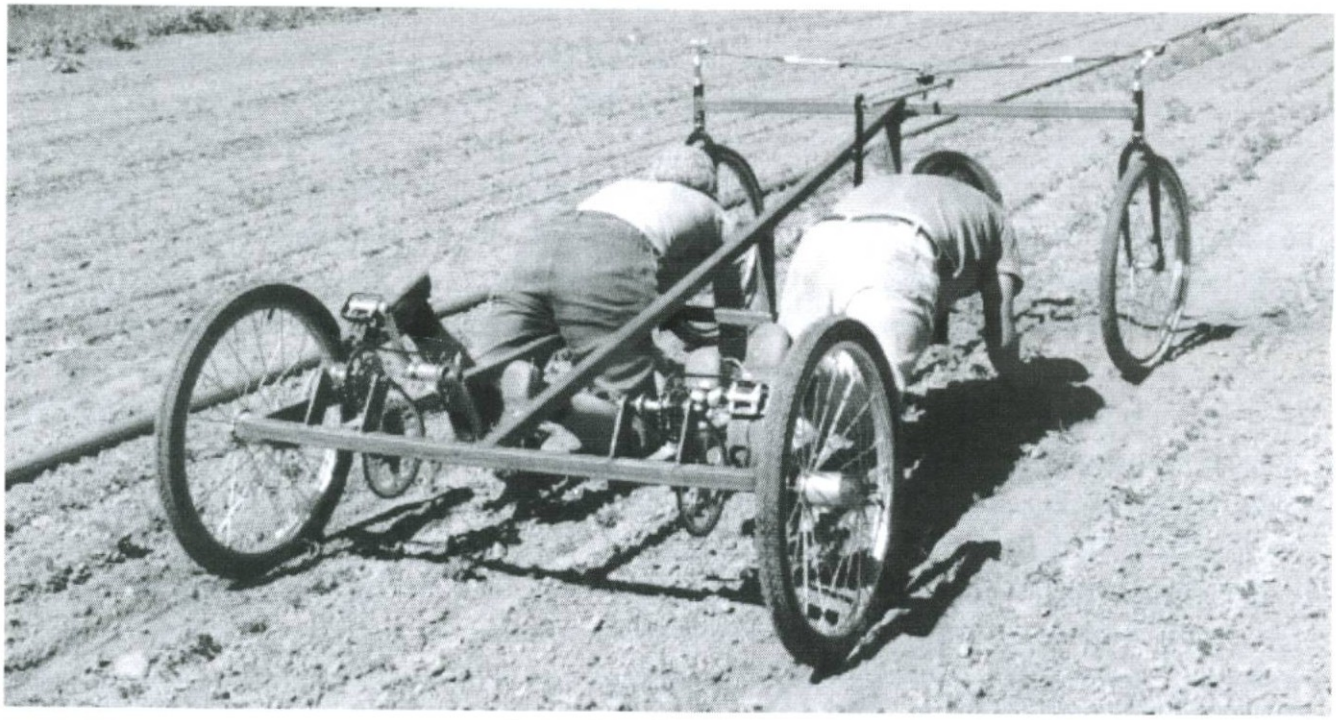
# INTERIM REPORT for SARE-FNE07-603

**Building and Evaluating a Pedal Powered Prone Workstation and Row Crop Cultivation Tool.**



**R.Rock and A.Crawford**

**Request to extend final reporting to end of 2008 season so that transplanting and cultivation trials can be completed:**

We first ask to extend our reporting period through next season because we still have more trials to perform as part of the grant. We under-estimated the time it would take us to build the vehicle as well as over-estimated the speed of the distribution of funds to begin work. Originally we had hoped to complete the construction of the vehicle before the needs of the farm became too pressing. Work on the grant slowed as the needs of the farm outstripped our available time. Furthermore, we needed a partial re-drafting of our design because of delays with a machinist we were working with. The result was that the vehicle was several months late in being ready for trials.

**Thanks:**

Rob and I would like to thank SARE Northeast for large portions of the funding for this project, Ron Hernandez of Stray Cat Farm for generous use of his welding equipment, Arethusa Farm for the beds used thus far in the trials, The staff of the Old Spokes Home for a wealth of ideas and a free used bicycle part here and there, and all of the Intervale farms for their encouragement, interest, and patience while we were building the prototype in and around the farmer barn.

**The Vehicle:**

The prone weeder is essentially a quadracycle, or four wheeled bicycle, with a redesigned frame. The design positions two people side-by-side, who would ordinarily be crawling on their hands and knees across from each other. The vehicle roughly resembles a massage table with head rests (without the restriction of their field of view), so that they are looking directly at the ground ahead of them. Each rider has their feet on a set of bicycle pedals, and turns a crank which transmits power to a rear wheel, one for each rider. In this position, all of the crop rows in the bed are within reach, the head and back are rested in a comfortable position, and both hands are free to work.

We did have a little help (and inspiration) from a book written by a very funny and eccentric bike builder calling himself the "Atomic Zombie". Some of the basic concepts for our machine's transmission were roughly adapted from one of his designs, but perhaps more importantly we were really encouraged by a number of his designs which he assures his readers he builds out of scrap metal and junked bikes in a very primitive welding shop. Some of his tutorials may be found at www.atomiczombie.com. We used only the most basic metal working tools, and the skills required for the project could be easily obtained from a night class at an area vocational school, with the help of a little bit of practice. Using the bare minimum of tools, a similar vehicle could be built using a drill press, an angle grinder, a sturdy vise, a 220V arc (or "stick") welder, as well as a few of the basic hand tools of the metal shop such as a tap and die set and files. We originally had planned to have some parts machined, but due to delays at the machine shop, we eventually went ahead and made our own parts from existing used bicycle components.

The design phase was fairly easy compared to the construction. It was probably late in August once it was actually completed and ready for field testing. (Note: When we suggest in the report that the vehicle has been "completed", keep in mind that this word is used rather loosely. Whenever you develop a prototype, it quickly becomes clear that there are always adjustments, revisions, and improvements that can be made, even when the prototype is fully operable. (Some of the challenge of developing a prototype is then determining when it no longer requires investment of further resources!) Some of the best advice we could give to folks hoping to develop a new tool or a prototype is to start as early as you can, and as much as possible keep the construction phase from dragging out into the growing season. There is a period of time between learning that you have been awarded grant funding and the actual moment when you receive the funds where you may be unable to proceed, but if you have any cash on hand whatsoever it would be wise to accomplish as much as possible.

**Summary:**

The goal of our project was to assess the viability of using human/bicycle powered vehicles to accomplish a number of tasks found in a vegetable row-cropping system. The project was chiefly a collaboration between Andrew Crawford and Rob Rock, two organic vegetable farmers working for Arethusa Collective Farm located on the Intervale in Burlington, Vermont. The farm cultivates roughly 14 acres, growing a variety of market garden crops for the Saturday Farmer's Market in Burlington, but realizes the greater part of its revenue from the wholesale of mesclun mix, carrots, eggplants, and hoop

house tomatoes to area restaraunts and grocers. During the last year, with the use of SARE funds, we designed, built, and tested what we have descriptively called a "two person pedal powered prone workstation". We anticipated this vehicle would realize gains in efficiency, limit exposure to physically painful and damaging hand work for the farmer or farmworker. We also anticipated that it would save farmers the most money as a tool to assist with hand weeding, transplanting, and cultivation. Here are the preliminary results.

**Hand Weeding Trials:**

Relative efficiency mesurements of prone weeding was made in a series of 14 time-based trials to assure some level of reproducability. In each trial (approx. 400' bed), prone or hand weeding was measured in total labor minutes per bedfoot (min./bed-ft.), accomplished through the use of a stopwatch and a measuring wheel to verify bed length before the trial. all beds were 56" wide (wheel track centers). The hand weeding for comparative trials occurred on the same date, on an adjacent bed of the same succession of the same crop. Once again total labor minutes per bedfoot (min./bed-ft.) was recorded. This provided control for variations in weather, weed pressure, and soil conditions. Each person on the prone platform participated in both handweeding and prone trials to control for variations in personal weeding speed. The order of trials within the workday was alternated to make an effort to control for fatigue levels. Subjective comfort levels were ascertained by noting the general feeling of the weeders at the end of each bed. Equal numbers of rows were weeded in crawling and prone positions for each bed. The crop being hand weeded was baby lettuce and should be similar to any other closely seeded 3-row crop. For each trial, beds had identical numbers of rows and all rows were completed in each trial. All visible weeds were removed. All beds had been cultivated once previously with a basket weeder mounted on a Tuff-Bilt cultivating tractor, removing most of the out-of-row weeds.

Given the contols above and a particular weed density, the weeding times for a particular method (prone, crawling) should be consistent. We assumed a gaussian distribution of weeding time measurements, following these general observations: If weed pressure and the number of weeds were low in particular beds, hand weeding for those beds was less likely to be considered as a time-efficient task on the farm. Similarly, if weed pressure and or the number of weeds were too high, weeding would incur an unacceptable cost for preserving the crop, Thus, in our minds, there was the greatest probablility of hand weeding taking place at moderate weed pressure and weed densities, with decreased incentives for farmers to engage in handweeding at the extremes of weed pressure and weed count. The one exception to this assertion is what is sometimes referred to as "pulling trees", where farmers or farm-workers pull several large weeds from a maturing crop, ususally where there is an opportunity to remove those weeds that will soon go to seed and consequently have a negative impact on weed pressure in that area. Because this task can be completed easily while simply walking down the bed, there would be no point in using the prone workstation for such a job, as the prone worksatation is not intended to travel much faster than that speed, and walking is not nearly as ergonomically stressful as weeding on hands and knees.

For our hand-weeding trials, we saw an average 28% decrease in the time spent per bedfoot hand-weeding a 3 row closely planted crop (in this case all the trials were baby lettuce) compared with crawling along the ground (hands and knees). This was equivalent to an average time savings of 19.7 minutes on a

400 foot bed. The standard deviation of the mean is equivalent to 7 minutes on a 400 ft bed. The 65% confidence interval is 13.7 min to 26.7 min saved per 400' bed. The 95% confidence interval is 5.7 min to 33.7 min saved per 400' bed. As weed density on the bed became high, the time savings using the prone workstation became low as the benefit of simpler mobility on the prone workstation was lost because the number of weeds necessitated a speed similar to that of crawling on hands and knees. We saw the largest time savings when weed density was moderate to low, which capitalized on the added mobility of the workstation. We attribute the remainder of the difference to the use of both hands for weeding, Weeding was consistently described in anecdotal accounts as "far more comfortable" on the prone work platform than on hands and knees. We consider this an effective vehicle for handweeding.

**Transplanting Trials:**

We assumed that the power output requirements for transplanting would be very similar to that of hand weeding, and thus far we believe this will be true, and that the vehicle will prove to be at least somewhat useful for transplanting. The anecdotal findings for transplanting rates are at this point inconclusive, sometimes it is faster than hand planting, and sometimes it is slower. All of our hand transplanting on Arethusa Farm takes place in teams of several people -- at least two, and sometimes even 4 or more workers. We often have people dropping out transplants at the proper spacing on the ground and others planting the transplants, two people on each of three rows. The speed of this work is actually quite fast. Since the vehicle is limited to two riders, and only two were available during the trial, we were doing work that would usually be done by 4 to 6 people. We did the anecdotal tests while planting garlic, and found a few key issues that will be addressed this spring. The postioning of the crates on the vehicle in which we had the garlic cloves were both too deep, and located too close to the soil, which obstructed or obscured our view of the dibbles as they came into view, and sometimes resulted in wasted time looking for where to plant the garlic cloves. On a positive note, planting the garlic cloves that had already been layed out on the ground at proper spacing ahead of us was extremely fast, as we were able to maintain a faster speed moving over the bed with the prone workstation.

**Cultivation Trials:**

The anecdotal findings for cultivation are that the vehicle can do light cultivation in-between rows (with wheelhoe or similar implements) in our sandy loam, even with just one rider powering it. Using co-linear hoe blades situated at 1-2" below the top of the soil, we were able to breakup and uproot small (2" tall and smaller) weeds. Anecdotally, it seems as though it is possible to cultivate in very sandy soil using bicycle power alone, although we're not sure yet how long it could be sustained (before we get too tired). In the following year we plan on performing the cultivation trials and constructing a few simple tools which will mount onto the vehicle, including a whole-bed stale seeder attachment, and a toolbar for mounting shufflehoe and co-linear blades.

**In the Future and Other Observations...**

We will be doing more trials with transplanting, cultivation, as well as tests of the vehicle's power through next season. We also hope make additional improvements in the ergonomics of the vehicle as well. In our grant we proposed comparing the efficacy of our quadracycle with an actual small cultivating tractor such as a Tuff-Bilt or an Allis Chalmers G. As news of our research has spread, some of the folks who have contacted us were in fact interested in exactly this aspect of bicycle power on the farm, wishing themselves to build a quadracycle to replace small cultivating tractors. The chief concern with human-powered cultivation is the amount of force needed to draw tools through the soil. The site which we work on, the Intervale, is flat, sandy river-bottom soil, ideal for cultivating with low horsepower inputs.

The machine best suited to accomplish this feat may be, we feel, something entirely different from where our prone workstation design has ended up. We have imagined, based on our work this past season with pedal-power in the field, that such a vehicle may require the addition of electric assist to human power, possibly with a photovoltaic shade, to supply the required power output over a sustained period of time. Such a vehicle could be tooled up to sweep a crop, stale a seedbed, or perhaps even be outfitted with some variation of the Buddingh basket weeder. It could also serve as a small Un-interruptable Power Supply (UPS) out in the field with just slightly more equipment on board.

It stands to reason that for there to be comparable efficiencies in person-hours between human-powered and tractor-powered cultivation, the vehicle must be designed for use by a single operator and would likely resemble an Allis-Chalmers G cultivating tractor in appearance and versatility.