"Innovative methods of capturing solar heat for earlier harvests" Project FNE06-578

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The project was divided into two components- prewarming of spring soil and a retractable night blanket for winter salad crops. The soil warming portion of the project was completed, and the report follows. Unfortunately, the night blanket portion was not. We believe the idea still has potential, and did spend time on a prototype roller and have some thoughts about how to proceed. What we did not anticipate at the time we applied for this project was the rapid growth of demand for our dairy products, such that the dairy has drawn time and attention that we had intended to spend on winter greens production, and also on the roller. At the time we applied for this grant we were raising three acres of vegetables and managing 3500 feet of greenhouse space, while preparing to milk 3 cows. The vegetable farm hasn't changed, but we are now managing 80 acres of pasture and hay for our herd of 30 (including young stock), and also producing and distributing yogurt. Following the demand, we have become busier than we expected. This miscalculation was a function of our own inexperience, and we take full responsibility for it. I just want to make clear that I have been trying to block out time each fall to focus on the roller, and I simply haven't been able to find the time to do it well. Thus it seems prudent, at this point, to forego the second half of this grant and simply report on what we did accomplish. I apologize for this, and hope the committee can understand that we have made an honest attempt. I also thank Dale for her patience and willingness to extend the project, in the hope that we could complete it. We still do hope to continue with the roller when our dairy stabilizes and we have time to focus again on winter greens.

Cecelia and Emmet Van Driesche did most of the data collection and entry for this project, and also much of the physical work in the field. Paul did some of the data and field work and spent time in the field collecting notes and observations, while also sifting through the numbers and writing this report. I also did work on prototypes of the roller- way back in 2006.

Our advisor, Ruth Hazzard, was not involved with the project after the initial planning, through no fault of hers. I simply never got to the point of asking her advice, as the project never presented questions that seemed to warrant her expertise. We certainly intended to involve her; for this I apologize, as well.

Summary

Pre-warming spring soil with used greenhouse plastic proved quite effective at raising soil temperatures. The technique could be beneficial to small-scale, intensive vegetable farms whose market offers a premium for early spring crops. The significantly higher soil temperatures (an average of 20 degrees at 5" depth after 3 weeks under plastic) gives an early germination boost to these crops. Of course, it does the same for weeds, and so the weed management strategy must be modified accordingly.

The technique appears to offer no benefit to long season, heat-loving crops, whether grown under mulch (plastic or straw) or on bare soil. However, in our trials we did not attempt to set plants earlier on the pre-heated soil, as this would have required frost protection. In our climate and market frost protection for these crops (primarily peppers and eggplants) does not pay. The one exception here is in pre-warming greenhouse tomato beds; by covering the soil with used greenhouse plastic for 2-3 weeks before spring startup, the soil pre-heating time is reduced from 4-5 days to approximately 2 days. This offers some fuel savings.

An ancillary benefit to the technique is that in a wet spring, the covered soil becomes workable earlier, as it is protected from spring rains.

A significant drawback is that in long-season crops, pest pressure seemed heavier in the covered areas than in uncovered areas. Oddly, this increase did not appear in spring crops, where it would seem more likely. A second drawback is the earlier weed pressure. Of course, this could also be seen as a benefit, as weed management can begin earlier.

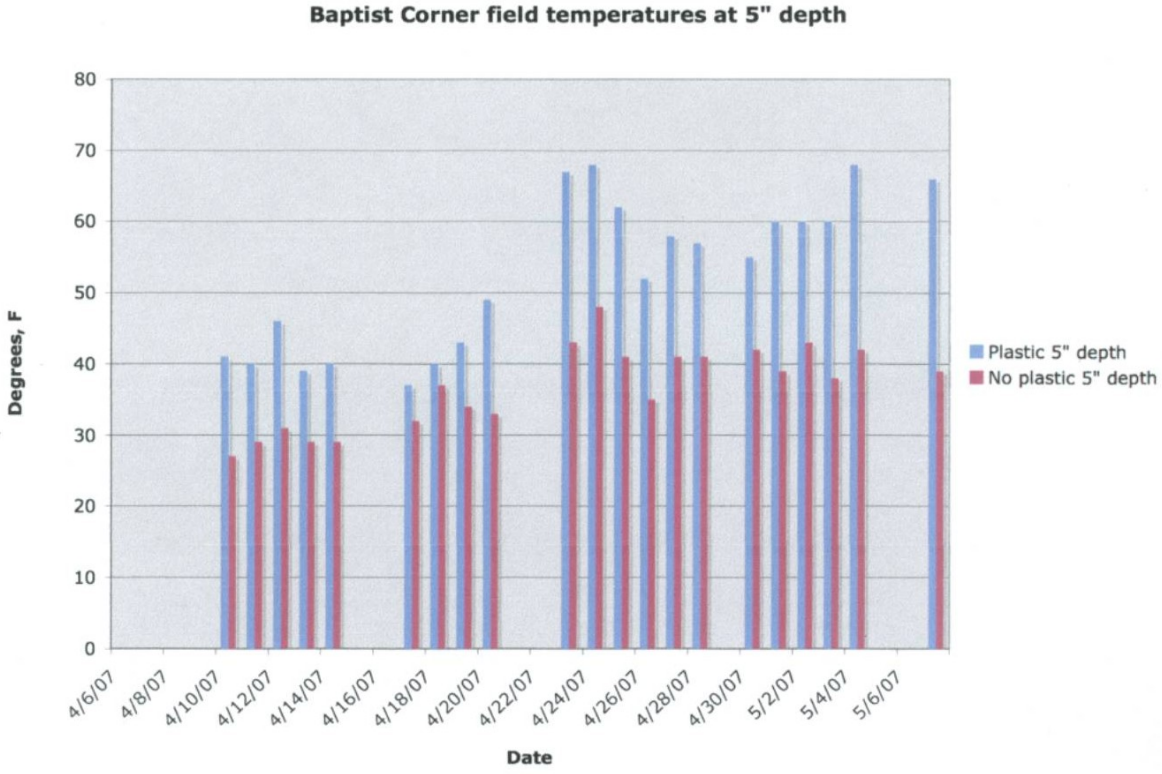
"Baptist Corner" test area.

Used Greenhouse plastic for soil warming

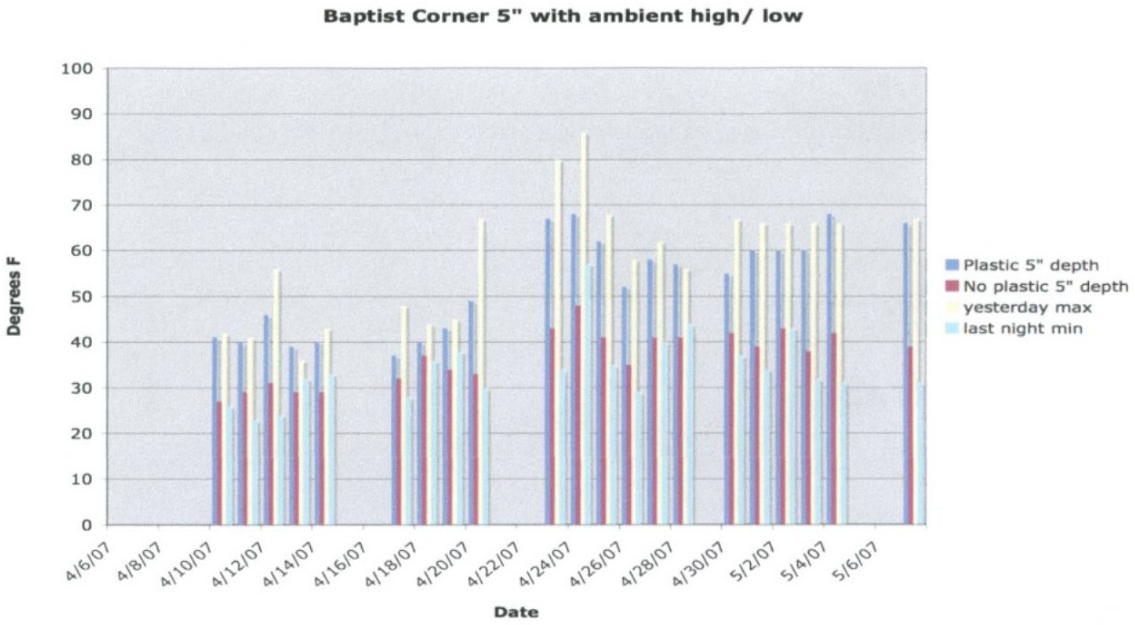
The purpose of the project was to answer three questions. First of all, does covering the soil with plastic lead to significant warming? Does this warmth remain in the soil once the plastic is removed, and what effect do mulches have on retention? And of course, what are the effects on germination, growth, and yields?

Trials were conducted in two different fields, Baptist Corner field and the Trailer Field. Results between the two fields were generally parallel. We will focus on results in the Baptist Corner field, as data there is cleaner. Plastic was laid on the 6th of April, and readings began on the 10th. It is critical to remember that all temperature readings were taken in the morning, and thereby include the moderating effect of the night air and the cold night sky. Afternoon readings under the plastic (we can thank the greenhouse effect) were wildly high.

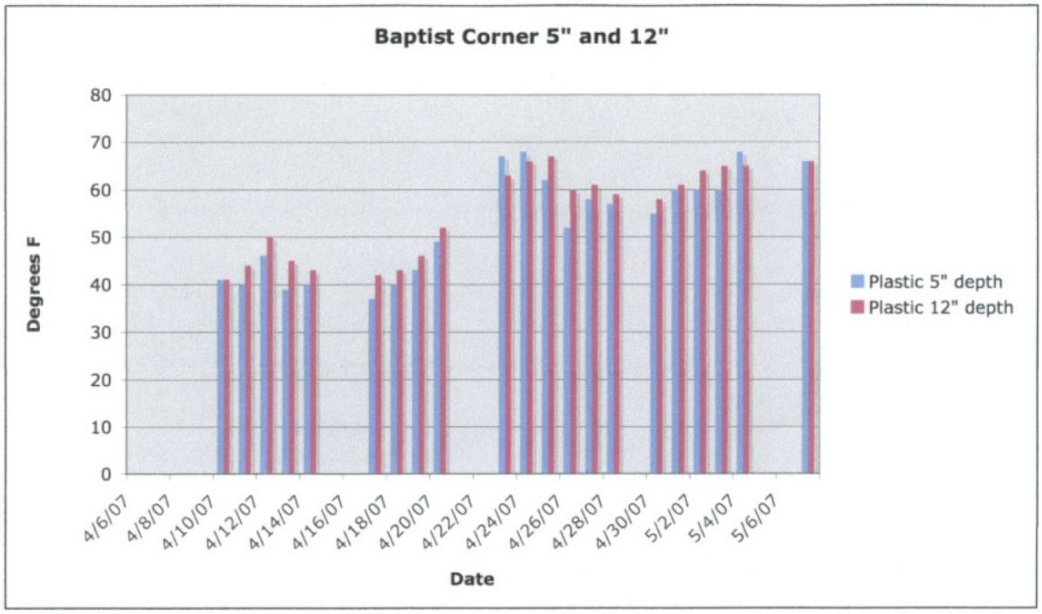
Looking at the graph below, we can see that after 4 days of sunny weather, the temperature under the plastic has already climbed 15 degrees, relative to bare soil. From the 13th through the 16th, there was a period of rain, followed by a mixture of rain and sun through the 19th. Temperatures, according, rose slowly. The 20th saw the beginning of a period of clear sunny weather, accompanied by a warming trend, in both the air and the soil. From that point onward, the difference in temperature between covered and uncovered soil grew slowly and consistently, such that it reached 24 degrees by May 7, the end of the month-long trial. At this point, the bare soil was still hovering around 40°, while the covered soil was above 60°.



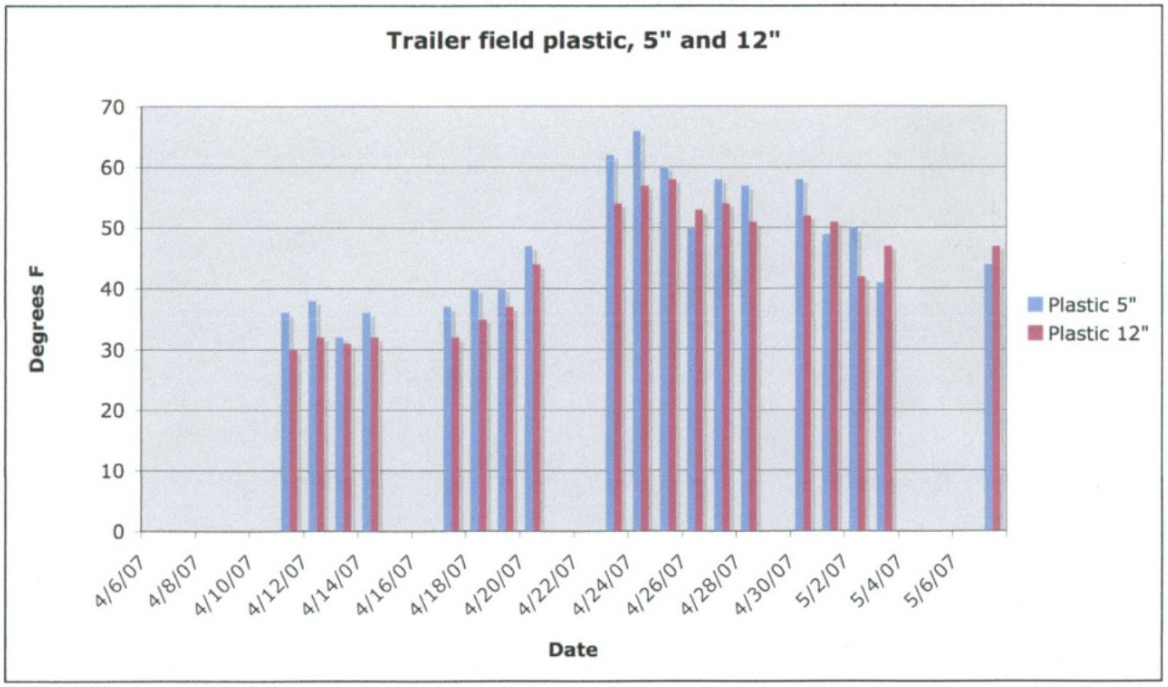
To get an overall picture of the conditions, we need to look at this same data in the context of air temperatures. In the graph below we have added overnight low temperatures and also high temperatures from the previous day. Remember- all readings were taken in the morning, and so increases in temperature in the soil correspond to insolation and air temp from the previous day. What is striking about this graph is the strong tendency of under-plastic temperatures to move in correlation to daytime highs, while the temperature of uncovered ground parallels nighttime lows.



So far, so good. Now, the correlation between soil temperatures at the 5" depth, and at 12":



Surprisingly, except during spikes of unusually warm weather (86° on the 24th of April) the soil is actually warmer at 12" than at 5". In this field, this holds true on the uncovered ground, as well. Meanwhile, in the Trailer Field, the opposite is the case:



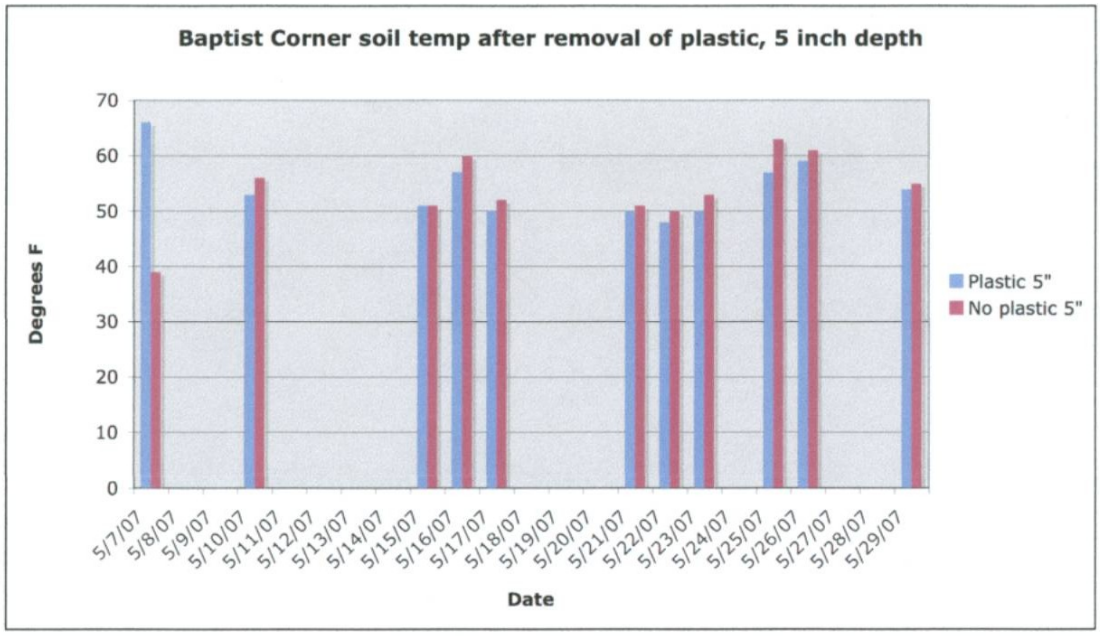
Though it is outside the scope of this project, the contrast here is interesting. The Baptist Corner field is protected from the wind by a wooded hill, and as such it holds snow. The Trailer Field is exposed along a hilltop; it is a lovely spot to spend the summer (thus the name) but in winter it's the windiest place on the farm. Snow cover is thin, and in low snow years it all blows away. This would seem to be the reason for the relative warmth at 12" in the Baptist Corner field.

20 degree difference in soil temperature at 5" depth, May 4, 2007, 3 days before removal of plastic. Difference at 12" is 18 degrees.

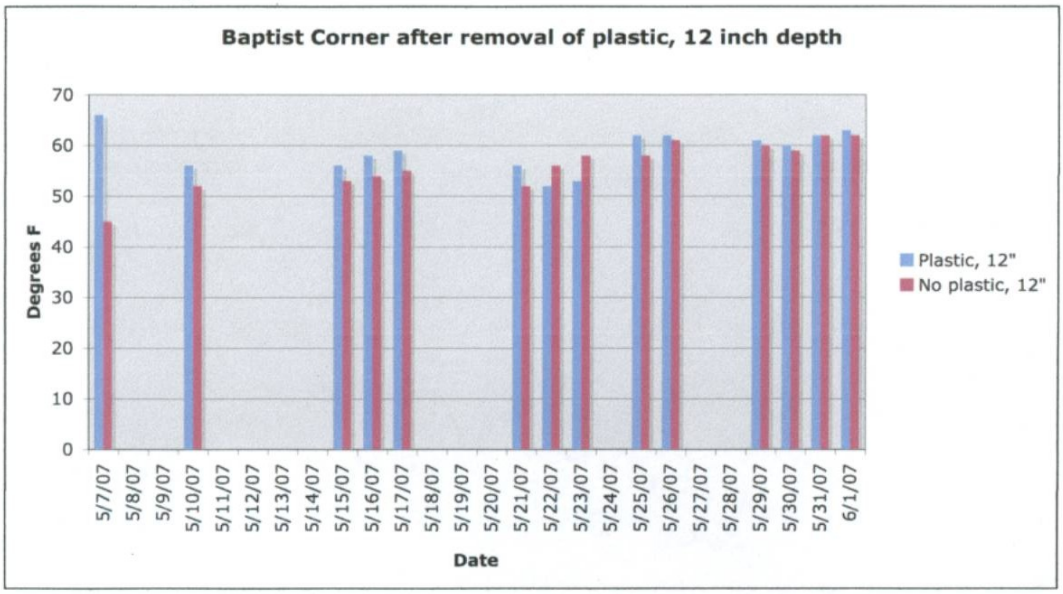
Does the warmth remain in the soil?

Disturbingly, the answer seems to be no. Left bare, the pre-warmed soil very quickly reverts to the same temperature as the uncovered soil. In the Baptist Corner field, all gains were lost after

only 5 days! The weather did turn quite warm at this point, with daytime highs in the 80's, and lows in the mid-40's, so it is hard to know whether what we are seeing is primarily a cooling of the preheated soil or a warming of the unheated soil. Please also note that by the 10th of May the unheated ground is actually reading warmer than the preheated ground. This is odd and it remains consistent for the rest of the trial; the difference is likely in the calibration of the thermometers.



At 12" the lag effect is longer; temperatures don't even out until approximately 2 weeks after the plastic is removed. But even at this depth we see a steep drop of some 10° in the first 3 days after uncovering the soil. See below:



Next, we should explain the effects of mulches on retaining heat in the previously covered soil. This was the intention of the project, and we did eventually cover portions of the test areas with both black plastic and straw mulches. But there was a problem- weeds. These trials were carried out in the spring of 2007; unfortunately in 2006 we had spread both of these fields with a

compost that turned out to be unfinished, and contained many weed seeds. The photo below shows the effects in the Baptist Corner field.

May 7, 2007. Difference in weed growth along boundary of covered, uncovered land. Minor residue to the left is remains of (formerly lush) oat cover crop after heavy grazing by deer in the fall.

Because of the need to get the weeds under control before laying plastic mulch, the Baptist Corner field was given a stale seedbed treatment for 3 weeks. By the time plastic and straw mulch were laid at the end of May, there was no difference in temperature between the formerly covered and uncovered ground.

Effects on germination, growth, and yield.

Here too, the onslaught of weeds made for a difficult comparison. After one round of cultivation the Trailer Field was planted to spring crops- salad mix, lettuce, and bok choi. No difference in growth rate was observed in the transplanted crops; approximately a week had passed by the time they were planted, and by that point the temperature in the upper portion of the soil had evened out. There seemed to be a very slight bump in germination rate for the salad mix, but by the time of harvest there was no difference in the volume or quality of the produce.

At the end of May, the Baptist Corner field was planted to longer-season crops; peppers and eggplant. Obviously, there was no difference in growth rate or yield; soil temperatures had long since leveled out. It did seem, however, that the previously covered portion of the field suffered greater damage from insects- primarily Japanese beetles. This problem manifested, strangely, in mid-summer. The (presumably) more likely scenario- increased flea beetle or other damage in the early brassica crops in the trailer field- did not occur.

Conclusion and further thoughts

It would be inaccurate to say that this project was a success. We succeeded in raising soil temperatures to an impressive degree, but with no consequent benefits in the field. The increased weed pressure led to a period of bare soil, during which the gains in temperature were

lost. There were, presumably, some longer term gains in using up a higher than usual proportion of the weed seed bank. This is a slender reward for the labor of lugging large sheets of plastic over the frozen spring fields.

Still, we can envision scenarios where this technique would be useful. The most obvious is in pre-heating soil in tomato greenhouses. We have tried this, and it works- by covering the ground two weeks before start-up, the time required to pre-warm the soil to 70° is reduced from 4-5 days to approximately 2. This is significant- during this start-up period the water heater or boiler is typically running full bore, so a 50% reduction in run time equals a 50% reduction in fuel consumption. Since the areas involved are relatively small and wind is not an issue, the return on labor is favorable.

Likewise, this technique should also be useful for soil pre-warming in unheated greenhouses and tunnels. The ground plastic, in this case, could be viewed as a second layer of glazing, albeit one employed only temporarily for the specific purpose of warming the soil. Even a few extra degrees of soil warmth at planting can be significant in an unheated house, in terms of both root growth and the soil's ability to act as a thermal battery during cold nights. If the crops were put in more or less immediately upon removal of the ground plastic, and especially if they were then protected by row cover, the losses should be significantly less than in the open field.

Heading further down the spectrum of value, we can still envision a use for the plastic in the field, under specific conditions. The farm where it could be useful would have low weed pressure (and maybe low pest pressure) and would also serve a market that paid well for early spring crops. If only light cultivation were required after removal of the plastic- such that plants could go in and row cover right on- it stands to reason that some of the Btu's expressed by that 20+ degree increase in soil temperature could be put to use.

And last, there is one mechanical benefit to covering the soil- the plastic sheds spring rain. In a wet spring, the jump provided a market gardener by a small patch of drier ground could make a real difference in early sales. Considering the new normal in weather- that every season is either too wet or too dry- this fringe benefit could turn out to be the most useful of all!

Outreach

We have done no outreach. My sense is that this project was not successful enough to merit articles or conference sessions. We have discussed the results with other Northeast farmers, and have not succeeded in generating any great interest. If the committee feels that some component of this project was successful enough to merit further dissemination, please let us know and we'll move forward.