

Homemade Interplant Weeding Broom – The Vibrating Weeding Broom (VWB)

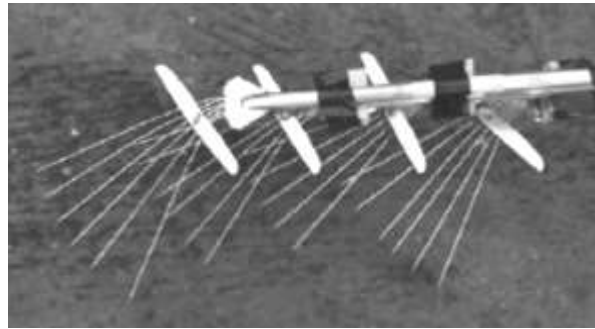
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- Easy early interplant (not just inter-row) weeding by *hawking**
- Can you weed a 100 m row of vegetables or upland field rice plants in one minute?

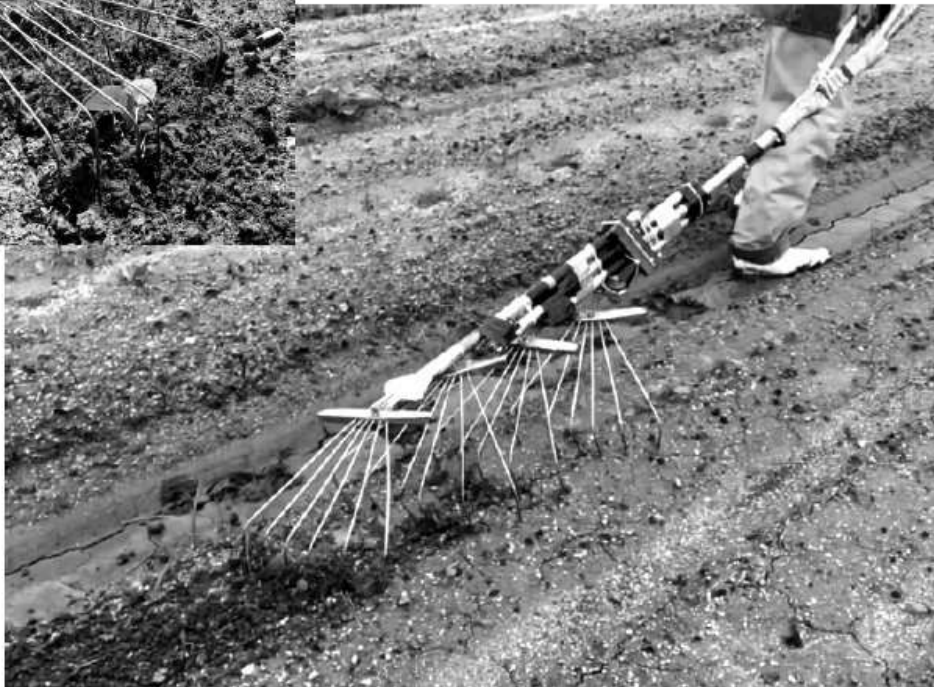
* As the weeding “broom” is based on a Japanese-style broom, called a *hawki*, this method has been named “*hawking*”.



Takao Furuno



Vibrating weeding broom with four broom units in series.



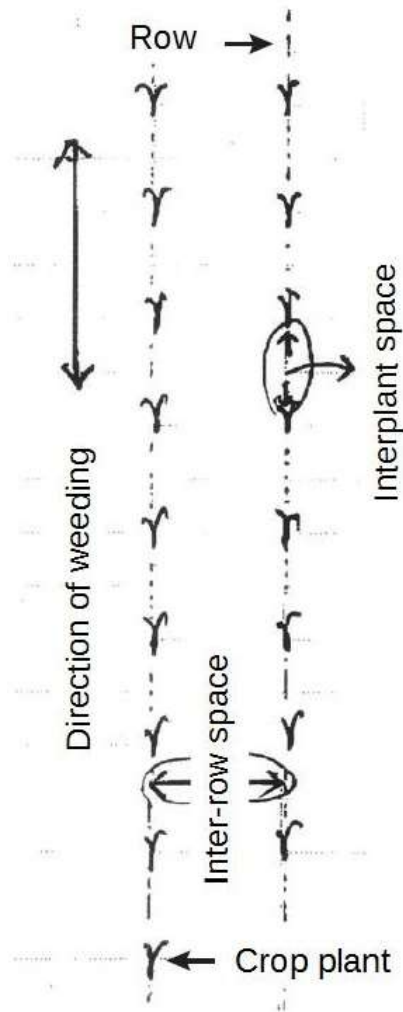
Top: Cabbage *hawking*. *Hawking* with cabbages is easy because they are transplanted.

Right: First *hawking* with Japanese *daikon* (while radish)

1. Is interplant weeding one of the bottlenecks of organic farming?

As in Fig. 1, crops (rice, wheat and other cereal grains, soybeans, maize, vegetables) are often planted in rows and the space between the rows is called the inter-row space. The spaces in between the crop plants in a row are called interplant spaces.

Figure 1. Inter-row and interplant spaces.



Inter-row weeding is called intertillage weeding. Since there are no crops growing in this space, weeding can be carried out quickly and moving forward (or backward) continuously with a hoe or other hand tool, or a machine. Mechanization is possible.

On the other hand, in the interplant spaces, the weeds and the crops are close to one another, so it would seem to be difficult to eliminate only the weeds by moving forward continuously with a machine without harming the crop. For nearly 40 years as an organic farmer I was convinced that “mechanization of interplant space weeding cannot be easily done” and quietly continued to weed between the plants using my hands or a triangular hoe. There are probably many farmers around the world who think and do the same, and this may be “common sense” in farming.

In 2016, however, after a long period of trial and error, I quite by chance tried out a “vibrating weeding broom” that uses a rake with thin, spring steel wires and was able to carry out continuous (down the row) early interplant weeding without damaging the crop. My conviction of 40 years melted away in an instant.

Weeding using the vibrating weeding broom (VWB) I named *hawking* after the Japanese-style broom, called a *hawki*.

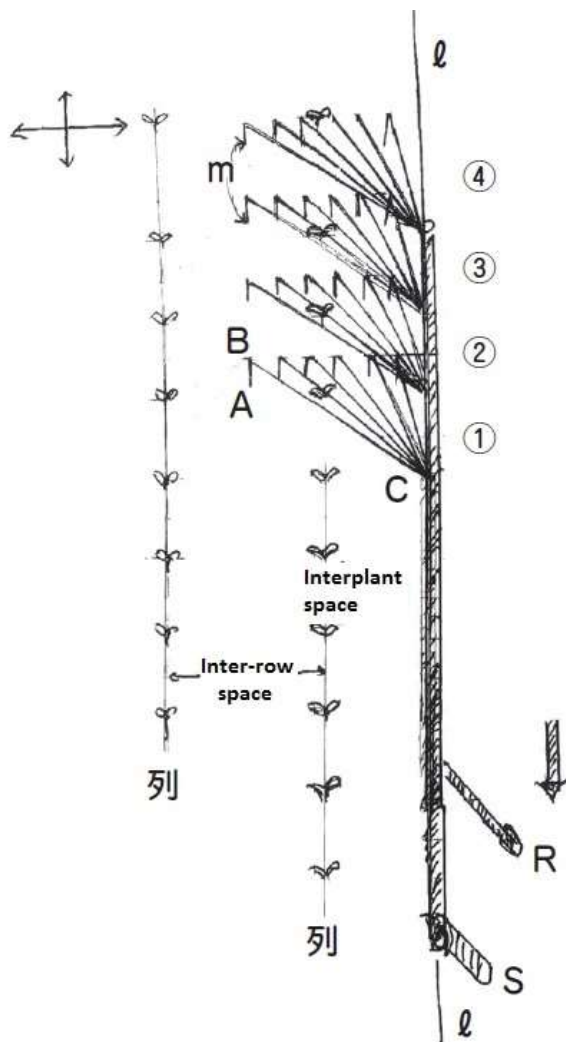
Video clips of *hawking* taken with a smartphone have been posted on a dropbox website.(1) You will understand instantly how this elegantly simple mechanism works.

2. The VWB is handmade

When I talk about the VWB, someone always asks, “Where can I buy it?” I made the VWB myself by buying this kind of rake (with the thin spring steel wires) at a store. I also recommend you make your own handmade VWB. Making it yourself will help you understand how it works and you will also be able to improve it by adding on your own ideas. This is known as “technological self-sufficiency.”

The rakes use stiff spring steel wires which radiate out in a fan-like manner. Looking at the shape of the broom, many people think that not only the weeds but also the vegetables will be uprooted. First widen the space between the steel wires on one of the rakes and try *hawking* an appropriately sized vegetable. You should see a “very convenient truth.”

Figure 2. Overview of the VWB



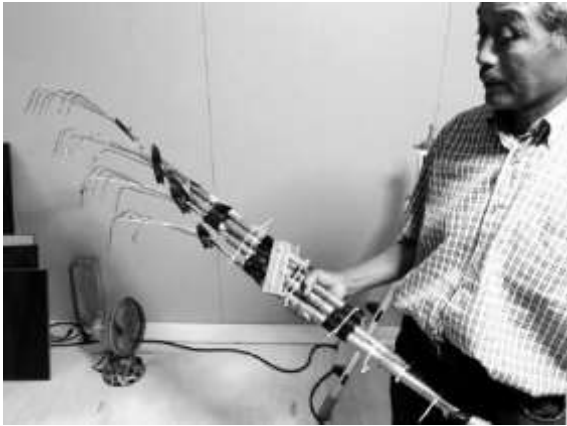
DIY stores sell different kinds of rakes, but the ones I am using are have spring steel wires that are angled down at the end, this part being about 12cm long (AB in Fig. 2), and the main part of the wire (BC in Fig. 2) being about 35cm long.

Of course, it is possible to use one rake, but the weeding effectiveness improves significantly if three or more are used in series. As in Fig. 2, I use four rakes held together in series.

As you can see in Fig. 2, the wires jut out toward the left when seen from the handle and some of the wires are cut off with wire clippers to leave only six on each rake. For the reason why the wires are made to jut out to the left of the handle, please see the explanation of the mechanism in section 3.

The handles on each rake, except for one, are cut off at a length of around 60cm. The distance between the tips of the wires on each rake in the series is about 12cm (m in Fig. 2). Using cardboard as packing material, fix the four handles firmly in

place using duct (waterproof) tape, as seen on the left in the photo.



The distance between the wires on each of the rakes is adjusted to about 6cm. The rakes usually come with a metal tool for adjusting this distance (B in Fig. 3). This adjustment is very important. If it is not just right, the vibration does not work correctly.

The final stage is to try *hawking* a plot of soil that has no weeds or grass. Look at the shape of the track to ensure that the wires are moving correctly, and adjust them while looking to see how they interact together (see (3) in Structure of the Multi-rake Broom on page 6 for more info). You can also adjust the angles of the wires on each of the rakes so that the wire tips are all on the same plane (i.e. they all touch the ground at the same time). The explanation may sound difficult, but it's actually very easy to do.

3. Mechanism of Interplant Weeding Using the VWB

In interplant weeding, where the crop and the weeds are close together, we firstly look for differences in the two that can be exploited and then think up a technology

(1) Differences in roots

In the paddy fields where I rotate crops, the crops germinate about two weeks after sowing. At about the same time, the sprouts of a great variety of early weeds, including shortawn foxtail (*Alopecurus aequalis*), green foxtail (or bristle-grass, a species of annual grass, *Setaria viridis*), Japanese barnyard millet (*Echinochloa esculenta* (A. Braun) H. Scholz (1992)), chickweed (or stitchwort, *Stellaria sp.*), shepherd's purse (or shepherd's pouch, *Capsella bursa-pastoris*), lamb's quarters (*Chenopodium album*), buttercup (*Ranunculus japonicus*) and others show above the surface of the soil to form a green carpet over the whole paddy field if you just leave them as they are.

There are, of course, exceptions, but these *early* weeds are like the Weeds (1) and (2) in Fig. 3, whose thin roots spread out *just under the surface of the soil*. A typical example is Japanese barnyard millet. The Japanese barnyard millet and the rice plant have very similar appearances aboveground, but have different types of roots.

Weed (3) in Fig. 3 is one that has just sprouted from a shallow point beneath the surface of the soil and has not yet sent out any roots. Weed (4) is one that has just sprouted by sending up a mesocotyl from some distance below the surface of the soil and has almost no roots.

Thus, although there are exceptions, almost all *early-stage weeds* have thin roots that spread out just below the surface of the soil or have almost no roots at all.

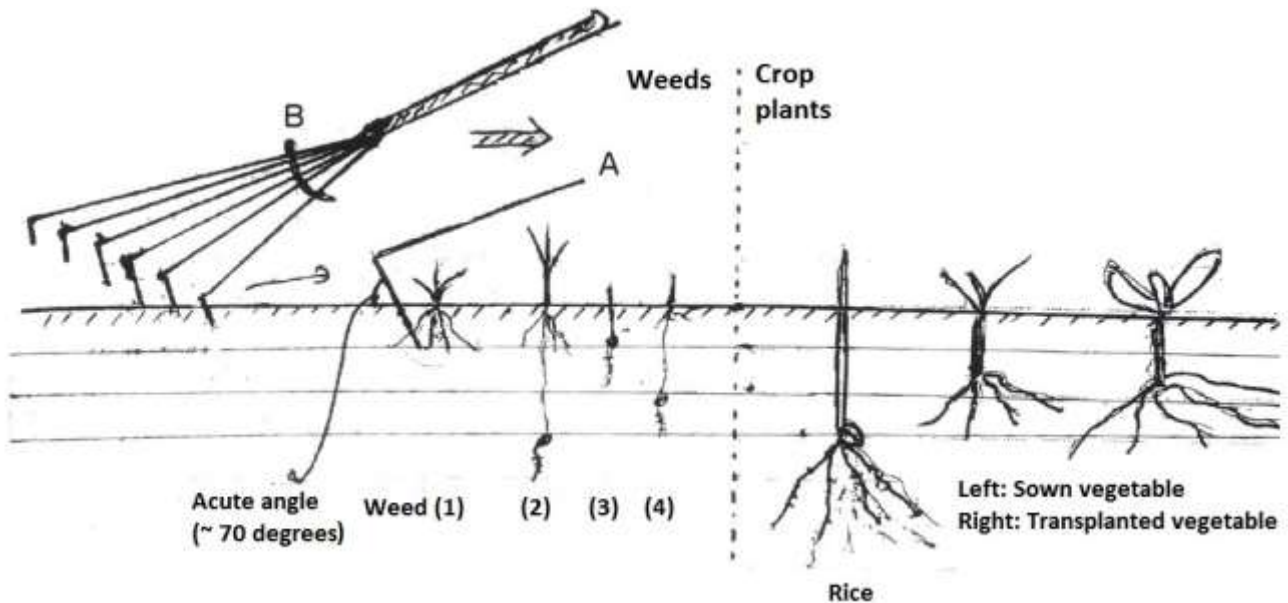


Figure 3. Difference in the roots of early-stage weeds and crops

Weeds:

Weed (1) Roots spray out just below soil surface

Weed (2) Shoot out a mesocotyl and roots spray out just below soil surface

Weed (3) Has sprouted but not yet sent out roots

Weed (4) Has shot out a mesocotyl and sprouted but not yet sent out roots

In contrast, crop plants such as rice, cereal grains, soybeans, vegetables, and so on, compared with weeds, have strong roots which have spread firmly and penetrated down to a deeper level (around 3 cm). This *early-stage dissimilarity* has a time limit, but is vitally important. *Hawking* is a technique that has been assembled by recognizing the importance of this *dissimilarity in roots*.

(2) Movement of the wires

Vertical vibration

As you pull the VWB along the ground, as in A in Fig. 3, the tip of the VWB wire pierces the soil under the roots of the weed at an acute angle, like a hoe, catching onto the roots and pulling them upward, pulling the whole weed out of the ground. It then drops the weed on the surface of the soil, where it withers and dies.

By combination of the wire's own weight and the power used to pull the broom, the tip of the wire is always forced to pierce the soil at an acute angle, but as it pierces deeper it meets with the resistance of the soil it is pushed back, but then returns to the original position due to the force of repulsion in the

stiff spring steel wire. Thus the tip of the wire vibrates vertically, piercing the soil at almost the same depth (1 to 2 cm) as the broom moves forward.

At the same time, as in Fig. 3, the crop plants, whose roots have sunk a bit deeper than those of the weeds, since the tip of the wire does not reach down far enough, the crop plants are not pulled out of the soil.

Even if the tip of the wire does reach the roots of a crop plant, since the roots of the plant are strong it will not be easily pulled out of the soil as the weeds are.

Horizontal vibration

What happens with weeds like Weeds (3) and (4) in Fig. 3 that have not yet developed roots that the tip of the wire can catch on to immediately after sprouting? These will be weeded by the horizontal vibrating motion of the wires. Fig. 2 shows the overall view of a VWB with four rakes in series. Grasping the handles R and S, if you pull the VWB over the crop plants, i.e. perform interplant weeding, each of the wires, spread out like a fan, pierce the ground at an acute angle, and due to the resistance of the soil and the springiness of the steel wire will oscillate (vibrate) horizontally violently and noisily, stirring up the soil as they go.

The result of this is that the Weeds (3) and (4) in Fig. 3, the weeds that have not yet developed any significant roots, will be moved around with the soil, their roots (if any) and mesocotyl being severed, and will dry out, be buried, wither and die.

In the video clips mentioned above, there is a slow-motion clip. Looking at this clip, you will notice that wires further up the backbone away from the handle of the VWB ("1" in Fig. 2) show a greater horizontal vibrating motion, stirring up the soil and weeds very well. As in Fig. 2, the wires are made to jut out to the left of the overall VWB in order to make good use of this *special property of the fan-like arrangement of the wires*.

At first, I carried out *hawking* with the rakes arranged symmetrically with respect to the backbone of the VWB. When I did that, the central wires located just under the backbone hardly showed any horizontal vibrations at all and weeds remained for a certain interval on both sides of the wires.

(3) Structure of the Multi-rake Broom

Why, as in the photo and Fig. 2, does the VWB use four rakes?

Naturally, the smaller the distance between the wires, the more effective we would expect the weeding to be, but in fact things are not that simple. This is because the crop plant's leaves and stems become

sandwiched between the wires, which will also pull along rice straw and clumps of soil, or push over, rip out or bury the crop plants. In contrast, if the distance between the wires is too large, some weeds will remain in the soil after you have carried out the *hawking* with the VWB.

It is the multi-rake broom structure that resolves this problem. As in Fig. 2, there are four rakes in series and the distance between the wires is set at 6cm. Since the early-growth vegetables are small, they easily pass through the 6cm interval, and they are not pulled out by the roots, as mentioned earlier. However, since the wires of each of the rakes are aligned so that they are offset from each other (i.e. are not following on from one to the next in a straight line), from the viewpoint of the weeds, which have shallow roots, this is the same as having a gap between the wires of 6cm divided by 4 = 1.5cm. Moreover, the horizontal vibrations of the wires further decrease this 1.5cm gap, pulling out and pushing aside the weeds, giving a very satisfactory weeding effect.

This can be easily seen by looking at the slow-motion video clip. As the interplant weeding is carried out, each of the wires does a “Munroe walk,” working together as a team.

4. Practical *Hawking*

The mechanism of *hawking* differs from all conventional weeding techniques and still requires some thinking and tweaking. The technique is still at the trial-and-error testing stage, and I will set out here a few of the points I have noticed.

(1) Plowing

Plowing carried out before sowing or transplanting of the crop plants is carried out carefully to break the soil up into fine particles so that the weeds do not survive. If quite large weeds are remaining at this stage, they cannot be dealt with by *hawking*.

However, it is not necessary to break up all the soil in the ridges and furrows into fine particles. I just take care to break up finely the surface layer of the ridges to a depth of 1 to 2cm.

(2) Appropriate crops

Grains such as rice directly sown into dry fields, wheat and other cereal grains, soybeans, maize and so on have large seeds, robust and flexible leaves and stems and sturdy roots and are therefore the easiest crops to use *hawking* on. Interplant weeding by *hawking* is also very easily carried out on potatoes and the yam eddoe (*Colocasia esculenta* (L.) Schott) at the early stage.

However, these crops are generally cultivated using land-extensive methods. For larger areas, it will be necessary to mechanize *hawking*. Since around 2007, I have been collaborating with the

development division of the Fukuoka agricultural machinery maker Orec to develop a weeding machine for dry fields. Since February 2016, after much creative activity, we have started work on the mechanization of *hawking*.

We found that, among sown vegetables, *hawking* works well with the daikon radish, white turnip, Japanese mustard spinach (*Brassica rapa* var. *perviridis*), spinach, edible chrysanthemum (*Chrysanthemum coronarium*), potherb mustard (*Brassica rapa* var. *nipposinica*), burdock and others. However, if the leaves and stems are pulled too much, branched roots occurred in burdock and the white turnip became an oval shape. It is therefore especially important when trying out *hawking* to look with your own eyes, think about what is happening and make your own judgements.

Among the transplanted vegetables, *hawking* was found to work well with cabbage, lettuce, *takana* (*Brassica juncea* var. *integrifolia*), *katsuona*, onion, *kujo* leek, chives and others. I'm sure there are other vegetables that *hawking* will work well with.

In general, as transplanted vegetables have firm roots that go deep into the soil, once they get settled into the soil, *hawking* is a very suitable technique for weeding.

In contrast, it was surprisingly difficult to use *hawking* with Chinese cabbage and carrots. I intend to take up the challenge with these crops again this year.

(3) Timing

There's no simple answer to the question "What's the right time to carry out *hawking*?" I simply look at the condition of the crops and weeds and make a judgment based on what I see. You'll soon find out if you give it a try. In general, when the crop plants have reached a certain size and the weeds are just beginning to sprout is a good time. In reality, however, the weeds sometimes sprout and grow before the crop plants do. In this case, I carry out inter-row *hawking* before doing interplant *hawking*. This is because when the soil on both sides of the crop row is soft and loose it is easier to carry out interplant *hawking*.

Once the weeds exceed 3 to 5cm in height, the roots are generally quite strong and it becomes difficult to remove them by *hawking*.

(4) Thinking about weeding

In contrast to conventional weeding methods, the weeding is not perfectly completed by carrying out *hawking* just once. During repetition of *hawking* a number of times, the vibration of the wires makes the soil soft and loose, fewer weeds are seen and it becomes more difficult for them to grow.

By carrying out *hawking* intensively two or three times when the crop plants have reached a certain size eliminates weeds well. If the interval between *hawking* sessions is too long, the weeds will become larger and much more difficult to remove by *hawking* with the VWB.

I am currently conducting an observation survey on how many weeks pass before weeds appear after *hawking*.

(5) Soil condition

As a rule, *hawking* should be carried out when the soil is dry. The soil will then become soft and loose and the weeding effect will be better.

With some types of soils, however, when the soil is very dry it will be too hard for the tips of the wired to penetrate in some places. In these cases, it is probably effective to carry out *hawking* after rain has fallen and the surface of the soil is a little softer.

(6) Causes of crop damage and avoidance measures

- 1) The crop plants are still small and the roots are not yet well developed → Wait.
- 2) The wire tips pierce too deeply → Adjust the angle of the wires and the weight of the VWB.
- 3) The wire tips do not pierce the soil and pass over the leaves of the crop plants → Adjust the angle of the wires and/or lower the handle when pulling the VWB.
- 4) The crop plants are injured just by contact with the wires. This mainly occurs in the morning with lettuce when the leaves are a little stiff after absorbing a lot of water. → In the afternoon, when the temperature has risen and the leaves are wilting a little from the sun and wind, *hawking* can be carried out by increasing the interval between the wires and passing slowly down the row. It is also possible to fix some sponge rubber on the wires to prevent leaf damage.
- 5) Lumps of soil and straw get caught between the wires, causing the crop plants to get pushed over → Increase the interval between the wires. Carry out more careful plowing.
- 6) The crop plants become covered in soil → The crop plants are too small; wait a while. Increase the interval between the wires and pass down the row more slowly.

5. Characteristics of the VWB

I'm an organic farmer, not a researcher, but I think the VWB has the following four special characteristics.

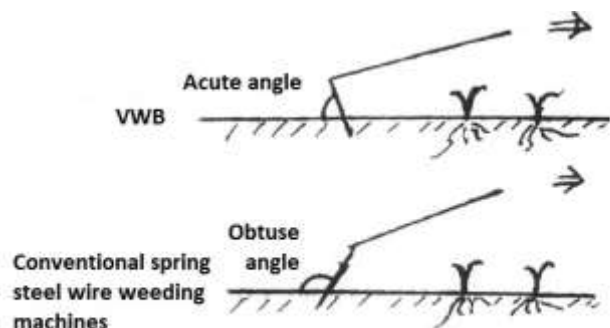
(1) The soil is pierced at an acute angle.

The rakes from which the VWB derive pierce the soil at an obtuse angle, as seen in Fig. 4.

With the acute angle, the resistance of the soil is greater, and the spring steel wires catch on to the

weeds, lifting them up out of the ground as the wires vibrate strongly both horizontally and vertically due to the properties of the spring steel wire.

Figure 4. Difference between the VWB and conventional spring steel wire weeding machines



In contrast, the spring steel wire weeding machines produced by British and Japanese makers that I have seen in books, manuals, video clips or practical demonstrations, as in Fig. 4, have the tips of the spring steel wires (sometimes known as “tines”) make an obtuse angle with the ground surface, seemingly stroking the soil. This is perhaps a different way

of thinking about the weeding mechanism.

(2) The VWB is a specialized interplant weeder

The VWB focusses on the interplant space to carry out aggressive interplant weeding.

(3) Requires less labor and strength, and is fast

To perform interplant weeding of 100 m of vegetables with a triangular hoe or by hand will take you two hours. If the conditions are right, carrying out *hawking* over 100 m will take you one minute. Check out the video clip!

(4) Pocketbook-friendly appropriate technology

A rake will set you back 980 yen (\$11) in the Japanese DIY store. This is appropriate and simple technology that is cheap and can be handmade by Asian farmers. My Indian friend said, “We don’t have this kind of rake in India, but we can make the VWB with bicycle spokes.” Bicycles are seen all over the world.

I wrote about “characteristics,” but actually this is the kind of simple technology that many people all over the world have worked to produce throughout the long history of humanity.

6. The Relationship between *Hawking* and Integrated Duck and Rice Farming (IRDF)

During *hawking*, the spring steel wires vibrate vertically and horizontally. In a paddy field, the *aigamo* ducks’ feet also move horizontally and vertically in the water. The oscillating movement is the same, the only difference being whether it is in a dry or wet field.

I have been working on the systemization of Integrated Duck and Rice Farming (IRDF) since 1988. The *aigamo* have now come to swim in paddy fields all over Asia. Since 2003, I have endeavored to combine direct sowing of rice in dry fields with the use of *aigamo*. Here, the most pressing issue was the weeding of dry fields, since the rice and Japanese barnyard millet sprout at the same time. Inter-row weeding was completely resolved by use of the spiral rotor developed by Orec. However, the interplant weeding was a difficult problem.

After many twists and turns, in February 2016 I just happened to notice a spring steel wire rake in my storeroom. After trying out interplant weeding of wheat with the rake, developments simply took off from there. In May, I tested the rake by attempting interplant weeding with rice sown directly into a dry field. This helped to raise the precision of interplant weeding to a completely new level.

In September, I carried out *hawking* trials with various kinds of fall and winter vegetables. These trials turned out so well that even I was surprised. In contrast to rice, vegetables have soft leaves which spread out and have differing shapes according to the type of vegetable. I thus tried out the multi-rake structure.

Then, in May 2017, on the basis of the experience gained using the multi-rake structure with vegetables,



I tried out the new VWB on directly sown dry field rice. The results were excellent. The Japanese barnyard millet decreased dramatically. At present (June 2017), water has now been released into the fields and the *aigamo* are having fun swimming around in the field, making the water sparkle. I think the work of organic farming is really interesting – even the mistakes.

June 2017

(1) Description of the video clips accessible at:

<https://www.dropbox.com/sh/qojbik0cifz3gau/AABFqf3yXFpHDrxyovzES5-ta?dl=0>

26.mov - Interplant weeding for turnips. The weed plant is the tough Japanese buttercup.

35.mov - Green pak choi – easy *hawking* without damaging the vegetable leaves. The wires do the ‘Munroe walk’.

42.mov - Early interplant weeding with onions.

54.mov - As cabbages are transplanted, *hawking* can be performed easily at an early stage. Note the movements of the wires and the cabbages.

1.mov - Comparison of weeding speed for triangular hoe and *hawking*.

38.mov - When the soil is hard, first carry out inter-row *hawking* to soften up the soil, then do the interplant *hawking*. Or, do the *hawking* after the surface of the soil has become soft after rain.

43.mov - Hawking on rice sown directly into a dry field. Hawking is easy to do with grains or beans such as rice, cereal grains, soybeans, adzuki beans, maize, etc. We are developing mechanized hawking for these land-extensive crops.

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Aigamo Family, Furuno Farm

A hundred varieties of crops by organic farming

Website: <http://aigamokazoku.com> (Japanese)

- Integrated Duck and Rice Farming (IRDF): 7.3 ha
- Various vegetables: 3 ha
- Wheat: 2 ha
- Natural egg-laying chickens: 300
- *Aigamo* duck chicks: 4000 (1,400 used by the farm, the remainder are sold)
- A variety of processed products from the agricultural produce.

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