Sustainable Flower Bulb Production: Prototyping Integrated Flower Bulb Production Systems on Sandy Soils in The Netherlands

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Abstract

Flower bulb production in The Netherlands is economically successful. However, production methods rely heavily on external inputs, causing contamination of surface and ground water. The use of pesticides has been estimated 100 kg active ingredient (a.i.) per ha in 1994. In the same year the annual use of nitrogen and phosphate was 310 and 130 kg per ha respectively. Over the last decade the Dutch government established targets for the input and emission of pesticides and (in)organic fertilizers, energy use and volume of production related waste. Prototype flower bulb farming systems, with regard to these objectives, were developed, tested and improved on three experimental farms. This article concentrates on the results of two experimental farms on sandy soils in the west of The Netherlands in the period 1991-1997: 'De Noord' at St. Maartensbrug and 'De Zuid' at Hillegom. At both experimental farms the use of pesticides was reduced with at least 75% compared to the reference year of 1987-1988. Considerable reduction in the use of soil fumigants and fungicides was realised, but not of herbicides and insecticides. The use of nitrogen and phosphate decreased to approximately 215 kg and 55 kg per ha respectively. The integrated prototypes of experimental farm 'De Zuid' were economically competitive with flowerbulb farms in the same region. Integrated farming prototypes of 'De Noord' were less profitable due to suboptimal soil conditions, over-ambitious research targets and inexperienced management. As a spin-off of this farming system research, 24 flower bulb growers are converting to integrated flowerbulb growing on their farms. They are supported by research and extension workers.

INTRODUCTION

Flower bulb cultivation in The Netherlands is a relatively fast growing and economically prosperous activity. On approximately 22,000 ha (5% of the dutch arable crop area) a yearly value of over NLG 1,200 million is reached (approximately US$ 500 million). This means that the national bulb production value is approximately NLG 55,000 per ha of flower bulbs. This income is generated by nearly 3,000 growers. Flower bulb production in The Netherlands constitutes 93% of the world production. The main countries to which the flower bulbs are exported are, Germany, United States and Japan. The export value of bulb flowers is NLG 900 million (Anonymous, 2000).

Approximately 40% of the production is concentrated on alluvial sandy soils in the west of The Netherlands (table 1). Flower bulbs here are produced by specialised growers in a bulb dominant rotation. Another 40% are produced on clay soils found throughout The Netherlands, whilst the remaining 20% are produced on sandy soils in the east. In these regions, bulbs are cultivated in a rotation with pasture, vegetable or arable crops. The production of flower bulbs on sandy soil in the western Netherlands is decreasing, due to lack of suitable land and national environmental policies. In other parts of The Netherlands production is still increasing (CBS, 1999).

The five main crops grown in The Netherlands are tulips, lilies, gladioli, narcissi and hyacinths (table 1). In the last 10 years the production of tulips and lilies has increased with 43% and 67% respectively. The production of iris and gladioli has decreased. Production of the remaining crops have remained more or less stable.

During the past fifty years, production methods have been developed that rely heavily on external inputs and mechanisation. This was caused by the following: (1) high prices of suitable land, (2) low costs of external inputs compared to product value, (3) research and extension was aimed at improving production and (4) high costs of labour (Rossing et al, 1997; Stokkers, 1992). Current flower bulb production systems use considerable quantities of pesticides and nutrients per unit area.

The input of pesticides has been estimated on 120 and 100 kg active ingredients (a.i.) per ha in 1987 and 1994 respectively (anonymous, 1991; Doelgroepenoverleg, 1999). The cost of input of these pesticides is low, approximately NLG 3,000 per ha (LEI, 1999). Pesticide use in bulb production is high in comparison with the average use in dutch arable farming, in 1994 arable farmers used 12 kg a.i. per ha. (CBS, 1996). Soil fumigants and fungicides cause the highest input of a.i. per ha in flower bulb production. Soil fumigants prevent the development of soil-borne pathogens that are caused by the bulb dominant crop rotation on the alluvial sandy soils. Fungicides are mainly used to prevent *Botrytis* 'fire' blight disease.

In 1994 the use of nitrogen and phosphate was 310 and 130 kg per ha respectively (Doelgroepenoverleg, 1999). Surpluses of nutrients are relatively high due to inefficient uptake by flower bulbs and low retention capacity of the alluvial sandy soils. In addition, large quantities of organic manure are being used on the alluvial sandy soils to improve the level of organic matter of the soil and, until 1995, to prevent wind erosion.

The high levels of external input in flower bulb cultivation (and dutch arable farming in general) cause contamination of surface and ground water. Carbendazim, pirimifos-methyl and prochloraz are flower bulb production related pesticides, which have been found frequently in surface water. Concentrations of nitrogen and phosphate in some flower bulb regions also exceeds environmental standards for surface water (Doelgroepenoverleg, 1999).

Consequently, in the early nineties Dutch government has made environment a point of special attention for agriculture. By the year 2000 Dutch agriculture should practise safe, sustainable and competitive farming (Anonymous, 1990).

These settings have stimulated researchers to integrate objectives on environment, economics and agronomics at farm level. Since these are, to some extent, conflicting objectives, this so called 'integrated' farming effectively means searching for 'acceptable' compromises. To develop flower bulb production in terms of both economic and environmental objectives three experimental farms were created: 'De Noord' (1991-1997) at St. Maartensbrug, 'De Zuid' (1991-1997) at Hillegom and 'Zwaagdijk' at Zwaagdijk (1991-1996). The first and second are situated in the major flowerbulb regions, on alluvial sandy soil. The third was aimed at flower bulb production in an arable farming system on clay soil. This paper concentrates on the results of the integrated systems of the two experimental farms on sandy soils in the west of The Netherlands: 'De Noord' and 'De Zuid'.

MATERIALS AND METHODS

Approach

The methodology of prototyping farming systems can be characterised as a synthetic research and development effort. Prototyping can be described in four steps: (1) analyses and objectives, (2) design, (3) testing and improving and (4) dissemination or implementation (Vereijken, 1994; Vereijken, 1995; Vereijken, 1996; Vereijken, 1998; Wijnands, 1999).

The method starts with a (regionally based) analysis of all aspects involved farming: agronomic and socio-economic situation of farmers involved, environmental effects, political conditions and urban needs. This is followed by defining the objectives in agronomic, environmental and economic terms. The second step is the design of one or more prototype farming systems which meets those objectives. The design is followed by testing and improving on practise scale on (experimental) farms. The process ends with implementation on a larger scale by the growers or farmers.

Prototyping is a method that structures the process of innovation of farming systems. Thus, innovation is a continuous process of design, testing and improving prototypes based on clear objectives (figure 1; Wijnands, 1999).

Analysis: Objectives

Based on the analysis of the shortcomings of current farming, and perspectives of the future a hierarchy of objectives has to be defined (Wijnands, 1999). In this project the main objective of integrated farming is the reduction of the environmental side effects, especially the emission of nutrients and pesticides to the biotic environment.

Over the last decade the Dutch government has launched long-term policy plans which set targets for farmers. These targets have been established to regulate the input of pesticides and (in)organic fertilizers, to reduce dependence on chemicals and to diminish emission of pesticides and nutrients. The 'MeerJarenPlan Gewasbescherming or MJP-G' [‘Multi-year Crop Protection Plan’] set out that, in the year 2000, the volume of pesticides used in arable farming had to be reduced by 50% and the emission by 90% compared to the reference year of 1987-1988 (Anonymous, 1991). The use of organic phosphate was restricted to 110 and 85 kg ha in 1995-1997 and 2000 respectively. From 2001 all arable farming systems are obliged to register the input of nitrogen from fertilisers and organic manure as well as the input of phosphate from organic manure. This so-called ‘MINeraal Aangifte Systeem or MINAS’ [Mineral registration system] is based on a rotational balance, between the input through fertilisers and manure and the output through crops, of nitrogen and phosphate. The maximum acceptable use in flower bulb production of these minerals is set by the government: 265 kg per ha nitrogen and 85 kg per ha phosphate in 2002. Farmers exceeding the maximum limit will be fined (De Haan et al, 1999).

Less priority has been given to energy use and volume of production related waste. In 1998 the ‘Meerjarenafspraak Energie’ [Multi-year Energy Commitment] was launched. Flower bulb and bulb flower growers have committed themselves to improve the energy efficiency by the year 2005 by 22%, compared to the reference of 1995. The national environment policy plan sets out a 55% target for the re-use of waste by the year 2000 (anonymous, 1989).

The second main objective is income. The target is a balance between income and costs. The quality of the production is considered more important for the realisation of an appropriate farm income than quantity, given the strong competition on the market (Wijnands, 1999).

Besides these two main objectives of integrated farming, a thirth objective has been considered. From our point of view integrated production also means preservation of long-term soil quality. Soil quality is divided into soil fertility (organic matter, water soluble phospores) and soil health (level of soil pathogens (including weeds)).

These objectives have to be transformed to a set of indicators to quantify them. Goals are the search directions of the objective: minimise or maximise. The target should, at least, be realised in the period studied. Table 2 gives the indicators for the integrated flower bulb systems on the experimental farms 'De Zuid' and 'De Noord'. Three objectives have been chosen in this study: environment, farm economics and soil quality. To specify them, both objectives are divided in separate themes. According to this approach each theme has a goal: minimise environmental pollution or maximise economics. The objectives are at least partially conflicting. Integrated farming is searching for ‘acceptable’ compromises between these conflicting objectives. The targets in table 2 represents these 'acceptable’ compromises. Most targets are based on political goals, like the MJP-G or MINAS.

Design: Location

Farm type and location are the starting points of prototyping integrated farming systems. This study is focused on specialised bulb growers on sandy soils in the west of The Netherlands. Because of the regional concentration of high input flower bulb culture, the environmental side effects of bulb growing are most crucial here.

Research started on special equiped 'experimental' farms because of the uncertainty due to the practice of new, not fully developed, methods and techniques: risks that individual commercial farms usually wouldn't take because of the potential financial consequences. In addition commercial farms normally aren't equipped to perform long-time research. A draw-back of working on experimental farms is the lack of replicates with respect to soil-, farm-, and management conditions (Wijnands, 1999).

The experimental farm 'De Noord' is located in St. Maartensbrug, 50 km northwest of Amsterdam. The bulbs are cultivated on a fully drained alluvial laom-sandy topsoil with 1-2 % organic matter, 5-6 % silt (2-50 um), pH between 7,0 and 7,5 and a ground water level at approximately 80 cm below the surface. Experts have classified the soil as moderately suitable for bulb production, mainly due to the bad structure of the subsoil. The crops cultivated are comparable to those in the region: lilies, tulips, narcissi and miscellaneous bulbs (for example crocus). Because of the relatively low ground water level, at least for flower bulbs, the bulbs of 'De Noord' are sprinkled in dry periods. 'De Noord' occupies 15 ha, of which approximately 9,5 ha are used for farming systems research.

'De Zuid' is located in Hillegom, 30 km southwest of Amsterdam. The bulbs are cultivated on alluvial sandy topsoil with 1-2 % organic matter, <4% silt (2-50 um), pH between 6 and 7 and a ground water level at approximately 50 cm below the surface. The soil has been qualified as very suitable for bulb production. Sprinkling is normally not necessary. The crops cultivated on 'De Zuid' are representatives to those in the region: hyacinths, tulips, narcissi and dahlias. Dahlias are grown as representative of the other groups (herbaceous perennials) of crops cultivated in this region. 'De Zuid' occupied 6 ha, of which approximately 4 ha was used for farming systems.

Two different integrated prototypes have been tested since 1991: integrated and experimentally integrated. The integrated system aims at objectives on a short term (maximum five year period) where the experimentally integrated system is aimed at the longer term.

Both farms have been founded by the bulb growers' association and the regional and national governments.

This paper concentrates on the results of the integrated systems on both experimental farms, as the results of both integrated and experimentally integrated prototypes were comparable.

Design: Crop Rotation

The multifunctional crop rotation plays a central role in farming. It is the major method to preserve soil fertility, soil health and soil structure (Wijnands, 1999). A balanced composition of crops should be designed.

The rotation schemes (table 3) are elaborated to prevent soil pathogens. The dependence on soil fumigants can be reduced by a balanced rotation of crops and inter-crop management. Inter-crop management refers to coherent activities between successive crops (Rossing et al, 1997). Inter-crop management can be used to prevent soil erosion, to reduce soil pathogens, to suppress weeds, to restore soil structure or to improve soil fertility (organic matter).

Based on the characteristics of the most important diseases in flower bulb culture a four year crop rotation is designed for both experimental farms. The tulips at both experimental farms have been planted in late autumn direct after the harvesting of the summercrops (lilies or dahlias). After harvesting the tulips at 'De Noord' in July, the field was inundated for six to eight weeks. Inundation kills several soilborne pathogens (f.e. *Pratylenchus penetrans* and *Rhizoctonia tuliparum)* and weeds. But after inundation there is a higher risk of infestation of *Pythium spp.*

Narcissus is less susceptible for *Pythium spp.* and therefore planted after inundation. At ‘De Zuid’ fodder radish is cultivated in stead of inundation, because soil conditions here make inundation impossible. Fodder radish neutralises the nematode Trichodoridea and the risks of the spread of Tobacco Rattle Virus (TRV) (Zoon et al, 2000). Early autumn narcissi are planted on both farms. Because of the short period (app. 1-2 months) between harvesting narcissus and planting crocus, the fast growing yellow mustard is sown. The nine months period between crocus or hyacinths and lilies or dahlias can be used for *Tagetes patula* culture. In case of abundance of the nematode *Pratylenchus penetrans* phacelia is sown after harvesting crocus (or hyacinths) in june (or july). Next spring a new rotation starts with planting the lilies (De Noord) or dahlias (De Zuid).

Design: Methods and Measures

The most important objective is to decrease the side effects of the high input of chemicals in flower bulb culture. Modern flower bulb cultivation relies heavily on pesticides. The role of chemical crop protection is to safeguard against expected losses. Additionally, the economic benefit of lowering the external chemical input is relative marginal. Much of the treatment can be characterised as 'no-risk' usage. In integrated farming the use of pesticides is concentrated on what is really needed. Pesticide use is reduced by giving maximum emphasis to prevention, supervised control of pests and the use of non chemical methods. If a chemical control is needed, the most efficient, selective and least harmful pesticides is used under appropriate field and weather conditions. Methods with controlled usage, such as (hot) water treatment of planting material or row or furrow treatments are preferred above full field application.

Prevention

Use of less susceptible varieties, pathogen-free planting material, adapted planting date and farm hygienic measures will help to decrease the need for pesticides. In the integrated farming systems varieties have been chosen which in general are moderately or less susceptible to *Botrytis* ‘fire’ blight, root rot (*Fusarium spp.*) and virus diseases. Virus free planting materials from tissue culture have been used in dahlia culture. The relatively late planting dates of tulips, narcissi and crocus are examples of adapted planting date. Because of the lower soil temperatures in late autumn virus transmission by nematodes (*Trichodoridea spp.*) and diseases like *Rhizoctonia spp.*, *Pythium spp.* and *Fusarium oxysporum* are prevented. Notably in this late, and regularly wet season, planting conditions can be less favorable. In addition, planting too late can have negative effects on harvesting. An optimum balance between the factors has to be chosen.

Seedbed preparation long before planting dahlias, is used to control weeds. On this so called false seedbed germinated weeds are controlled before planting the dahlias. Farm hygienic measures, like removing chopped flowers, diseased plants and necrotic plant material before harvesting, will decrease disease pressure. All organic waste is composted. Composting under good conditions prevents spread of pests, diseases and weeds.

Supervised Control of Pests

Modern knowledge and techniques can be an aid to help farmers to predict whether control of pests is needed or not. BoWaS is a computerised system of supervised control of the air-borne disease *Botrytis spp.* ‘fire’ blight in tulips, gladioli and lilies. This system warns farmers when weather conditions for ‘fire’ exposure are favorable. When the expected disease pressure will exceed a threshold, preventive treatment is needed. Traditional weekly treatments of fungicides are superfluous (Van der Ende et al, 2000). The flight of aphidious virus vectors usually starts around the first week of may, mainly depending on weather conditions of past weeks. Control of aphids only should start in this period.

Non Chemical Methods

Inundation is an example of non chemical control of pests and is partly an alternative for soil fumigation. Mechanical weed control is practiced between the rows in dahlias and full-field weed harrowing is performed in lilies. In the other bulb crops these methods were not fully developed for use in integrated farming. Spread of diseases due to mechanical treatment was estimated as risky. To suppress weed germination a thick layer of straw (app. 15-20 ton of straw per ha) has been used in crocus and narcissi. A full field layer of straw is effective when it is dense and free of grain. It does not hamper the growth of the bulbs. In common practise this bed of straw is only used in winter to protect bulbs against frost. In early spring the straw is removed.

The input of nutrients can be optimized by using low mineral organic manure and accurate dosages of fertilisers. The estimated optimum level of soil organic matter is 0,8 to 1,3% for flower bulb production on alluvial sandy soils. Dairy manure, with a high nutrient level per unit organic matter, is normally used to improve the level of organic matter. In the integrated farming systems only composts are being used to improve soil organic matter. Compost is partly produced of organic waste of the experimental farm. However, as this is not sufficient, so-called 'GFT' compost (produced of organic domestic waste) is used.

In integrated farming the dosage of nitrogen and phosphate fertilizers is based on available reserves in soil and the specific needs of the crop (table 4). In case of nitrogen, split dosage methods are applied based on repeated monitoring of soil reserves and (expected) crop uptake (Anonymous, 1998).

The economic results have been estimated according to the standard calculation in flower bulb production i.e. yields minus direct costs (planting material, fertilisers, crop protection, insurance and handling) give the amount to compensate capital investments (soil, labour and equipment). These have been put in terms of return per unit costs, in which all economic components are compressed. In order to enable a fair comparison between the integrated prototypes and current growing, the size of the prototypes has been enlarged to the average of bulb farms (Snoek et al, 2000a).

RESULTS

Testing and Improving

Developing the prototypes in practice means running of the total prototype on farm scale in the long term, with annual improvements where required. Prolonged research is necessary to test the prototype under all field, weather and management conditions. The research period of this study was six years. During this period all agro- and economic data have been recorded.

This means input of planting material, seed, pesticides, fertilisers, labour, machinery and the output of planting material, saleable bulbs and (organic) waste. In addition, data according to soil fertility, soil health and weed pressure and all kind of qualitative observations of the crops during growing season have been recorded. Selections of the integrated bulbs have been forced to compare the quality of the product with what is available in common practice.

All these data have been frequently evaluated with a group of bulb growers, researchers and extension workers. In this evaluation actual results are linked with the targets to analyse the shortcoming of the prototypes. This has lead directly to improvements of the prototypes for next year.

Figures 2a and 2b presents the results of the integrated prototypes at four themes: (1) pesticide input, (2) nitrogen use, (3) phosphate use and (4) surplus. The results of both experimental farms are compared with current flower bulb practice in both regions where the experimental farms are situated (Doelgroepenoverleg, 1999; LTC, 1999). The figures are presented relative to the target (table 2), which has been set at 100%.

Environment

*1. Pesticides***.** Both experimental farms reduced the use of pesticides with at least 75% compared to the reference year (1987-1988). The average use in the research period was approximately 28 and 20 a.i. per ha for 'De Noord' and 'De Zuid' respectively. The use of pesticides per ha on both experimental farms was less than half of the use in current flower bulb practice (1996-1998) in both regions.

Considerable reduction was realised on the use of soil fumigants (incl. soil fungicides) and fungicides, but not of herbicides and insecticides. The four-year crop rotation plays a central role in the reduction of soil fumigants use. During this research period, a soil fumigant was used once only at 'De Zuid', due to the change from former two-year to the four-year rotation. 'De Noord' used only soil fungicides before planting tulips susceptible for *Rhizoctonia* disease. Only low doses in furrow treatment have been used to reduce the use of these soil fungicides. Supervised control of Botrytis blight 'fire' reduced the use of fungicides considerably on both experimental farms, with maintenance of an adequate disease control. In addition, modern low dose fungicides were an aid to reduce a.i. per ha. Some reduction of fungicide use has been realised, by lowering desinfection dosages of less susceptible cultivars and by using new (tray less) methods of desinfection.

In the research period herbicide use has not been reduced notably, due to lack of non-chemical alternatives. Apart from this, current chemical methods proved to be inadequate to suppress weeds effectively.

Because of the use of mineral oil to prevent spread of virus by aphids in lilies, the use of insecticides has not been significantly reduced. There are no alternatives to the use of mineral oil. By supervised control of aphids the use of insecticides in the other bulb crops has been reduced, but this reduction was relatively low. In general, few a.i. per ha are needed to control insects in bulb crops.

*2. Nutrients***.** Nitrogen use in integrated farming has been reduced to approximately 215 kg N (organic and inorganic) per ha on both experimental farms. This reduction was attained by using split mineral dosage techniques, which are based on the specific needs of the crop during growing season and frequent monitoring of the available reserves in soil. In addition, the use of low-mineral compost to improve soil organic matter has been an aid to reduce the input of organic nitrogen. The nitrogen use in current flower bulb production (1996-'98) is slightly higher than on the experimental farms. Split dosage techniques of nitrogen are already common practice.

The use of organic phosphate has been reduced to 50 and 60 kg P_2O_5 per ha on 'De Noord' and 'De Zuid' respectively. Phosphate fertilisers (inorganic) have rarely been used because of the sufficient soil reserves of water soluble phosphate. In the integrated farming systems only low-mineral organic manure (composts) have been used to improve soil organic matter. The organic phosphate use is nearly half of current farming in both regions (fig 2a and b). Current flower bulb farming still uses considerable amounts of dairy manure, with a high phosphate level per unit organic matter.

*3. Organic waste***.** Since the start of the experimental farms all organic waste, including diseased plant material, have been composted. The compost has been re-used as organic manure to improve soil organic matter. There are no figures of the percentage of flower bulb farmers practising composting. The general impression is that the interest in on-farm composting is growing. This is due to a growing focus by bulb growers on soil quality and increasing prices of transport to public waste processors.

Farm Economics

*1. Surplus***.** The surplus of the integrated system was NLG 95 and 101 return per NLG 100 costs for 'De Noord' and 'De Zuid' respectively. The integrated prototypes of the experimental farm 'De Zuid' were economically competitive with flowerbulb farms in the same region, which realised NLG 102, return per NLG 100 costs. The integrated farming prototypes of 'De Noord' were less profitable. Current farmers in this region had, in the same period a return of NLG 103 per NLG 100 costs.

*2. Product Quality***.** Product quality can defined by the 'BKD-standards': at least 'Standaard' for saleable bulbs and 'Algemeen' or 'Klasse I' for planting material (table 2). These standards are mainly based on percentage virus present. Planting material and saleable bulbs of the integrated systems have, in general, been meeting these standards. In some cases material were (temporarily) de-classed and in one case condemned (Tulips with bulb mite's *Aceria tulipea*). None of these is viewed as an exception in current bulb farming.

Product quality can also be defined by quality of artificially forced bulbs (bulb flowers). Selections of integrated flower bulbs have been forced together with current bulbs. In general, the forcing quality of the integrated bulbs was comparable to the current ones. In some cases a too low level of nitrogen in the integrated bulbs caused a lower flower quality. Especially, the quality of hyacint and narcissus was in certain years not acceptable.

Soil Quality

*1. Organic Matter***.** The soil organic matter content in the topsoil (0 – 30 cm) started at a relatively high level at both farms, due to an history of high input of dairy manure (Table 5). The change to compost based organic fertiliser management caused a decline of soil organic matter in the first years. The main reason of this decline was that the high decomposition of dairy manure based organic matter could not be compensated by input of compost based organic matter. After several years a new balance developed between input and decomposition. At the end of the research period the soil organic matter content was at the target level of 1.2-1.3%.

*2. Water-Soluble Phosphate***.** The water soluble phosphate content in the topsoil (0 – 30 cm) started at a high level on both farms. A history of high input of dairy manure and phosphate fertilisers had also increased the soil phosphate content considerably. In the research period both farms realised a decrease of the water soluble phosphate content (Table 5). Phosphate fertilisers have rarely been used because of the sufficient soil reserves. Besides, the input of organic phosphate with organic fertilisers was nearly in balance with the uptake by the flower bulbs. At the end of the research period the phosphate content in soil was still above target.

*3. Soil Pathogens***.** Each year the amount of the pathogenic nematodes *Trichodoridea* and *Pratylenchus penetrans* in the topsoil (0-20 cm) have been quantified (nematodes per 100 ml soil). In the research period both nematodes have rarely been detected. Other major pathogens, with two exceptions, never caused loss of any significance. *Fusarium oxysporum* caused, in some cultivars of lilies and narcissi, considerable loss and rejects at sorting. Because of a lack of sufficient chemical control, weeds did sometimes hamper growth and harvesting of the bulbs. An expected growth of the seed bank could not be proved.

DISCUSSION

Current flower bulb production methods rely heavily on external inputs, causing contamination of surface and ground water. Since the last decade bulb growers have had to, besides income objectives, face up to the (quality of the) environment as a major objective. Targets have been established with respect to input and emission of pesticides and fertilisers. By 2000, bulb production (and all of Dutch agriculture) should practice safe, sustainable and competitive farming methods (Anonymous, 1990).

This paper describes three of the four steps of an approach to find an acceptable 'integrated' compromise between environment and income. This methodology of 'prototyping' of integrated farming systems has, in the early nineties, been successfully used in arable farming with relatively low input (Wijnands and Vereijken, 1992; Wijnands, 1999). In this study this methodology proved, in this stage, to be also successful in high input production systems, like flower bulbs.

The experimental farms 'De Noord' and 'De Zuid' realised a reduction in the use of pesticides and nutrients without losing much income. But we can make some annotations to this general positive conclusion.

Considerable reduction of pesticide use has been realised on the use of soil fumigants (incl. soil fungicides) and fungicides, but not of herbicides and insecticides. Weed control, specifically, proved to be problematic, due to a lack of alternatives. Chemical control was not always sufficient. Mechanical weed control is relatively new in current Dutch arable farming and in particular in flower bulbs. In most of the bulb crops these methods are still in the experimental stage. On both experimental farms mechanical weed control have been tested, but this have not yet led to an integrated strategy. The presumed risk of disease spread is an important draw-back of mechanical weed control. To suppress weed germination, a thick layer of straw (app. 15-20 ton of straw per ha) has been used in crocus and narcissi. Nevertheless, chemical control was needed to suppress weeds and grains. Disadvantages of a straw layer are also the risk of losses due to ground frost in spring and higher costs (Snoek et al, 2000b). A draw-back of all alternatives is the need of more hand weeding (in the row) without having labour available. Thus, research on weed control in flower bulb crops has to intensify.

Some reduction in nitrogen input was realised. This reduction in some cases have led to an unacceptable reduction of flower quality. It is doubtful whether a further reduction of nitrogen input can be achieved with current methods. New techniques like fertigation and planting bed dosage possibly make a further reduction feasible without losing (forcing) quality. The reduction of phosphate input was possible because of the use of low-mineral compost to improve soil organic matter and the high level of available phosphate in the topsoil.

The financial results of the integrated production system of 'De Zuid' were comparable to the current flower bulb farming. The system of 'De Noord' was less profitable. The main reason for the lower financial results of 'De Noord' were sub-optimal soil conditions for bulb production, too ambitious research targets and young, inexperienced, management. The bad structure of subsoil at 'De Noord' sometimes led to crop failure. Some new methods tested at 'De Noord' to reach the research targets did not give the results expected. More suitable soil and an experienced bulb grower as manager, gave 'De Zuid' a better chance of success. Management is undoubtedly an important factor for the success and feasibility of integrated farming. Integrated farming is more knowledge intensive than current farming. Prevention, supervised pest control and split dosage techniques require more insight, skill and knowledge of the manager. The sharper the objectives of an integrated system, the more demands are made to the production system and management. The integrated systems of 'De Noord' apparently balanced on the edge of what was feasible under current (biotic and abiotic) circumstances.

Soil quality is one of the key-factors of a production system. It is a consequence of each farming strategy. An integrated strategy can only be sustainable when the quality is stable over a long period. It is hard to verify the effect of the chosen integrated strategy, only because of the relative short research period and because of short insight in the effect of yield limiting (nutrients) and - reducing (pathogens) factors on crop yield. (For example effect of lower soil fertility on product quality and quantity). Due to lack of measuring instruments soil quality can also not always be measured objectively.

The effect of the environmental measures on income (surplus) from integrated systems was relatively low. Thus, between income and environment, a range of acceptable integrated compromises could be found. Rossing et al (1997) produced a model based study, which came to a similar conclusion. They showed that, to a certain extent, environmental measures had marginal effect on income. Moreover, reducing pesticide input had less influences on income than reducing nitrogen surplus. The effect of a decrease of the input of 'tactical' pest management on income could be constrained by strategic choices, like crop rotation or inter crop management (Rossing et al, 1997). The negative effect of environmentally oriented 'integrated' production systems on farm income could be largely off-set by strategic choices.

An important draw-back of this prototyping approach is the small number of prototypes that can be tested at experimental farms under limited abiotic and biotic conditions. The perspectives of newly developed prototypes can only be evaluated in current practice. Wijnands (1999) recommends a dissemination in two steps: first on small scale and then on large scale. The small scale test on a limited number of so called pilot farms is considered to be an indispensable step before introducing new prototypes on a large scale. The two major objectives of this phase are (1) to evaluate the effectivity and feasibility (manageability and acceptability) of the integrated prototype and (2) to gain the knowledge that is necessary to implement the prototype safely and successfully on a large scale (Wijnands, 1999). This first phase of dissemination needs a group of well-motivated growers producing under varying soil-, farm- and management conditions. In 1997 this first phase has been started with the project 'Bollenteelt na 2000' [Flower bulb production beyond 2000]. A group of 24 growers are converting to integrated flower bulb growing on their farms. Extension workers and researchers provide intensive support. The result of such projects depends on a good interaction between these growers, extension and research workers. In the first year, these growers have reduced the input of pesticides considerably. A reduction of the input of nutrients proved to be more difficult. This project will be completed and evaluated by the end of the year 2000. A large-scale dissemination of integrated growing data has not yet been started.

After this research period, the experimental farm 'De Zuid' was closed due to lack of funds. The innovation of farming systems has been continued on the experimental farm 'De Noord'. New prototypes have been developed and tested in order to meet the more restrictive Dutch policies of the near future and new objectives such as contribution to nature and preservation of landscape. One of the newly developed and tested prototypes is a fully ecological (organic) flower bulb farming system. These prototypes will meet new levels of bulb production and research.

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Tables

Table 1. Flower bulb production in The Netherlands (in ha) per region. Source: BKD, 1999.

Region	tulip	narcissi	hyacinths	iris	crocus	miscel-laneous bulbs	gladioli	lilies	dahlias	total
Northern-Holland-sandy soil ('De Noord')	2,276	1,061	430	488	490	172	15	869	59	5,860
Northern-Holland-clay soil	3,259	30	41	133	71	40	31	407	4	4016
Kennemerland-sandy soil	346	70	118	36	50	98	2	83	10	813
Bollenstreek -sandy soil ('De Zuid')	866	534	527	11	46	48	22	37	297	2,388
Flevoland-clay soil	2,401	1	0	86	15	7	476	363	3	3,352
Northern-East Netherlands –sandy soil	370	3	0	3	7	2	61	1,438	1	1,885
South-East Netherlands-sandy soil	144	75	4	1	1	5	886	853	92	2,061
South-West Netherlands-clay soil	496	1	0	0	0	1	303	162	0	963
Total	10,158	1,775	1,120	758	680	373	1,796	4,212	466	21,338

Table 2. Objectives of integrated flower bulb farming systems at the experimental farms 'De Noord' (=N) and 'De Zuid' (=Z).

Objective	Theme	Goal	Target	Reference
Environment	pesticide use[1]	Minimize	58,3 a.i./ha (Z) 47,5 a.i./ha (N)	MJP-G 2000 (Anonymous, 1991)
	nitrogen use[2]	Minimize	265 kg N/ha	MINAS 2002 (de Haan et al, 1999)
	phosphate use[2]	Minimize	85 kg P2O5/ha	MINAS 2002 (de Haan et al, 1999)
	waste	Minimize	100% re-use[3]	Structuurnota Landbouw (Anonymous, 1989)
Farm economics	surplus	Maximize	> NLG 100 return per NLG 100 costs	-
	product quality	Maximize	no decrease	BKD-standards[4]
Soil quality	organic matter[5]	Maximize	0,8-1,3 %	Anonymous, 1998
	Pw[5]	Minimize	25-35	Anonymous, 1998
	soil pathogens	Minimize	no increase	-

1) Pesticide use in a.i.: active ingredients
2) Use of organic and inorganic nitrogen and organic phosphate.
3) Re-use of organic waste.
4) BKD: Bloembollen Keuringsdienst [Flower Bulb certifying agency]: at least 'Standaard' for saleable bulbs and 'Algemeen' or 'Klasse I' for planting material.
5) Pw: Water-soluble phosphate (mg P_2O_5/l) in 0-30 cm topsoil or tilth.

Table 3. The four year-rotation of flowerbulb crop and *inter-crop management* (ICM) at the experimental farms 'De Noord' and 'De Zuid'.

	De Noord		De Zuid	
Year	crop	*ICM*	crop	*ICM*
1.	tulips		tulips	
		inundation		*fodder radish*
2.	narcissi		narcissi	
		yellow mustard		*yellow mustard*
3.	crocus		hyacinths	
		phacelia		*phacelia*
4.	lilies		dahlias	

Table 4. Uptake of nitrogen (kg N/ha) and phosphate (kg P_2O_5/ha) by flower bulb crops (Landman, 1994; Landman et al, 1997).

Crop	**Nitrogen (kg/ha)**	**Phosphate (kg/ha)**
tulips	146	37
narcissi	104	37
crocus	68	36
hyacinths	163	57
lilies	88	34
dahlias	115	80

Table 5. Water-soluble phosphate (mg P_2O_5/l) and organic matter (%) in topsoil (0-30 cm) at start (1991) and end (1997) of integrated flowerbulb prototypes of experimental farms 'De Noord' and 'De Zuid'.

	Phosphate (mg P_2O_5/l)	**Organic matter (%)**
De Noord		
1991	50	1.6
1997	45	1.2
De Zuid		
1991	45	1.6
1997	35	1.3

Figures

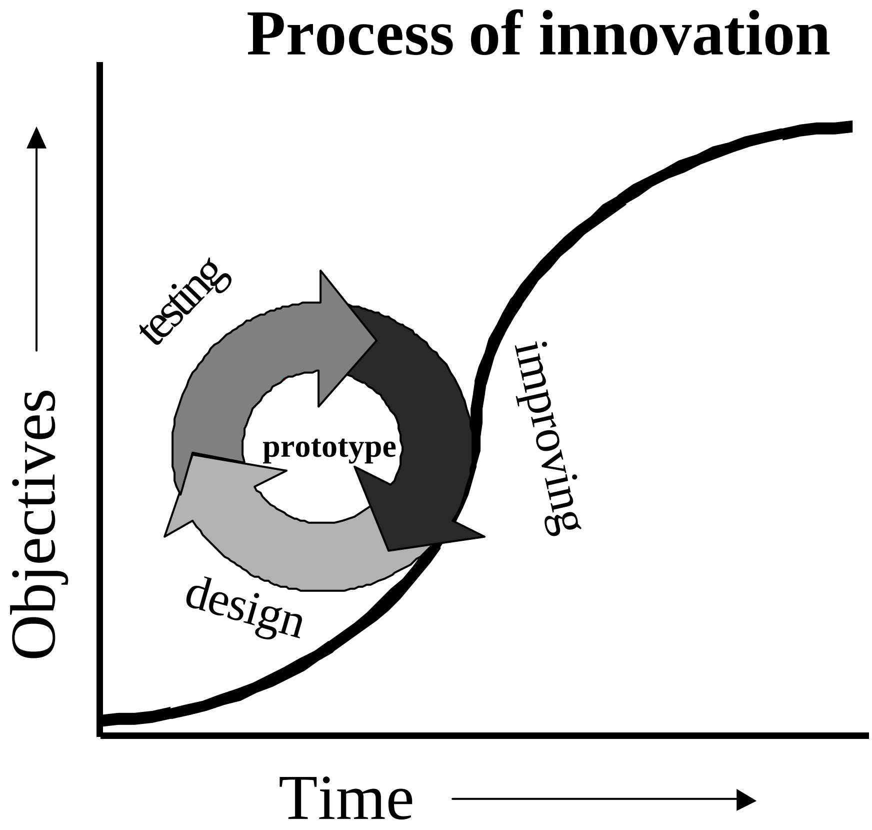

Fig. 1. Innovation of farming systems is a continuous process of design, testing and improving prototypes based on clear objectives (after: Wijnands, 1999)

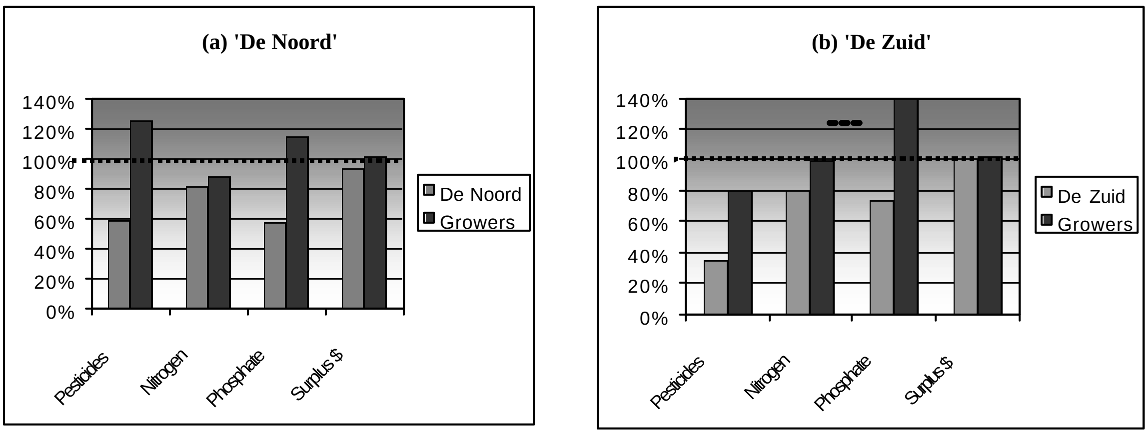

Fig. 2. The relative pesticide use, input of nitrogen, input of organic phosphate and return per NLG 100 cost (surplus $) of the integrated farming systems at (a) 'De Noord' (1991-1997) and (b) 'De Zuid' (1991-1997). These results are compared with current flower bulb growers (1996-'98 for pesticide input, nitrogen input and phosphate input; 1991-1997 for surplus) in both regions where the experimental farms were situated (Doelgroepenoverleg, 1999; LTC, 1999). All figures are relative to the target (·····) which has been set at 100%.