Chapter 1

Aims and structure of the thesis

1.1 Introduction

Organic farming is an agricultural production system that attempts to achieve closed nutrient cycles as much as possible without the use of highly soluble mineral fertilizers and synthetic pesticides. The system depends on internal self-regulation and soil organic matter to enhance its chemical, biological, and physical properties for optimal nutrition, weed, pest, and disease suppression. Management approaches to resolve the related problems in organic farming are quite different from those in conventional agriculture (Lundkvist et al., 2008).

Organic systems are prophylactic rather than reactive. Site specific crop rotations are made use of for nutrient cycling and conservation and for weed, pest and disease control (Stockdale et al., 2001; Lammerts van Bueren et al., 2002; Watson et al., 2002). Organic amendments, crop residue management, tillage, and rotations all aim at returning sufficient amounts and quality of organic matter to the soil to provide nutrients and improve soil health (Dima & Odero, 1997; Bailey & Lazarovits, 2003). In organic farming system circulation of nutrients mainly N is important part of farm budget it can be achieved by applying different organic measures (Möller, 2009). In Europe legumes contribute to livestock production as animal forage and are used as protein supplements in food and feed (Stockdale et al., 2002; Rochon et al., 2004; Siddique et al., 2011). It is a challenge for the farmer to achieve the full benefits of legume crops and to avoid N losses because leguminous crop residues are easily decomposable and leaching may result in less residual N for subsequent crops (Jensen, 1994; Hauggaard-Nielsen et al., 2003).

The main grain legumes in Germany are peas (*Pisum sativum* L.) and faba beans *(Vicia faba* L.). Despite the positive effects of legumes on the agricultural system the production is declining. In Germany, pea cultivation was 141320 ha in 2000 and decreased to 58700 ha in 2010 while beans were cultivated on 4412 ha in 2000 and 3925 ha in 2010 (FAOSTAT, 2012). The decline in their production is due to many challenging factors. Pea and faba beans are weak competitors to weeds and weeds are very efficient users of available N (Hauggaard-Nielsen et al., 2001; Grenz et al., 2005; Lundkvist et al., 2008; Deveikyte et al., 2009; Urbatzka et al., 2011).

Besides suffering from competition by weeds, peas and faba beans are commonly affected by a number of soil-borne, seed-borne and foliar pathogens; making, it very

difficult to grow and get profitable yields. The most important diseases are the ascochyta blight complex (Grünwald et al., 2004; Bretag et al., 2006; Tivoli et al., 2006; Pflughöft, 2008) and *Fusarium* spp. (Buxton, 1955; Oyarzun et al., 1994; Etebu & Osborn, 2012).

Legumes are also very sensitive to poor soil conditions such as erosion, soil acidification, and compaction (Bezdicek et al., 2003; Whitmore & Schröder, 2007). Soil compaction caused by agricultural practices such as axle loads, heavy rainfall and tillage operations or by field topography are the basic causes of subsoil compaction that deteriorates soil structures (Allmaras et al., 1989; Flowers & Lal, 1998; Jr, 1998; DeJong-Hughes et al., 2001). Compaction influences host-pathogen contact and the dynamics of root-pathogen interactions (Allmaras et al., 1989) and affects the mineralization of soil C and N. Water logging of soils also enhances pea root infection by *A. euteiches* and decreases soils oxygen contents which leads to poor plant development (Cannell et al., 1979; Belford et al., 1980; Allmaras et al., 2003).

In organic farming, legume production problems due to weeds and pathogens are not easy to overcome as no pesticides/weedicides are available and synthetic chemicals are prohibited. Thus, weeds, diseases and general soil structural problems need to be dealt with in the agricultural system based on cultural methods. As cultural methods interact with host, pathogen, and environment there is a need to study these interactive effects to improve their understanding and to avoid negative effects. It is known that several cultural practices can be partially effective, however, knowledge about combination and integration of more than one method is necessary which may improve the crop production system.

1.2 Objectives

The overall objective of the presented thesis is to contribute to improved grain legume health for N conservation in organic cropping systems in Germany. In the first part, the main seed-borne pathogens affecting peas and faba beans in organic agriculture as well as the health of the harvested crops were assessed in a four-year survey across Germany. In the second part, the focus was on peas as these suffer especially from problems in the field. Field experiments were conducted from 2009-2012 to determine the effects of mixed cropping of peas with oats, the use of various

brassica cover crops for potential biofumigation effects, and reduced tillage on weed infestation, diseases, and grain yield of peas, oats, and the following winter wheat crop.

This study is embedded in a large on-going research project on soil fertility in organic farming, titled “Increasing income from organically produced crops through the optimisation of soil fertility management” (www.bodenfruchtbarkeit.org) funded through the Federal Ministry of Food, Agriculture and Consumer Protection, Germany (BMELV).

1.3 Structure of the thesis

In the second chapter, peas and faba beans are briefly presented followed by a more detailed review about the problems occurring in pea production in the field. Chapter 3 describes the pea and faba bean seed health situation under organic conditions. Seed samples were obtained from 32 organic farms throughout Germany before sowing and after harvest from 2009-2012 to study the frequencies of seed-borne pathogens in the seed used to establish fields as well as in the harvested crop. In chapters 4 and 5, the field experiments that were conducted from 2009 to 2012 are described. A two-year sequence starting with a brassica cover crop followed by a pure stand of peas, or a species mixture with oats, or oats, and then by winter wheat was established in 2009 and in 2010, respectively. The purpose of these field trials was to evaluate the effects of pea-oat intercropping, reduced tillage, and the use of three different brassica species varying in their glucosinolate contents as cover crop before the pea growing system on grain yield, weed infestation, residual N and the performance of subsequent wheat (chapter 4) and on pea diseases (chapter 5). Finally, in chapter 6 the results and their possible implications for pea management in organic farming are synthesized and discussed.

1.4 References

Allmaras, R., Fritz, V. , Pfleger, F. & Copeland, S. (2003). Impaired internal drainage and Aphanomyces euteiches root rot of pea caused by soil compaction in a fine-textured soil. Soil and Tillage Research 70(1), 41–52.

Allmaras, R. R., Kraft, J. M., & Miller, D. E. (1989). Effects of Soil Compaction and Incorporated Crop Residue on Root Health. Annual Review of Phytopathology 26(1), 219-243.

Bailey, K. & Lazarovits, G. (2003). Suppressing soil-borne diseases with residue management and organic amendments. Soil and Tillage Research 72(2), 169–180.

Belford, R. K., Cannell, R. Q., Thomson, R. J. & Dennis, C. W. (1980). Effects of waterlogging at different stages of development on the growth and yield of peas (*Pisum sativum* L.). Journal of the Science of Food and Agriculture 31(9), 857–869.

Bezdicek, D., Beaver, T. & Granatstein, D. (2003). Subsoil ridge tillage and lime effects on soil microbial activity, soil pH, erosion, and wheat and pea yield in the Pacific Northwest, USA. Soil and Tillage Research 74(1), 55–63.

Bretag, T. W., Keane, P. J. & Price, T. V. (2006). The epidemiology and control of ascochyta blight in field peas: a review. Australian Journal of Agricultural Research 57(8), 883–902.

Buxton, E. W. (1955). *Fusarium* diseases of peas. Transactions of the British Mycological Society 38(4), 309–316.

Cannell, R. Q., Gales, K., Snaydon, R. W. & Suhail, B. A. (1979). Effects of short-term waterlogging on the growth and yield of peas (*Pisum sativum*). Annals of Applied Biology 93(3), 327–335.

Deveikyte, I., Kadziuliene, Z., Sarunaite, L. & others (2009). Weed suppression ability of spring cereal crops and peas in pure and mixed stands. Agronomy Research 7, 239–244.

DeJong-Hughes, J., Moncrief, J. F., Voorhees, W. B., & Swan, J. B. (2001). Soil compaction: Causes, effects and control. University of Minnesota, Extension Service.

Dima, S. J. & Odero, A. N. (1997). Organic farming for sustainable agricultural production. A brief theoretical review and preliminary empirical evidence. Environmental and resource Economics 10(2), 177–188.

Etebu, E. & Osborn, A. M. (2012). A review of indicators of healthy agricultural soils with pea footrot disease suppression potentials. Sustainable Agriculture Research 1(2), p235.

Flowers, M. D., & Lal, R. (1998). Axle load and tillage effects on soil physical properties and soybean grain yield on a mollic ochraqualf in northwest Ohio. Soil and Tillage Research 48(1), 21-35.

FAOSTAT (2012). Data available at http://faostat.fao.org. Accessed in December 2012.

Grenz, J., Manschadi, A., Uygur, F. & Sauerborn, J. (2005). Effects of environment and sowing date on the competition between faba bean (*Vicia faba*) and the parasitic weed *Orobanche crenata*. Field Crops Research 93(2–3), 300–313.

Grünwald, N. J., Chen, W. and Larsen, R. C. (2004). Pea diseases and their management, In: Diseases of Fruits and Vegetables: Volume II, Diagnosis and management. pp 301-331. Washington State University-IAREC, USA.

Hauggaard-Nielsen, H., Ambus, P. & Jensen, E. S. (2001). Interspecific competition, N use and interference with weeds in pea–barley intercropping. Field Crops Research 70(2), 101–109.

Hauggaard-Nielsen, H., Ambus, P. & Jensen, E. S. (2003). The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. Nutrient Cycling in Agroecosystems 65(3), 289–300.

Jensen, E. S. (1994). Availability of nitrogen in ^{15}N-labelled mature pea residues to subsequent crops in the field. Soil Biology and Biochemistry 26(4), 465–472.

Jr, J. E. B. (1998). Root demographics and their efficiencies in sustainable agriculture, grasslands and forest ecosystems: Proceedings of the 5th Symposium of the International Society of Root Research, Held 14-18 July 1996 at Madren Conference Center, Clemson University, Clemson, South Carolina, USA (Vol. 200, No. 1). Kluwer Academic Pub.

Lammerts van Bueren, E. T., Struik, P. C. & Jacobsen, E. (2002). Ecological concepts in organic farming and their consequences for an organic crop ideotype. NJAS - Wageningen Journal of Life Sciences 50(1), 1–26.

Lundkvist, A., Salomonsson, L., Karlsson, L. & Gustavsson, A. M. D. (2008). Effects of organic farming on weed flora composition in a long term perspective. European Journal of Agronomy 28(4), 570–578.

Möller, K. (2009). Influence of different manuring systems with and without biogas digestion on soil organic matter and nitrogen inputs, flows and budgets in organic cropping systems. Nutrient Cycling in Agroecosystems 84(2), 179–202.

Oyarzun, P. J., Postma, J., Luttikholt, A. J. G. & Hoogland, A. E. (1994). Biological control of foot and root rot in pea caused by *Fusarium solani* with nonpathogenic *Fusarium oxysporum* isolates. Canadian Journal of Botany 72(6), 843–852.

Pflughöft, O. (2008). Pilzkrankheiten in Körnerfuttererbsen (*Pisum sativum* L.) – Diagnose, Epidemiologie, Ertragsrelevanz und Bekämpfung. PhD Thesis, Georg-August-Universität Göttingen, Germany. Available from: http://d-nb.info/993482147/34. [Accessed 2012-10-06].

Rochon, J. J., Doyle, C. J., Greef, J. M., Hopkins, A., Molle, G., Sitzia, M., Scholefield, D. & Smith, C. J. (2004). Grazing legumes in Europe: a review of their status, management, benefits, research needs and future prospects. Grass and Forage Science 59(3), 197–214.

Siddique, K. H. M., Johansen, C., Turner, N. C., Jeuffroy, M.-H., Hashem, A., Sakar, D., Gan, Y. & Alghamdi, S. S. (2011). Innovations in agronomy for food legumes. A review. Agronomy for Sustainable Development 32(1), 45–64.

Stockdale, E. A., Lampkin, N. H., Hovi, M., Keatinge, R., Lennartsson, E. K. M., Macdonald, D. W., Padel, S., Tattersall, F. H. & Watson, C. A. (2001). Agronomic and environmental implications of organic farming systems. Advances in Agronomy 70, 261-327.

Stockdale, E. A., Shepherd, M. A., Fortune, S. & Cuttle, S. P. (2002). Soil fertility in organic farming systems – fundamentally different? Soil Use and Management 18, 301–308.

Tivoli, B., Baranger, A., Avila, C., Banniza, S., Barbetti, M., Chen, W., Davidson, J., Lindeck, K., Kharrat, M., Rubiales, D., Sadiki, M., Sillero, J., Sweetingham, M. & Muehlbauer, F. (2006). Screening techniques and sources of resistance to

foliar diseases caused by major necrotrophic fungi in grain legumes. Euphytica 147(1), 223–253.

Urbatzka, P., Graß, R., Haase, T., Schüler, C., Trautz, D. & Heß, J. (2011). Grain yield and quality characteristics of different genotypes of winter pea in comparison to spring pea for organic farming in pure and mixed stands. Organic Agriculture 1(4), 187–202.

Watson, C. a., Bengtsson, H., Ebbesvik, M., Løes, A.-K., Myrbeck, A., Salomon, E., Schroder, J. & Stockdale, E. A. (2002). A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. Soil Use and Management 18, 264–273.

Whitmore, A. P. & Schröder, J. J. (2007). Intercropping reduces nitrate leaching from under field crops without loss of yield: A modelling study. European Journal of Agronomy 27(1), 81–88.