Technology versus Agro-Ecology in Designing Vegetable Production Systems in the Netherlands

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Abstract

Current open field vegetable production systems in the Netherlands do not meet market and societal demands. These demands could not be fulfilled by adapting current production systems. Other kinds of production systems are needed and therefore two types of systems are designed by 1) a technological and 2) an agro-ecological vision. The technological vision aims at excluding and predicting external influences with the focus on control. Variants of this vision are production systems with fertigation and mulching with foil and hydroponic systems. Fertigation combined with mulching improves nutrient and water use efficiency and reduces leaching. Hydroponic systems exclude soil effects as well. The agro-ecological vision aims at creating buffers to make systems resilient against negative external influences with the focus on prevention. The general hypothesis is that diversity improves resilience and sustainability. Examples of various forms of diversity are discussed. The difference in paradigm between both visions is a mostly fundamental difference. The question is whether technological and agro-ecological farming systems can fulfill societal demands and in what timeframe systems will be ready for application in practice. Both visions need to be developed further to have a diverse set of production systems ready.

INTRODUCTION

Current open field vegetable production systems in the Netherlands do not meet market and societal demands. Society demands low emissions of nutrients and pesticides. The market demands healthy, good quality products and continuous delivery of uniform products. Additionally, financial returns in vegetable production are low and shortage of qualified labor is expected (Berkhout and van Bruchem, 2008).

Dutch agriculture is one of the most intensive in the world in terms of capital and external inputs (van Bruchem et al., 1999). Especially, vegetable production on sandy soils can hardly comply with the EU Nitrate Directive and the EU Water Framework Directive (Oenema et al., 1998). Ground water and surface water quality near vegetable farms do not meet the requirements set in these directives. High emissions of nutrients and pesticides are inevitable because of inefficient nitrogen uptake (Neeteson and Carton, 2001; Thorup-Kristensen, 2001), harvest during full growth, cropping during periods with high rainfall and low risk cropping strategies. Low risk cropping strategies are used because of relative high financial crop values and stringent quality requirements of retail organizations (Oerke and Dehne, 2004).

Over the past few years, fertilizer inputs in Dutch vegetable production systems have been approximately reduced to the official recommendations. However, leaching has only been marginally reduced, and is still far above the standards of the Nitrate Directive. Model and experimental studies indicate that further reduction of fertilizer inputs will be insufficient to reach the standards and may result in yield losses (de Haan et al., 2005; van der Bolt et al., 2008).

In recent years, growers have reduced emissions of pesticides by 25%. However, in surface and groundwater, various pesticides are still found at concentrations higher than ecological or drinking water standards (van der Lindern, 2006).

New production systems are needed to meet these societal demands. This paper describes two visions on new production systems that may better meet societal and market demands (Fig. 1): the technological vision aims at excluding and predicting external influences with the focus on control (Fig. 1b); and the agro-ecological vision aims at creating buffers to make systems resilient against negative external influences with the focus on prevention (Fig. 1c). In the technological vision high yields are possible; however when control is lost, yield reduction is large. In the agro-ecological vision, average yield is lower; but more stable than in the technological vision. In this paper, both visions are described and compared to each other. Attention is paid to effects on nutrient use, pesticide use, yield and quality.

TECHNOLOGICAL VISION

In the technological vision, we distinguish several variants with different levels of control. A first variant is a production system with fertigation and mulching with polythene film, eventually combined with ridges and interception and purification of drain water in constructed wetlands. Most important aspects of this type of system are higher nutrient and water use efficiency and reduced leaching, especially in periods of high rainfall. A second variant is outdoor vegetable production in hydroponic systems. Hydroponics is a technology in which plants are cultivated in nutrient solutions (water and fertilizers) with or without use of an artificial medium (e.g., sand, vermiculite, Rockwool or peat moss) to provide mechanical support (Jensen, 2001). The most important aspect of this type of system is exclusion of soil effects. The extreme variant is indoor vegetable production in hydroponic systems. In these greenhouse systems, it is possible to control almost every growth factor: air and root temperatures, light, water, humidity, carbon dioxide and plant nutrition.

Production Systems with Fertigation, Mulching

Production systems using fertigation and mulching involve: a) a drip irrigation system with nutrient applications for efficient water and nutrient application, b) mulching with polythene film to control weeds and reduce risks of leaching by high rainfall. In arid and semi-arid conditions, drip irrigation and fertigation improved yield, water and nutrient use efficiency (Hagin and Lowengart, 1996; Camp, 1998; Ayars, 1999). In climates that are more humid, effects were less pronounced. Various studies in the Netherlands show much higher water use efficiencies by drip irrigation, somewhat higher nutrient use efficiencies and somewhat higher yields compared to sprinkler irrigation. In leek and potato production, yield and quality increase was not sufficient to cover extra costs of fertigation (Postma and van Erp, 2000; Sukkel and Koot, 2004; van Geel, 2004). The combination of mulching with polythene film was studied for strawberry and has given good results for yield and nutrient efficiency (Smit et al., 2005). For other crops, experimental data on use of mulches are not available in the Netherlands. The use of pesticides in these systems were little different from standard systems except for herbicide application when using foil. This year, research is continuing to study the effect of fertigation and mulching on nitrate leaching in leek and lettuce. Questions remain whether these systems can sufficiently reduce nutrient emissions and can improve yields in such a way that that the higher costs of these systems can be covered.

Hydroponic Systems

A more effective and extreme variant of the technological vision is greenhouse horticulture technology with hydroponic systems applied in the open field. These kinds of systems could provide almost a complete control of nutrient and pesticide emissions to ground and surface water.

The advantages of hydroponic systems are high-density maximum crop yield, independence of soil quality, higher water and nutrient use efficiency, minimal use of land area, and suitability for efficient mechanization and disease control. The disadvantages of hydroponics, compared to conventional open-field agriculture, are high costs of capital and energy inputs, and a high degree of management skills required for successful production. Because of its significantly higher costs, successful applications of hydroponic technology are limited to crops with a high economic value, to specific regions, or to specific times of the year, when comparable open-field production is not feasible.

The main challenge is to develop systems that are economically viable and still solve the societal demands. Simple, cheap and robust systems are necessary to withstand the conditions in the open field. Current technology from greenhouse horticulture has to be translated to outdoor situations. Remaining emissions could be controlled well by collecting water from the hydroponic systems and purifying this water with chemical or biological techniques, e.g., constructed wetlands.

Technology is not limiting the creation of such systems for open field vegetable crops. Outdoor vegetables in the Netherlands are cropped in various other countries in hydroponic systems, indoor as well as outdoor. However, for some crops, e.g., leek, no commercial hydroponic cropping systems are available yet.

Various hydroponic systems are available. Systems vary in their use of substrate and their use of water. Examples are Deep Flow Hydroponics, Nutrient Film Technique systems (NFT), Ebb-Flood systems, Aeroponics and Aggregate hydroponic systems with a solid inert medium (Jensen, 1997, 2001).

Research on outdoor hydroponic systems in the Netherlands started for lettuce in 2007 and for leek in 2008. A large research program for hydroponics in outdoor horticulture is in preparation.

AGRO-ECOLOGICAL VISION

The agro-ecological vision in agricultural production means making use of ecology, nature and external influences instead of excluding it. The general hypothesis is that diversity has a positive effect on the sustainability of the production system and is a tool to create resilience. Diversity is used to control weeds, pests and diseases, to make better use of nutrient resources, to make efficient use of nutrients and prevent their losses, to make landscape more attractive for preservation of biodiversity.

Organic agriculture, conservation agriculture, permaculture but also integrated agriculture and various low input systems are making use of this principle by applying diversity in time and space in crop rotation, field margins, intercropping, undersowing and the use of cover crops. Crop rotation for example has proven to be very effective in the prevention and control of soil born pests and diseases (de Haan and Garcia Diaz, 2002). The ago-ecological farm layout has a function in prevention and control of pests (Hopster et al., 2002).

Organic agriculture is now the most prominent example of the agro-ecological vision making use of various aspects of diversity. In various studies, the agronomic and environmental performance of Organic Production System (OPS) has been compared with Conventional Production Systems (CPS) or integrated production Systems (IPS). Most examples are from arable oriented production systems. The environmental and ecological performance of the OPS is generally better than the CPS (Mäder et al., 2002; Pimentel et al., 2005; Sukkel et al., 2007). Comparisons for vegetable productions systems were less numerous, but in general the same conclusions were drawn as for arable systems (Drinkwater, 1995; de Haan and Garcia Diaz, 2002; Poudel et al., 2002; Sukkel and Koot, 2002a,b). However, the variation in yields seemed to be higher in vegetable OPS than in arable OPS. In an international comparison of vegetable OPS, the relative yield varied approximately from 70 to 120% compared to vegetable IPS (Sukkel and Garcia Diaz, 2002).

The effects of more diverse systems concerning nutrient management and soil quality were related to soil tillage, organic matter management and crop rotation. Organic matter plays an important role as a buffer for nutrients, enhancing soil biodiversity and soil health. Soil biodiversity has a function in making nutrients available to the plants, for example phosphorus availability in relation to mycorrhizae (e.g., Smith et al., 2003).

Cover or catch crops have shown to be an important instrument for reducing nitrate leaching and improving soil quality (Wyland et al., 1996). Also the sequence, alternation or combination of crops that have superficial rooting patterns (leek, lettuce) with crops that have deep rooting patterns like cabbage species, seemed to have a positive effect on nitrogen use efficiency (de Haan, 2002; Sukkel and Koot, 2002a,b).

Farming systems with high biodiversity often have higher costs per unit product (due to lower yields) and higher labor input compared to CPS (Mäder et al., 2002; Sukkel and Garcia Diaz, 2002). However, various studies indicate comparable economic results of low input systems and high input conventional systems (Jackson et al., 2004). In organic agriculture, higher production costs are often compensated by higher product prices.

Besides higher costs, farming systems with high diversity do often not meet market demands for uniformity. New technologies like micro arrays, GPS and automatic plant recognition for weed control or automated harvest techniques can be used to reduce production costs and increase product uniformity.

SIMILARITIES AND DIFFERENCES BETWEEN THE VISIONS

The difference in paradigm between the visions is quite fundamental. The technological vision is based on the traditional paradigm of agricultural research, which is based on solving problems with knowledge and technology. Although technological farming systems have changed radically, little attention is paid to whole systems approaches: innovations in part of the system can have negative consequences for other parts. Therefore, agricultural research methodology needs to change as the paradigm in which agronomic research is caught automatically leads to further 'conventionalizing' agriculture (Leiber and Fuchs, 2008). Every innovation will have other negative effects. Leiber and Fuchs (2008) proposed to use "cognitive holism" as a technique of contextualization at different levels. The agro-ecological vision is based on a holistic paradigm. In research as well as in practice, diversity is hard to handle. Researchers prefer to deal with monofactorial relations and study them objectively. The multi-objective and multi-factor studies are complex and universal principles are hard to find. Additionally, practice prefers easy recipes for their management.

Agro-ecological farming systems and technological farming systems are both under market pressure for cost price reduction. To achieve low costs in vegetable farming requires specialization, scaling-up and enhancement of uniformity. Moreover, the market asks for large and uniform quantities of products. The technological vision contributes to these demands as it is partly developed from a market perspective, whereas the agro-ecological vision is developed from an ecological perspective. Agro-ecological farming systems such as OPS do support some market demands better than technological systems because of the emphasis on the intrinsic quality of products (free of residues, no GMO's, emphasis on taste). Currently, agro-ecological systems have a relatively little market share.

The question is whether technological and agro-ecological farming systems can fulfill societal demands and in what timeframe systems will be ready for application in practice. Assessments of sustainability are difficult as a lot of knowledge is missing, the assessment is multi-factorial and weighing of factors is subjective and based on the applied paradigm. Given these differences, both visions are worth investigating simultaneously. Both visions need thorough system design, combined with testing and improving. Methods such as prototyping methodology (de Haan and Garcia Diaz, 2002) can help in development of these new systems. Both visions should exchange experiences as they can learn from each other: the agro-ecological vision needs technology as was stated and the technological system needs agro-ecological knowledge. Both visions should be developed further to have a diverse set of production systems ready in future.

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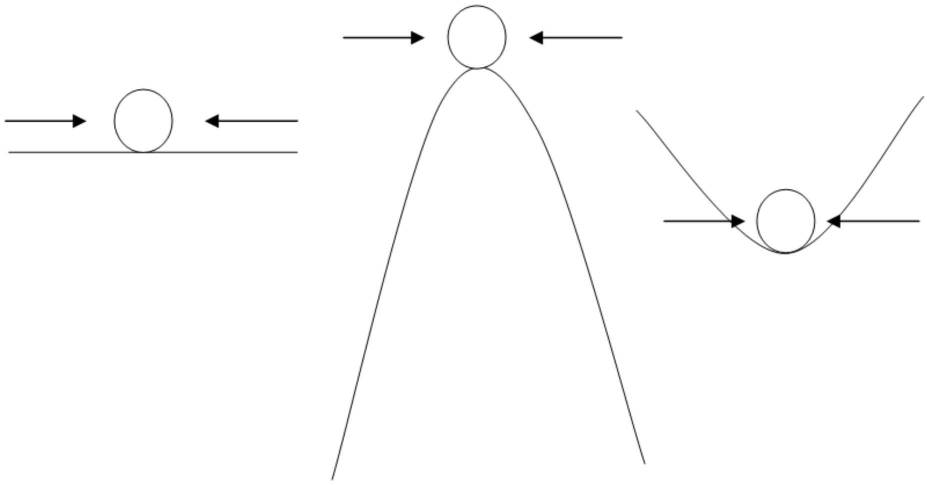
Figures



a) Medium diversity, instable Conventional

b) Low diversity, maximum control Technical, monoculture

c) High diversity, resilient, Agro-Ecological

Fig. 1. Schematic description of the conventional production systems and the technological and agro-ecological vision.