Impact of organic practices on growth, yield, and greenhouse gas emissions by pea landraces

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Abstract

Legume crops constitute an essential component of rotations in organic farming systems due to their ability to provide plant available nitrogen to agricultural ecosystems arising from symbiotic N_2 fixation. However, there is a general need to increase grain legume protein production in Europe so as to meet the increasing demand while reducing resource utilization, thereby contributing to mitigation of global climate change. Taking this need into consideration, a field-based experiment with pea (*Pisum sativum* L.) was carried out in a field certified for organic agriculture from November 2014 to June 2015. The experiment was laid out in a split-plot design with two main treatments (conventional and organic farming system) and four sub-plots per main plot corresponding to four different pea genotypes, particularly one commercial cultivar ('onward'), and three local landraces ('Amorgos', 'Andros' and 'Schinousa'). Standard inorganic fertilizer (11-15-15, $N:P_2O_5:K_2O$) and sheep manure were used as base dressings in the conventional and the organically-treated plots, respectively. The aim of the experiment was to test the performance of each pea genotype in organic farming crops as compared to conventional cropping, in terms of: green seed yield, and greenhouse gas (GHG) emissions. The results of this study indicate that 'Andros' increased significantly the above-ground biomass and the fresh green seed production on the harvesting date when compared with all the other genotypes. In addition, there were significant differences in cumulative N_2O fluxes between the pea cultivars with 'Schinousa' producing the highest N_2O amounts and 'Andros' the lowest. In conclusion, the pea genotype seems to have a strong influence on both GHG emissions and production and therefore, appropriate selection of cultivars is imperative for efficient use of this legume in organic cropping systems.

Keywords: conventional, genotype, legume, organic agriculture, *Pisum sativum.*

INTRODUCTION

Organic farming can be self-sufficient in nitrogen being dependent on the fixed nitrogen and other management practices (Pietsch et al., 2007). Mixed organic farms aim to target practice highly efficient recycling of manures from livestock and crop residues. Leguminous crops can deliver additional nitrogen in sufficient quantities for the agricultural systems. The establishment of the symbiotic relationship allows the nitrogen (N_2) in the atmosphere to be converted into organic nitrogen compounds, which are then released into the soil as rhizo-deposition that then becomes available to living organisms. Recent estimates (Brady and Weil, 2002) reported that, globally, soil microorganisms can fix biologically an amount of nitrogen equal to 139 million tons per year, a potential which exceeds by far the nitrogen production from fossil fuel and which is not fully understood within conventional farming techniques.

Up to date several studies have been conducted to evaluate different legumes performance under application of different types of organic manure (Adeoye et al., 2011;). It is well documented that organic farming systems rely on ecologically sound practices, such as biological pest control, composting, enhancement of soil fertility through biological processes, and crop rotation, while excluding the use of synthetic chemicals in crop production. Although, the use of chemical fertilizers to sustain cropping systems has proved to be very convenient, given the higher yield performance (Ayoola and Makinde, 2014), the long term decrease in soil organic matter content and increased soil erosion (Avery, 1995; Doran et al., 1996) impose the reduction of their use (Adediran et al., 2004).

Organic manure plays a direct role in plant growth as a source of all necessary nutrients improving both the physical and the biological properties of the soil (Abou El-Magd et al., 2006) and also ensuring sustainable crop productivity by immobilizing nutrients that are susceptible to leaching (Abou El-Magd et al., 2006; Zhang et al., 2008). Application of organic manures, also improves the water holding capacity of soil, soil structure and aeration (Bill, 2001). They act on the soil's biological properties by activating the soil microbial biomass (Chang et al., 2007) and also decompose to give humus which plays an important role in the chemical behavior of several metals in complex and chelate forms (Abou El-Magd et al., 2005).

However, in organic agriculture, the supplied N is organically bound and thus the N availability to plants depends on mineralization rates of soil organic matter, which is hardly predictable under field conditions. As a result, timely supply of sufficient plant-available N can be a problem in organic agriculture and this may result in lower yields (Seufert et al., 2012). Legumes play a vital role in agriculture, but most of the legumes used are grown outside Europe. Protein crops are now grown on only 1.8% of arable land in the EU, compared with 4.7% in 1961.

The major greenhouse gases (GHGs) contributing to global climate change are carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), the emissions of which from the soil are related to the cultivation of legumes (Kontopoulou et al., 2015). Agricultural activities contribute 10-12% of total GHG emissions worldwide (Smith et al., 2007). According to Schulze et al., (2009), CO_2 is the main anthropogenic greenhouse gas. However, GHG emissions from the agricultural sector are dominated by N_2O and CH_4. N_2O is considered the single most important ozone-depleting substance in the 21st century (Ravishankara et al., 2009). Although, losses from legumes during pre-cropping and cropping are thought to be lower but post-harvest N losses, particularly of N_2O-N, may be higher due to legume residue decomposition (Rochette and Janzen, 2005). Nevertheless, greenhouse gas emissions from legumes can have great diversity not only due to species but also the varieties or landraces, but the actual relationship with the yields is not well known (Pappa et al., 2011).

Landraces are farmer-developed populations of cultivated species that show among- and within population diversity (Negri, 2005). Their populations often reproduced parallel from more than one farmer (Bellucci et al., 2013) and therefore, landraces reserve the bulk of genetic diversity of a species (Camacho Villa et al., 2005). Therefore, landraces can serve as important genetic resources for adaptive traits (Bertoldo et al., 2014) and be useful in the development of locally adapted high yielding varieties with resistance to environmental stresses (Hedge and Mishra, 2009). Indeed, the integration of interesting traits in breeding programs could contribute to improving crop adaptation to several environmental stresses and farming practices and enhancing productivity (Hamidou et al., 2007).

Pea is one of the most popular pulse crops and has various uses for human consumption due to their high protein content (23 to 31% of seed dry matter), minerals, carbohydrates and fibre (Dahl et al. 2010; Świątecka et al., 2010). There is large genetic variation in cultivated pea and a wide range of varieties with a wide range of traits available. When selecting a pea variety, crop use, region, sowing date, yield potential, frost and diseases resistance or tolerance, harvesting ease and marketing options are considered.

Taking the above into consideration an experiment was designed aiming to investigate the impact of organic farming of three pea Greek landraces ('Amorgos', 'Andros' and 'Schinousa') and one commercial variety as control ('Onward') in terms of growth, grain yield components and greenhouse gas emissions differences.

MATERIALS AND METHODS

Site and Soil

A field experiment was carried out in central Greece (Aliartos, 95 km northwest of Athens (38°23’51’’N, 23°05’41’’E, 95 m a.s.l.)) in 2014-15. The pea crop was sown on 20 November 2014. The experiment was laid out in a split-plot design with four replicates having two main plots (conventional and organic farming system) and four sub-plots (pea varieties: Onward (commercial variety as control), Amorgos, Andros and Schinousa (local varieties). The sub-plot size was 10.5 m^2. The seeding rates were 67 and 22 plants per m^2 for pea and faba bean, respectively in 0.02 m depth. The plant spacing was 0.30 m by 0.10 m for peas in plots of 3.00 m by 3.50 m size (10.5 m^2).

The two cropping systems were established according to farm management practices for organic and conventional systems in durum wheat (*Triticum turgidum* L.) preceding plots. On conventional plots, the herbicide pendimethalin (Stomp Aqua 455 CS; BASF, Athens, Greece) was applied pre-emergence at a rate of 1137.5 g a.i. ha^{-1}. Moreover, 570 kg ha^{-1} of fertilizer (11-15-15, $N:P_2O_5:K_2O$) and 7.6 ton ha^{-1} of sheep manure was applied before sowing, in the conventional and organic plots, respectively. During the production no additional fertilization of irrigation was provided to the plants.

Greenhouse gases (GHGs) measurements

Direct fluxes of N_2O were measured using the static chamber technique (Clayton et al., 1994). Initially, one chamber was located in each of the plots summing up to 32 plots. The chambers were sealed for 40-60 min with a lid having a small open sampling point sealed with a grommet in which the syringe was inserted to collect two samples per chamber. Air and soil temperature were recorded at the same time for the fluxes calculations.

Gas samples were collected in portable evacuated glass vials (Scott et al., 1999) and analyzed for N_2O, CO_2 and CH_4 by electron-capture gas chromatography (HP 5890, Series II) using high purity standards (0.41, 0.95, 5.4 and 10.1 ppm) for calibration and calculations. For consistency, gas sampling was carried out between 10:00 and 12:00h (Clayton et al., 1994). The sampling was done under specific dates and not targeting events (e.g. freeze, rain).

Weather data collection

During the experimental period, weather data, including mix/max temperature and rainfall were collected in an hourly base. Monthly temperature (mix, max and average) and rainfall (mm) is presented below (Table 1).

Biomass and yield measurements

Aboveground biomass samples were obtained at harvesting stage and separated in yield and straw. The fresh weighs were being recorded and oven-dried at 70°C for 72 h to determine their dry weight. After the harvest, crop residues were removed from the field and returned back only in the organic treated plots on, when ploughed at 0.30 m depth and disk harrowed (0.10 m depth).

The impact of the experimental treatments on crop yield (fresh pods) was assessed by manually harvesting twice per week all commercially ripe pea pods from sub-plots of the same area in each plot.

Statistical analysis

All data were statistically analyzed by ANOVA using the STATISTICA software package, version 9.0 for Windows. A two-factorial analysis of variance with randomized blocks was applied to evaluate the farming practices, the genotype effect and the interactions between them. Data are presented in graphs as means ± SE of four replicates. A Duncan’s Multiple Range Test was performed when the ANOVA was significant at $P = 0.05$ level.

RESULTS AND DISCUSSION

Climatic data during the experimental period

During the experimental period, there were period that the field was covered with snow and it was difficult to collect the gas samples. However, all the samples collected with care and without any disruption/damage to the surroundings. The climatic data were within normal values in comparison with the last decades (data not shown).

Table 1: Monthly average, max average and min average temperatures (T) including also the rainfall (summary per month) during the experimental period in Aliartos, Greece.

Month	T_avg	T_max (avg)	T_min (avg)	Rain (sum)
November	13.0	18.0	8.6	68.7
December	10.0	15.6	5.4	111.7
January	7.0	13.0	1.4	62.3
February	8.2	13.1	3.3	133.6
March	10.6	14.9	6.3	164.3
April	14.6	22.2	6.9	16.5
May	20.3	28.3	12.4	55.8
June	22.7	29.5	15.5	76.4
July	26.4	33.5	18.4	35.3
August	26.9	32.7	20.9	2.2

Above ground biomass

Conventional management practices did not result in significantly different fresh shoot biomass (18.70 ton ha^{-1}) than organic farming (20.26 ton ha^{-1}) at the harvesting date (Fig. 1). On the other hand, the above ground biomass, estimated in terms of fresh weight, was significantly influenced by the use of different Greek local landraces or commercial cultivar. Specifically, the use of 'Schinousa' pea landrace reduced significantly the fresh shoot biomass on the harvesting date (8.95 ton ha^{-1}) when compared to 'Andros' landrace, 'Onward' pea commercial variety and 'Amorgos' pea landrace (26.19 ton ha^{-1}, 24.92 ton ha^{-1} and 17.66 ton ha^{-1}, respectively). No interaction was found between the farming system and the genotypes used. Nevertheless, when the shoot biomass data were expressed on a dry weight basis, the differences between treatments were much smaller and thus neither the conventional farming system nor the genotypes showed significant differences (data not shown).

Yield components

The fresh yield pea seeds harvested throughout the cropping period was significantly influenced by the different genotypes used and not by the organic cropping practices, without any interaction between the cropping system and the genotypes (Fig. 2). In specific, the use of conventional 'Andros' pea landrace gave a production of 3.12 ton ha^{-1} of green seeds while the lowest green seed production was given by 'Schinousa' pea landrace (2.16 ton ha^{-1}) and the commercial pea variety 'Onward' (2.24 ton ha^{-1}). The reduction of the fresh pea seeds biomass by the genotypes used was due to a restriction in the number of seed per pod per m^2, while the mean seed weight per plant was not influenced either by the farming system or by the pea genotype (data not shown).

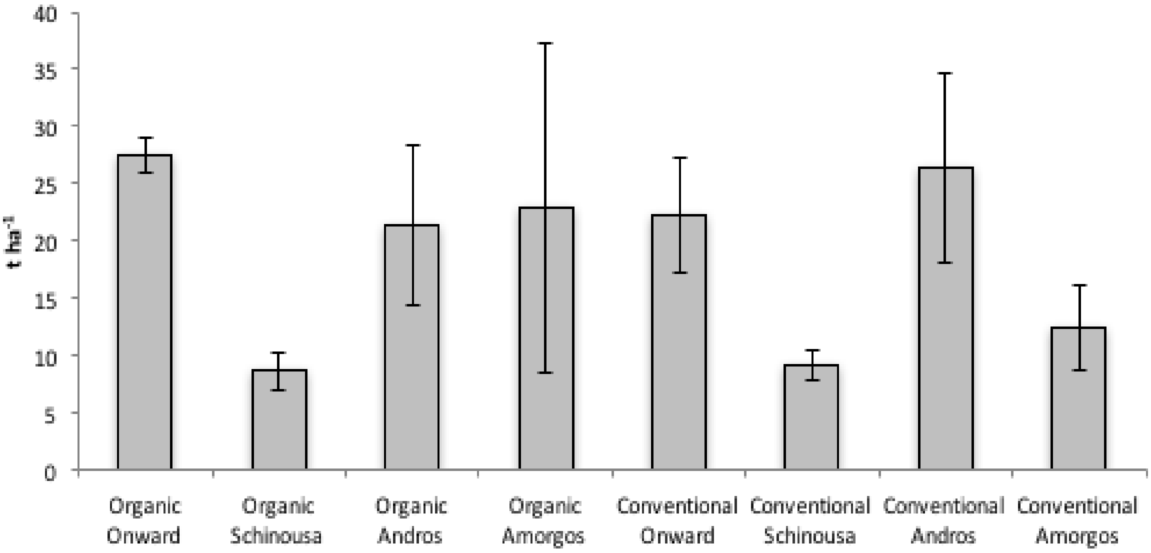

Figure 1: Above ground-fresh biomass of the four pea genotypes starting with the commercial at the top (Onwards) and following 'Schinousa', 'Andros' and 'Amorgos' under organic (solid bar) and conventional (stripped bar) management. The values are the mean (n=4) ± the SE (bars) of each treatment.

N_2O emissions

The cumulative amount of N_2O emitted during the whole cropping period was higher when conventional farming practices were applied (401 g ha^{-1}) when compared with organic farming (355 g ha^{-1}) even though these differences were not statistically significant. Moreover, the use of different genotypes had significant impact on the cumulative N_2O emissions (Fig. 3). Indeed, 'Andros' presented the lower emission values (239 g ha^{-1}) and 'Schinousa' the highest cumulative amount of N_2O emitted (464 g ha^{-1}). 'Onward' and 'Amorgos' on the hand gave similar cumulative amount of N_2O emitted (409 g ha^{-1} and 403 g ha^{-1}, respectively). No interaction between farming system and genotypes was found with respect to the cumulative amount of N_2O emitted, when expressed either on an area or intensity basis (using fresh grain biomass). However, the emissions were low most of the experimental period (data not shown).

The present study indicates that organic farming practices in N_2-fixing legume crops did not result in a clear reduction of the N_2O emissions per unit of cultivated area which is in agreement with many other investigators (Robertson et al., 2000; Kramer et al., 2006; Syväsalo et al., 2006). On the other hand others have reported lower N_2O emissions from organic cropping systems when compared with conventional cropping (Kontopoulou et al., 2015) due to reduced input of mineral-N and thus lower levels of reactive nitrogen in the topsoil (Qin et al., 2010). Pea grain yields were in general among the average values for Mediterranean climate (Scalise et al., 2015). As far as the genotypes are concerned the data of the emission intensities (which is the g or kg of N_2O-N per t of product) has shown that 'Andros' is the most "environmentally" friendly landrace from the three followed by 'Amorgos', which had almost double values (data not shown).

CONCLUSION

In summary, pea cultivars have shown significant differences in the cumulative values, but the fluxes were not majorly affected by the faming system (organic or conventional). Considering the use of peas within a rotation, forage legumes and legumes as intercrops would be beneficial both in terms of reducing fertilizer inputs and cumulative N_2O

emissions, but in the case of nitrification/denitrification, N_2O flux would be dependent on N inputs through mineralisation of the previous crop.

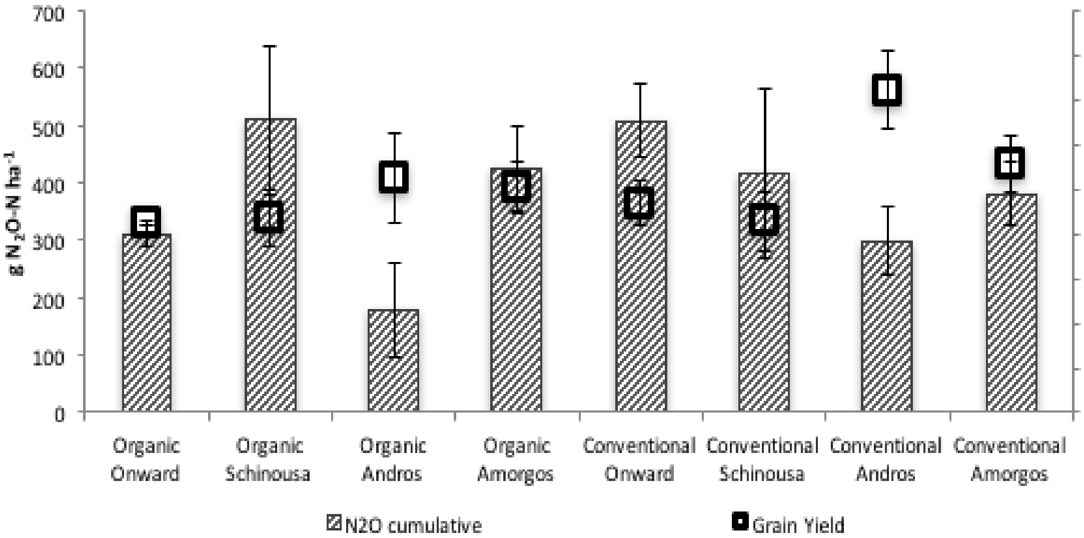

Figure 2: Cumulative N_2O fluxes (bars) and final grain yields (small box at the top of the bars) for the four pea genotypes starting with the commercial at the top (Onwards) and following Schinousa, Andros and Amorgos umder organic (solid bar) and conventional (stripped bar) management. The values are the mean (n=4) ± the SE (bars) of each treatment

Greenhouse gas data from the Mediterranean region are very limited and such studies help to have a greater view and draw further conclusions on the environmental effects of legumes. Choice of grain legume species and cultivars may influence annual emissions of nitrous oxide. From preliminary studies, it would seem that careful selection of cultivar and rhizobium inoculants may achieve reductions in N_2O flux. Growing plants may influence the N_2O flux to the atmosphere in a variety of ways. Annual variation in emissions of N_2O must be taken into consideration when evaluating choice of crop or cultivar. Inter-annual changes in soil condition, namely rainfall alter the aerobic nature of the soil and hence N_2O flux, the capacity of the soil to produce N_2O e being determined by substrate supply, organic carbon status and percentage clay fraction of the soil. The present study demonstrated lower emissions per unit area and non-significant differences in intensity of emissions of N_2O in organic and conventional systems. Given that there are wider potential benefits associated with organic farming in addition to the avoidance of fertilizer N manufacture (which has a carbon cost), this suggests that maximizing productivity within organically farmed systems is an effective route to delivering environmental benefits.

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Literature Cited

Abou El-Magd, M.M., Hoda, M.A., and Fawzy, Z.F. (2005). Relationship, growth, yields of broccoli with increasing N, P or K ratio in a mixture of NPK fertilizers. Ann. Agric. Sci. Moshtohor *43*, 791-805.

Abou El-Magd M.A., El-Bassiony M. and Fawzy Z.F. (2006). Effect of organic manure with or without chemical fertilizers on growth, yield and quality of some variety of broccoli plants. J. Appl. Sci. Res. *2*, 791-798.

Adediran, J.A., Taiwo, L.B., Akande, M.O., Sobulo, R.A., and Idowu, O.J. (2004). Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. J Plant Nutr. *27* (7), 1167–1181 doi:10.1081/PLN-120038542.

Adeoye, P.A., Adebayo, S.E., and Musa, J.J. (2011). Growth and yield response of Cowpea (*Vigna unguiculata*) to poultry and cattle manure as amendments on sandy loam soil plot. Agric. J. *6* (5), 218-221 doi: 10.3923/aj.2011.218.221.

Avery, D.T. (1995). Saving the planet with pesticides and plastic: the environmental triumph of high-yielding farming. Indianapolis (IN): Hudson Institute, p.476.

Ayoola, O. T., and Makinde, E. A. (2014). Soil nutrient dynamics, growth and yield of green maize and vegetable cowpea with organic-based fertilization. Arch. Agron. Soil Sci. *60* (2), 183-194 doi: 10.1080/03650340.2013.775422.

Bellucci, E., Rau, D., Nanni, L., Ferradini, N., Giardini, A.,Rodriguez, M., Attene, G., and Papa, R. (2013). Population structure of Barley landrace populations and gene-flow with modern varieties. PLoS ONE, *8* (12): e83891 doi:10.1371/journal.pone.0083891.

Bertoldo, J.G., Coimbra, J. L. M., Guidolin, A. F., de Andrade, L. R. B., and Nodari, R. O. (2014). Agronomic potential of genebank landrace elite accessions for common bean genetic breeding. Sci. Agric. *71* (2), 120-125 http://dx.doi.org/10.1590/S0103-90162014000200005

Bill, U. (2001). Manure and soil organic matter. Pennsylvania Stat. Field Crop News *1*, 11.

Brady N.C., and Weil R. R., (2002). The Nature and Properties of Soils. 13th ed., 543-575. Prentice Hall, Upper Saddle River, New Jersey.

Camacho Villa, T.C., Maxted, N., Scholtena, M., and Ford-Lloyda, B. (2005). Defining and identifying crop landraces. Plant Genet. Resour. Charact. Util. *3*, 373-384 doi:10.1079/PGR200591.

Chang, E.H., Chung, R.S., and Tsai, Y.H. (2007). Effect of different application rates of organic fertilizer on soil enzyme activity and microbial population. Soil Sci. Plant Nutr. *53* (2), 132–140 doi: 10.1111/j.1747-0765.2007.00122.x.

Clayton, H., Arah, J.R.M., and Smith, K.A. (1994). Measurement of nitrous oxide emissions from fertilised grassland using closed chambers. J. Geophys. Res. Atmos. *99*, 16599–16607 doi: 10.1029/94JD00218.

Dahl, W.J., Foster, L.M., and Tyler, R.T. (2012). Review of the health benefits of peas (*Pisum sativum* L.). Br. J. Nutr. *108*, S3-S10 doi:10.1017/S0007114512000852.

Doran, J.W., Sarrantonio, M., and Liebig, M.A. (1996). Soil health and sustainability. Adv. Agron. *56*, 42–45 doi:10.1016/S0065-2113(08)60178-9.

Hamidou, F., Zombre, G., and Braconnier, S. (2007). Physiological and biochemical responses of cowpea genotypes to water stress under glasshouse and field conditions. J. Agron. Crop Sci. *193*, 229–237 doi: 10.1111/j.1439-037X.2007.00253.x

Hegde, V. S. and Mishra, S. K. (2009). Landraces of cowpea, *Vigna unguiculata* (L.) Walp., as potential sources of genes for unique characters in breeding. Genet. Resour. Crop. Evol. *56*, 615–627 doi:10.1007/s10722-008-9389-8.

Kramer, S.B., Reganold, J.P., Glover, J.D., Bohannan, B.J.M., Mooney, H.A. (2006). Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. Proc. Nation. Acad. Sci. *103* , 4522-4527. doi: 10.1073/pnas.0600359103

Kontopoulou C.K., Bilalis, D., Pappa V.A., Rees, R.M., and Savvas, D. (2015). Effects of organic farming practices and salinity on yield and greenhouse gas emissions from a common bean crop. Sci. Hortic. *183*,48-57. doi:10.1016/j.scienta.2014.12.012.

Negri, V. (2005). Agro-biodiversity conservation in Europe: Ethical issues. J. Agric. Environ. Ethics *18*, 3–25.

Pappa, V.A., Rees, R.M., Walker, R.L., Baddeley, J.A. and Watson, C.A. (2011). Intercropping reduces nitrous oxide emissions and leaching from an arable rotation. Agric. Ecosyst. Environ. *141*, 153-161 doi:10.1016/j.agee.2011.02.025.

Pietsch, G., Friedel, J.K., and Freyer, B. (2007). Lucerne management in an organic farming system under dry site conditions. Field Crops Res. *102*, 104-118. doi:10.1016/j.fcr.2007.03.003.

Qin, Y., Liu, S., Guo, Y., Liu, Q., and Zou, J. (2010). Methane and nitrous oxide emissionsfrom organic and conventional rice cropping systems in Southeast China. Biol. Fertil. Soils *46*, 825-834 doi:10.1007/s00374-010-0493-5.

Ravishankara, A.R., Daniel, J. S., Robert, W., and Portmann, R.W. (2009). Nitrous oxide (N_2O): the dominant ozone-depleting substance emitted in the 21st century. Sci. *326*, 123–125 doi: 10.1126/science.1176985.

Robertson, G.P., Paul, E.A., and Harwood, R.R. (2000). Greenhouse gases in intensiveagriculture: contributions of individual gases to the radiative forcing of theatmosphere. Sci. *289*, 1922–1925 doi: 10.1126/science.289.5486.1922.

Rochette, P., and Janzen, H. (2005). Towards a revised coefficient for estimating N_2O emissions from legumes. Nutr. Cycl. Agroecosyst *73*, 171-179. doi: 10.1007/s10705-005-0357-9.

Scalise, A., Tortorella D., Pristeri, A., Petrovičová, B., Gelsomino, A., Lindström, K., Monti, M., 2015. Legume-barley intercropping stimulates soil N supply and crop yield in the succeeding durum wheat in a rotation under rainfed conditions. Soil Biology & Biochemistry 89, 150-161. doi:10.1016/j.soilbio.2015.07.003

Schulze, E., Luyssaert, S., Ciais, P., Freibauer, A., Janssens, I., Soussana, J., Smith ,P., Grace, J., Levin, I., Thiruchittampalam, B., Heimann, M., Dolman, A., Valentini, R., Bousquet, P., Peylin, P., Peters,W., Roedenbeck, C., Etiope, G., Vuichard, N., Wattenbach, M., Nabuurs, G., Poussi, Z., Nieschulze, J., and Gash, J. (2009). Importance of methane and nitrous oxide for Europe's terrestrial greenhouse-gas balance. Nat. Geosci. *2*, 842-850. doi:10.1038/ngeo686.

Scott, A., Crichton, I., Ball, and B.C. (1999). Long-term monitoring of soil gas fluxes with closed chambers using automated and manual systems. J. Environ. Qual. *28*, 1637–1643 doi:10.2134/jeq1999.00472425002800050030x.

Seufert, V.M., Ramankutty, N., Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. Nat. *485*, 229-232 doi:10.1038/nature11069.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., and Sirotenko, O. (2007). Agriculture. In: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (Eds.), Climate Change 2007:Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K., pp. 497–540.

Światecka, D., Światecki, A., Kostyra, H., Marciniak-Darmochwa F, K., and Kostyra, E. (2010). The impact of pea protein hydrolysates on bacterial physiological activity-An in vitro study. Int. J. Food MicrobioL. *140* (2-3), 263-270 doi: 10.1016/j.ijfoodmicro.2010.03.015.

Syväsalo, E., Regina, K., Turtola, E., Lemola, R., and Esala, M. (2006). Fluxes of nitrousoxide and methane, and nitrogen leaching from organically and conventionallycultivated sandy soil in western Finland. Agric. Ecosyst. Environ. *113*, 342–348 doi:10.1016/j.agee.2005.10.013.

Zhang, L., Wang, Y.X., Wang, X., Wel, Q.P., Zhang, Q., and Liu, J. (2008). Effects of chicken manure and peat combination on soil property and root distribution and fruit quality of peach tree. J North West A&F Univ (Natural Science Edition). Available from: http://en.cnki.com.cn/Article_en/ CJFDTOTAL-XBNY200803026.htm.