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In relation to Organic Soil Management Reduces Damping Off Enhancing Maize Seedling Health

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Abstract

Super sweet corn cultivars are notably susceptible to *Pythium ultimum Trow*., soil-borne fungal pathogen and chief cause of seedling damping-off in maize *Zea mays* L. Because of their susceptibility, they are ideal bio-indicators of soil seed health. In 2008, soil was harvested from either; 1) organic and 2) conventional corn and soybean systems at the Rodale Farming Systems Trial (FST). Soils were bioassayed for their influence on germination and emergence of super sweet corn using either the Iowa cold test or cellulose pad warm germination without seed. Super sweet corn seed cultivars from Seeds of Change were tested including:

i. Chorus,

ii. HMX6358,

iii. Ice,

iv. Reflection,

v. Renaissance,

vi. Revelation and

vii. Rhythm.

Seed health was also test by either treating seed with maxim RT syngenta fungicide treatment (Maxim fludioxonil active ingredient) at (2g a.i./kg seed) or 2) or not-treated control. Seed germination and emergence was tested either by warm moist cellulose pad germination at constant 25C. In addition cold test germination under ISU cold test protocol was conducted. Cold Test was superior for differentiating the cultivar reactions compared to warm cellulose pad germination. Warm test while poor for differentiating genotypic reactions but was able to show phytoxicity from seed treatment fungicide not apparent in cold test. In cold test, organic soil gave significantly higher emergence than conventional soil medium. Organically managed soils showed higher 32% (P=0.0001) compared to 15% emergence in cold test emergence for the conventional soil. Organic soil increased emergence was about 120% over the conventional soil. While cultivar differences were less in warm cellulose germination than for ISU cold test, germination rates were much higher in warm test. Under the severe stress of cold test range and differential was optimized compared to optimized warm germination. The warm laboratory germination tested done without soil on cellulose pads showed 72.9% of fungicide treated seeds and 95.6% of non fungicide, respectively. By eliminating the role of soil borne pathogen *Pythium* ultimum that is critical to the results of the cold test, the effect of treatment for phytotoxicity was shown. At the optimum germination environment, 3 of seven varieties showed the seed treatment fungicide significantly lowered (P=0.05) for their germination rates and grand means between fungicide and conventional indicating seed fungicide phyto-toxicity. In cold test the only cultivars showing no difference between Organic and Conventional Soil was Reflection. The differential effect among the different varieties under the organic and conventional soil was accompanied by a significant Soil by Variety interaction (P=0.05). While cultivar differences were very clear in the organic soil, in conventional soil they were less differentiated because emergence was so low across the cultivars. Organic soil reduced corn seed damping off and the difference in cultivars were most apparent in the cold test with organic soil. Damping off of *Pythium ultimum* is known to be influenced by biological activity of soils. Under organic management heightened soil organic matter heightened potential for naturally present biological control. While difference between cultivars was best differentiated by cold test in the organic legacy soil, warm tests with and without Standard fungicide seed treatment was effective for revealing fungicide phyto-toxicity. Soil pathogen works to confound the assessment of the hidden seed and seedling phytotoxicity as it overwhelmed this effect by the confounding action of the pathogen.

Introduction

The Rodale Institute motto of Healthy Soil=Healthy Food=Healthy People is the keystone of this nonprofit organization whose mission is to support organic agriculture as the basis of a global food system. Previously Rodale research demonstrated how long term soil organic practices represent a competitive farming system. The organic and conventional field crop systems also resulted in clearly differentiated soil characteristics including increased

i. Biological activity,

ii. Soil organic matter and

iii. Nutrient availability.

We hypothesized soil improvement would reflect on seedling health results using laboratory and greenhouse standard test procedures to test the hypothesis.

In this test, we compared the organic soil legacy versus a conventional soil legacy utilizing cold test emergence the so called Iowa cold test. This test depends on the role of controlled cold and moisture in soil stimulating Pythium naturally in the field soil. We took advantage of Rodale Institute FST which has clearly differentiated soil based on long term experimental histories and legacies to determine if these legacies differentially affected soil borne disease and seedling health.

As a type of experimental control we compared a soil-less cellulose pad germination at optimum warm temperature and the Iowa cold test protocol. We also looked at seed applied fungicide efficacy with and without fungicide seed treatment design to see how that effect might look like compared genotype and soil legacy effects.

Super sweet corn Zea mays L was selected as our test plant. These genotypes are bred for enhanced sweetness which stimulates a notable increased susceptibility to fungal pathogens such as Pythium ultimum Trow. This fungus is a chief cause of damping off or seed and seedling mortality. Sweet corn stand failures are particularly problematic when seeds are subject to chilling damage and in super sweet genetic backgrounds such as sh2. Keeling showed that host susceptibility to the pathogen in soybean Glycine max (L) Merr was related to seed exudates and Callan et al. [1] suggested the same mechanism work in maize.

Host plant genetics genotype effect were assayed by using seven super sweet varieties, and standard fungicide treatment and control nontreated were used to assay treatment ability to combat damping off in super sweet corn and test for fungicide phytotoxicity.

Besides soil quality, seed quality can be viewed as a plant's capacity to adapt to its environment and its ability to perform vital functions and be productive. Tekrony & Egli [2] stressed the importance of plant population and vigor to final crop results. Burris & Navarati [3] stressed the need for testing that would correlate to field emergence. Seed germination is a start the rate and persistence of development the result. Many times seed vigor is best differentiated in a stress environment. Compared to standard germination tests under optimized condition field emergence is often better correlated to stress test such as the Iowa cold soil emergence.

One of the primary causes of reduced yield per unit area for most cultivated varieties of plants is unsuccessful stand establishment that results of crops substandard populations in number distribution and health of seedlings of the various vigor tests used for maize growth, the Iowa cold test is the most recommended because of its strong correlation with plant emergence in the field under normal stresses.

In the major food crops of North America, sweet corn particularly super sweet corn varieties show highest potential for damping off damage. Reduction of corn stands challenges the ability to optimize primary plant productivity of sweet corn stand compromising both crop production and economic returns. Cool soils in temperate areas and anaerobic soil conditions put the seeds into stress potentially compromising stand, development and performance in terms of yield and quality.

In commercial sweet and dent maize production fungicides such as Maxim fludioxonil syngenta are widely used in attempts to mitigate damage from fungal damping off of seeds and seedlings. These are most often applied to the seed in small doses to moderate the detrimental effects these agents engender on the health of the environment due to their toxicity. Warm soil emergence temperatures and moist aerobic seed bed environment can avoid many issues related to emergence and vigor but later planting dates also can cut into the ability to get maximum use out of limited growing season [4].

In cold soils seed rot and seedling disease can cause poor stands of sweet corn. In pre-emergence rot the seeds decay and perish even before they reach the soil surface. Some emerge but grow poorly and can perish later. In warmer soils, it is more typical that you will have emergence, but then have rotten roots and stems at the soil line. Cool wet soils typically slow seed germination and the development of young seedlings so they are exposed to fungi for a longer period of time. Fungi such as Pythium spp., Macrophomina phaseolina, Gibberella zeae, Penicilllium oxalicum and others are typical fungi that may infect the seeds and seedlings. Typically low quality seed produce seedlings that are weak and survive poorly in cold wet soils.

Natural biological control has been demonstrated especially when soil management leads to greater numbers and activity of soil microorganisms. This natural biological control is optimized when soil conditions favor a highly active and diverse microbial community. This active and diverse reaction occurs naturally in soil which is rich in organic matter content.

Soil microbiologists have stressed the role of the soil habitat as a home for vast array soil microorganisms. While a minority are pathogenic, most microbes are beneficial for the positive roles. For example, they play critical roles in recycling nutrients and in addition can have notable biocontrol potential

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by suppressing soil borne pathogens such as Pythium ultimum. Many beneficial micro-floral components reside and feed off soil organic matter and suppression of pathogenic potential is known when soil microflora is abundant and attractive. Many soil micro-organisms have been proven effective in both reducing plant disease and promoting plant health. In particular Pythium species are known for their biological sensitivity to soil micro-flora. Pythium species are economically important and well known as principle biological agents causing seedlings rot or damping off of various plant species.

Under disease conducive conditions, micro-organisms in soil and seed are well known for their ability to proliferate causing damaging disease epidemics. Spread of seed damping off fungi can decimate seedling stands, reduce plant health of survivors and diminish seedling vigor and performance. These pathogenic effects are hidden and can require detailed measurement and analysis by specialists. Young seedlings can often be especially susceptible to these issues in first stages of germination. At this stage, their growth is tender and seedlings are perishable. Parasitism by these organisms can lead to their death in the condition commonly called damping off. One of the most important groups of fungi causing this malady is the class of Oomycetes and its family of Pythiaceous fungal species. These fungal species are commonly called water molds. They proliferate particularly in high moisture low oxygen environments when seedling are under environmental stress. Notable among these are cold germinating conditions, when seed is mechanically damaged during its harvest, handling and other extremes or insect damage. Even when damaging stands and symptoms are visible hidden root rot can become chronic hidden impact for crop production.

Water molds are activated by the leaking of soluble nutrients from the seed during the early stages of seed germination Keen [5]. Seed nutrient release at germination triggers the activation of soil fungus parasitic development. Subsequent fungal growth results in the invasion of the seedling tissues. This invasion in turn leads to compromised host plant cells cellular disruption while providing a nutritional base for the parasitic fungus for the host plant early death can occur and compromised growth and vigor in compromised plants. Chen and collaborators showed that suppression of the damping off by this pathogen was related to the activity and presence of soil micro-organisms which acted to inhibit the growth of the soil pathogen. When looking at emergence issues it becomes apparent that one component is the genetics of the seeds but the soil environment including biological factors are also critical

Conditions of high soil water saturation and cold soils are particularly challenging to optimum seed germination. Mechanical damage of the seeds and varieties which can have compromised seed metabolism such as super sweet corn are particularly prone to damping off and root rot. This perfect storm of pathology can make damping off a severe economic constraint for commercial farmers and bioindicator of soil and seed health issues.

Our tests aimed to elucidate

i. The ability of organic management in curtailing damping off,

ii. Look for the best conditions to evaluate our hypothesis,

iii. Look to comparative value of seed treatment fungicide and define the value of genotype variation in relation to seedling emergence and vigor issues.

Material and Methods

Since 1981, the Rodale Institute Farming Systems Trial has compared organic and conventional corn and soybean production systems. In conventional corn and soybean system there was no statistically significant change in soil organic carbon over the trial. Over 28 years of consistent application of organic and conventional soybean and corn production systems, these systems have created legacy effects that are evident in changes in the soil.

Within a decade of soil organic management soil respiration was increased by over 120%. Over the almost 3 decades of system differentiation, soil organic carbon gained approximately 1% a year in its base organic matter (from 1.9 to 2.5% soil organic carbon). Soil nitrogen was increased under organic management by about have the rate of soil carbon (from 0.29 to 0.35%).

An array of soil and agronomic responses have been compared using randomized replicated complete block design with 4 replicates of 100 seed for each replicate. Variance was analyzed means were separated by Fischer's Least Significant Difference after calculating F values.

Seed germination and emergence tests provided a standard methodology to assess the comparative influence and importance of

i. Soil legacy organic or conventional quality,

ii. Varietal genetic background (7 cultivars)

iii. Fungicide seed treatment and

iv. Cold or warm seedling assay.

In addition the interaction of these factors on seedling health was analyzed. The design was a randomized complete block design with a factorial arrangement of treatment.

Germination was assayed either in soil with cold treatment (stress test) or on cellulose pads without soil in non-stress environment. Soil was harvested from the plow layer of 4 meter square quadrants either from organic legacy or from side by side conventional legacy plots. The cold stress test was the results of planting into the differentiated field soils and exposing the experimental units to cold. This is Iowa State Standard cold

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germination test protocol 10 C for 7 days in moist soil, prior to warm germination followed at 25 C also in soil. Each treatment combination consisted for 4 replications of 50 seed. Seedling emergence counts were performed at weekly intervals for 3 weeks. Emergence rates were analyzed for their variance, factor influence, and potential for factor interactions. Means were separated using Fischer's Least Significant Difference. Cellulose pad germination was performed at 25 C on moist Kimpac pad. Germination was counted at one and two weeks after incubation [6].

Maxim treated fludioxonil fungicide was applied according the recommendation of Syngenta (2g a.i./1 kg seed) conversely the seeds were not treated. All seeds were provided by Richard Bernard Seeds of Change, Santa Fe New Mexico (Figure 1).

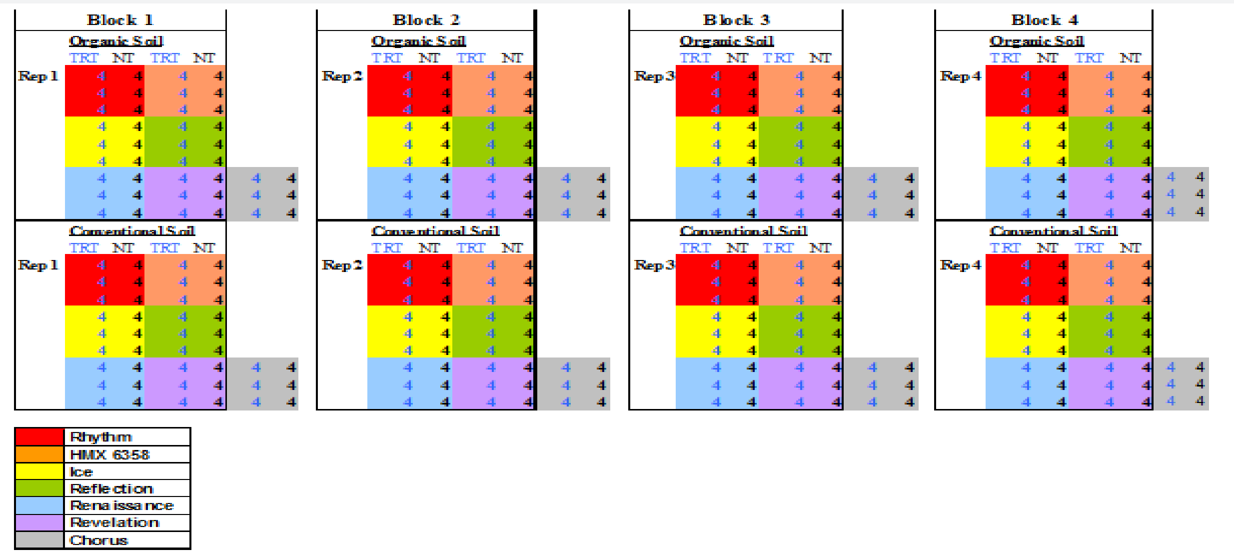

Figure 1

Results and Discussion

Table 1 shows of the seven cultivars only one Reflection show no significant difference between the Organic and Conventional soil legacy in the cold test assay. Organic legacy gave emergence of 5 to 53% for Chorus the most susceptible to Revelation the most resistant. Conventional soil legacy in the same range of cultivars was 2 to 21% for the same respective cultivars, Chorus and Revelation. The Organic legacy was over double for those of conventional legacy in the tests. The six other varieties all were statistically higher in Organic legacy soil than in conventional. The grand mean was over double for Organic legacy (32) compared to Conventional legacy (15) for all varieties [7-9] (Figure 2).

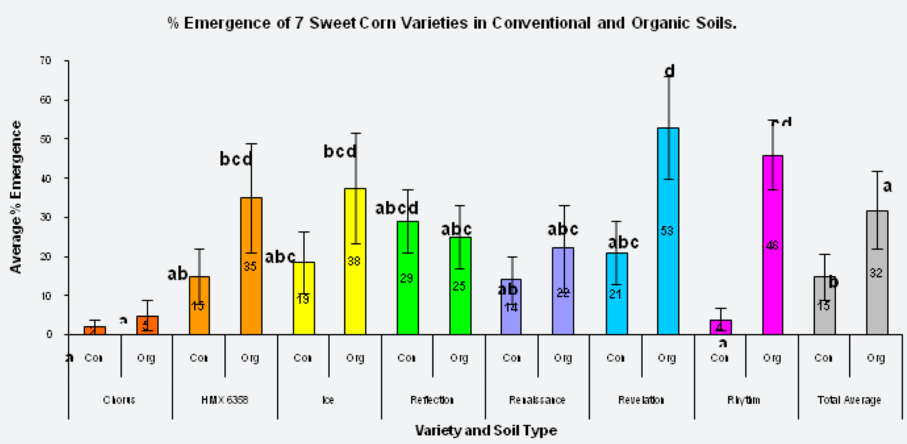

Figure 2

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Table 1: Cold test emergence of organic and conventional soil management legacy in 7 varieties of super sweet corn varieties.

Variety Name	Organic Legacy	Conventional Legacy	Statistical Sign
Chorus	5	2	*
Renaissance	22	14	*
Reflection	25	29	Not Stat. Sign.
HMX6358	35	15	*
Ice	39	18	*
Rhythm	46	4	*
Revelation	53	21	*

Table 2: Warm germination on cellulose pads and warm temperature 25C.

Variety Name	Maxim Fungicide	Nontreated	Statistical Sign
Chorus	100	100	Not Stat. Sign.
Renaissance	40	70	*
Reflection	80	100	Not Stat. Sign.
HMX6358	90	100	Not. Stat. Sign.
Ice	90	100	Not Stat. Sign.
Rhythm	40	100	*
Revelation	70	100	*
Overall Mean	72.9	95.6	*

In Table 2 On kimpac cellulose pads using warm constant germination temperature maxim and nontreated seeds showed much less capacity to differentiate the cultivars and much higher germination rates. Three out of seven varieties were significantly lowered when treated by maxim fungicide seed treatment. The three which show no difference were high in both treated and nontreated seed above 80%. The grand mean for Maxim seed treatment compared to Nontreated were 73 and 96% respectively this showed the overall phytotoxicity of Maxim when the pathogenic soil factor and cold stress were not confounding the effects (Figure 3).

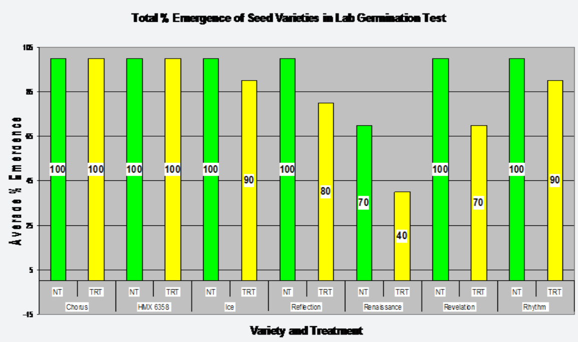

Figure 3

While soil legacy had a highly significant large effect on super sweet corn varieties in cold tests, the treatment or non treatment of the same seed did not influence the final over emergence in any significant way.

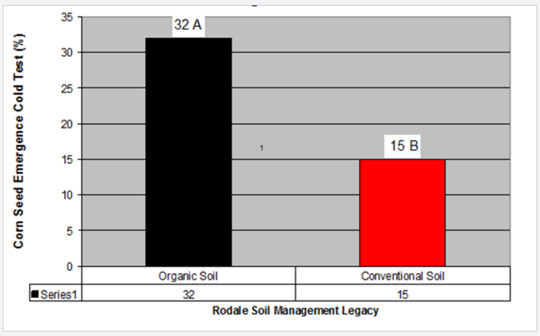

Figure 4: Effect of soil management legacy on Corn seed Emergence in cold test.

In this Figure 4 we that no statistically significant difference was found for treatment with maxim and nontreatment in the Iowa State Cold Test emergence. Cellulose pad warm germination was able to identify phytoxicity in 4 three varieties Renaissance, Rhythm, Revelation and in Fungicide 73 versus Nontreat 96 means.

In these assays the following order was found highest to lowest. One, Nontreated warm germination gave the highest and most consistent germination. Secondly maxim treated warm germination which had lower but parallel response among the cultivars. Thirdly, Organic soil was higher and more consistent in their reaction than Conventional soil. Conventional soil legacy in cold test was the lowest of all assays.

The non parallel tendency of sweet corn cultivars was apparent among sweet corn varieties in the soil test. While in the most susceptible varies Chorus, Renaissance and Reflection there was parallel responses, in more resistant cultivars HMX6558, Ice, Rhythm, and Revelation that showed ability to differentiate between organic soil from conventional soil. This nonparallel interaction showed by distinctly higher emergence in organic soil legacy in the cold test more obvious in more resistant varieties (Figure 5).

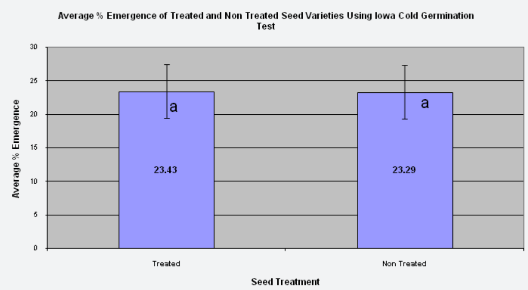

Figure 5

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This variation from parallel response in the more susceptible and nonparallel in the more resistant is a confirmation of the ANOVA analysis of a significant Soil legacy by Cold test by cultivar interaction.

When the total emergence in cold test from conventional and organic soil legacies were regressed against either conventional alone or the organic alone.

In the cold test the regression on the organic soil legacy showed a steeper slope 0.699 as m and less variability r-square 0.81 corresponding values in the conventional soil legacy were 0.301 for the m-slope and 0.45 for r-square value.

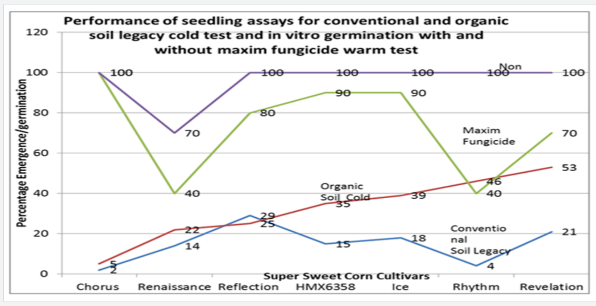

Figure 6

Disease incidence and severity are good negative indicators of plant health. The results show the organic systems practices in the Rodale Institute FST engendered significant changes in critical soil properties and this led to sizable potentially economic impacts through transformation in vigor and emergence characteristics related to the soil. Intentionally biologically based farming methods such as organic farming can change plant health outcomes by changes in the impact of pathogenic fungi. This was reflected in changes of disease severity estimates in seed emergence and germination analysis especially elucidated in Iowa Cold Test assay which accentuated the role of Pythiumaceae fungi. The increased ability to response in organic legacy correlates with increases in soil organic, Nitrogen and biological respiration under organic legacy and a host of other soil parameters. These changes have been long documented in the extensive documentation and publication related to Rodale Institute FST (Figure 6).

Applying disease parameter for differentiating effects in long term trials has been less frequently employed than many other criteria. The use of Iowa State Cold Test was highly effective when combined with use of sensitive super sweet varieties under controlled conditions as a sensitive bioindicator system. The use of organic soil allowed a better differentiation of these varieties for their performance potential under the uniform stress of cold incubation in soil. The Iowa State Cold test was effective in the differentiation of soil legacies. The organic soil behaved superior in relation to super sweet corn emergence than the same cultivars in conventional soil in all cultivars with the exception of Reflection super sweet corn. The value added of the organic soil legacy was demonstrated by the large and statistical significant bump in percentage of emergence under the controlled stress environment. Under the highly favorable warm germination without soils this differentiation was muted. In addition while warm did not demonstrate susceptible to the Pythium population in the soil it did give a clear differentiation of phytotoxicity of seed treatment fludioxinil. While it would appear that seed treatment was not effective in either our warm or cold analysis the differences in cultivar reaction are significant but only discernable under the cold test. Varietal differences were more able to be identified under the organic soil than under conventional soil in the cold test (Table 3).

Table 3

Variety	Chorus	Reflection	HMX6358	Ice	Rhythm	Revelation	
Conv Cold Test	2	14	29	15	18	4	21
Org Cold Test	5	22	25	35	39	46	53
Warm Fung	100	40	80	90	90	40	70
Warm No Fung	100	70	100	100	100	100	100

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Rodales long term field trial was designed as a soil first approach. The Institute motto of healthy soil healthy food healthy people is supported in the sense that soil health was intentionally increased and the result was healthier plants confirmed in our controlled germination and stand assays (Figure 7).

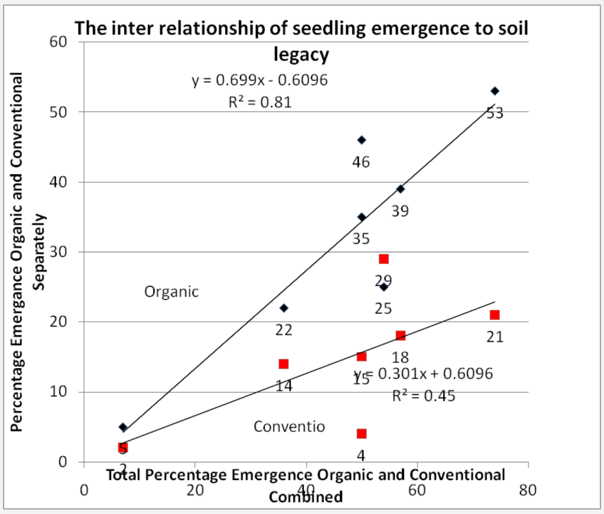

Figure 7

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