Tillers'

Tech*Guide*

Themi-Tillers Manual Hay Baler

by Richard Roosenberg and Janelle Wheelock

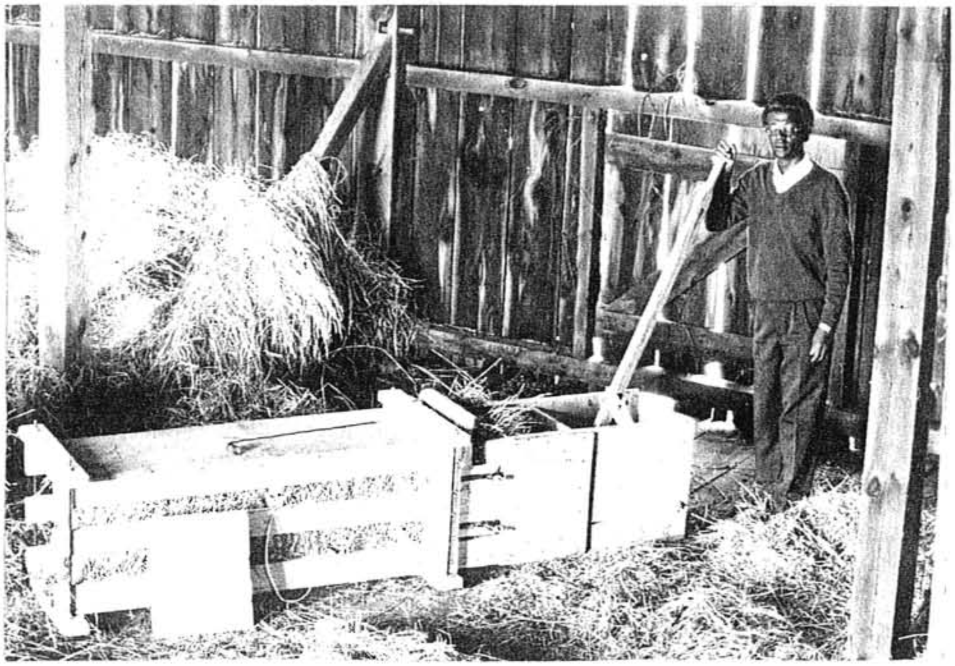

***FIGURE 1:** Walter Muro tries the prototype hand-powered hay press in Tillers' hayloft.*

Acknowledgements

Special credit must go to Walter Muro for his perspective on the need for balers. At that time he worked for a company called Themi Farm Implements, Arusha, Tanzania. David Kramer of Tillers drafted the plans and Debra Reich drew the perspective drawings. Please send comments to: TILLERS International, 10515 East OP Avenue, Scotts, Michigan 490?8 USA.

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The Challenge

Walter Muro, one of several owners of Themi Farm Implements in Arusha, arrived at Tillers looking for "new" designs of farm tools which were affordable and appropriate for the resources available to farmers and implement makers in Tanzania. He told us of the need for small hand-powered balers. His group had orders for several. They were experimenting with a few designs but were not satisfied.

Initially we questioned the need for baling hay at all, especially with the labor required to operate a hand-powered press. We recounted how American farms used loose hay to feed their cattle until the arrival of the mechanically powered baler in the

1940s. While animal-powered balers existed prior to that time, their use was largely limited to preparing some hay for sale in the urban market -- for use by city horse owners. In that case the transportation and marketing advantages of bales justified the added efforts required to press hay into bales. Animal-powered balers were advertised as pressing 6 to 8 tons per day.

Walter Muro, bright and sensitive engineer, was quick to respond to our hesitation. He explained that dairies in Tanzania are emerging in a pattern more like we described the historical US carriage horse market than that of the US dairy industry. The tropical heat and lack of rural refrigeration has lead to the movement of small commercial dairies to the fringes of cities. This permits them to sell their milk immediately and fresh without complications of refrigerated storage. Rather than requiring the transport of rapidly perishable milk, this system transports the much less perishable hay. It is currently being transported in loosely tied bundles. However, in this cumbersome and bulky state, it is difficult to find commercial truckers to haul it at reasonable rates. Bales would be much faster to load and would allow heavier and thus more valuable loads. Bales could also lend themselves to the development of a standardized size and weight for market purposes.

The circumstances developing in Tanzania clearly suggested greater advantages to baling than existed for early American dairies. The advantages of reduced storage space and ease of handling extend beyond transport to dairy operations as well. Where repeated handling is required, bales can retain more of the nutritious leaves. Further, compressing hay into tight bales keeps out air and reduces decomposition and evaporative loss of nutrients.

Having agreed to the advantages of baling in Tanzania, we had to find out what technical constraints applied and what resources were available. Walter Muro's discussions with dairies had convinced him that the cost of balers must be kept under $70 US. That is about 1% of the cost of a small modern baler. Themi had not explored the rate of production (tons of hay baled per day) required to make the baler economical, but the economic situation in Tanzania suggests that the cost of labor is low enough to make even slow production profitable.

Ideally we would like a greater knowledge of the local situation before selecting from optional solutions or designing adaptations. But we know that most small rural enterprises such as Themi and even PVOs such as Tillers must act under limited resources. We probe nonetheless for indicators of: rural labor costs for baling, conflicting farm tasks, the rural price of loose hay per bundle and weight, price of bales, price of transport for each, and the price of each at urban hay markets. From such data the available margin to be divided among rural hay sellers, transporters, and urban dairies can be calculated. This gives some idea of the payback possible from a farmers investment. Knowing that helps in deciding manufacturing and materials limitations.

Walter Muro said wood is available from local sources and is much less expensive than metals. Accordingly, his experimental designs were made largely from wood. Skilled artisans are available at about $25 US per month. This low cost for skilled labor suggests that labor-intensive manufacturing techniques should be favored over investments of scarce capital in labor saving production machinery.

The primary design with which Themi had been experimenting included a compression box with a door on the exit end and a hand-powered plunger on the entrance end. It pressed hay in one bale batches. The most frustrating problem to Walter Muro with this design was its failure to keep the hay from springing back each time the plunger was pulled back to add more hay. Their experimentation pointed out basic challenges in baler design.

We knew where there were potential appropriate solutions and took Walter Muro to the Abbey Collection where we explored the design of a 1920s McCormick International animal-powered baler and an Ann Arbor stationary engine powered model. They had most of the essential features of modern balers without the confusing complications of pick-up heads, knotters, etc, of the models currently used. We had field tested the McCormick model and we knew they

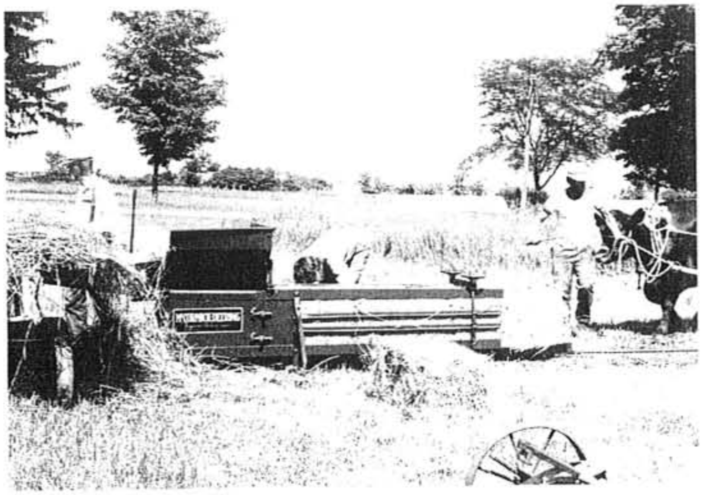

FIGURE 2: Field testing a 1920s McCormick animal-powered restored by Carroll Abbey.

had solved the challenges frustrating Themi Farm Implements (Figure 2).

Essential Design Elements

From the historical balers, three design concepts seemed most critical to the success of low-cost manual balers. While increasing efficiency substantially, these concepts can be implemented at very low cost.

First, to keep the hay from springing back from the compression chamber when the plunger was withdrawn, the early balers used "**dogs**," a set of one-way ratchets (Figure 3). Two of these were placed on each side of the compression chamber at the plunger end. Toward the plunger they have a 45 degree angled face and a 90 degree, or perpendicular face, toward the compression chamber. Each dog is spring-loaded and extends about 1 inch (25mm) into the compression chamber near the end of the plunger's stroke. As the plunger presses hay into the compression chamber, it swings the dogs out against the springs as the hay advances on the angled faces of the dogs. Once the plunger passes the dogs, they spring back into the chamber with their perpendicular faces toward the hay now in the compression chamber. The edges of the plunger have notches which permits it to return over the dogs. As the hay, however, attempts to spring back, it hits the perpendicular faces of the dogs and is

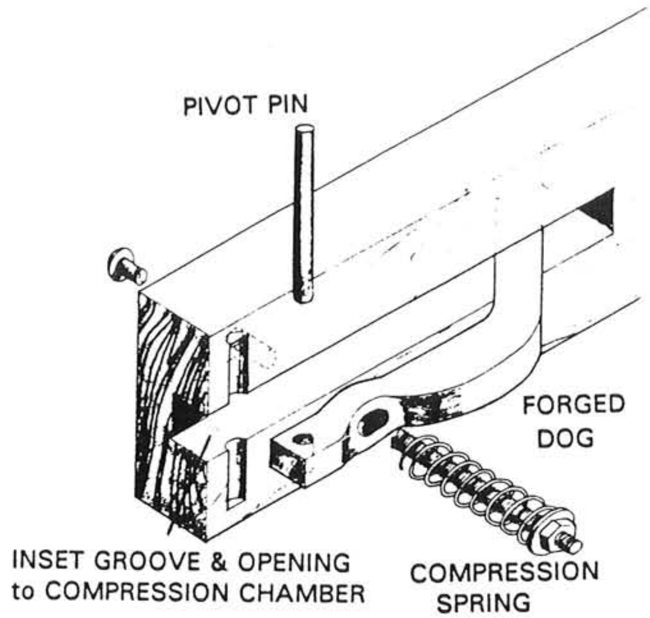

FIGURE 3: An exploded view of the "dog" mechanism for holding hay in its compressed position while the plunger is pulled back for added hay (Debra Reich, 12/92)

stopped. From the chamber side the force of the hay cannot swing the dogs outward to so it can spring backward. Thus, hay can be added to the chamber in repeated small amounts, or flakes, to create bales in a continuous operation.

Secondly, a **tapered compression chamber** permits a continuous flow of hay. This provides a more consistent resistance against each press of the plunger than a batch system with a door on the far end. The open-ended chamber also eliminates the need to interrupt the baling process to remove each bale. With that system the first additions of hay after removing a bale meet very little resistance and thus are looser than the last additions of hay. With a tapered chamber the hay is being forced into an increasingly narrow opening as it moves through the chamber. Once the chamber is full, the resistance stabilizes as hay flows through. Most balers adjust the resistance with vertical threaded rods at the end of the chamber. Tightening the nuts on these rods narrows the exit of the chamber and increases resistance. This added resistance packs the hay more tightly and increases the tension on the twine or wire used to tie the bales. The ties are placed around the bales as they move through the compression chamber.

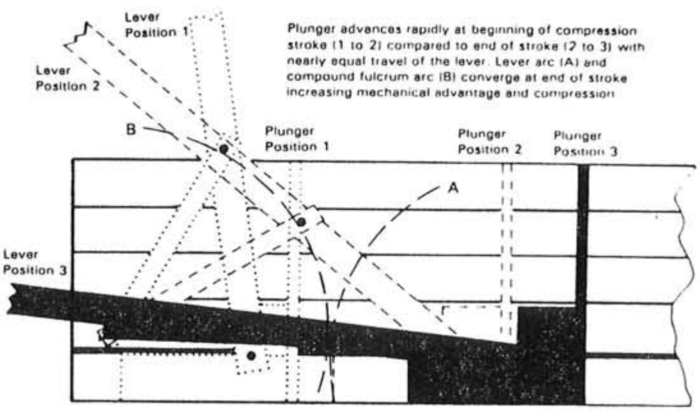

***FIGURE 4:** Drawing of the mechanical affects of the compound leverage system (Richard Roosenberg, 12/92)*

A third design essential is **compound leverage** to increase the mechanical advantage of the operator at the final threshold of each stroke (Figure 4). Modern balers use a pitman to power the plunger. The pitman also concentrates the mechanical advantage at the end of the compression stroke. At the beginning of the stroke the loose hay is fluffy. The force required to move the plunger increases as it moves toward the compression chamber. By hinging the lever on 2 angled braces, we increase the mechanical advantage as the lever is pushed downward. At the beginning of the stroke the lever handle travels 3/4 inches (19mm) for 1 inch (25mm) of plunger movement. Near the end of the compression stroke, the handle travels 12 inches (300mm) for the last 1 inch (25mm) of plunger movement. The handle travels 6 inches (150mm) for the second to last inch of plunger movement. These ratios (minus friction) determine the mechanical advantage and mean that a person weighing 183 pounds (83 kg) could put one metric ton of pressure against the hay through the plunger at the end of its stroke. However, the face of the plunger (14 x 18 inches) (350 x 450mm) is 252 inches^2 (1575 cm^2) so the pressure per square inch is about 8 pounds (.57 kg per cm^2).

Other important features were the **dividing boards** (shown on plans as **spacer boards**) and **plunger guides**. The dividing boards serve to separate bales within the compression chamber. Grooves left in the faces of the boards permit twine or wire to be strung through the baler so bales can be encircled and tied while in the compression chamber. The dividing boards are spaced at the desired length of bale. The openings on the side of the compression chamber are long enough to permit access to two dividing boards and thus to circle a bale with twine or wire. The twine seats into the sides of bales better when the grooves in the dividing boards are lined up with the dogs. The dogs scratch indentations in the sides of the bales which help hold the twine in place.

Plunger guides are a set of 2 steel edges which keep the plunger face stable. They slide in tracks, or spaces, in the sides of the baler and keep the face of the plunger perpendicular to the bottom of the baler. As loose hay is fed into the baler, it is usually pushed to the bottom of the chamber. This tends to create greater resistance at the bottom of the plunger and without glides would push the bottom back.

These concepts were so attractive and promising to Walter Muro, who is a very talented and critical engineer, that he called his partners at Themi and urged them to hold work on the old design for a couple weeks until he got back with a new design. Seeing his enthusiasm and designing on his reactions, we offered to build a quick prototype to test and refine the design concepts before his return to Tanzania.

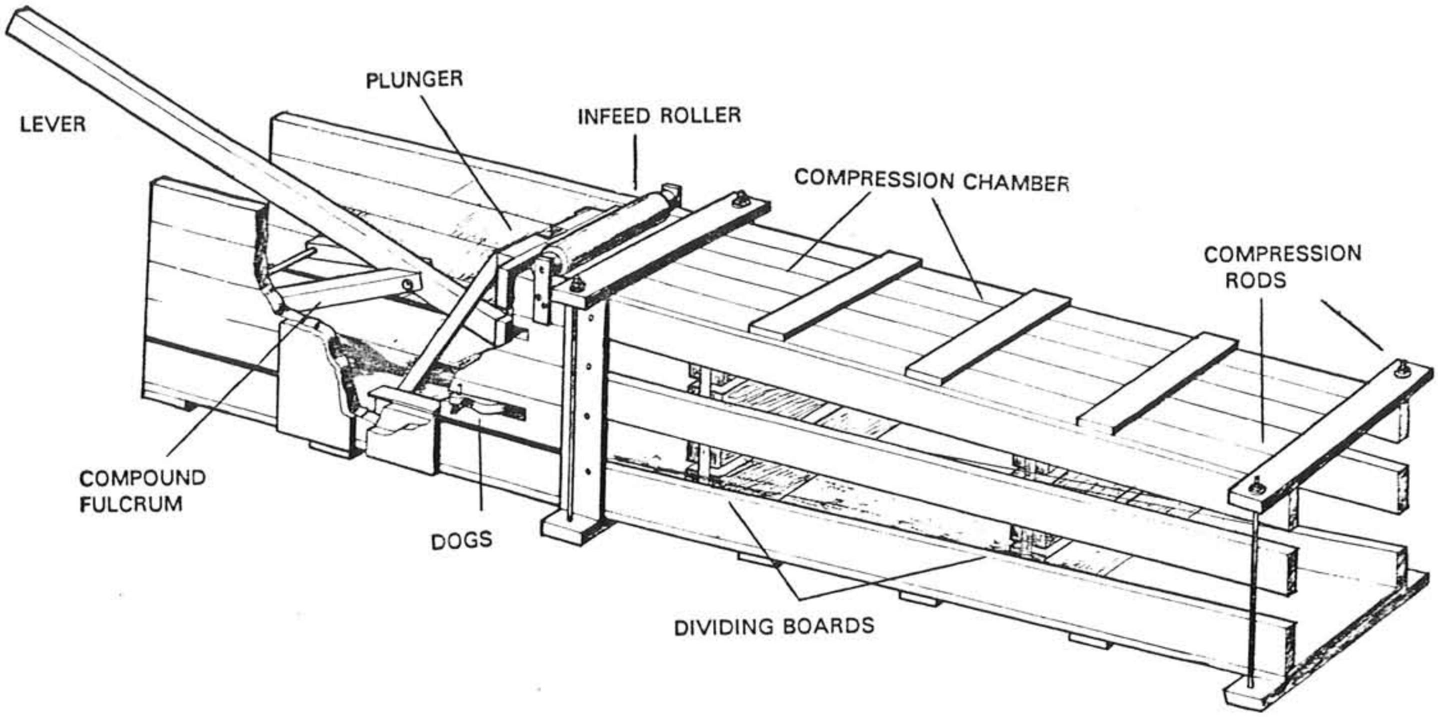

***FIGURE 5:** Perspective drawing of the manual baler with a cut-away showing the compound lever that powers the plunger. (Debra Reich, 11/92)*

Construction Suggestions

Following Walter Muro's advice that wood is less expensive than metal in Tanzania, we laid out plans for a baler framed in a wooden box with interior dimensions of 14 x 18 x 96 inches (350 x 450 x 2400mm)(Figure 5). The first two measurements are the traditional height and width of bales. The third was a common length of wood available. Available resources always dictate construction techniques and materials. We also wanted the baler to be small enough to be carried short distances or loaded onto carts by two people.

The top of the baler needs to flex over the compression chamber to accommodate the adjustment of the compression rods. Thus, the horizontal boards at the top and bottom of the sides must be narrow enough to allow bending. We used material 3.5 inches (88mm) high. The compression adjustment rods can be cut from 1/2 inch (13mm) dia mild steel rods and threaded on each end. Dies are needed for the threading. To permit adequate adjustment, the threads should extend some distance on the top ends of the rods.

The dogs can be forged from mild steel in 15 to 30 minutes each (including punching holes if drills are not available). We made ours from 5/8 inch (16mm) square bars. Uniformity and quality control are helpful but not critical. They need to be planned so they will extend into the compression chamber by about 1 inch (25mm). Since the dogs are mounted outside the chamber, their design must accommodate for the thickness of the side boards. Since we were using thick material, we set the dogs into grooves chiseled into the boards (Figure 3). If thinner material is used, build up the pivot points with blocks of hard wood or steel.

The plunger structure needs to be stronger than might intuitively be expected (Figure 6). The force passing through it equals up to 12 times the operator's weight depending on the resistance of the hay. That is, the force would exceed a ton with an operator placing more than 183 pounds of weight on the handle. The

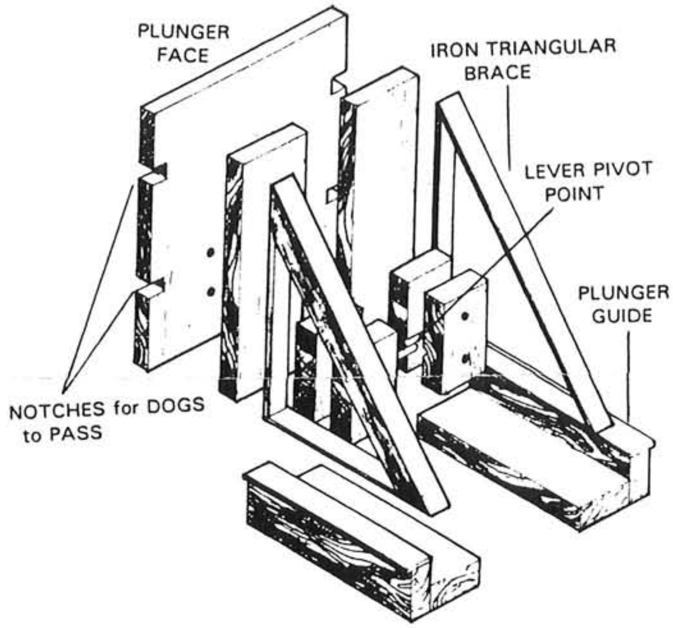

FIGURE 6: *An exploded view of the plunger mechanism (Debra Reich, 12/92)*

3/4 inch (19mm) plywood (just 14 inches wide) that we used in the prototype plunger visibly flexed under the pressure. We had just used screws to attach the 4 inch (100mm) horizontal boards supporting the guides. They quickly broke loose. We strengthened that connection with wood braces and then had to support them with metal sheets. After the trials we strongly recommend fabricated metal reinforcing triangles for future models.

Care should be taken in making the guides for the plunger. We mounted 1/4 x 2 x 8 inch (6 x 50 x 200mm) flat iron on top of the pieces extending horizontally from the back of the plunger. The edges of these irons extend outward about 3/4 inches (19mm) into a 1/2 inch (13mm) space left between the side boards. Since these irons are sliding in wooden grooves, their ends need to be rounded and their surfaces filed smooth to minimize wear to the wood.

We made the lever pivot point repositionable on the plunger. We moved it several times and are not sure we have it right. We are fairly satisfied, however, with it at about the 1/3 point from the bottom of the plunger. Others may want to experiment with this further.

Placement of the plunger relative to the dogs at the end of the compression chamber depends on desired stroke and size of throat, or opening for adding hay. Greater leverage is attainable with a shorter stroke, or movement of the plunger. But a shorter stroke means the plunger will not return as far and will not leave as large a throat opening for adding hay. We found our prototype permits more hay to be added in the fully opened throat than can readily be compressed by hand. We reduced the stroke in the blueprints in the belief that smaller additions of hay will compress into tighter flakes (segments) and make better bales. Feedback from on-farm trials would assist in that judgement.

For those who would appreciate more construction information than this article can provide, detailed blueprints (7 pages) are available from TILLERS along with more construction pointers in the "Manual Hay Baler" **TechGuide** for $15 US.

While we are pleased with the operation of this baler, we want to remind readers that no on-farm results on its use are yet available from developing countries. We think, nonetheless, that its construction is sturdy and efficient without being too over-built.

Operating Guidelines

Attention to a few details will yield the best quality of hay bales and maintain the baler in good operating condition.

With a tapered compression chamber, it is best to **leave the last bale in the chamber** to provide resistance for the first of the next batch of bales. However, if the hay is moist, leaving it in the baler may swell the grain of the wood and increase its resistance. If possible end each baling session by feeding in dry hay.

Make every effort to **keep the baler dry**. If the chamber becomes wet, the wood will swell. The moisture will roughen the chamber sides and greatly increase future resistance. At least once a year, preferably before storing the baler for the off-season, clean it out and wax or oil the interior to help it resist moisture.

Getting good bales will require attention to detail. Good bales of hay are free of mildew, retain a maximum of leaves, and are pressed tightly enough so little air circulates through. There obviously is less power available with a hand baler than with motor or animal-driven balers. To achieve tight bales with hand power, **feed the hay into the baler in small amounts**. Small flakes will compress more tightly. With attention to timing, the lever operator and the feeder should be able to develop a rhythm that will add considerable hay in small increments.

Since hay that is very dry becomes stiffer and more difficult to compress, **bale hay with a little moisture remaining**. Hay compresses more tightly when it has some moisture and flexibility. Provided it is dry enough not to mildew, more tightly baled hay should retain better quality. And baling hay before the sun bleaches it too much increases its quality. If the bales are a little moist, leave them in a cool dry place with air circulation so the hay can dry more in the bale without over heating.

The compression of the hay will vary according to the moisture in the grasses. The **compression adjustments need to be tightened more for dry hay** than for moist hay. The nuts on the adjustment rods at the end of the compression chamber are tightened down evenly to increase the compression. Frequently the compression of bales is referred to as the "tension" of the twine. The greater the pressure in the compression chamber the more the hay will spring out against the twine when it exits. Thus, extra pressure creates more tension in the twine on a tightly pressed bale.

Putting hay into the baler requires attention. If it is stomped to the bottom of the chamber bales will be tighter at the bottom than at the top. This irregular shape makes them prone to breaking and difficult to stack well. Most hay forks have tines that are too long for this task. They will not push the hay down close enough to the bottom of the chamber. It is best to **shorten the tines of your feed fork** so it will push the hay down far enough -- the bulk centered top to bottom -- so bales are regular. A low-cost alternative is to find a forked branch to use as a feeding fork and cut the forks to lengths that work well for you.

With a rotating crew of 4, two threading and knotting twine around bales and carrying bales away, one feeding hay into the baler, and one operating the lever, we estimate production of 6 to 12 bales per hour. These bales should weigh about 45 pounds, or 20 kg. By these estimates 4 people might produce 2 tons of hay per day. But caution, these are estimates based on limited experiments and should not be relied on heavily. We look forward to on-farm data to give better projections. Cutting and hauling the grass to the baler will demand much more labor.

Conclusions

We were pleased to hear from Walter that he was placing about 6 units into the field shortly after returning. Jack Shoemaker is visiting Themi Farm Implements in an upcoming trip to Tanzania. We look forward to learning more of the balers field test then. We enjoyed the opportunity to adapt our knowledge of historical agriculture to this need. We see forage production as excellent opportunities for small farms to profit from animal-power. As the scale of production increases, draft animals can power the timely transport and cutting work essential to quality haymaking.

For more information on Tillers' publications, training programs and support services, please

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