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# Short-term effect of soil disturbance by mechanical weeding on plant available nutrients in an organic *vs* conventional rotations experiment

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## Summary

The question whether soil disturbance from mechanical weeding in organic systems affects nutrient release from organic matter in compost-amended soil was examined in a long-term organic-versus-conventional rotational cropping system experiment over three years. The experimental design included continuous snap beans, and a fully phased snap beans/fall rye crop rotation sequence. Treatments were combinations of yearly applied fertiliser (synthetic fertiliser, 1× compost, 3× compost) and weed control (herbicide, mechanical weeding). The 1× compost rate was calculated to deliver the equivalent of 50 kg N $ha^{-1}$: equal to the rate of N in the synthetic fertiliser treatments. Ion exchange membranes were buried for 24 hours following mechanical weeding in bean plots. Adsorbed ions were then eluted and quantified. Available ammonium-nitrogen was not affected by weeding treatment, but nitrate-nitrogen was consistently less in mechanically weeded plots than in plots treated with herbicide. Principal component analysis of $NH_4$-N, $NO_3$-N, P, K, Ca and Mg availabilities showed distinct groupings of treatments according to fertility treatment rather than weeding treatment. The effect of cropping sequence on available nutrients was pronounced ($P \leq 0.001$) only in plots amended with synthetic fertilisers.

**Key words:** Mechanical weeding, compost, organic matter, nitrate, ion exchange

## Introduction

Tillage decreases soil organic nitrogen and carbon pools because disturbing the soil structure exposes protected soil organic matter to microbial degradation (Kristensen *et al*., 2003). In organic agricultural systems, organic matter is incorporated into the soil so that as it mineralises, it will release nitrogen for crop production. Compost is a common source of nitrogen for organic vegetable crop production. Light tillage is commonly used to uproot and destroy weeds in organic systems. The question arises whether soil disturbance from mechanical weedings affects the short-term release of nutrients from soil amended with compost.

## Materials and Methods

*Long-term organic-versus-conventional rotations experiment*

This research was conducted over three years of a long term organic-*vs*-conventional rotations experiment. The layout consisted of three replicates at a research farm site and three replicates at a commercial farm site, each comprising three strips, to which each was assigned a rotational cropping sequence. This was continuous beans (CB), or one of the two phases of a beans/fall rye two-year rotation (BRB or RBR). Strips were divided into six plots. To each was assigned a treatment combination (Table 1) of yearly-applied fertiliser and weeding method. Compost had a C:N ratio of 15.2, with total nitrogen on a dry matter basis of 1.5%. The 1× compost rate was calculated to deliver the equivalent of 50 kg N $ha^{-1}$: the same rate of N applied in synthetically fertilised plots. In herbicide-treated plots, herbicides were applied following commercial standard practices. Mechanical weeding was carried out twice per season using a tractor-mounted implement with metal fingers mounted on spinning disks, which disturbed soil to a depth of 15 cm. The soil loosened by the mechanical tillage was loose and fine.

Table 1: *Details of the six weed control and yearly applied fertiliser treatment combinations*

| Treatment identification | Combined factors | |
|---|---|---|
| | Weed control method | Yearly applied fertiliser |
| HF | Herbicide | Synthetic fertiliser |
| H1× | Herbicide | 1× rate of compost |
| H3× | Herbicide | 3× rate of compost |
| MF | Mechanical weeding | Synthetic fertiliser |
| M1× | Mechanical weeding | 1× rate of compost |
| M3× | Mechanical weeding | 3× rate of compost |

*Monitoring of nutrients using anion and cation exchange membranes*

Anion and cation exchange membrane technology was used to monitor plant-available ions in the soil solution of bean plots following weeding events. The membranes, in the form of Plant Root Simulator™ probes (Western Ag Innovations, Saskatoon) were buried vertically in the soil. Each 15-cm probe exposed 17.5 $cm^2$ of ion-exchanging surface area to the soil at approximately 6–13 cm depth. Four pairs of anion and cation probes were buried in the inter-row of each bean plot to form composite samples to account for soil heterogeneity. Probes were buried 12 hours after mechanical weeding events, and were removed 24 hours later. They were rinsed with distilled water, and transported to Western Ag Innovations laboratory for elution of the ions adsorbed to the membranes and for colorimetric quantification. Analysis of Variance (ANOVA) was conducted on resulting nutrient availability data.

## Results

Plant roots take up ions from the soil solution as growth nutrients. Concentrations of ions in soil solution are in constant flux. Data from the ion exchange membranes provide a relative measure of the plant available ions in the soil solution, and entering the soil solution over the burial period. Differences in the plant available nutrients in soil solution 12 to 36 hours following mechanical weeding were identified using ANOVA (Table 2). More ammonium-nitrogen ($NH_4$-N) was available in plots treated with synthetic fertiliser than in compost-amended plots. Use of synthetic fertiliser also resulted in increased concentrations of available nitrate nitrogen ($NO_3$-N). Mechanical weeding played a role by depressing Ca, Mg, and especially $NO_3$-N in compost-amended and synthetically fertilised treatments. In some years, e.g. 2005, this effect was pronounced (Fig. 1). Weed control method interacted significantly with cropping sequence in affecting $NO_3$-N and K availabilities. No clear pattern emerged for K, but in the case of $NO_3$-N, concentration in soil solution was consistent in the following relationship between cropping sequences: BRB<CB<RBR. The greatest concentrations of available P, K and Ca and Mg were found at the 3× rate of compost application. When mean available nutrients were averaged over the three years and weeding treatments, and were divided into their principal components, cropping sequence effects became clearer (Fig. 2).

Table 2. *Mean plant available nutrients across sites and years from 12 to 36 hours following mechanical weeding in bean plots treated with combinations of weeding method (Mechanical weeding or Herbicide) and fertiliser (Synthetic Fertiliser, 1x rate compost or 3x rate compost) in different cropping sequences (Continuous Beans, Beans/ Rye/Beans or Rye-Beans-Rye)*

| | | | Three-year mean nutrient availabilities ($\mu g \cdot 10cm^{-2} \cdot 24hrs$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Weed Control | Fertiliser | Cropping sequence | $NH_4$-N | $NO_3$-N | P | K | Ca | Mg |
| M | F | CB | 24.3 | 153.3 | 3.4 | 177.7 | 408.3 | 77.3 |
| M | F | BRB | 12.3 | 110.5 | 2.8 | 139.2 | 340.2 | 63.7 |
| M | F | RBR | 32.8 | 262.3 | 5.8 | 220.6 | 571.8 | 83.7 |
| *M* | *F* | *Mean* | *23.1* | *175.3* | *4.0* | *179.2* | *440.1* | *74.9* |
| M | 1× | CB | 7.7 | 114.8 | 3.8 | 136.7 | 390.8 | 78.1 |
| M | 1× | BRB | 3.5 | 81.0 | 4.6 | 146.7 | 366.2 | 69.7 |
| M | 1× | RBR | 3.4 | 151.1 | 6.0 | 180.8 | 503.0 | 85.4 |
| *M* | *1×* | *Mean* | *4.9* | *115.6* | *4.8* | *154.7* | *420.0* | *77.7* |
| M | 3× | CB | 3.4 | 116.3 | 7.6 | 220.4 | 461.2 | 94.4 |
| M | 3× | BRB | 3.8 | 100.8 | 8.1 | 266.1 | 413.6 | 93.1 |
| M | 3× | RBR | 3.0 | 129.2 | 9.9 | 269.4 | 475.9 | 90.6 |
| *M* | *3×* | *Mean* | *3.4* | *115.4* | *8.5* | *252.0* | *450.2* | *92.7* |
| *M* | | | *10.47* | *135.5* | *5.8* | *195.3* | *436.8* | *81.8* |
| H | F | CB | 24.7 | 165.9 | 3.0 | 201.6 | 447.7 | 84.4 |
| H | F | BRB | 15.3 | 131.9 | 3.4 | 165.0 | 395.0 | 76.6 |
| H | F | RBR | 32.5 | 222.0 | 6.8 | 192.0 | 585.2 | 96.7 |
| *H* | *F* | *Mean* | *24.2* | *173.2* | *4.4* | *186.2* | *475.9* | *85.9* |
| H | 1× | CB | 3.9 | 121.4 | 3.4 | 147.0 | 413.6 | 83.0 |
| H | 1× | BRB | 3.9 | 118.1 | 4.1 | 167.5 | 387.6 | 77.4 |
| H | 1× | RBR | 2.6 | 152.1 | 5.7 | 138.3 | 486.6 | 75.6 |
| H | 1× | Mean | 3.5 | 130.5 | 4.4 | 151.0 | 429.3 | 78.7 |
| H | 3× | CB | 3.8 | 139.7 | 6.8 | 260.4 | 485.5 | 103.7 |
| H | 3× | BRB | 3.4 | 131.7 | 8.4 | 291.8 | 486.0 | 112.5 |
| H | 3× | RBR | 3.3 | 143.7 | 9.9 | 278.0 | 509.1 | 110.1 |
| *H* | *3×* | *Mean* | *3.5* | *138.3* | *8.4* | *276.7* | *493.5* | *105.4* |
| H | | | 10.39 | 147.4 | 5.7 | 204.6 | 466.2 | 90.0 |
| SEM individual means | | | 7.44 | 13.61 | 0.95 | 17.58 | 32.68 | 7.30 |
| SEM Weed control* Fertiliser group means | | | 4.87 | 6.76 | 0.54 | 10.85 | 15.73 | 4.21 |
| SEM Weed control group means | | | 0.90 | 3.74 | 0.19 | 4.29 | 9.64 | 1.69 |
| F probabilities | | | | | | | | |
| Fertilisers | | | ** | *** | *** | *** | ** | *** |
| Weeding | | | ns | * | ns | ns | * | *** |
| Weeding*Fertiliser | | | ns | ns | ns | ns | ns | Ns |

Statistical significance: $P \leq 0.001$ indicated by ***, $P \leq 0.01$ indicated by **, $P \leq 0.05$ indicated by *, and $P > 0.05$ indicated as non-significant by ns.

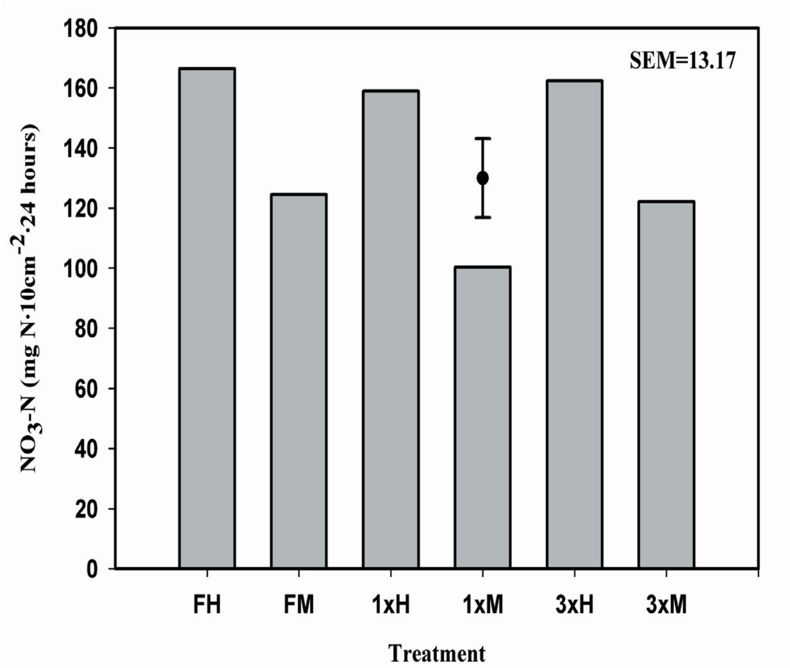


Fig. 1. Plant available $NO_3$-N (black) and $NH_4$-N-N (grey) from 12 to 36 hours following mechanical weeding in bean plots treated with combinations of weeding method (Mechanical weeding or Herbicide) and fertiliser (Synthetic Fertiliser, 1× rate compost or 3× rate compost) in 2005 at the experimental farm site, and averaged across two burials and rotational cropping sequence.

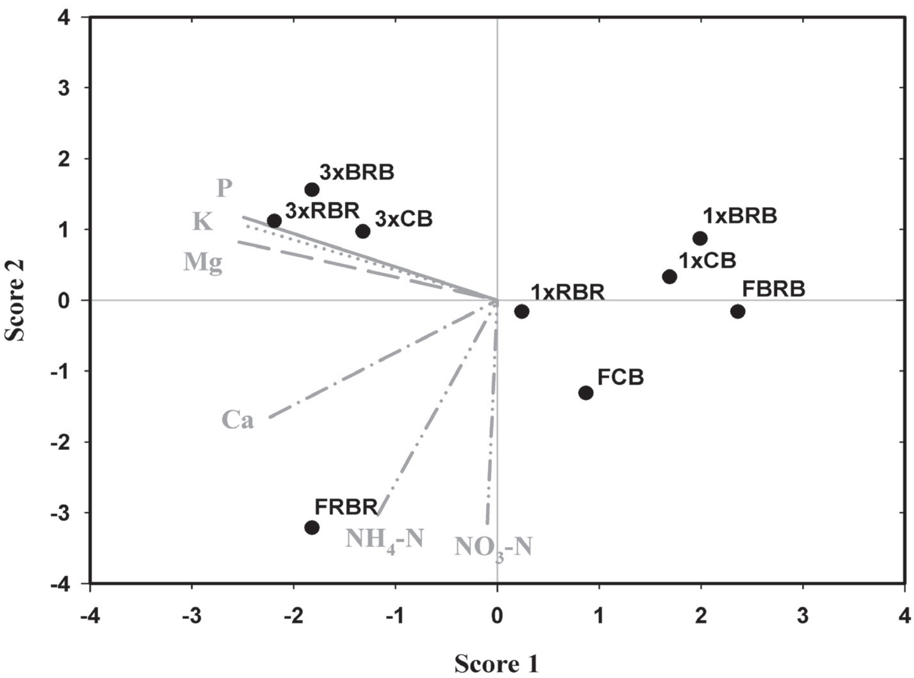


Fig. 2. Bi-plot of score 1 versus score 2 derived by Principal Component Analysis of mean $NO_3$-N, $NH_4$-N, P, K, Mg and Ca availabilities from 12 to 36 hours following mechanical weeding averaged across three years, two sites and weeding treatments.

All three cropping sequences (CB, BRB and RBR) were closely clustered when they received the 3× compost rate. The 1× compost rate treated sequences formed a looser cluster. The cropping sequences that received synthetic fertiliser were widely scattered across the plot.

## Discussion

Much literature exists to support the idea that tillage increases the mineralisation rate of organic matter in the soil by exposing organic matter protected within aggregates to microbial action (Beare *et al*., 1994; Kristensen *et al*., 2003; McCarty *et al*., 2003). The results here indicate that soil disturbance from mechanical weeding had an opposite effect, at least in the short term, of depressing available $NO_3$-N and, to a lesser extent, Ca and Mg. Soil moisture, temperature and aeration affect mineralisation (Sierra, 1997). Soil drying and increased aeration in mechanically weeded plots may have inhibited N mineralisation. Another possibility is that a flush of carbon mineralisation caused $NO_3$-N to be immobilized. For example, in a study, which examined disturbed and intact soil cores, a flush of carbon mineralisation occurred 0 to 3 days following soil disturbance, causing nitrogen immobilisation (Franzluebbers, 1999).

Fertility regime affected available nutrients. In the PCA (Fig. 2), a clear grouping of treatments involving 3×compost rate emerged, whereas with no organic amendment, synthetically fertilised cropping sequences were separated. This points to a greater mineralisable reserve of nutrients in compost-amended treatments, resulting in reduced effects of cropping system factors such as crop removal. Future work will examine these results in relation to aggregate stability, soil organic matter fractions, and crop N removal.


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