

The Science Behind Biodynamic Preparations: A Literature Review

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ADDITIONAL INDEX WORDS. alternative agriculture, DOK studies, homeodynamic, homeopathic, organic, Rudolph Steiner

SUMMARY. Biodynamics is a form of organic agriculture first described in the 1920s by Rudolph Steiner, and practitioners can become certified biodynamic farmers by following specified practices. What distinguishes biodynamic from organic certification is the required use of nine preparations thought to improve soils and increase crop yields. This literature review focuses on the published, peer-reviewed science behind the use of biodynamic preparations, with the goal of providing objective information to extension educators, including Master Gardeners.

Major news outlets including National Public Radio (Musiker, 2008), Time magazine (McLaughlin, 2007), and the New York Times (Halweil, 2004) have featured biodynamic agriculture (or biodynamics) as the newest version of organic agriculture. With the high visibility and promotion of biodynamic products such as wines (Smith and Barquin, 2007), farmers and gardeners alike are increasingly interested in biodynamics as an alternative agricultural practice. Extension educators and Master Gardener volunteers who receive questions from curious clients on the topic need science-based answers—the focus of this literature review.

THE ORIGINS OF BIODYNAMIC AGRICULTURE. Biodynamics is an agricultural management system based on a series of lectures given by Rudolf Steiner in 1924 (Steiner, 1958). Over his lifetime, Steiner became concerned with the degradation of food produced through farming practices that increasingly relied on additions of inorganic fertilizers and pesticides. Biodynamics were thought to be one of the first alternative approaches to modern agriculture, and in 1942 it was listed by Lord Northborne as one of three alternative or “organic” agricultural methodologies (Paull, 2011).

A philosopher by training, Steiner sought to influence organic life on earth through cosmic and terrestrial forces via nine preparations (Table 1)

that would stimulate vitalizing and harmonizing processes in the soil (Kirchmann, 1994). For example, Preparations 500 and 501 are made by packing cow manure or silica, respectively, into cow horns and burying them for a number of months before use. Steiner believed that cow horns, by virtue of their shape, functioned as antennae for receiving and focusing cosmic forces, transferring them to the materials inside. After exhumation, the contents are diluted with an unspecified amount of water to create a homeopathic solution, which when applied to soil (Preparation 500) or crops (Preparation 501), was thought to influence root or leaf growth. Six other compounds (Preparations 502–507) are extracts of various plants packed into either the skulls or organs of animals (e.g., deer bladders, cow peritonea and intestines) or peat or manure, where they are aged before being diluted and applied to compost. Steiner believed that the chemical elements contained in these preparations were carriers of terrestrial and cosmic forces and would impart these forces to crops and thus to the humans that consume them.

Steiner did not believe plants suffered from disease, but merely appeared diseased when “moon influences” in the soil become too strong (Smith and Barquin, 2007); nevertheless, he recommended a weak infusion of dried horsetail (*Equisetum arvense*) for treating soil and crop fungal diseases (Preparation 508). For other pests, Steiner recommended “pest ashing,” a practice whereby the offending insect, weed, or rodent species was burnt. The ashes were then scattered over the fields as a way

of preventing future infestation. Perhaps, Steiner believed these preparations and practices would make crops more resistant to pests and diseases, reducing the need for pesticides. Unfortunately, he gave no rationale for most of these processes.

In his article, Kirchmann (1994) states that as Steiner developed his biodynamic philosophy through meditation and clairvoyance, he rejected scientific inquiry because his methods were “true and correct unto themselves.” Nevertheless, both proponents and critics of Steiner’s teachings have attempted to demonstrate the effectiveness of biodynamic preparations through scientific testing. Much of the published research has focused on these nine preparations, possibly because their use is required by any farmer wishing to become biodynamically certified (Demeter Association, 2013).

The science behind biodynamic preparations

Over the last century, biodynamic agriculture has evolved to include many nonconventional farming practices, such as crop rotation, polyculture, and cover cropping (Table 2), which have demonstrable benefits on land use and crop production. Steiner’s original teachings did not include these methodologies, which along with other practices are the basis of organic farming as proposed by Lord Northborne in 1942 (Paull, 2011). In fact, the biodynamic certification standards (Demeter Association, 2013) and those for organic farming (International Federation of Organic Agriculture Movements, 2011) are nearly identical except for the required inclusion of Steiner’s nine preparations in the former.

These post-Steiner additions have confounded scientific study of biodynamics, as many researchers compare biodynamic and conventional methods to one another. Since modern biodynamic agriculture includes well-established organic practices that improve the soil by adding organic matter or decreasing compaction, the comparison may not be valid as the efficacy of biodynamic preparations themselves can be masked by these additional practices. Many organic methods have significant, positive impacts on such qualities as soil porosity

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Table 1. Components of biodynamic preparations.

Preparation	Ingredients ^z
500	Cow manure packed into a cow's horn
501	Silica from finely ground quartz, mixed with rain water, packed into a cow's horn
502	Yarrow (<i>Achillea millefolium</i>) flower heads packed into a stag's bladder
503	Chamomile (<i>Matricaria</i> sp.) flower heads fermented in soil
504	Stinging nettle (<i>Urtica</i> sp.) tea
505	Oak (<i>Quercus</i> sp.) bark packed into the skull of a domestic animal
506	Dandelion (<i>Taraxacum officinale</i>) flower heads packed into cow mesentery
507	Extract from valerian (<i>Valeriana officinalis</i>) flowers
508	Horsetail (<i>Equisetum arvense</i>) tea

^zSpecies of plants used differ with global geography.

Table 2. A comparison of practices and products used in organic and/or biodynamic agriculture.

Practice or product	Organic	Biodynamic
Crop rotation	X	X
Polyculture/intercropping	X	X
Cover cropping	X	X
Low-till or no-till	X	X
Green manures and compost	X	X
Biological, cultural, mechanical, and physical means of pest control	X	X
Biodynamic preparations ^z		X
Lunar and astrological calendars for planting, managing, and harvesting crops		X
Menhirs ^y		X
Pest ashing ^x		X
Sensitive testing ^w		X

^zInvolves alchemy and homeopathy.

^yStones used for channeling cosmic energy and radiant fields through geo-acupuncture.

^xAlso called "D8" solution.

^wIncludes image-forming practices variously called biocrystallization, capillary dynamolysis, morphochromatography, sensitive crystallization, and the Steigbild method.

and fertility, beneficial insect and microbe diversity, pest and disease suppression, and crop quality and yield. The benefits of these methods have been reviewed in the scientific literature (e.g., Dima and Odero, 1997; Gasser and Berg, 2011; Kaval, 2004; Mason and Spaner, 2006; Pandian et al., 2005; Turner et al., 2007). Essentially, the only difference between organic and modern biodynamic farming lies in the application of Steiner's preparations (Carpenter-Boggs et al., 2000a; Giannattasio et al., 2013), which must be "applied in minute doses, much like homeopathic remedies are for humans" (Demeter Association, 2013). Therefore, this review is limited to those studies that compare organic and biodynamic systems to one another in which the only variable is the presence or absence of biodynamic preparations.

A review of the relevant research

PREVIOUS REVIEWS. Even after several decades of research, there are relatively few refereed, easily accessible articles on biodynamics. The earliest studies were published in Germany and other European countries and had limited international distribution. Reganold (1995) found many of these to be of questionable scientific quality and called for more peer-reviewed publications on the efficacy of biodynamic preparations. Leiber et al. (2006) provide an overview of modern biodynamics and a call to develop "a complex, holistic, systemic form of science . . . appropriate to biodynamic farming" as opposed to the inconclusive assessment of "the effect of individual biodynamic practices in isolation from the overall

method." More recently, Turinek et al. (2009) published an update on biodynamic research progress, but much of the focus was on long-term trials and case studies. As a result, their review of scientific literature was incomplete and neglected a number of articles by researchers not associated with these particular field trials (e.g., Carpenter-Boggs et al., 2000b; Jayasree and George, 2006; Stepien and Adamiak, 2007; Tung and Fernandez, 2007a,b; Valdez and Fernandez, 2008). A review of these latter articles was incorporated into a book chapter targeted to gardeners and other non-scientists (Chalker-Scott, 2010).

THE DOK TRIALS. Much of the published research on biodynamics has arisen from the DOK trials, a decades-long field experiment in Therwil, Switzerland, whereby biodynamic (D), organic (O), and conventional (K from "konventional") agricultural practices could be continually compared (Mäder et al., 2002). This study has provided a rich trove of scientific information delineating the differences between conventional and organic methodologies. Unfortunately, a flawed experimental design makes comparisons between biodynamic and organic methods in the DOK trials untenable. Specifically, the biodynamic treatment receives farm-sourced, aerobically composted manure along with Steiner's biodynamic preparations, whereas the organic treatment receives slightly rotted manure from a different farm source (Heinze et al., 2010) and additions of rockdust, potassium, and magnesia (Fließbach et al., 2007). Even more significantly, copper sulfate was used as a broad spectrum fungicide in the organic treatment until 1991, undoubtedly altering the microbial community compared with that found in the biodynamic treatment. This uncontrolled variation in experimental treatment calls into question any purported benefit of biodynamic preparations in the DOK trials, as others have also pointed out (Carpenter-Boggs et al., 2000a; Heinze et al., 2010).

Nevertheless, several insights may be gleaned from the DOK system. Although significant differences were generally found when comparing conventional treatments to organic and biodynamic methods, few differences have been reported between the latter two treatments. Presence and abundance

of 11 earthworm species [Lumbricidae (Pfiffner and Mäder, 1997)] and carabid beetle (Carabidae) diversity and number (Pfiffner and Niggli, 1996) were the same; wheat quality [*Triticum aestivum* (Langenkamper et al., 2006)] and disease incidence [*Fusarium* head blight (*Fusarium poae*), microdochium patch (*Microdochium nivale*); (Gunst et al., 2006)] were unaffected. Neither were differences found in microbial parameters (Heinze et al., 2010, 2011; Joergensen et al., 2010) or any soil characteristics (Heinze et al., 2010), though others researching the DOK plots found increases in total hydrolysable protein amino acids (Scheller and Raupp, 2005) and pH (Birkhofer et al., 2008) in the biodynamic plots compared with the organic plots. The practical significance of these last two findings is not apparent, nor did the authors speculate on possible benefits.

The DOK trials represent a systems approach to biodynamic research, which has not lent itself well to traditional scientific experimentation where variability is controlled. In the last few decades, other researchers have studied biodynamic preparations under more controlled conditions.

SOILS. In the words of one research team (Carpenter-Boggs et al., 2000a,b), “no significant differences were found between soils fertilized with biodynamic [Preparations 500–508] vs. nonbiodynamic compost.” Other studies confirm a lack of efficacy on soil fertility [Preparations 500–507 (Berner et al., 2008)] and quality (Reeve et al., 2005), though the combined application of Preparations 500–507 and other biodynamic field sprays were found to be “moderately effective” in increasing soil pH (Reeve et al., 2011). On the other hand, organic matter in organically treated soils (with manure incorporated as a fertilizer) was higher than that in unmanured soils treated with biodynamic Preparations 500–504 (Tung and Fernandez, 2007a), which may explain why earthworm populations were also greater than those under biodynamic treatment (Tung and Fernandez, 2007a). Similarly, Foissner (1992) reported enhanced soil life in organically managed fields compared with those under biodynamic management, which he attributed to the quality and quantity of organic matter in the former plots.

COMPOST. Only a few studies have looked at the effect of biodynamic preparations (Preparations 502–507) specifically meant for use on compost. Carpenter-Boggs et al. (2000c) reported a consistently higher pile temperature and more nitrate in the finished compost using these preparations. However, there were no differences in several other variables measured, including pH, cation exchange capacity, moisture content, and ammonium, potassium, and phosphate levels. The significance of these few differences is unclear. In contrast, Reeve et al. (2010) found that biodynamic preparations reduced both compost pile temperature and nitrate concentration.

MICROBES. Researchers have consistently found no differences in microbial activity (Heinze et al., 2011; Reeve et al., 2011), biomass (Heinze et al., 2011), or fungal colonization (Heinze et al., 2011) in biodynamically treated soils compared with organically managed soils. Nor have differences been seen in microbial efficiencies, defined as dehydrogenase activity per unit carbon dioxide respiration, dehydrogenase activity per unit readily mineralizable carbon, and respiration per unit microbial biomass (Reeve et al., 2005). A single report of greater dehydrogenase activity in biodynamically treated compost linked to greater microbial activity (Reeve et al., 2010) was the only significant difference among several tested parameters and whose potential significance was unexplained. When Preparation 500 was analyzed for bioactivity in the laboratory, researchers concluded that the product was unlikely to be either a structural organic fertilizer or microbial inoculant at the dosages used in field settings (Giannattasio et al., 2013).

CROPS. When added to organically grown crops, biodynamic preparations have been uniformly ineffective. Compared with organically managed systems, additions of biodynamic preparations did not affect yields of cover crops (Berner et al., 2008), forage grasses (Reeve et al., 2011), lentil [*Lens culinaris* (Carpenter-Boggs et al., 2000b)], rice [*Oryza sativa*, Preparations 500–501 (Garcia-Yzaguirre et al., 2011)], spelt [*Triticum spelta* (Berner et al., 2008)], sunflower [*Helianthus annuus* (Berner et al., 2008)], or wheat (Berner et al., 2008; Carpenter-Boggs et al., 2000b). At the plant level,

a similar lack of efficacy can be found in wheat seedling root and shoot growth (Reeve et al., 2010) or in lettuce (*Lactuca sativa*, Preparations 500–501) nitrogen uptake and usage (Bacchus, 2010). Perhaps not surprisingly, organically grown soybeans (*Glycine max*) fertilized with cow manure were superior in yield and quality than those treated only with biodynamic Preparations 500–504 (Tung and Fernandez, 2007a,b). But both organically grown rice (Valdez and Fernandez, 2008) and cabbage [*Brassica oleracea* var. *capitata* (Bavec et al., 2012)] were ranked higher in cost-effectiveness (Valdez and Fernandez, 2008) and consumer preference (Bavec et al., 2012) than organic treatments with additional biodynamic preparations. Organically raised mangoes had significantly greater phenolics, flavonoids, and antioxidant activity than those from biodynamic fields (Maciel et al., 2010), which may be of importance from a nutritional standpoint.

Wine makers are particularly interested in biodynamic grapes (*Vitis vinifera*), and researchers have provided some insight into the effectiveness of the preparations. In a thorough analysis, Reeve et al. (2005) found no difference in leaf nutrients or cluster numbers, weights, or yield of California-grown cultivar Merlot. Though some small differences were found in grape chemistry, they were of “doubtful practical significance” according to the authors (Reeve et al., 2005), leading them to conclude that “there is little evidence the biodynamic preparations contribute to grape quality.” In fact, the finished product may be negatively affected; in one trial organically grown California merlot was notably more preferred by tasters than the biodynamically grown product (Ross et al., 2009).

PESTS AND PATHOGENS. No differences were found in weed control using Preparations 500–508 (Carpenter-Boggs et al., 2000b) or in cover, species richness, diversity, and evenness of weed species (Sans et al., 2011). In one long-term study, biodynamic Preparations 501 and, especially, 502 increased disease intensity in organically grown wheat (Stepien and Adamiak, 2007).

ECONOMICS. Addition of biodynamic preparations did not increase economic return (Jayasree and George, 2006) or improve yield (Bacchus,

2010; Stepien and Adamiak, 2007) over organic methods. In fact, organically produced soybeans (Tung and Fernandez, 2007a) and rice (Valdez and Fernandez, 2008) were more profitable than those produced using biodynamic methods, both in terms of yield and of production costs. Addition of biodynamic preparations not only increases labor and materials costs but also widens the ecological footprint of the practice because of higher machinery use for applying the preparations (Turinek et al., 2010).

In summary, the peer-reviewed research published thus far provides little evidence that biodynamic preparations improve soils, enhance microbes, increase crop quality or yields, or control pests or pathogens. Given the homeopathic nature of the applied preparations (i.e., extremely low concentrations of nutrients), it is not surprising to see a general lack of efficacy over the benefits provided by organic methods. Finally, the additional costs associated with formulating and applying the preparations represents an economic loss over and above that found in an organically maintained farm or garden.

Evaluating the literature critically

In considering the current body of literature on biodynamic agriculture, there are some points to keep in mind. First, when the number of comparisons made among treatments increases, the likelihood of finding a significant difference also increases, if only by chance. The way to reduce this sort of systematic error is to use a statistical correction factor, which sets a higher bar for what is considered “significant.” None of the authors who reported some effect of biodynamic preparations corrected for multiple comparisons. This does not necessarily discount their findings: it simply points out a possible source of statistical error.

Second, it is tempting for researchers to focus on isolated positive results: in other words, they highlight the significant results and have little to say about the rest, especially in the article’s abstract or conclusion. Reading the entire article, not just a summary, will provide a more complete picture.

Finally, more peer-reviewed research is specifically needed on the

effectiveness of biodynamic preparations, pest ashing, lunar planting, and other experimentally testable practices originally recommended by Steiner. These studies must be conducted and reviewed with appropriate scientific rigor to avoid the pitfalls of faulty experimental design and incomplete statistical analysis. Without a robust body of knowledge to consider, it is impossible to judge the effectiveness of biodynamics as an alternative agricultural practice.

Much of the work on biodynamics has been published by just a few research groups. Scientific advancement in any topic is strongest when many researchers work collaboratively as well as independently, conducting exploratory studies in other crops and in different locations around the world, and publishing the results (both positive and negative).

Education without alienation

Extension educators have a fine line to walk. They need to provide current, science-based information to their clients, but they must also be sensitive to those in their audience who have opted for value-based belief systems. Beyfuss and Pritts (1994) summarized it well: the popularity of nonscience-based practices has created hostility between the scientific community and many proponents of biodynamic gardening. Alda (2007) agrees, stating we’re in a culture that increasingly holds science as just another belief. Although part of the tension between science and society is a cultural shift, the other part is a failure of agricultural researchers and educators to draw clear lines between methods that have been rigorously tested and supported, and those that have not. For example, a survey administered to agricultural faculty and practitioners measured attitudes regarding attributes associated with conventional and alternative agricultural practices (Beus and Dunlap, 1990, 1991). Unfortunately, “alternative agriculture” in this survey combined science-based practices (e.g., organic, sustainable, and low-input agriculture) with those more spiritually or philosophically based (e.g., biodynamics and permaculture). Thus, the comparisons of attitudes (and the survey conclusions drawn from the study) were flawed. If the comparisons of attitudes had been

made among three categories (conventional, science-based alternative, and other alternative systems), the study results would have enabled an accurate comparison of “apples to apples” rather than “apples to oranges.” The point of this rather lengthy example is that if academic researchers do not fully understand the differences between management systems that are science based and those that are not, we can hardly be surprised when the general public is confused as well.

To date, there are no clear, consistent, or conclusive effects of biodynamic preparations on organically managed systems. Other alternative practices not discussed in this review have become part of the biodynamic movement, including use of cosmic rhythms to schedule various farm activities and image formation to visualize nutritional quality of plants. These practices do not lend themselves to rigorous experimental testing, nor do they provide practical scientific information for improving crop production. Given the thinness of the scientific literature and the lack of clear data supporting the efficacy of biodynamic preparations, biodynamic agriculture is not measurably distinct from organic agriculture and should not be recommended as a science-based practice at this time.

Literature cited

- Alda, A. 2007. Things I overheard while talking to myself. Random House, New York, NY.
- Bacchus, G.L. 2010. An evaluation of the influence of biodynamic practices including foliar-applied silica spray on nutrient quality of organic and conventionally fertilised lettuce (*Lactuca sativa* L.). *J. Organic Systems* 5:4–13.
- Bavec, M., M. Turinek, S.G. Mlakar, N. Mikola, F. Bavec, I. Mourão, and U. Aksoy. 2012. Some internal quality properties of white cabbage from different farming systems. *Acta Hort.* 933:577–583.
- Berner, A., I. Hildermann, A. Fliessbach, L. Pfiffner, U. Niggli, and P. Mäder. 2008. Crop yield and soil fertility response to reduced tillage under organic management. *Soil Tillage Res.* 101:89–96.
- Beus, C.E. and R.E. Dunlap. 1990. Conventional versus alternative agriculture:

- The paradigmatic roots of the debate. *Rural Sociol.* 55:590–616.
- Beus, C.E. and R.E. Dunlap. 1991. Measuring adherence to alternative vs. conventional agricultural paradigms: A proposed scale. *Rural Sociol.* 56:432–460.
- Beyfuss, R. and M. Pritts. 1994. Companion planting. Cornell Univ. Ecogardening Factsheet No. 10. 21 July 2013. <<http://www.gardening.cornell.edu/factsheets/ecogardening/complant.html>>.
- Birkhofer, K., T.M. Bezemer, J. Bloem, M. Bonkowski, S. Christensen, D. Dubois, F. Ekelund, A. Fliessbach, L. Gunst, and K. Hedlund. 2008. Long-term organic farming fosters below and aboveground biota: Implications for soil quality, biological control and productivity. *Soil Biol. Biochem.* 40:2297–2308.
- Carpenter-Boggs, L., A.C. Kennedy, and J.P. Reganold. 2000a. Organic and biodynamic managment: Effects on soil biology. *Soil Sci. Soc. Amer. J.* 64:1651–1659.
- Carpenter-Boggs, L., J.P. Reganold, and A.C. Kennedy. 2000b. Biodynamic preparations: Short-term effects on crops, soils, and weed populations. *Amer. J. Altern. Agr.* 15:110–118.
- Carpenter-Boggs, L., J.P. Reganold, and A.C. Kennedy. 2000c. Effects of biodynamic preparations on compost development. *Biol. Agr. Hort.* 17:313–328.
- Chalker-Scott, L. 2010. The myth of biodynamic agriculture, p. 17–22. In: *The informed gardener blooms again*. Univ. Washington Press, Seattle, WA.
- Demeter Association, Inc. 2013. Demeter Biodynamic® farm and processing standards. 28 Sept. 2013. <<http://www.demeter-usa.org/learn-more/biodynamic-farm-standard.asp>>.
- Dima, S.J. and A.N. Otero. 1997. Organic farming for sustainable agricultural production: A brief theoretical review and preliminary empirical evidence. *Environ. Resources Econ.* 10:177–188.
- Fliessbach, A., H.R. Oberholzer, L. Gunst, and P. Mäder. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. *Agr. Ecosyst. Environ.* 118:273–284.
- Foissner, W. 1992. Comparative studies on the soil life in ecofarmed and conventionally farmed fields and grasslands of Austria. *Agr. Ecosyst. Environ.* 49:207–218.
- Garcia-Yzaguirre, A., V. Dominguis, R. Carreres, and M. Juan. 2011. Agronomic comparison between organic rice and biodynamic rice. *Span. J. Agr. Res.* 9:280–283.
- Gasser, F. and G. Berg. 2011. Organic versus conventional agriculture: A review from a microorganism's point of view. *Current Trends Microbiol.* 7:41–51.
- Giannattasio, M., E. Vendramin, F. Fornasier, S. Alberghini, M. Zanardo, F. Stellin, G. Concheri, P. Stevanato, A. Ertani, S. Nardi, V. Rizzi, P. Piffanelli, R. Spaccini, P. Mazzei, A. Piccolo, and A. Squartini. 2013. Microbiological features and bioactivity of a fermented manure product (Preparation 500) used in biodynamic agriculture. *J. Microbiol. Biotechnol.* 23:644–651.
- Gunst, L., H. Krebs, D. Dubois, and P. Mäder. 2006. Fungal diseases and yield in organic and conventional wheat production. *Agrarforschung* 13:430–435.
- Halweil, B. 2004. Vintners go back to organic basics. 21 July 2013. <<http://www.nytimes.com/2004/08/08/nyregion/vintners-go-back-to-organic-basics.html>>.
- Heinze, S., J. Raupp, and R.G. Joergensen. 2010. Effects of fertilizer and spatial heterogeneity in soil pH on microbial biomass indices in a long-term field trial of organic agriculture. *Plant Soil* 328:203–215.
- Heinze, S., M. Oltmanns, R.G. Joergensen, and J. Raupp. 2011. Changes in microbial biomass indices after 10 years of farmyard manure and vegetal fertilizer application to a sandy soil under organic management. *Plant Soil* 343:221–234.
- International Federation of Organic Agriculture Movements. 2011. Organic standards. 29 Sept. 2013. <<http://www.organic-standards.info/index.php/en/documents/IFOAM-COROS,13>>.
- Jayasree, P. and A. George. 2006. Do biodynamic practices influence yield, quality, and economics of cultivation of chilli (*Capsicum annuum* L.)? *J. Trop. Agr.* 44:68–70.
- Joergensen, R.G., P. Mäder, and A. Fliessbach. 2010. Long-term effects of organic farming on fungal and bacterial residues in relation to microbial energy metabolism. *Biol. Fertil. Soils* 46:303–307.
- Kaval, P. 2004. The profitability of alternative cropping systems: A review of the literature. *J. Sustain. Agr.* 23:47–65.
- Kirchmann, H. 1994. Biological dynamic farming: An occult form of alternative agriculture? *J. Agr. Environ. Ethics* 7:173–187.
- Langenkamper, G., C. Zorb, M. Seifert, P. Mäder, B. Fretzdorff, and T. Betsche. 2006. Nutritional quality of organic and conventional wheat. *J. Appl. Bot. Food Quality* 80:150–154.
- Leiber, F., N. Fuchs, and H. Spiess. 2006. Biodynamic agriculture today, p. 141–149. In: P. Kristiansen, A. Taji, and J. Reganold (eds.). *Organic agriculture: A global perspective*. Comstock Publishing Assoc., Ithaca, NY.
- Maciel, L.F., C. da Silva Oliveira, E. da Silva Bispo, and M. da P. Spinola Miranda. 2010. Antioxidant activity, total phenolic compounds and flavonoids of mangoes coming from biodynamic, organic and conventional cultivations in three maturation stages. *Brit. Food J.* 113:1103–1113.
- Mäder, P., A. Fliessbach, D. Dubois, L. Gunst, P. Fried, and U. Niggli. 2002. Soil fertility and biodiversity in organic farming. *Science* 296:1694–1697.
- Mason, H.E. and D. Spaner. 2006. Competitive ability of wheat in conventional and organic management systems: A review of the literature. *Can. J. Plant Sci.* 86:333–343.
- McLaughlin, L. 2007. Virtuous vino. *Time Mag.* 169:76.
- Musiker, C. 2008. Biodynamic wine? Try it before you smirk. 21 July 2013. <<http://www.npr.org/templates/story/story.php?storyId=5725850>>.
- Pandian, P.S., S. Subramanian, P. Paramasivam, and K. Kumaraswamy. 2005. Organic farming in sustaining soil health: A review. *Agr. Rev.* 26:141–147.
- Paull, J. 2011. The Betteshanger Summer School: Missing link between biodynamic agriculture and organic farming. *J. Organic Systems* 6:13–26.
- Pfiffner, L. and P. Mäder. 1997. Effects of biodynamic, organic and conventional production systems on earthworm populations. *Biol. Agr. Hort.* 15:2–10.
- Pfiffner, L. and U. Niggli. 1996. Effects of bio-dynamic, organic and conventional farming on ground beetles (Col. Carabidae) and other epigeic arthropods in winter wheat. *Biol. Agr. Hort.* 12:353–364.
- Reeve, J.R., L. Carpenter-Boggs, and H. Schmsdorf. 2011. Sustainable agriculture: A case study of a small Lopez Island farm. *Agr. Syst.* 104:572–579.
- Reeve, J.R., L. Carpenter-Boggs, J.P. Reganold, A.L. York, G. McGourty, and L.P. McCloskey. 2005. Soil and wine grape quality in biodynamically and organically managed vineyards. *Amer. J. Enol. Viticult.* 56:367–376.
- Reeve, J.R., L. Carpenter-Boggs, J.P. Reganold, A.L. York, and W.F. Brinton. 2010. Influence of biodynamic preparations

- on compost development and resultant compost extracts on wheat seedling growth. *Bioresour. Technol.* 101:5658–5666.
- Reganold, J. 1995. Soil quality and profitability of biodynamic and conventional farming systems: A review. *Amer. J. Altern. Agr.* 10:36–45.
- Ross, C.F., K.M. Weller, R.B. Blue, and J.P. Reganold. 2009. Difference testing of Merlot produced from biodynamically and organically grown wine grapes. *J. Wine Res.* 20:85–94.
- Sans, F.X., A. Berner, L. Armengot, and P. Mäder. 2011. Tillage effects on weed communities in an organic winter wheat-sunflower-spelt cropping sequence. *Weed Res.* 51:413–421.
- Scheller, E. and J. Raupp. 2005. Amino acid and soil organic matter content of topsoil in a long term trial with farmyard manure and mineral fertilizers. *Biol. Agr. Hort.* 22:379–397.
- Smith, D. and J. Barquin. 2007. Biodynamics in the wine bottle: Is supernaturalism becoming the new worldwide fad in winemaking? *Skeptical Inquirer* 31: 44–48.
- Steiner, R. 1958. *Agriculture* (English translation). 1 Aug. 2013. <http://wn.rsarchive.org/Biodynamics/GA327/English/BDA1958/Ag1958_index.html>.
- Stepien, A. and J. Adamiak. 2007. Effect of spray of biopreparates on diseases and yielding of spring wheat. *Fragmenta Agronomica* 24:300–306.
- Tung, L.D. and P.G. Fernandez. 2007a. Soybeans under organic, biodynamic and chemical production at the Mekong Delta, Vietnam. *Philipp. J. Crop Sci.* 32:49–62.
- Tung, L.D. and P.G. Fernandez. 2007b. Yield and seed quality of modern and traditional soybean [*Glycine max* (L.) Merr.] under organic, biodynamic and chemical production practices in the Mekong Delta of Vietnam. *Omonrice* 15:75–85.
- Turinek, M., S. Grobelnik-Mlakar, F. Bavec, M. Bavec, S. Marić, Z. Lončarić, and J. Josip. 2010. Ecological footprint of beetroot and cabbage in different production systems. *Zbornik Radova* 147–151.
- Turinek, M., S. Grobelnik-Mlakar, M. Bavec, and F. Bavec. 2009. Biodynamic agriculture research progress and priorities. *Renewable Agr. Food Systems* 24:146–154.
- Turner, R.J., G. Davies, H. Moore, A.C. Grundy, and A. Mead. 2007. Organic weed management: A review of the current UK farmer perspective. *Crop Protection* 26:377–382.
- Valdez, R.E. and P.G. Fernandez. 2008. Productivity and seed quality of rice (*Oryza sativa* L.) cultivars grown under synthetic, organic fertilizer and biodynamic farming practices. *Philipp. J. Crop Sci.* 33:37–58.