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CHALLENGES FOR SUSTAINABLE GREENHOUSE HORTICULTURE IN THE DUTCH COASTAL AREA

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Summary

The Netherlands is a small country, which for a greater part is formed, shaped and affected by the sea, and consist for 2/3 of coastal plain, which partly lies below sea level. The country is highly industrialized and has a huge population density. Due to favourable geoclimatical conditions, water resources and fertile soils, the coastal plain was developed as agricultural area, though in recent eras there is strong competition from urbanisation and industrialisation. Nevertheless agriculture and in particular greenhouse horticulture are still important sectors in the economy. Greenhouse horticulture in the Netherlands is modern and high tech, with almost all crops grown in soil less culture and with an intensive use. However, given its situation in a densely populated coastal plain, there are issues about leaching of nutrients and pesticides, as well as the pressure on fresh water resources. Enforced by EU regulations also, it is obligatory for Dutch growers to re-use the drainage water. This necessitates the maximum use of rainwater collection, but even then the accumulation of salts, mainly sodium (Na) can be a thread. By proper water-and nutrient management, the water – and nutrient use use efficiency can be increased to almost 100 %

The Netherlands; brief introduction

The Netherlands is a small, highly populated and industrialized country with roughly 18 million people living on 38 * 10^3 km^2, ranking it among the countries with the highest population density. For about 2/3 it is surrounded by the North sea, and a couple of mighty rivers originating in mountainous areas in Germany, Belgum and France meander through the country. Both sea and rivers have contributed to the origin and influenced the landscape largely. About 50 % of the surface consists of flat lands, originating from fluviatile sediments. Due to the steady sea level rise and stagnant waterflows after the last ice age, peat and marsh lands covered these flats, which then were frequently flooded by the sea or rivers. Not surprisingly the soils found in the coastal area are for a great deal peaty soils, alternated by bands of sediments of clays, silts and sands. Due to further sea level rise, a lot of the land was drowned and taken by the sea in the early middle ages. To protect the land from flooding, people start to establish dykes along rivers and estuaries to protect the land from flooding from the late middle ages. Later on, the land was further drained by ditches and windmills were installed to pump water out and so the polder areas were created. Moreover, huge parts of land, previously taken by the sea, were reclaimed from the sea. However due to drainage, the surface of the peat and clay soils went down due to oxidation of the organic matter and shrinkage of the clay, and so gradually large areas of land eventually got below sea level, sometimes up to 6 meters. Today 18 % of the land is actually below sea level, and another 30 % just at or not more than a few meters above it, making the Netherlands vulnerable, for storm surges and for high water flows from rivers. From historical times into the 20^{th} century, the land as well as cities have been flooded, drowning people, animals and ruined buildings and agricultural fields. After the last heavy flood, in February 1953, which drowned almost 2500 people and caused immense damage to the economy, the Dutch government launched a huge programme, the so called “Delta Works”, aiming at protection of the lower parts of the south-west part of the country. This programme consisted partly of dyke-enforcements, building new sluices and cutting off large estuaries from the sea. The result is that the lowest parts of the coastal plain is now protected against storm surges which occur statistically once in 10.000 year.

New challenges have arrived in the last decade related to climate change and further sea level rise.

Coastal agriculture in the Netherlands

Despite the dense population and high industrialization, agriculture is still a rather important economic factor. Although no more than 3 % of the Dutch GDP, with 80 Billion € of export value, ranks the Dutch agricultural as the 2nd largest exporter of agricultural products, after the US, whereas the agricultural area is 160 times smaller ! (worldbank, 2015).

Among the reasons why the Dutch agriculture is still thriving despite its high population density and industrialization, is that the coastal zones are blessed with fertile soils, and the absence of mountains, deserts or ‘bad lands’ , make that 68 % of its surface arable. Moreover, the area has mild winters, due to the vicinity of the sea and prevailing winds from the Atlantic. In particular Horticulture and more in particular Protected horticulture has been developed in the coastal zone. This is due also to the vicinity of huge markets like the urbans of London, Paris and the German Ruhrgebiet. Today, the Dutch Greenhouse Horticulture is very modern and highly productive, and world-wide known for its innovative power.

Although the Dutch agriculture benefits from the geographical situation, located in a coastal zone has some drawbacks, which are related to water resources and water quality. Moreover, modern societal demands puts pressure on the enterprises to comply with the societal demands.

Greenhouse horticulture in the Netherlands

The area of greenhouses in the Netherlands has been a stable 10 000 ha for many years. Although it is less than 1 % of the area, it contributes for 20 % to the total production value and for 33 % to the total agricultural export. Roughly half of the area is floriculture and the other half vegetables, with tomato, sweet pepper, cucumbers and strawberries being the main crops. The majority of the crops are grown soil less, with rockwool as the growing medium commonly used. In the last decades the greenhouse horticulture in the Netherlands has developed into an intensive high productive and technological driven branch of agriculture, with a high degree of innovative power. In this development main focuses were quality improvement of the produce and strong reductions on the environmental impact. With respect to last item, three subjects accompanied the research in the greenhouse industry: reduction of the use of energy, reduction of the use of plant protection chemicals and reduction of the emission of minerals, focussed on N and P. Solutions in these directions were found in high technological developments, for example increasing yields, storage of energy over seasons, use of residual heat, co-generation of electricity, biological control of pests and diseases, and reuse of drainage water for substrate grown crops.

Societal demands

Over the recent years, society's demands have been changing. People are increasingly aware of the impact that agricultural production systems have on the environment. In particular in highly populated coastal zones, the effect of leaching nutrients and pesticides on surface water quality is more evident. Recently, European Union regulations such as the water framework directive (European Union, 2000) and nitrate directive (European Union, 1991) that aim at safe and good water quality were developed and implemented.

Greenhouse crops require high fertilisation rates and over-irrigation is common practice at the same time to avoid any risk of growth reduction or decline of produce quality (Sonneveld and Voogt, 2009). This results in significant nutrient leaching. Both nutrients and plant protection agents follow the water flow, and the reduction of waste water is becoming an issue in dense greenhouse areas like in the Netherlands. This waste water is discharged to municipal waste water systems and into surface water, containing high concentrations of both nutrients (Balthus and Volkers-Verboom, 2005) and residues of plant protection agents (Teunissen 2005). Soon after soilless culture was well established in the early 1980's the easy leaching of nutrients from this growing system was a concern in the Netherlands. Therefore reuse of drainage water was promoted and these so called closed systems were developed (Van Os 1994). From the 1990's the Dutch government stimulated this development and eventually, from 1995 the reuse of drainage water became obligatory (Roos- Schalij et al., 1994).

Water resources

The essential of soilless culture is that crops grow in a restricted root volume. This means that there is a high risk of salt accumulation and this will occur easily. Therefore water of the highest quality standards is a primary requirement. For this reason, rainwater is the major water source in the coastal zone, since surface water and groundwater have a too high salt contents due to salt intrusion form the nearby sea in the main greenhouses areas. However Na and Cl are present in rainwater also, not only along direct close to the coastal zone, but also more inland (Voogt and Sonneveld, 1996.

Precipitation in the coastal area in Netherlands is usually sufficient to cover the total crop demand, but it is not evenly distributed over the growing season, so storage and buffering is needed to bridge dry spells. However the storage capacity at individual holdings is limited due to economic constraints, given the high price of plots for establishing basins, especially in concentrated greenhouse areas. Moreover, to bridge dry years, compared to the costs a disproportionate large storage buffer is needed and for intensive cropping systems the yearly average precipitation sum is lower than the demand. Therefore secondary sources are required, to supplement in dry periods. Reverse osmosis treatment of saline groundwater is commonly used, as it is a flexible, reliable and relatively cheap alternative. Alternatively growers use tap water or surface water as secondary source, however both sources have a too high content of residual salts.

Na accumulation and Na uptake capacity

Accumulation of residuals salts like Na and Cl in the root environment will cause an increase of the EC value, which will affect negatively the yield or quality of the produce (Sonneveld, 2000). In soil-less systems, the EC in the root environment is controlled and more or less kept at a certain set point, so Na or Cl accumulation cause reduction in the nutrient concentrations eventually (Voogt and Sonneveld 1996). For many crops maximum acceptable Na and Cl concentrations have been established based on the threshold values for these ions. In a closed growing system, the input of ions should match the crop need, otherwise depletion or accumulation will follow. Hence, the input of Na and Cl should be not higher than the uptake capacity of a crop (Voogt and Sonneveld, 1996). An important parameter in this context is the Na and Cl uptake concentration, which is the total uptake in a given of an ion expressed on the total water uptake. Accumulation occurs when the input concentration is higher than the uptake concentration. For a number of crops the uptake concentration of Na and Cl were derived from experiments in closed systems with series of Na and Cl treatments (Baas et al., 1994; De Kreij and Van den Berg, 1990; Sonneveld and Voogt, 1983; Sonneveld and Van den Burg, 1991; Sonneveld et al., 1999). The data clearly shows the great variety in uptake concentrations of different crops, which implies for instance that cucumber can be grown in closed systems without discharge better than roses. Without exception the uptake concentration of Na is lower than for Cl, so consequently Na will be the bottleneck element (Voogt and van Os, 2012). These uptake concentrations could be used as parameter for judging the suitability of water sources for closed growing systems. The uptake concentration appears to be strongly related with the existing concentration in the root environment. Data of experiments show high linear correlations between the uptake concentration and the prevailing concentration in the root environment (Voogt and van Os, 2012).

Dynamic fluctuations in the root zone

The required discharge can be estimated from the uptake concentrations of Na and Cl and the concentrations of these ions in the input sources using a quite simple equation given by Sonneveld (2000). However, the uptake depends highly on the prevailing Na and Cl concentration. Moreover, in practice the use of the various water sources fluctuates according to the demand (evapotranspiration) and the availability. Consequently the Na and Cl input and so the accumulation rate will fluctuate dynamically during the growing cycle. At the same time, the water fluxes in the growing system fluctuate connected with changes in irradiation and greenhouse climate as well as factors of crop development. The water fluxes can be described by the model WATERSTREAMS (Voogt et al, 2013). By linking the Na and Cl concentrations to the input water fluxes and using Na and Cl uptake functions, the accumulation rate in the root environment of both ions can be described. This results in an accurate estimation of the required discharge, as well as an estimation of the total N loss, based on the average NO3 and NH4 concentrations in the root environment (Voogt et al, 2013).

Towards maximum water- and nutrient use efficiencies

Given the facts that in many situations, rainwater will not cover the water demand completely and supplemental water sources contain Na and Cl, higher than the uptake capacity of crops, periodic discharge of circulating nutrient solution is almost inevitable. In order to keep the water use efficiency as high as possible and at the same time trying to achieve the lowest nutrient emission, several nutrient management and discharge strategies are worked out (Voogt and van Os, 2012).

i) Reduction of nutrients. The main problem of discharge is the emission of nutrients to the environment, next to that of plant protection chemicals. Reduction of the concentrations of N and P in the water to be discharged may diminish the problem. Experiments with tomato and rose showed that the N concentration in the root environment can be lowered quite significantly and to some extent, without yield effects, in case of tomato even with some positive effects on fruit quality (Voogt and Sonneveld, 2004; Voogt et al., 2006). For rose this was elaborated successfully in some treatments allowing the nutrient solution to deplete intermittently for N to almost zero, which moments could be used for discharge. For P it obviously will work out in the same way, since plants can deplete P to even lower concentrations than N. So both for N and P the concentration in the root environment is less important rather than adequate supply of a required quantity. However management practices based on this principle can be carried out successfully only if on-line monitoring of nutrients becomes possible, which is not feasible at the moment.

ii) Maximize Na uptakes. Obviously the accumulation rate of Na in the system depends highly on the ratio between the input (Na_I)- and the uptake concentration Na_U). Since Na_U is linearly correlated with the prevailing Na concentration in the root environment (Na_{RE}), the higher Na_{RE} the higher the uptake. Na_{max} is defined as the threshold value for yield reduction (Sonneveld, 2000). The legal target levels for permitted discharge are usually considerably lower than Na_{max}. Moreover, the values of Na_{max} are a combination of EC and Na. The EC itself is a parameter resembling the osmotic pressure and this parameter is used in crop management. The optimum value for a crop is described as the target value for EC (EC_{ss}) (Sonneveld, 2000). Besides this, it also resembles the sum of the required nutrients concentrations (EC_{ss-nu}). These two aspects of the EC are for obvious reasons not necessarily equal. Hence the EC from the total of the minimum required nutrient concentrations can be defined as the minimum required EC value (EC_{ss-nu}) for optimum crop development. The difference between the EC_{ss} and EC_{ss-nu} gives the "playroom"can be defined as EC_{ss-re} available for Na accumulation if subjected to the cations or for Cl in case of anions. The Na concentration derived from EC_{ss-re} is in many cases much higher than Na_{max}, accepting Na to accumulate to much higher concentrations, with then higher uptake and consequently less discharge is necessary than in case of the legal targets are followed as has been shown by simulation runs with the model WATERFLOWS (Voogt et al 2012).
By taking the right choice of water resources in the first place, the proper fertilisers and nutrient solutions as well as proper nutrient management in the second place, extremely high water- and nutrient use efficiencies can be reached (Katsoulas and Voogt, 2014).

To conclude

Greenhouse Horticulture in the Dutch coastal zone faces quite some challenges. Apart from socio-geographic issues as urbanization and competition for land, issues related to water are the strongest bottle-necks. Not at least because of the legal obligatory re-use of drainage water (closed system) for all crops. Given salinity problems of main water sources, rainwater is the best option, though it requires large storage capacity given the dry spring/summer spell and strong fluctuations in precipitation. As supplemental source, reverse osmosis is mostly suitable, but increases the costs of water. Among all ions, Na is the bottle-neck element in all cases. Accumulation of Na will occur even in case of rainwater sources, since some crops, like rose and sweet pepper are hardly able to absorb Na. Periodic discharge of a part of the circulating solution is therefore unavoidable. This will be a serious constraint for reaching the target of zero emission. The lowest discharge will be reached if the Na concentration in the root environment is kept at its maximum acceptable level. This can be achieved if the maximum EC level is kept, together with the minimum required concentrations of nutrients and filling this gap in "EC" with Na.

References

Baas, R., Nijssen, H.M.C., Van der Berg, T.J.M. and Warmenhoven, M.G. 1994. Yield andquality of carnation (*Dianthus caryophyllus*) and gerbera (*Gerbera jamesonii* L.) in a closed nutrient system as affected by sodium chloride. Sci. Hort. 61:273-284.

Katsoulas, N.; Voogt, W. , 2015. Recent trends in salinity control for soilless growing systems management. Acta Horticulturae 1034 (2014). p. 433 - 442.

Roos-Schalij, G.B.K., Leunissen, M.P. and Krijt, K. 1994. Lozingenbesluit WVO Glastuinbouw. Ministry of transport and communications, The Hague. 53p.

Sonneveld, C. and Van der Burg, A.M.M. 1991. Sodium chloride salinity in fruit vegetable crops in soilless culture. Neth. J. Agric. Sci. 39:115-122.

Sonneveld, C. and Voogt, W. 1983. Studies on the salt tolerance of some flower crops grown under glass. Plant and Soil 74:41-52.

Sonneveld, C., Van den Bos, A.L. and Voogt, W. 2003. Modelling osmotic salinity effects on yield characteristics of substrate grown greenhouse crops. Journal of Plant Nutrition 27-11:1931-1952.

Van Os, E.A. 1994. Closed growing systems for more efficient and environmental friendly production. Acta Hort. 361:194-200.

Voogt, W. and Sonneveld, C. 1996. Nutrient management in closed growing systems for greenhouse production. In: Plant Production in Closed Ecosystems; Automation, Culture and Environment. Kluwer Academic Press Dordrecht p.83-102.

Voogt, W. and Sonneveld, C. 2004. Interactions between nitrate and chloride in nutrient solutions for substrate grown tomato. Acta Hort. 644:359-368.

Voogt, W. and Van Os, E. 2012. Managing chemical water quality related problems in closed hydroponic systems. Acta Hort. 927:949-955.

Voogt, W., Garcia, N., Straver, N. and van der Burg, N. 2006. Verlaging N bij roos. applied Plant Research, Naaldwijk, report 4161067, 38 pp.

Voogt, W.; Swinkels, G.L.A.M.; Os, E.A. van 2012. 'Waterstreams': A model for estimation of crop water demand, water supply, salt accumulation and discharge for soilless crops. In: Proc. IVth International Symposium on Models for Plant Growth, Environmental Control and Farm Management in Protected Cultivation - HortiModel2012. - Acta Horticulturae 957 . - p. 123 – 130

Worldbank 2015. http://data.worldbank.org/indicator/AG.SRF.TOTL.K2.