HYPOTHETICAL PEAR SYSTEM INNOVATION THROUGH PROMOTION OF SOIL BIODIVERSITY

M.P. van der Maas[1], B. Heijne[1]
[1]Wageningen University and Research Centre, Applied Plant Research (WUR/PPO), P.O. Box 200, 6670 AE Zetten, The Netherlands, rien.vandermaas@wur.nl

Keywords: pear, system innovation, soil biodiversity, organic manure, artificial fertiliser, earthworms, earwigs.

Abstract

We developed a hypothetical view on a pear system innovation through promotion of soil biodiversity. Two types of measures form the central idea of the innovation. The first type of measure is to replace part of the now 100 % artificial fertilisation by compost plus a limited amount of precision nutrition by artificial soil and leaf fertilisers. And, the second type of measure is to replace pesticides harmful for soil life by alternative measures or non-harmful pesticides. We anticipate that these measures have three main effects. The first effect is improved soil life, the second one is a reduced environmental impact, and the last one is a better economic profit for the fruit grower. We will test this innovative system on commercial fruit farms in close co-operation with extension service.

INTRODUCTION

Intensive pear growing practices are common in the Netherlands. These systems are based on small trees on dwarfing quince MC rootstock, with typically 3000 trees per ha and average yields of 50.000 kg/ha per year (Peppelman, 2004). This intensive pear growing is accompanied with ample use of artificial fertilisers and pesticides. On average 170 kg N, 60 kg P and 120 kg K is given mainly through fertigation systems (Kodde, 1994). And in general 34 kg a.i. of pesticides per ha is used (Linden, 2006). Both artificial fertilisers and pesticides have negative effects on the environment and soil biodiversity (e.g. Devine and Furlong, 2007). Therefore there is a need for a more sustainable pear production system.

Our purpose is to develop a system innovation for economic and environmental sustainable intensive pear production. The central idea is to take all sorts of measures to improve soil biodiversity. And by that increasing quantity of first class fruits, reducing use of artificial fertilisers, reducing environmental impact of pesticides, reducing human health risks, obtaining more efficient pest and disease control and higher economic yield.

INNOVITIVE PEAR SYSTEM

We intend to achieve our purpose through partly replacing artificial fertilisation by compost plus precise nutrition with artificial soil and leaf fertilisers. And by replacing pesticides harmful for soil life by alternative measures or non-harmful pesticides. More precise measures are described hereafter.

Fertilisers

The central element of the innovation deals with fertilisation. It is proposed to change the present situation of 100 % artificial fertilisation by a fertilisation mainly based on the use of compost. Substantial part of the fertilisation in the innovative system is given as compost (organic manure) and only a small portion is given as inorganic artificial fertilisation. The basic nutrition is derived from the organic manure. However, optimal tree growth related to fruit bearing is achieved by accurate timing of small amounts of specific fertilisation though soil and leaf applications, the so-called precision nutrition schemes. The specific fertilisation is based on established optimum nutrient values in soil and leaves combined with monitoring actual nutrient values in soil and leaves.

Organic manure applied as basic nutrition will have several effects on soil biodiversity. In general it is hypothesised that numbers and diversity of soil organisms will change (Giller et al., 1997). For organic farming, where no artificial fertilisers and synthetic pesticides are used, Bengtsson et al. (2005) demonstrated that species richness increased and organisms were 50 % more abundant in the majority of studies. In a long term study, there were clear tendencies of increased abundancy of earthworms and microbial activity in manure fertilised fields (Jordan et al., 2004). And cattle manure applications improved earthworm populations and diversity (Estevez et al., 1996)

Pesticides

Pesticides may have adverse effects on soil life. Scientific toxicological effects of pesticides are transformed into environmental impact points by the CLM organisation in the Netherlands. For soil life there is a specific impact indicator with correlated impact points. We checked commonly used pesticides in pear cultivation in the Netherlands, and identified five products with adverse effects on soil life. Those were the insecticides indoxacarb and pirimicarb, the fungicides thiophanate-methyl and fludioxinil, and the herbicide linuron. We propose to replace those pesticides by alternative methods or pesticides with non-harmful effects on soil life for the innovative pear system.

Indoxacarb meant for control of leaf rollers and codling moth (*Cydia pomonella*), is harmful for earwigs (*Forficula auricularia*) in the Netherlands (Helsen et al., 2011). We suggest the use of alternative methods like the pheromone disruption technique, insect pathogenic viruses or other insecticides with no harmful effects on earwig. Pirimicarb could be replaced by flonicamid to control aphids. One of the best practices to control European fruit canker caused by *Nectria galligena* is the use of slaked lime (Heijne et al., 2005). This method is suggested as an alternative for use of thiophanate-methyl during autumn applications against the disease. The replacement of fludioxinil is more complex. It is only available in a product containing cyprodinil and fludioxinil, and therefore fitting well in the strategy to avoid resistance of pathogens against fungicides. None-the-less, we think it should be replaceable by other fungicides like boscalid and pyraclostrobin or trifloxystrobin. Finally, we propose to abandon the use of linuron and use one of the many alternative herbicides without harmful effect on soil life. A reduction of soil impact points of over 70 % is calculated, based on the five suggested replacements.

Mycorrhiza

It is known that apple roots are colonised by arbuscular mycorrhizal fungi (AM) and growth of apple is promoted under certain conditions by the presence of AM (e.g. An et al. 1993; Plenchette et al., 1981; Morin et al. 1994). However, only few publications exist on the AM relationship with pear. Rapparini et al. (1996) found however, that growth of pear was promoted by inoculation with *Glomus* species. And the micro-propagated pear rootstock OHF-333 inoculated with *Glomus intraradices* and *G. mossae* also promoted plant development in phosphorus poor soil (Lopez et al., 1997). Furthermore, it is demonstrated that pesticides like copper (Hagerberg et al., 2011) and herbicides (Hamel et al., 1994) can have adverse effects on AM symbiosis. We therefore speculate that omitting pesticides harmful to soil organisms from the spray schedule in the innovative pear system, such as linuron, might promote AM functioning. And hopefully, improved phosphorus uptake could be the result. Increased phosphorus uptake is much desired, since phosphorus fertilisation is close to the maximum allowed threshold.

Earthworms

There is evidence that soil mircoarthropods (Kautz et al. 2006) populations and earthworm activity (Sharpley et al., 2011) increase as sole use of artificial fertilisers is changed to compost or organic manure. The increased microbial (Jordan et al., 2004), microarthropod and earthworm activity in the compost amended pear growing system will most probably lead in the long run to a better soil structure and an improved growth of pear trees. Moreover, earthworms are promoted by not using copper and thiophanate-methyl fungicides in the innovative pear growing system, which are harmful for them (e.g. Tu et al., 2011). It is expected that this will additionally contribute to favourable effects of earthworms on soil health and plant growth.

Moreover, some species contribute to improved leaf degradation (Edwards, 2004). Important pear diseases, like pear scab (*Venturia pirina*) and brown spot of pear (*Stemphylium vesicarium*) hibernate in fallen leaves. Therefore, theoretically, improved leaf degradation by earthworms contributes to lower disease pressures. And consequently, contributes to a more effective disease control, or in a very optimistic view, to a lower use of fungicides.

Earwigs

Earwigs (*Forficula auricularia*) are general predators which contribute to natural control or pear psylla pest (*Cacopsylla pyricola*). Part of their life cycle is in soil and nymphs feed on mites, Collembola, algae, etc. It is expected that well drained soils, with a high porosity favour the winter survival of earwigs and their nymphs in early spring. Additionally, pesticides harmful for earwigs are removed from the innovative pear growing system. And thereby contributing to larger populations of earwig and consequentially to an improved natural control of the most important pest pear psylla.

CONCLUSION

In conclusion we expect that with the specific measures suggested, and aimed at improvement of soil biodiversity, an innovative sustainable pear growing system could be developed, with better profits for the fruit grower, a reduced environmental impact and a higher soil biodiversity.

References Cited

An, Z.Q., Shen, T. and Wang, H.G. 1993 Mycorrhizal fungi in relation to growth and mineral nutrition of apple seedlings. Sci. Hort. 54:275-285.

Bengtsson, J., Ahnström, J. and Wiebull, A.C. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. J. Appl. Ecol. 42,261-269.

Brussaard, L., Ruiter, P.C.de and Brown, G.G. 2007. Soil biodiversity for agricultural sustainability. Agr. Ecosys. Environm. 121:233-244.

Devine, G.J. and Furlong, M.J. 2007. Insecticide use: Contexts and ecological consequences. Agric. Human Values 24:281-306.

Edwards, C.A. 2004. Earthworm ecology. 2nd ed. CRC Press, Boca Raton, Fl.

Estevez, B., Dayegamiye, A.N. and Coderre, D. 1996. The effect on earthworm abundance and selected soil properties after 14 years of solid cattle manure and NPKMg fertilizer application. Can. J. Soil. Sci. 76:351-355.

Giller, K.E., Beare, M.H., Lavelle, P., Izac, A.-M.N., Swift, J.J. 1997. Agricultural intensification, soil biodiversity and agroecosystem function. Appl. Soil Ecol. 6:3-16.

Hagerberg, D., Manique, N., Brandt, K.K., Lasen, J., Nybroe, O. and Olsson, S. 2011. Low concentration of copper inhibits colonization of soil by the arbuscular mycorrhizal fungus *Glomus intraradices* and changes the microbial community structure. Microb. Ecol. online 20 January 2011.

Hamel, C., Morin, F., Fortin, R.L., Granger, R.L. and Smith, D.L. 1994. Mycorrhizal colonization increases herbicide toxicity in apple. J. Amer. Soc. Hort. Sci. 119:1255-1260.

Heijden, M.G.A. van der, Klironomos, J.N., Ursic, M., Moutoglis, P., Streitwolf-Engel, R., Boller,T., Wiemken, A., Sanders, I.R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. Nature 369:69-72.

Heijne, B., de Jong, P.F., Wenneker, M., Jansonius, P.J. 2005. Slaked lime against European fruit tree canker: efficacy and introduction into practice. 15th IFOAM Organic World Congress, Proceedings of the Conference Researching Sustainable Systems, 21-23 September 2005, Adelaide, South Australia, pp 142-145.

Helsen, H., Peusens, G., Beliën, T., de Vlas, M. 2011. Aantal middelen blijkt schadelijk voor oorworm. Fruitteelt 101:12-13.

Jordan, D., Miles, R.J., Hubbard, V.C., Lorenz, T. 2004 Effect of management practices and cropping systems on earthworm abundance and microbial activity in Sanborn Field: a 115-year-old agricultural field. Pedobiol. 48:99-110.

Kautz, T., López-Fando, C. and Ellmer, F. 2006. Abundance and biodiversity of soil microarthropods as influence by different types of organic manure in a long-term field experiment in Central Spain. Appl. Soil. Ecol. 33:278-285.

Kodde, J. 1994. Adviesbasis voor de bemesting van fruitteeltgewassen in de vollegrond. Informatie en Kennis Centrum Akker- en Tuinbouw, tweed herziene druk, 34pp.

Lenfant, C., Lyoussoufi, A., Chen, X., Faivre d'Arcier, F., Sauphanor, B. 1994. Potential of Forficula auricularia L. as predator of pear psylla Cacopsylla pyri (L.). Ent. Exp. et Appl. 73:51-60.

Linden, A.M.A. van der, Beelen, P. van, Kruijne, R., Merkelbach, R.C.M., Groenwold, J.G., Vijftigschild, R.A.N., Wal, A.J. van der, Vijver, M.G., Snoo, G.R. de, GA van den Berg, Huijsmans, J.F.M., Gaag, D.J. van der, Boer, M. de, Kool, S.A.M. de, Kalf, D.F. 2006. Evaluatie duurzame gewasbescherming 2006: milieu. RIVM rapport 607016001.

Lopez, A., Pinochet, J., Fernandez, C., Calvet, C. and Camprubi, A. 1997. Growth response of OHF-333 pear rootstock to arbuscular mycorrhizal fungi, phosphorus nutrition and *Pratylenchus vulnus* infection. Fundam. Appl. Nematol. 20:87-93.

Morin, F., Forting, J.A., Hamel, C, Granger, R.L. and Smith, D.L. 1994. Apple rootstock response to vesicular-arbuscular mycorrhizal fungi in a high phosphorus soil. J. Amer. Soc. Hort. Sci. 119:578-583.

Peppelman, G., Groot, M.J. 2004. Kwantitatieve Informatie voor de Fruitteelt 2003-2004. PPO-publicatienr. 611, 154.

Plenchette, C., Furlan, V. and Fortin, J.A. 1981. Growth stimulation of apple trees in unsterilized soil under field conditions with VA mycorrhiza inoculation. Can. J. Bot. 59:2003-2008.

Rapparini, F., Baraldi, R. and Bertaza, G. 1996. Growth and carbohydrate status of *Pyrus communis* L. plantelets inoculated with *Glomus* sp. Agronomie 16:653-661.

Sharpley, A., McDowell, R., Moyer, B. and Littlejohn, R. 2011. Land application of manure can influence earthworm activity and soil phosphorus distribution. Comm. Soil Sci. & Plant Analysis 42:194-207.

Tu, C., Wang, Y., Duan, W., Hertl, P., Tradway, L., Brandenburg, R., Lee, D., Snell, M. and Hu, S. 2011. Effects of fungicides and insecticides on feeding behaviour and community dynamics of earthworms: implications for casting control in turf grass systems. Appl. Soil Ecol. 47:31-36.