Sustainable Agriculture Research and Education Program
Final Report for Producer Grant FNE 96-129

1. Restate the goals of your project.

The goals were three-fold:

1. To design and construct a pedal-powered drive train that, from a stationary position at the end of a raised bed, can cable-pull a tilling attachment through it, and in so doing mix in manure, compost, and other amendments;
2. to design and construct, or alternately retrofit, an appropriate tilling attachment; and
3. to test and compare this pedal-powered system to manual and gas-powered tilling, with respect to time, ease, and effectiveness of operation.

2. Update the information on your farm since you received a producer grant. Include acres farmed, crops/livestock.

In the 1997 season, we expanded our acreage. We formerly (and still do) hand-work slightly less than 1 acre of raised beds on our parcel, but beginning last season, also began to farm a neighbor's field down the road. This field is about ¼ acre, and quite flat (especially as compared to our parcel). No irrigation is available for this field. Its soil, while in generally good health, is considerably more compacted and rock-filled than those in our beds. All of our training, and most of our experience, is in raised bed growing. But in both 1997 and 1998, we are experimenting with row-cropping on this field, for crops which need more space than we can give them in our raised beds, or which in other ways are more suited to this kind of growing (corn, potatoes, etc.).

3. Who were your cooperators and what were their roles in the project?

- Bill Duesing (a farmer, activist, NOFA officer, and syndicated radio host of a program dealing with agricultural matters) provided names of contacts with information on horse-powered and historical farm implements.
- Walter Greist (another CSA farmer, in nearby North Haven, who works with tractors) did the same, and also consulted with us regarding the techniques for cultivation which he employs on his farm.
- Joel LaChance, a bike shop owner, assisted with design, modifications, technical advice, and equipment for constructing the pedal-powered drive train.
- Sylvia Dorsey, director of community gardening projects in New Haven, engaged in conversations regarding application of pedal-powered technology to local inner-city community gardens.
- Kim Stoner, entomologist at the CT Agricultural Experiment Station, assisted in locating sources for needed tilling implements.
- Ed Grant, director of an inner-city recycling firm and also Soil Conservation Commissioner for New Haven, cooperated with discussions regarding applications for inner-city uses, and in supplying some needed parts.

Additional significant cooperators not listed on our SARE application include:

- Billy Beaumont, owner and operator of Equipment Diagnosis and Repair as well as a tractor farmer in Wallingford, CT—who provided access to his microfiche library on historical farm equipment design. He also loaned some tilling equipment from his extensive collection of antique equipment;
- Henry Church, tractor farmer in Watertown, CT—who advised on horse-powered tilling and also loaned a horse-drawn single-row cultivator;
- Phil Bacon, an engineer who gave major technical and engineering support, as well as an equipment loan;
- Jim and Chris Hubbell, who loaned a small disc set from a cub tractor;
- Roger Uihlein, who assisted with design;
- Frank Cunningham, who built the pedal-powered drive train; and
- Job Ebeneezer, who sent detailed documentation of his work in India and New Mexico on applications of pedal power.

4. Tell us what you actually did in your project and how it was done.

In the terms of our goals expressed above: We accomplished our first goal, the construction of a powerful drive train that can cable-pull heavy apparatuses through the soil with minimal exertion by the cyclists operating it. We made many experiments in pursuit of our second goal, that of finding an appropriate tilling attachment which would accomplish our most labor-intensive farm task: that of mixing manure, compost, and other amendments into the raised beds. We have not yet found such an attachment. We have some leads as to how we may progress on the front of finding attachments appropriate to raised-bed cultivation. As for our third goal, we gathered some data by which to compare the pedal-powered tilling with hand-forking and rototilling.

More specifically:

We began by constructing a simple pedal-powered drive train prototype (SEE PHOTOGRAPHS 1, 2, and 5) to get a sense of the potential physical power of such a system, about which we had gathered widely varying opinions. (Some tractor farmers were adamant that it would be impossible to generate sufficient power.)

This prototype was adaptable to the rear wheel of any bicycle with a free-wheel chain sprocket. In this prototype, the rear wheel is replaced with a retrofitted boat winch with galvanized cable which turns when the rider moves the pedals. The cable on the winch is drawn out to the far end of the bed and attached to an implement. The rider sits on the bicycle seat, necessarily facing away from the bed (since the cable emanates from the rear wheel of the bike).

A two-person pedal-driven power train was then constructed (SEE PHOTOGRAPHS 3 and 4). This was made of welded tubular steel and salvaged bicycle parts. This is a dedicated power drive train which can be moved from bed to bed by 2 people (or 3, if uphill movement is required).

In the 2-person model, the riders sit side by side facing the bed. Its frame consists of 2 parallel "V"-shaped sections of steel, positioned upside down, reaching about 4 feet in height. These Vs are about 5 feet apart, and connected by several crossbars for stability, and by one

long threaded axle. From the sides of each V that are distal to the bed being worked on, two more 5-foot-long tubular steel pieces extend, parallel to and about 2' above the ground. Two riders sit on seats at the end of these steel bars and pedal on free wheel sets that are mounted on the V itself. The riders are recumbently oriented—that is, their legs are virtually parallel to the ground while pedaling. The consensus of the bike power literature we reviewed was that this is the position which enables the greatest transfer of power from rider to pedal. The riders' free wheels are both connected by looped chains to the axle. Their free wheels are offset from one another by 90 degrees, because there is a time of "dead movement" in each pedaler's cycle (when the pedals are at 12 and 6 o'clock), and with the offset, one cyclist can compensate for the other's dead time. A third free wheel on this axle is connected through a looped chain to a boat winch and cable set which is mounted to the crossbar that's on the side of the apparatus that is proximal to the bed being worked on.

In both models, the power produced by human legs is geared up or augmented owing to the differential size of the sprockets employed in the free wheels and in the boat winch itself.

Research and field visits to the farms of Walter Greist, Billy Beaumont, Henry Church, and the Hubbell family were done to establish what type of equipment might best work with pedal power for our goals. Specifically, we were looking at two questions here: what types of hardware to work the soil with (i.e., plowshares v. disks, v. harrows, etc.); and what type of carriage would work best to support this hardware as it moved down the garden bed.

We found very little consensus as to which attachments would be best, so we experimented with a wide variety. We borrowed some tools that we used as found, others that we modified specifically for pedal-powered application. Specifically, we tried 3 basic pieces of equipment:

- a 100-year-old walk-behind horse-drawn 12-inch plowshare (because it was at hand on our farm, left over from its days as a dairy farm);
- a horse-drawn single-row cultivator which has a wheel-borne carriage with a seat between its wheels for the operator—known as a "sulkie" to some farmers—that matched well with our bed widths. This carriage pulls a tool bar set that at its center has two opposing discs, and then—fanning out from there—a series of small chevron-shaped cultivator shares;
- and a small disc set from a cub tractor (discs of 9" in diameter).

We made some modifications, such as altering the angle or opposition of the discs, or replacing the discs or cultivator shares with larger versions of themselves for greater depth penetration.

In each case, we ran through various of our garden beds several times to gather information on depth and time of tilling, ease of effort for riders, impact on soil structure, effectiveness of cultivation, ease of moving and maintaining equipment, and noise and air pollution.

We also rented 2 different rear-tine 6-horsepower rototillers and tested them on 3 of our beds to assess the same factors. Specifically, we used the rototillers to turn in cover crops of winter rye on three 80-foot beds.

5. What were your findings and accomplishments? Did you have unexpected results? If so, what were they?

The one-person pedal-powered prototype was able to pull the 12-inch plowshare through previously cultivated beds. The physical exertion required was minimal with only minor heart rate elevation and rapid recovery to baseline heart rate for the several riders who tried it. Some difficulties were encountered with riders weighing less than 160 pounds. As these riders pedaled, the prototype would slowly move towards the bed. Evidently, a light rider's relative weight was insufficient compared to the combined weight of the plowshare and the load of soil being displaced. It was moderately time-consuming to fit the prototype to a bicycle. The prototype was fairly slow at moving the plowshare down the bed, although the displacement of soil was effective.

We used the plowshare with this prototype largely because it was on hand and—being relatively heavy—a good way to test the sheer power of the prototype. Its effect on the soft soil of our raised beds was to dig a foot-deep trench in the middle of the bed (SEE PHOTOGRAPH 4)—fine if you're about to plant potatoes, but not the general tool for mixing in amendments. We also were not, in the main, looking for a walk-behind tool, because the point in raised-bed cultivation is not to walk in or otherwise compress the bed soil.

More attention was given to the potential of the 2-person pedal-powered drive train—hereafter referred to as the "Cunningham" (after its builder). This unit is sturdy and does not move while pulling a heavy load through the soil. It is heavy, but can be moved and maneuvered by 2 people on the flats, and 3 people on the hills, of Mad Mares Farm.

The single-row cultivator sulkie with riding seat and steering and tool bar control levers was used extensively for testing the Cunningham. The basic design of this carriage is a good fit for pedal-powered traction on raised beds. For one, the 4-foot wheelbase fit nicely over most of our beds (which are mostly 3-3 ¼" across). Second, the levers for controlling steering and the depth of penetration of the tool bar gave the sulkie rider a good measure of control. Particularly, the sulkie rider can control the left- and right-hand sides of the tool bar independently, which means that on hilly terrains such as prevail at Mad Mares, the penetration can be controlled to be equivalent for the up- and down-hill sides of the bed. Finally, the added weight of the sulkie rider, who is positioned essentially in the air over the middle of the bed, acts as a helpful force in getting the tool bar to penetrate the bed.

In contrast, the small disc set did not penetrate very far even in well-cultivated beds, since the set itself was very lightweight, and the vector of force of the tractor pull is horizontal down the length of the bed. There was no easy way to attach "donuts" or metal weights to the disc set's tool bar to compensate for this problem.

We also tried pulling a small tool bar on which were mounted **several rotary hoes,** on the advice of tractor farmer Billy Beaumont. Again, we did not find that the hoes sunk into the soil very far, and that rather than mixing amendments into the soil, they merely kicked up a superficial amount of the bed's surface.

The one way in which the carriage design of the sulkie cultivator did not work well was that the wooden shaft that extended out in the front of it, to which horses are meant to be

yoked, was far too long for our purposes. In the end, it required 5 people to operate the pedal power and the sulkie cultivator in our trials: 2 to pedal, 1 to ride the sulkie and control the steering and tool bars, and 2 to support the 2 horse yokes and long wooden shaft so that they did not fall down onto the ground. Had we been free to modify this equipment (which was borrowed) by shortening the bar, these last 2 people would not have been necessary.

As for effectiveness and speed of tilling, when tested with the sulkie cultivator, which was the heaviest basic piece of equipment used in all of our trials, the Cunningham could pull a load considerably more rapidly than the 1-person prototype could pull the much lighter plowshare. For example, when the sulkie was equipped with its standard tool bars containing 2 12-inch discs and 4 3-inch shares, **the Cunningham pulled the sulkie through a 70-foot-long bed in less than 10 minutes.** To hand-dig the same bed, it would take us 1-2 hours. Physical exertion was minimal, with pedalers experiencing only brief heart-rate elevations (10-20 beats per minute) and rapid recovery time (2 minutes or less). The pedaling was fun and relaxing, not at all stressful. Tilling depths of 3-4 inches were reached.

The mixing in of the manure that had been applied to the beds, however, was minimal. To what we deemed an unacceptable extent—as compared to what happens when we dig the beds with forks—the manure remained on the surface of the bed. We achieve a tilling depth of much greater than 3-4 inches when forking the bed—something more on the order of 10-12 inches. We are concerned that leaving nutrient-rich amendments so much on the surface of a bed would discourage properly deep root growth in our crops.

As concerns maintenance, all that the Cunningham requires is some oiling and two types of adjustment: that of the rider's seat height, and the relative heights of the 2 Vs, for when the apparatus is being used on a slope. Both adjustments are easy to make—the Cunningham's design anticipated these needs. Its frame was built with metal sleeves, a series of bolt holes, and pegs in the right places to enable these adjustments.

Our experience with the rototillers was not encouraging. Three passes were needed merely to cover the width of each bed (in this case, 4 feet). Each pass needed to be made twice, in order for the rye to be even somewhat incorporated. The rye was turned in 2-4 inches deep, with some of the rye still showing. In order to transplant into these beds, 3 weeks later, we still needed to work them over with forks and rakes to remove clumps of vegetation, and found many areas that seemed to have been missed by the rototiller operator. It took about ½ hour for the rototiller to till each bed. The tilling was physically strenuous, especially due to the terraced nature of the beds. The rototillers pulled strongly downhill, especially at the lowest edge of the bed—and took a lot of soil with them. It took 4 hours of work with spades to restore the beds to their original shape.

The noise pollution with the rototillers was less than farmworkers had expected, roughly equal to a lawn mower. Nearby workers could hear each other, but little else (not the birds, for example!). Spilling of oil from the tiller was noted in the beds.

Finally, both rototillers broke down in the course of their use, and could not be repaired on-farm, which necessitated our completing the tilling by hand.

We experienced one very unexpected circumstance which impeded our work. It has been difficult for us, in our interviews with tractor farmers, to gain a consensual understanding as to which attachments work best, and how deeply they work, and whether this depth would be effective in a raised-bed intensive method such as we currently rely on. The lack of clear consensus has impeded our search for appropriate attachments. All 3 partners of the farm came to the land with experience only in hand-worked raised bed growing, which emphasizes the importance of cultivating beds by hand to a depth of at least 1 foot. We have a strong limitation of understanding both as to how deeply tractor farmers have traditionally worked the soil, and as to which tractor attachments they have used for that purpose. This limitation was sadly not much expanded during the course of our interviews with tractor farmers.

6. Is there any site-specific information relevant to your project or the results?

The following factors (which consist varyingly of circumstances, values, and limitations) are relevant to our projects and results: the terrain of our farm, our values concerning work environment, our training with respect to soil cultivation methods, and our experience interviewing farmers as to the best way to work amendments into a field. To elaborate:

Mad Mares Farm raises produce for approximately 100 households on less than an acre of land, most of which is sloped. The farm's history is as a dairy farm. Its slope and native rockiness is such that it would not be suitable or even safe to cultivate it by tractor for large-scale vegetable production. Walk-behind tractors or rototillers would be more feasible, but here other objections common to the partners come into play: we like to minimize our reliance on non-renewable resources (i.e., without relying on petroleum-powered machines); we like to work in the absence of noise pollution; we are averse to the regular use of the rototiller owing to its tendency to pulverize soil, etc.

As detailed in the answer to the preceding question, none of the partners nor workers on the farm have had any experience working with large mechanized tractors. Nor did we find it possible to obtain a clear sense from interviewing tractor farmers of how they work amendments into their fields, or how deeply they do so. If at least one of us had this kind of farming experience, we'd have a much clearer sense of where to go in our search for attachments.

Additionally, most of the attachments currently available for traction across fields are configured for row-cropping or narrow-bed cropping in fields, rather than for 3-to-4-foot wide raised beds.

7. What were your economic findings? (If relevant to your project)

Since we have not yet found an attachment that works well to accomplish our most labor-intensive task—the mixing in of manure and compost on our raised beds—the impact of the pedal-powered drive train on the economics of the farm is as yet negligible. There are 2 possibilities, however, as we look to the future:

1. We will find such an attachment (see next section) for use on the raised beds;

2. We will increasingly turn to row-cropping, or otherwise find that shallower cultivation "works" for us, in which case either the plowshare attachment (for rowcropping) or something like the sulkie, will suffice.

In either event, the time saved as well as the physical stress reduction that we experience will have a significant economic impact on the farm. We will either be able to cultivate more land in the same amount of time, or work the same amount of land in less time, in both cases with less physical stress. And in either way, we will get more return for our labor.

8. Have the results from your project generated new ideas about what is needed to solve the problem you were working on? What would be the next step?

To date the project has not succeeded in finding attachments well-suited to using pedal-powered traction on raised beds. The discs, shares, and rotary hoes tested did not effectively incorporate manure or compost into the beds, at least according to our standards of hand-worked raised-bed growing.

The next steps are as follows:

- Develop a better understanding of how tractor farmers use discs and shares, and possibly harrows, to their satisfaction for mixing in amendments. It may be that shallower mixing is acceptable. We noted in the early spring of 1998, when a fellow local farmer used his tractor and disc sets to turn in the rye on our row-cropped field, that his discs did not work the soil any deeper than 4 inches.
- Visit J. Arnold Voehringer, a former employer of Rodale (see section 11), currently associated with the New England Small Farm Institute, who has some attachments that he is optimistic might work with our drive train.

9. Will you continue to use the practice you investigated? Why or why not?

At present we do not use the Cunningham pedal-powered train, owing to the lack of a suitable attachment. Also at work here is the "bird in hand is worth two in the bush" factor: we are generally so pressed for time, that it has been hard to make more time to travel and search for attachments or otherwise do the research outlined above, when we know that hand-forking, while stressful and time-consuming, will at least get the job done.

To the extent that the "next steps" outlined above can be accomplished during our limited discretionary time, pedal-powered traction may yet come to play the significant role at our farm that it presently does not. We will keep you informed as any progress arises.

10. What do you tell other producers about your project and the results?

We generally tell other producers that we have created a powerful drive train, seemingly equivalent to the power of two horses, but have yet to find appropriate attachments for working raised beds. In the terms of an old fairy-tale: that we are like the prince looking for Cinderella: we have the shoe, now all we need is the princess. Most of the growers in our area are tractor farmers and receive the information but are not looking to do anything with it. We occasionally get a more proactive response (see question 11). In general, it is not likely that we will get other growers interested in using pedal power until we can work out some suitable attachments.

11. Explain what you did in your outreach program? Please send a copy of any articles written about your project.

The Cunningham was displayed and demonstrated at Mad Mares Farm in two fairs open to the public, one in October of 1996, one in October of 1997. Both fairs were attended by about 100 people, including several bed growers.

We also attempted to get follow-on funding for the project, having been solicited through a personal connection at the Lindbergh Foundation. We were rejected for that funding, but forwarded copies of our proposal to several of our collaborators, including Bill Duesing, Job Ebeneezer in New Mexico, and Dan Gunther in Wisconsin. A copy of our Lindbergh proposal is enclosed.

We also attended a conference specifically for Community-Supported Agriculture projects (CSAs) in November of 1997, at which we networked with other farmers concerning the project. One farmer who gave a presentation on farm equipment adapted to CSA growing turned out to have been involved in Rodale's own pedal-power research, back in the 1970s. That research yielded the book *Pedal Power*, one of our inspirations. We had already heard that Rodale had ceased this research before its fruition (they too developed a power train, and were beginining to work on the question of attachments) owing not to any factors inherent to the project but rather to a shift in Rodale's management, and a consequent shift in its funding priorities. This farmer, J. Arnold Voehringer, heard with eagerness of our progress and invited us to come visit his farm. He has some attachments that he was optimistic would work well with our drive train.

12. Please include 2-3 slides or photographs of your project. Please include clear information describing the slides or photographs.

Please see the enclosed sheet of Xerox reproductions of photographs. These photographs are numbered and explained in the previous sections of this report.