Comparisons of Conventional, Organic, and Biodynamic Methods

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Exploring Biodynamics in Research Trials: Results with Crops

Introduction:

Little research has been done on this continent with organic and especially with biodynamic farming methods. Both of these methods generally abstain from synthetic fertilizers and pesticides. They utilize leguminous forages, rotations, organic manures and cultivation to sustain soil fertility, supply N to crops, and control weeds. Biodynamic farmers also attempt to enhance a spiritual factor in agriculture. They structure their farms as 'super-organisms' involving ruminant animals, pastures, diversified cash crops, ponds, windbreaks, etc, and they use biological growth regulators made from fermented natural substances to improve soil and crop quality. These regulators include herbs that are used to inoculate manure compost (made from yarrow (Achillea millefolium L.), chamomile (Matricaria chamomilla L), stinging nettle (Urtica dioica L.), oak bark (Quercus robur L.), dandelion (Taraxacum officinale L.), and valerian (Valeriana officinalis l.)). Also field sprays are used that are made from fermented cow manure and silica (Koepf et al. 1989) or from composted mixtures of cow manure with concentrated applications of the above-mentioned herbs ('compound preparations'). Biodynamic farmers often make these substances on their own farms.

Two 21-year old experiments in Germany (Raupp, 1995), and Switzerland (FIBL, 2000) and one 33-year old experiment in Sweden (Pettersson, 1995) compared conventional, organic, and biodynamic methods. In general, the alternative systems resulted in enhanced soil quality and somewhat lower production than conventional management. The biodynamic soils in all three experiments had greater quantities of soil organic matter and greater soil enzyme activity than the organic system. Results of the German experiment suggested that the regulators had changed the efficiency of the soil microbial biomass, but part of the effect of these regulators may be due to increased root growth (Bachinger, 1995).

Examination of 28 different experiments in Germany showed that the use of the biodynamic sprays increased crop yields (cereals and vegetables) on years where yields were low (Raupp and Koenig, 1996). This so called 'yield-balancing' effect could possibly be important for reducing financial risk for farmers, and it may indirectly due to enhanced soil quality and rooting. These regulators have been shown to have hormone-like effects on various crops grown in several studies (Goldstein, 1979; Goldstein and Koepf, 1982; Fritz, et al., 1997).

Methods:

Our experiment focused on testing the biodynamic growth regulators in Wisconsin. This field experiment was carried out for 6 years near Elkhorn, Wisconsin. The soil is a McHenry silt loam (alfisol). Initial values for soil organic matter content, pH, and soluble P and K were 2.5%, 6.9, 19 ppm, and 110 ppm. The site had been in continuous, conventional maize production before the experiment. In 1993 a uniform crop of oats and alfalfa was established. The crop of oats was harvested in a checkerboard fashion to give a yield map, possibly revealing differences in the inherent fertility of the soil. Using this information small test plots for the three systems were set out in 1994 on uniform, equally yielding parcels of soil in a randomized, complete block design. Four treatments tested were conventional, organic, biodynamic (BD), and biodynamic+ (BD+). The biodynamic treatment differed from the organic only in the application of the biodynamic regulators. The BD+ treatment differed from BD because it received two applications of a field spray consisting of a 'compound preparation' made from cow manure, stinging nettle and the herbal preparations mentioned above.

Conventional Management:

Consists of a corn-soybean rotation with annual applications of mineral fertilizer to corn (mostly 150-100-100 lbs of N, P, and K per acre).

Organic and Biodynamic Management:

Used a 6-year rotation:

1. Maize
2. Oats + under seeded sweetclover
3. Sweetclover for seed
4. Winter wheat + grass & legume
5. Grass + legume hay
6. Grass + legume hay

Fertilizer for these systems consisted of applying approximately 10 tons per acre of composted sheep manure before corn was grown. Mechanical cultivation controlled weeds in all systems. All crops in each phase of the two rotations were grown each year.

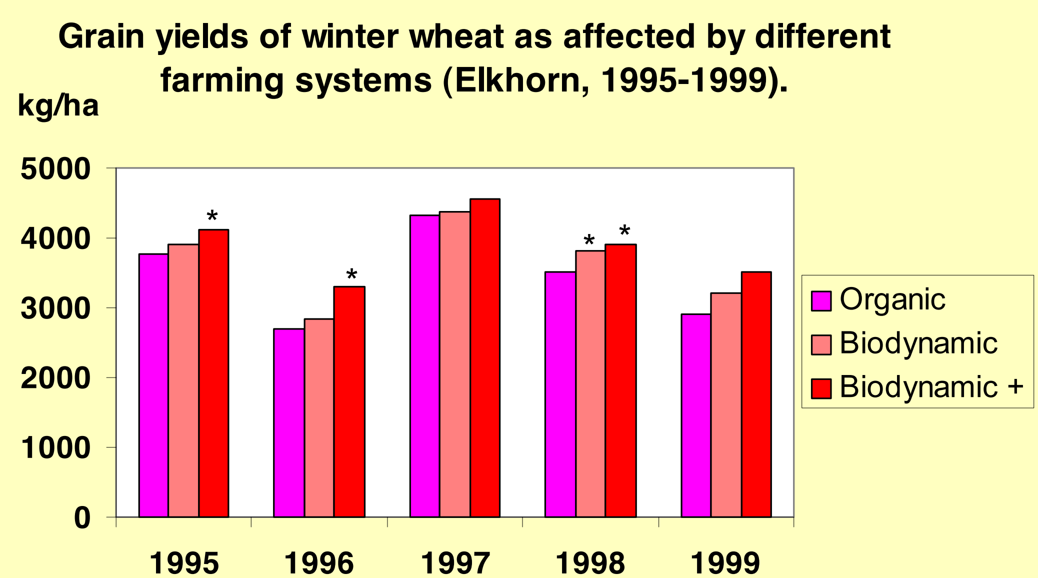
Yields were determined with a small plot combine. Roots of maize were evaluated in 1998 and 1999. In 1998 a 15.2 x 15.2 x 15.2 cm monolith was excavated around the crown of three plants from each plot, in June, July, and August. Rooting systems were washed and root length and root necrosis was determined using root intersections with a 3-cm grid. This line intersect method was applied to dissected root nodes (Goldstein, 2000). In 1999 a larger monolith that extended from the row to the center between rows (96.5 x 15.2 x 15.2 cm). These monoliths were extracted from the crown of three plants per plot in July and August. Roots were washed and root length and necrosis were determined on a nodal basis on the basis of color using 'WinRhizo', a computerized scanning/measuring system developed by Regent Instruments, Inc., Quebec, Canada. In 1998, Particulate organic matter C was determined in the fall of 1996 from the maize, alfalfa-grass, sweetclover, and wheat phases of the organic and biodynamic+ systems, and from the maize and soybean phases of the conventional system. Soil microbiological characteristics were determined in the spring of 2000 utilizing samples taken before cropping maize and after cropping maize.

Results With Yields of Crops:

Five years of data are available for wheat (1995-1999) and maize (1994-1998). In 1999, the maize crop was damaged badly by deer before harvest and yield data was not used. Yields of other crops will be reported elsewhere.

Yield of Wheat:
Examination of data in figure 1 shows that the BD+ system resulted in 403 to 605 kg /ha more grain than did the organic system. The magnitude of the effect varies from year to year. The effect of the regulators (especially the BD+ combination) seems more intense in years that yields are poorer. Figure 3 displays data for all replicates, showing that a negative linear relationship existed. When the organic plots yielded below 4.5 Mg/ha, the biodynamic + treatment had a positive effect on wheat yields. A negative effect occurred when corn yields

Fig. 1



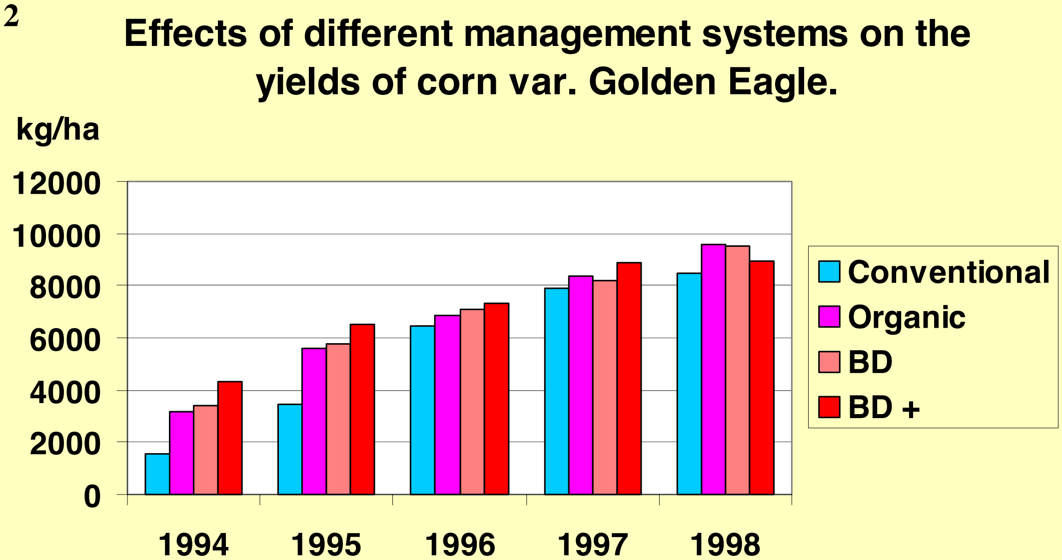
* Indicates that the treatment differs from the organic treatment at p < 5%. The 1999 results were not yet statistically evaluated.

were higher than this. If the organic wheat yielded 2, 3, 4, 5 Mg/ha, the predicted yield increase from using the preparations was 0.89, 0.54, 0.12, and –0.15 Mg/ha, respectively.

Yield of Maize:

Five years of trials showed average yields of 5.58, 6.71, 6.77, and 7.15 Mg/ha of grain for the conventional, organic, biodynamic control and biodynamic + treatments, respectively (figure 2). Yields from the conventional plots lagged behind the organic and biodynamic plots throughout the experiment. Conventional maize did especially poorly in the first 2 years (figure 2). This may have been because it received 150 lbs/a of N the first year, 150 and 100 lbs of N and P in 1995, and a complete NPK fertilizer only in 1996.

Fig. 2

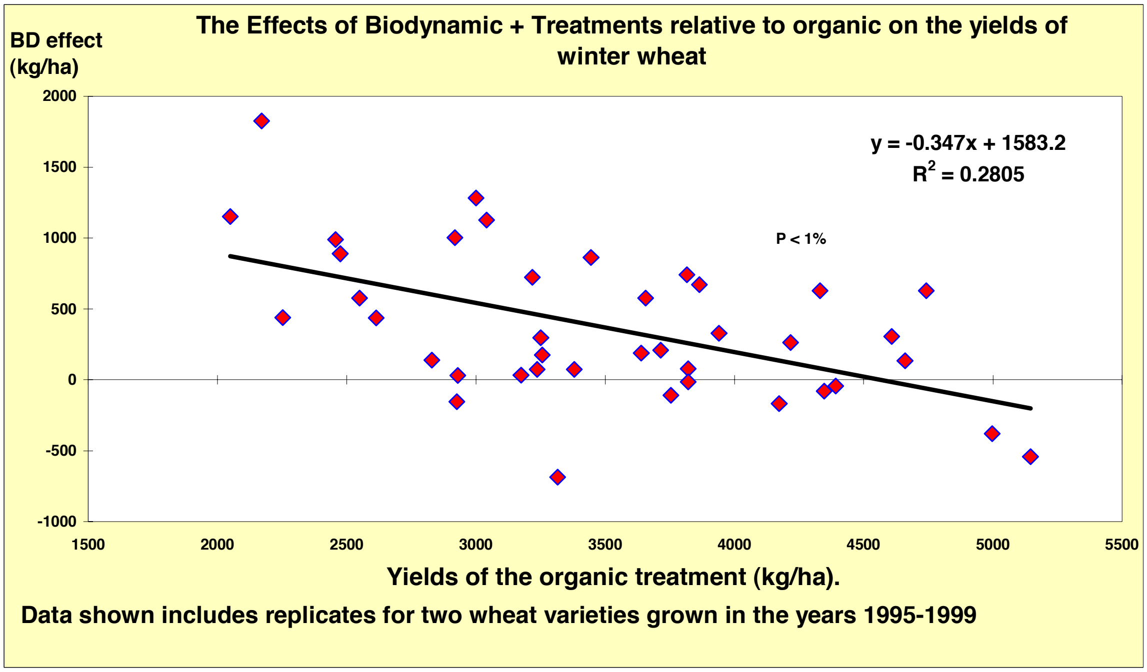


Conventional yielded the lowest in 1994 and 1995 ($p < 1\%$). Organic yielded lower than BD + NCP in 1994 ($p < 5\%$) and in 1995 ($p < 10\%$).

As had been the case with wheat, the largest differences between organic and biodynamic+ treatments occurred in those years where yields were low (figure 2). These happened to be the first two years of the conversion period.

When the organic plots yielded below 7.78 Mg/ha, the biodynamic+ treatment had a positive effect on maize yields (figure 4). A negative effect occurred when maize yields were higher than this. If the organic maize yielded 2.5, 5, 7.5, or 10 Mg/ha, the expected yield increase from using the preparations was predicated to be 1.95, 1.02, 0.1, or –0.82 Mg/ha, respectively.

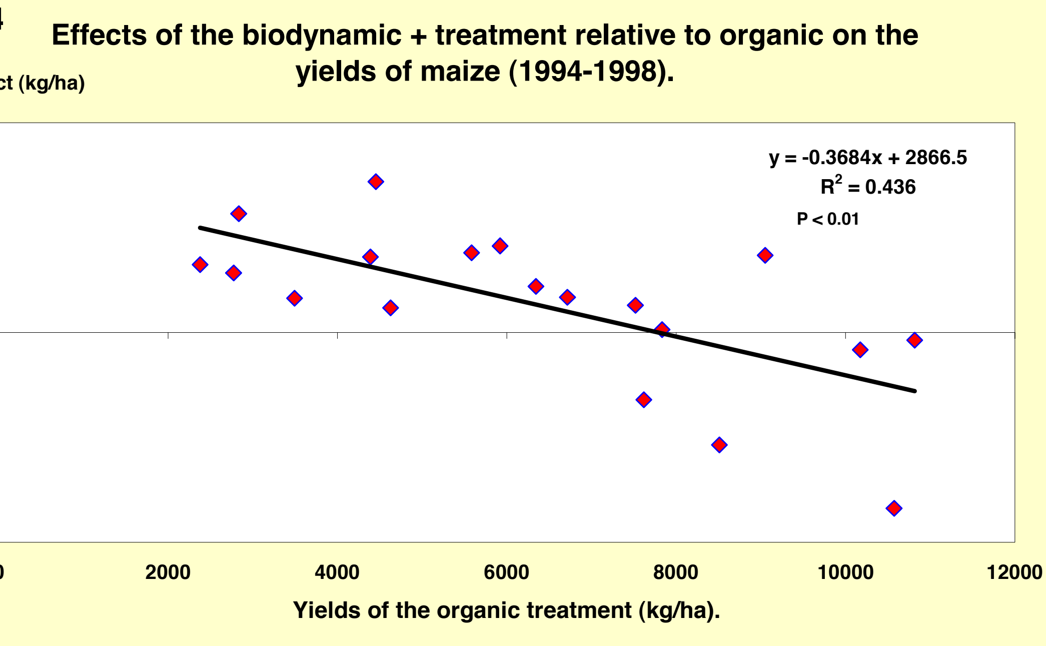
Fig. 3



<u>*Maize Roots:*</u>

In 1998, roots were sampled three times. On average, the organic system had significantly less total root length than the conventional treatment. The two biodynamic treatments were intermediate for length. There were no significant differences in the length of healthy and diseased roots between treatments (Figure 5). The conventional and BD+ treatments produced significantly more root weight than the other two systems (Figure 7). The organic

Fig. 4

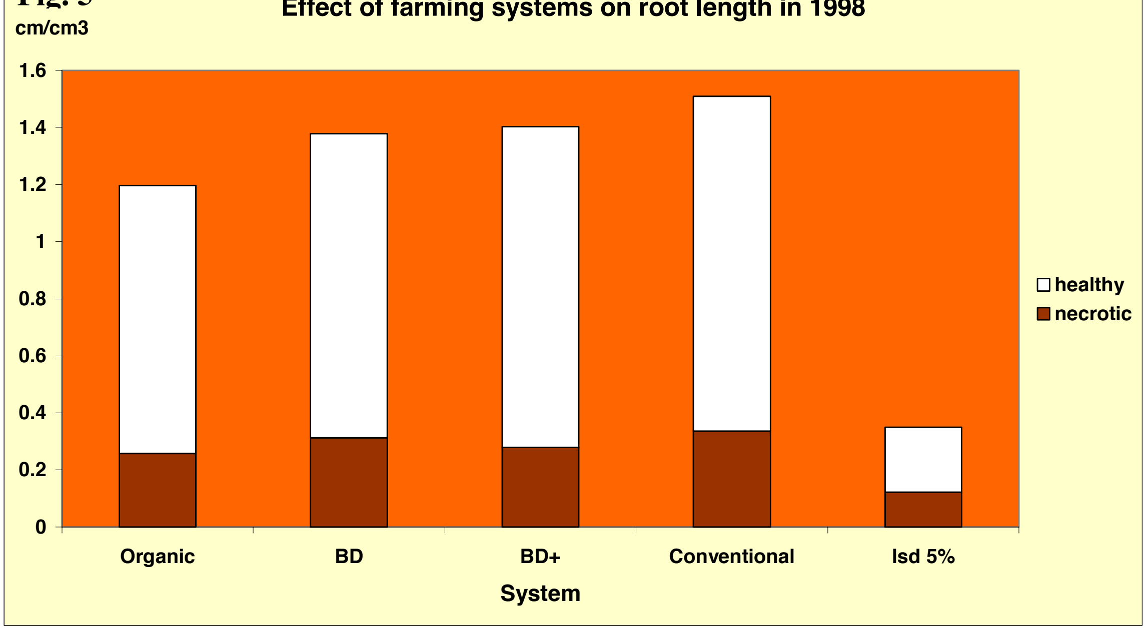


treatment produced only 75% and 69% of the root weight achieved by the BD+ and conventional treatments, respectively.

In 1999, the maize was sampled twice. Maize grown in BD+ had significantly more total root length and healthy root length than did the organic and conventional treatments (Figure 6). Both of the biodynamic treatments had significantly more root weight than the organic and conventional treatments (Figure 8).

Particulate Organic Matter:
The quantities of particulate organic matter (POM) were affected by system. BD+ had the highest level of POM in the fall, and differed significantly at the p=5% level from the organic treatment. This may not be surprising as current studies of POM suggest that its temporal quantities in the fall may be proportional to the quantity of decaying roots.

Fig. 5



Summary of Crops work:

Our results show that the biodynamic growth regulators have a yield stabilizing effect on wheat and maize. Raupp and Koenig (1996) have reported similar results. What is remarkable is that the kind of response as exemplified by the response slopes is practically identical for wheat and maize. This indicates that the effect is of the same magnitude for both crops. The results may be explained by the hypothesis that these regulators are having hormonal effects on crops. Goldstein (1986) showed that the use of preparations stimulated root growth of winter wheat in trials carried out in Washington State. The trials reported here indicate that the regulators also increase root growth strongly in maize and that the magnitude of the effect was greatest with the biodynamic treatment that received the most use of the regulators.

Fig. 6 Effects of farming system on root length in 1999

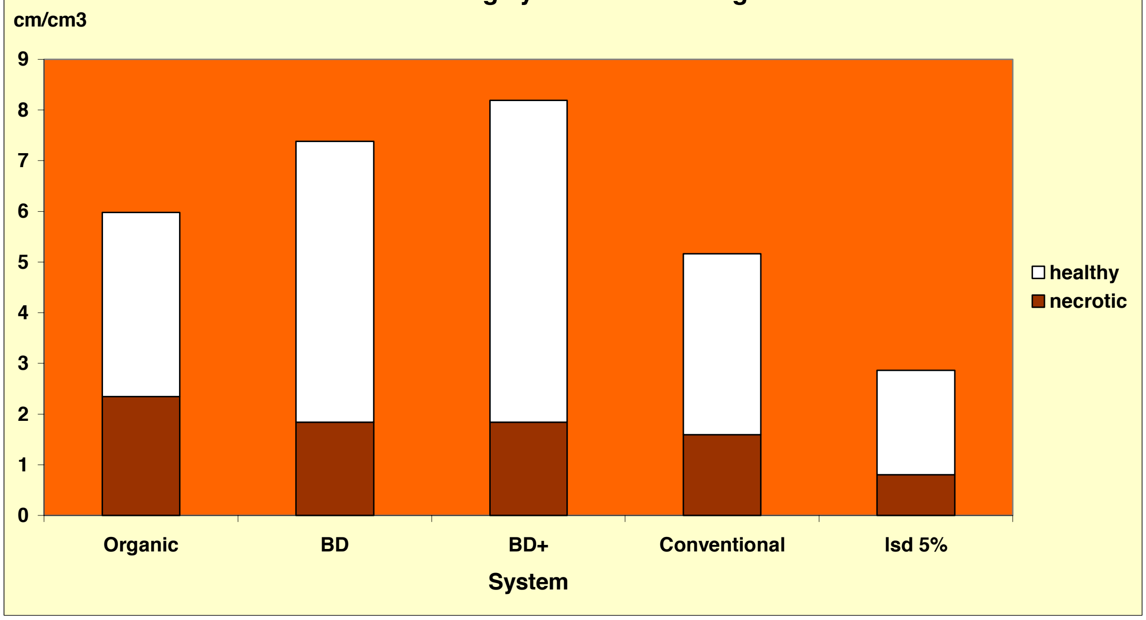
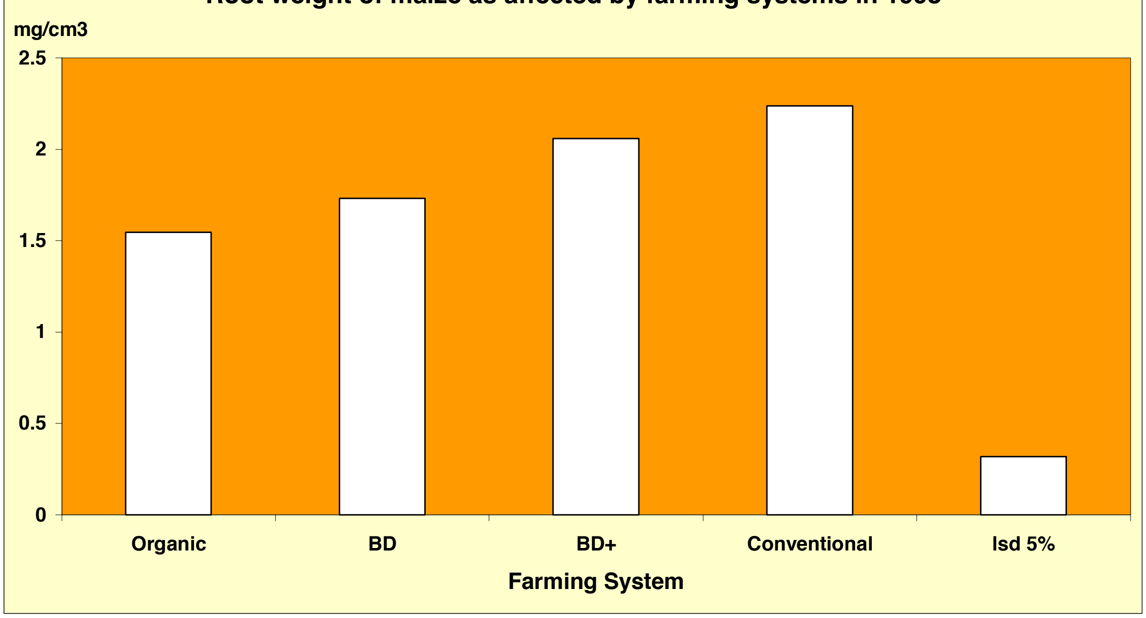
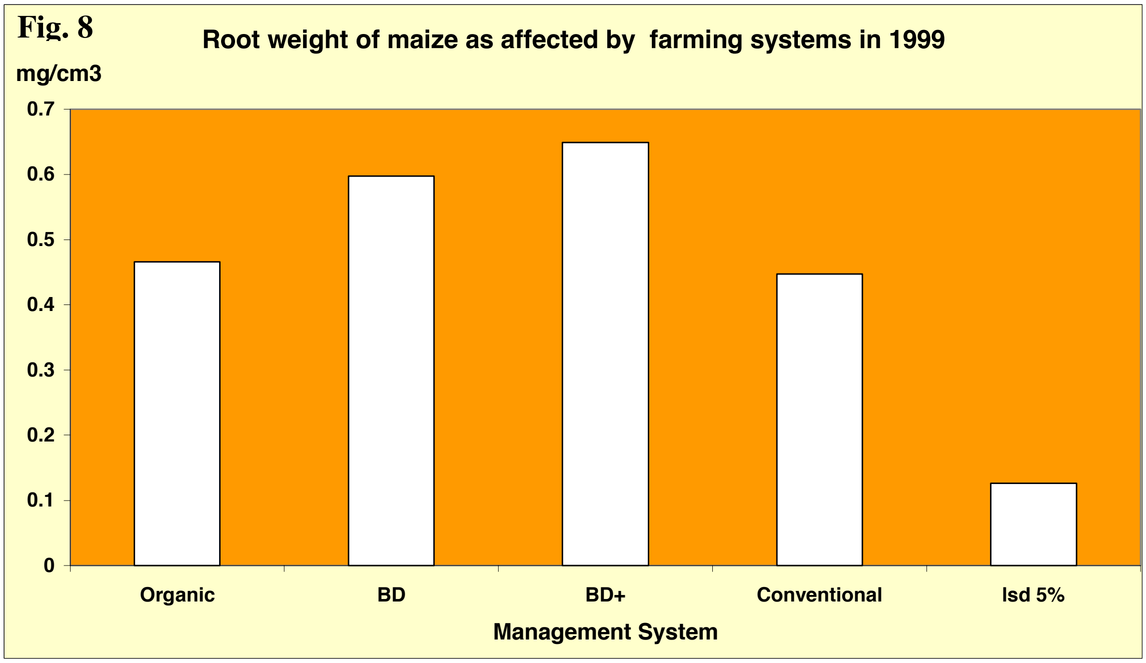


Fig. 7 Root weight of maize as affected by farming systems in 1998





Soil Biology:

BD and organic treatments supported greater soil microbial biomass and activities, and provided a better environment for microbial habitat. Total microbial biomass (*figure 12*, by substrate induced respiration) was generally greater in BD and organic treatments and least in the conventional treatment, particularly after corn. The ratio of fungal to bacterial biomass (determined by changes in respiration due to antibiotics) tends to be lower in conventional treatment, particularly at the 20-40 cm depth (data not shown).

Dehydrogenase (*figure 11*) enzyme activity, which is a general measure of microbial oxidation activities, was also generally least in the conventional treatment, especially after corn. Respiration (CO_2 release) tended to be greatest in conventional treatment soils before corn, but least in conventional soils after corn (data not shown). The ratio of respiration to microbial biomass (*figure 13*), however, was consistently greatest in conventional treatment soils, particularly in topsoil. Respiration per unit biomass is a measure of energetic requirements; a higher number often represents a population under stress or otherwise “working harder” to produce an equal amount of living biomass.

The level of labile C (*figure 14*) (mineralized in 12d) indicates the amount of organic matter readily utilized by microbes. Labile C was much greater in BD and organic treatments, which likely contributed to the greater microbial biomass in these solid.

Greater microbial biomass and activities can and does affect crop nutrition. The amount of nitrate-N (*figure 10*) was much lower in conventional treatment soils. The amount of nitrate present suggests that additional N fertilization is not required for maximum crop yield in BD and organic soils, whereas additional N may be required in the conventional treatment.

Fig. 9

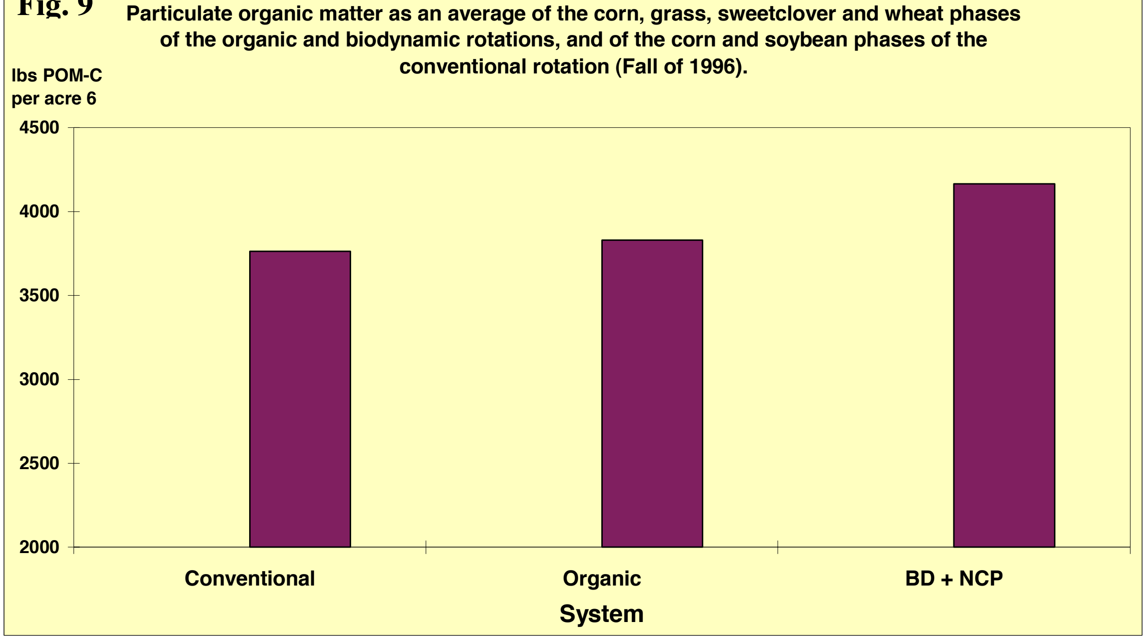

Particulate organic matter as an average of the corn, grass, sweetclover and wheat phases of the organic and biodynamic rotations, and of the corn and soybean phases of the conventional rotation (Fall of 1996).
lbs POM-C per acre 6
4500
4000
3500
3000
2500
2000
Conventional
Organic
BD + NCP
System

Fig. 10

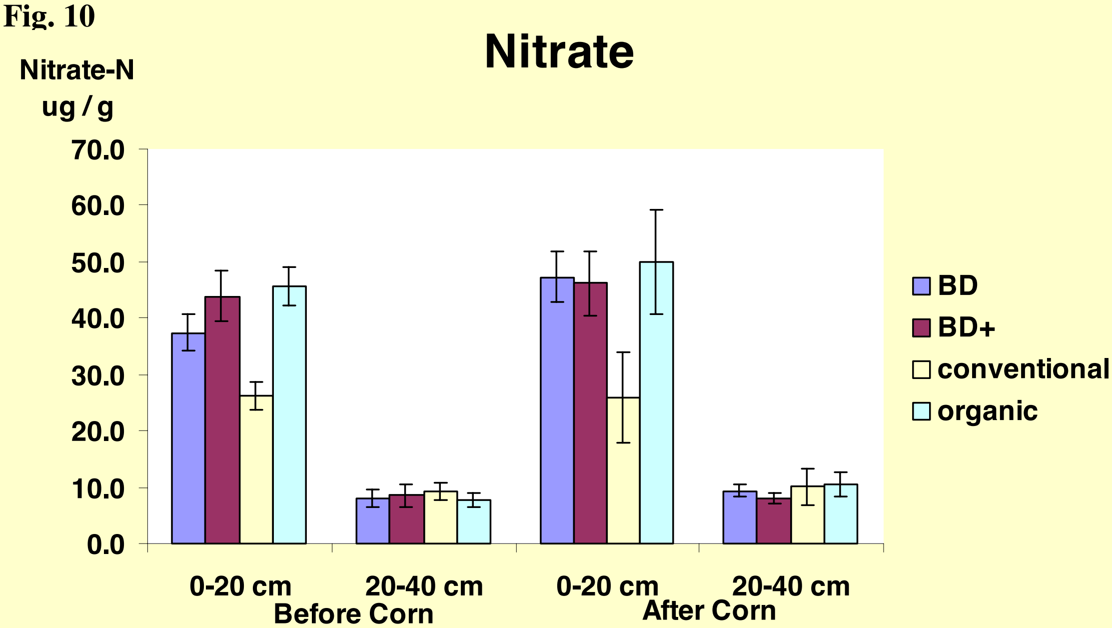

Nitrate
Nitrate-N ug / g
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
BD
BD+
conventional
organic
0-20 cm
20-40 cm
Before Corn
0-20 cm
20-40 cm
After Corn

Fig. 11

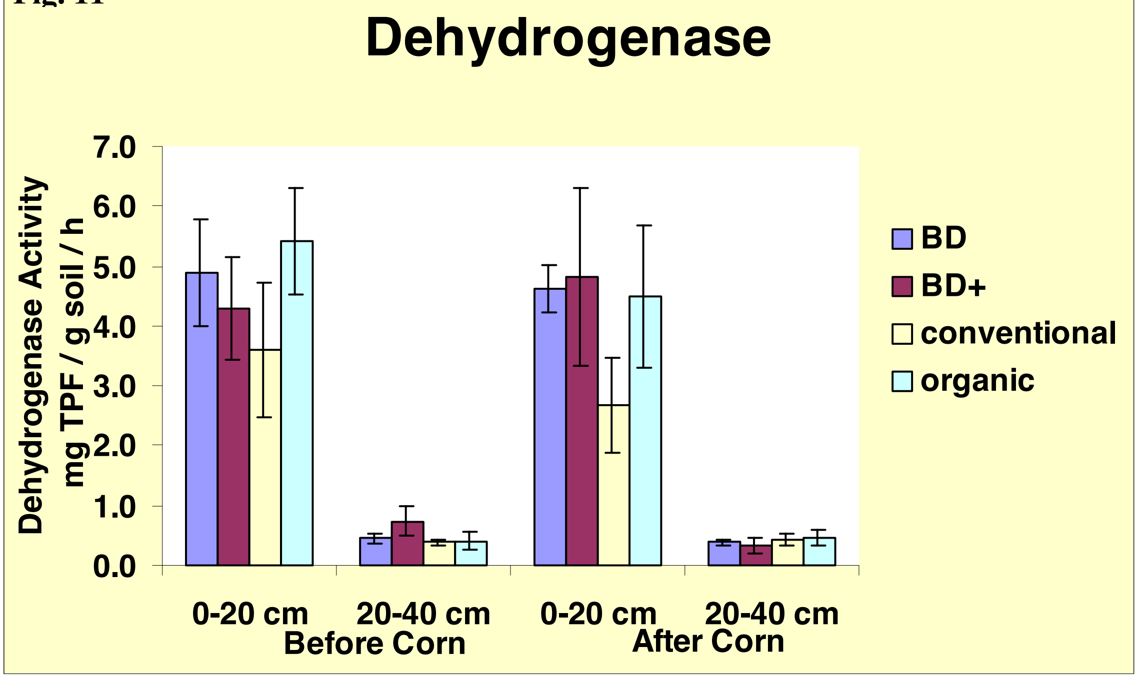

Dehydrogenase
Dehydrogenase Activity
mg TPF / g soil / h
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0-20 cm
20-40 cm
Before Corn
0-20 cm
20-40 cm
After Corn
BD
BD+
conventional
organic

Fig. 12

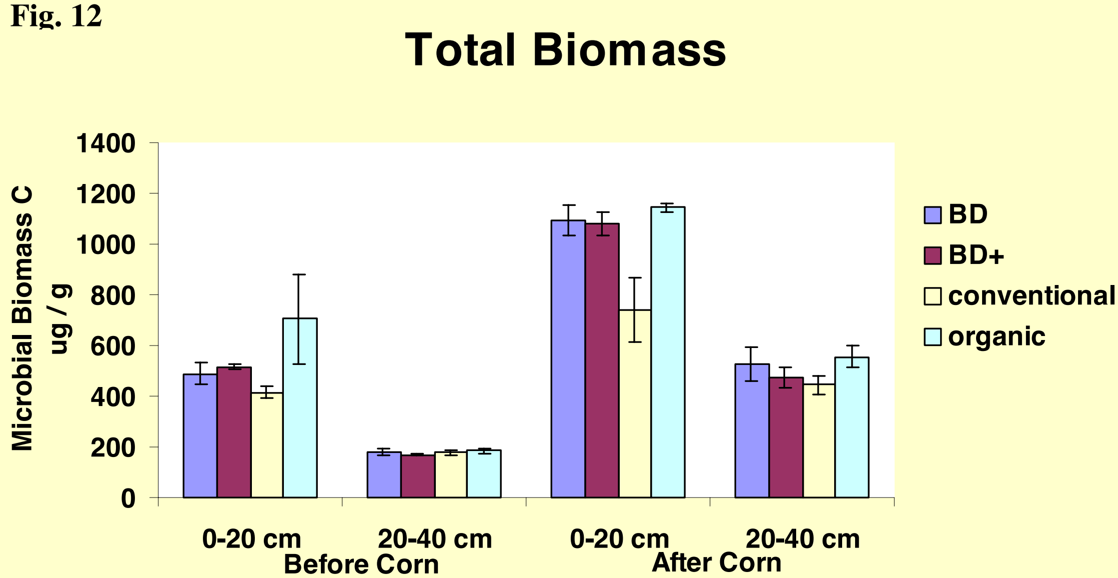

Total Biomass
Microbial Biomass C
ug / g
1400
1200
1000
800
600
400
200
0
0-20 cm
20-40 cm
Before Corn
0-20 cm
20-40 cm
After Corn
BD
BD+
conventional
organic

Fig. 13

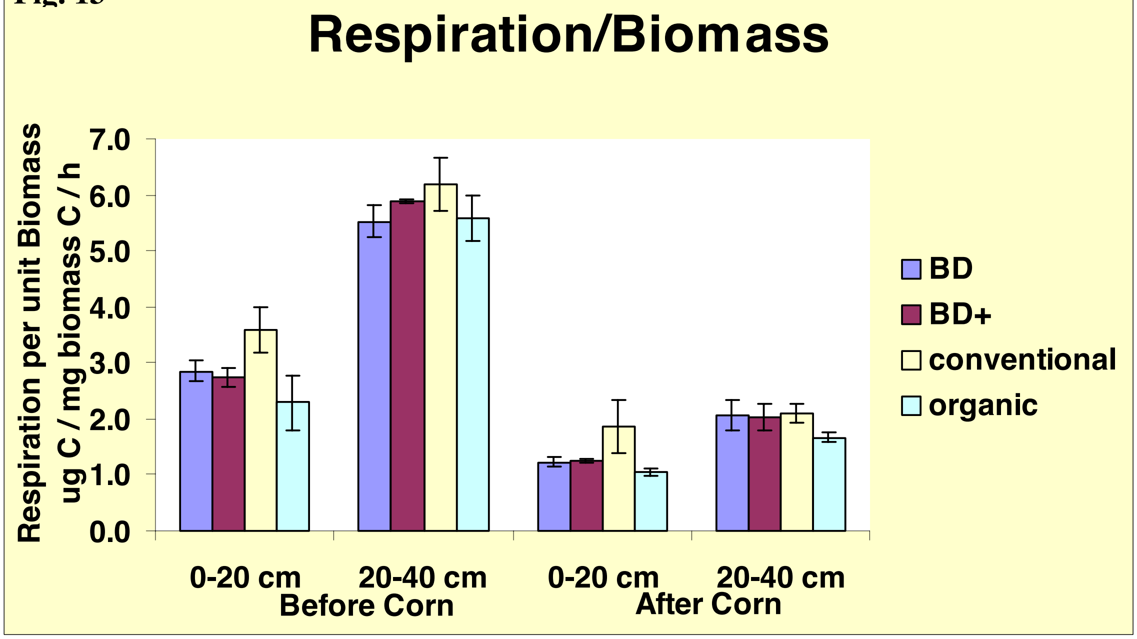
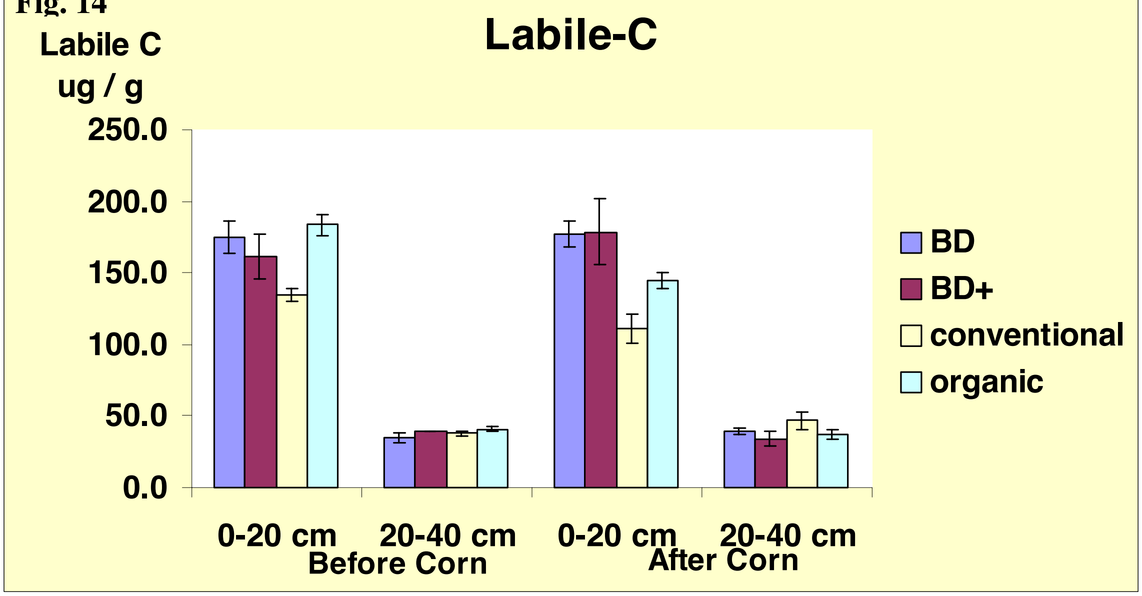

Respiration/Biomass
Respiration per unit Biomass
ug C / mg biomass C / h
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0-20 cm
20-40 cm
Before Corn
0-20 cm
20-40 cm
After Corn
BD
BD+
conventional
organic

Fig. 14


Labile-C
Labile C
ug / g
250.0
200.0
150.0
100.0
50.0
0.0
0-20 cm
20-40 cm
Before Corn
0-20 cm
20-40 cm
After Corn
BD
BD+
conventional
organic