar conclusion and devised fertilizer recommendations for this crop growing under different conditions. *Wessel* (1971) studied the fertilizer requirements of cocoa in Nigeria. After establishing the critical values for the N and P contents of the leaves and of the ratio between these elements, he was able to draw up preliminary recommendations for cocoa crops of different age and grown on different soils. *Butijn* (1961) carried out extensive research to investigate the effect of physical and chemical soil factors on the yield of apple trees. Critical values were found for the K : Mg ratio in connection with the occurrence of magnesium deficiency in orchards. He also studied the supply of minor elements, especially of iron and zinc.

Nitrogen being one of the main factors determining the yield of deciduous fruits, Butijns work was continued by *Delver* (1973) who carried out a thorough study of the utilization of nitrogen by apple and pear. His study provided a physiological background for the recommended fertilizer policy under different growing conditions prevailing in the Netherlands.

Detailed studies on the nutritional requirements of sugar-beet have been carried out by *Henkens* (1972) and *Houba* (1973) the former mainly concentrated on molybdenum deficiency occurring in several regions on soils rich in iron and showing low values of pH. As a result of this study a clear picture was obtained of processes taking place in the soil and affecting the availability of molybdenum to plant roots. Houba's work was concentrated on the uptake and utilization of nitrogen and their influence on the development of the crop during the successive stages of growth. Both studies have contributed to the understanding of the nutritional physiology of an economically very important crop.

Beside the above mentioned studies on the physiology of plant nutrition studies have been carried out by Schuffelen's doctoral students, meant to assess the soil fertility status of soils in a more general sense. *Ferrari* (1952) contributed to this line of research, by application of a multifactorial analysis in a well-defined region and was able to discern quantitatively the effect of different factors. Effects of pH value, potassium content and application, contents of organic matter, clay content and soil water-table could be evaluated as to their effect on potatoes used as test crop. His observations were made in 'sample plots'. This method of collecting data was also applied by *van der Boon* (1967). In case of strawberries, which served here as test crop, this method proved to be of use for a quantitative treatment of effect of several nutrients although a difficulty was met in finding correlations between the exactly determined yields and visual descriptions of soil types based on soil profile studies. A study of the phosphate management in soils and phosphate release was made by *Sissingh* (1961) and formed a basis for further work which in turn determined the now generally accepted method of phosphate analysis on routine basis. Another work on phosphate was done by *van Lieshout* (1961) who, by injecting ^{32}P into the soil profile, studied the effects of soil conditions on the activity of root systems of crops and so found important criteria for the technique of fertilizer application.

Contributions to the theoretical background of the knowledge of the effect of nitrogen application for different crops were the theses of *van Roon* (1959), *Dilz* (1964) and *Slangen* (1971). Several aspects such as the effect of fractional application, application of surplus doses during the different stages of development of crops and effects of intermittent nutrition were covered in their work.

A special way of approach for obtaining information on the status of fertility of soils was taken by *Bouma* (1965) and afterwards by *Janssen* (1970). By producing and subsequently removing a nutritional stress in young plants grown in pots in nutrient columns or on different soils, they both devised a simple method to identify qualitatively the nutritional disorders in soils. Because of their simplicity and the possibility of quickly obtaining an impression of the state of fertility of tropical and subtropical soils of which little is usually known this methods have the full attention.

The wide range of subjects covered by Schuffelen's doctoral students illustrates the magnitude of knowledge and experience collected by this generation of students. The knowledge that more than thirty owners of the elegantly preserved dung beetles – which Schuffelen uses to give his disciples as a remembrance to the day their doctor's degree was conferred – will be able to pass on this thinking to the next generation, must give him a great satisfaction never granted to a man who wants it for his own benefit.

List of Doctor's theses prepared under guidance of Professor Schuffelen

1951 P. L. Arens, A study of the differential thermal analysis of clays and clay minerals. Wageningen, pp. 132.

1952* Th. J. Ferrari, An agronomic research with potatoes on the river ridge soils of the Bommelerwaard. (Dutch: English summary.) Wageningen, pp. 132.

1952 C. van den Berg, The influence of adsorbed salts on growth and yield of agricultural crops on salty soils. (Dutch: English and French summaries.) Wageningen, pp. 118.

1953* C. T. de Wit, A physical theory on placement of fertilizers. Wageningen, pp. 71.

1955 H. Broeshart, The application of foliar analysis in oil palm cultivation. Wageningen, pp. 114.

1955** H. Bloksma, The suspension effect. The significance of the electrometric determination of ion activities in suspensions. (Dutch: English summary.) Amsterdam, pp. 124.

1957 J. M. Wybenga, A contribution to the knowledge of the importance of sodium for plant life. Investigations with radio-active sodium. Wageningen, pp. 214.

1958** D. G. Jacobs, The electrochemical behaviour of excised pea roots. University of Illinois, Urbana, Ill., USA, pp. 130.

1958* W. H. van der Molen, The exchangeable cations in soils flooded with sea water. Wageningen, pp. 168.

1959 J. H. Grobler, Initial phase ion uptake by plant roots and the interpretation of root potentials. Amsterdam, pp. 96.

1959 L. J. B. Zeegers, The application of the addition method for spectrochemical determination of minor elements in soil samples. (Dutch: English summary.) Wageningen, pp. 112.

1959 E. van Roon, The application of divided nitrogen dressings to some seed crops. (Dutch: English summary.) Wageningen, pp. 131.

1961 J. W. van Lieshout, Effect of soil conditions on development and activity of the root system. (Dutch: English summary.) Wageningen, pp. 92.

1961* J. Butijn, Soil management in fruit culture, 1, 2 and 3. (Dutch: English summary in Part 3.) Wageningen, pp. 404.

* With a second promotor; ** Under supervision of Professor Schuffelen.

1961 H. A. Sissingh, Components of the phosphate in the soil as related to the phosphate supply of plants. (Dutch: English summary.) Wageningen, pp. 130.
1961 A. F. A. M. El Kholi, An experimental study of the influence of the micro-elements on the uptake of macro-elements by plants. Wageningen, pp. 80.
1961 F. F. R. Koenigs, The mechanical stability of clay soils as influenced by the moisture conditions and some other factors. Wageningen, pp. 172.
1963 J. Kortleven, Quantitative aspects of increase and decrease in humus. (Dutch: German summary.) Wageningen, pp. 110.
1964 K. Dilz, Optimum nitrogen nutrition of cereals. (Dutch: English summary.) Wageningen, pp. 136.
1964 F. Yoshida, Interrelationships between potassium and magnesium absorption by oats *(Avena sativa* L.*)*. Wageningen, pp. 104.
1965 D. Bouma, Growth changes of plants following the removal of nutritional stresses. Wageningen, pp. 98.
1965 H. D. W. van Tuil, Organic salts in plants in relation to nutrition and growth. Wageningen, pp. 84.
1967 J. van der Boon, Analysis of soil fertility by sample plots with a perennial market-garden crop, strawberries on sands. (Dutch: English summary.) Wageningen, pp. 214.
1969* A. R. P. Janse, Sound absorption at the soil surface. Wageningen, pp. 215.
1969 P. W. F. de Waard, Foliar diagnosis, nutrition and yield stability of black pepper *(Piper nigrum* L.*)* in Serawak. Wageningen, pp. 149.
1970 R. Arnold Bik, Nitrogen, salinity, substrates and growth of gloxinia and chrysanthemum. Wageningen, pp. 89.
1970 B. H. Jansen, Soil fertility in the Great Konya Basin, Turkey. Wageningen, pp. 113.
1971 M. Wessel, Fertilizer requirements of cacao *(Theobroma cacao* L.*)* in South-Western Nigeria. Wageningen, pp. 104.
1971 J. H. G. Slangen, Intermittent nutrition of wheat. (Dutch: English summary.) Wageningen, pp. 130.
1972 Ch. H. Henkens, Molybdenum uptake by beets in Dutch soils. Wageningen, pp. 54.
1973* V. J. G. Houba, Effect of nitrogen dressings on growth and development of sugar-beet. Wageningen, pp. 65.
1973 D. Delver, Nirogen nutrition, soil management and nitrogen dressing of fruit crops (apple, pear). (Dutch: English summary.) Wageningen, pp. 187.
1974 J. P. N. L. Roorda van Eysinga, The uptake of fluoride by the root and its effect on various crops, particularly freesias. (Dutch: English summary.) Wageningen, pp. 83.

Theses in preparation

F. van Egmond, The ionic balance of the sugar-beet plant.
H. Breteler, Carboxylates and ammonium uptake by excised maize roots.
W. G. Keltjens, Ion uptake in relation to membrane permeability and root potential by corn roots.
J. van den Ende, Soil testing for greenhouse crops by aqueous extraction methods.

* With a second promotor.