The 4 Wheel Hoe

The Ultimate Pedestrian Hoe

Happy Weeding!

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www.physicalweeding.com

Simplicity is the ultimate sophistication

Leonardo Da Vinci

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The 4 Wheel Hoe – An explanation

1. Summary

The 4 Wheel Hoe has been designed from first principles of physical weed control and ergonomics to produce an optimum design both in terms of weed kill and usability.

The 4 Wheel Hoe fills a gap among weeding machines being created for growers producing crops on the bed system, i.e., not on ridges, with cropping areas to large to hand hoe and too small to justify tractor mounted hoes.

It can control both interrow (between the crop row) and intrarow (in the crop row) weeds by a combination of horizontal knife blade 'T' hoes and 'mini-ridger' hoes.

The 4 Wheel Hoe is designed to the highest standards and to last long enough to pass down to your grandchildren and so effective they will be grateful to have inherited it!

This all adds up to a machine that has the potential to do a better weeding job, for less effort and in less time, which means potentially significant reductions in costs and therefore a rapid return on investment. In short the 4 Wheel Hoe is designed to save you time and money.

2. Open Hardware Licence

The design of the 4 Wheel Hoe is licensed under the TAPR Open Hardware Licence (www.tapr.org/OHL). See page 47 for more information and the licence.

3. Introduction

The 4 Wheel Hoe addresses a crucial gap among weeding machines. While there is a burgeoning choice of tractor-mounted weeding machinery for larger scale growers, smaller scale growers and farmers only have a choice between modern one-wheel, or antique two-wheel, wheel-hoes (Figure 1).

Figure 1. One wheel hoe (left), two wheel hoe (right).

While brand-new one-wheel hoes are flexible this comes at the sacrifice of usability and effectiveness. In comparison, two-wheel hoes are a considerably superior design, however, the lack of current manufacturers means they can be difficult to locate and often considerable 'TLC' is required in their use and upkeep. The 4 Wheel Hoe is a revolutionary design that solves this problem (Figure 2). It has been designed from first-principles of physical weed control, engineering efficiency, and usability to fulfil the in-crop weeding needs of commercial growers producing crops grown on the bed system, i.e., not on ridges, with fields to large to practically weed with hand hoes, yet too small to justify the expense of tractor mounted weeding machinery. The result is a machine that looks very simple, even basic, but is the result of hundreds of hours of deep deliberation and brain-bending analysis coupled with extensive field testing to ensure every single component is optimised for its purpose. It has also been designed to be built by farmers and growers. The result is a hoe that is supremely effective while easy to use and very robust, or to put it slightly more poetically, the

4 Wheel Hoe is designed to last long enough to pass down to your grandchildren and so effective they will be grateful to have inherited it!

Figure 2. The 4 Wheel Hoe.

4. The 4 Wheel Hoe Design Concept

Despite its apparent simplicity a lot of thinking went into the 4 Wheel Hoe, with every single component designed from first principles.

4.1. Hoe blades

The essential design aspects, both biological and mechanical, of hoes blades were established long ago, and are exemplified by the 'Nicholson Webb' L bade hoe (Figure 3). However, after 50 years of nearly complete dominance of weed management by herbicides, most of this knowledge has been lost from living memory. This has resulted in well intentioned, but unfortunately, considerably sub-optimal hoe designs, especially in the area of pedestrian hoes. The 4 Wheel Hoe has been designed to squarely address this problem. It has been designed from scratch, working from the primary principles of how knife-blade hoes kill weeds, combined with the best engineering and ergonomics to produce a machine perfectly matched to its job. The design of the 4 Wheel Hoe literally starts at the 'cutting edge' where steel meets soil and weeds…

Figure 3. Nicholson Webb L blade hoe

4.2. Horizontal knife-blade hoes

Horizontal knife-blade hoes kill weeds through a combination of severing, burying and uprooting. To effectively kill weeds by severing they should be cut through the hypocotyl stem - i.e., the stem below the cotyledons and above the roots. The hypocotyl stem often starts only a few millimetres under the soil surface so hoeing too deep merely undercuts and transplants weeds. Keeping the hoe blade as close as possible to, but still ensuring it remains under, the soil surface, results in the greatest possible weed kill and also least soil resistance (draft). However, this requires very precise depth control.

4.3. Mini-ridgers - killing weeds by burial

Weeds, even quite large one, e.g., up to 10 cm, can be killed by burial under just 1 cm of soil (see https://bhu.org.nz/future-farming-centre/information/bulletin/2018-v2/mini-ridgers-lethal-burial-depth-for-controlling-intrarow-weeds). This effect can be used to kill intrarow (within the crop row) weeds without harming the crop, even 'close-to-crop' weeds – the 'holy grail' of physical weed control. However, for this technique to be practically effective sufficient soil has to cover the weeds to kill them without covering the crop so much that it is killed or significantly harmed. Research has shown (see above link) that if just 2 cm of a crop plant remains above the soil it will survive. Consistent and accurate burial depth is therefore essential to maximise weed kill while minimising crop damage. Therefore, just as for knife blades, mini-ridger also depend on precise depth control (Figure 4).

Figure 4. 4 Wheel Hoe: T hoes and sight guide (left), mini-ridgers (right).

4.4. Four wheels give optimum depth control

One and two wheel hoes are clearly unable to provide the very precise depth control required for the twin tasks of keeping horizontal knife blade and mini-ridger hoes at their optimum depths, as they rely on the user to control the depth via the hoes handles. Worse, in the case of one wheel hoes, lateral stability also has to be maintained by the operator, the result is highly variable depth control - the opposite of what is required.

Mounting tools between four wheels gives the most stable, precise and practical depth control practically possible, i.e., in engineering terms it is an optimal design that cannot be surpassed. The same principle underlies mid-mounted toolcarrier tractors, road graders and many seed drills. Therefore, the optimum design for a wheel hoe is four wheels, no more, no less. Hence the 4 Wheel Hoe was born.

While four wheels gives the best possible depth control, building a hoe based on this principle while also achieving all the other design requirements, such as effectiveness, usability, ergonomics, practicality, simplicity, low weight without an exorbitant price was no simple task. Many of these objectives conflict with each other, requiring innovative solutions to solve these dilemmas. Here are just a few examples…

4.5. Optimum knife hoe blade design

To kill weeds by burying and/or uprooting them requires that the soil they are growing in be mixed and broken up by the hoe blades as much as possible. However, mixing requires energy (increases draft), so a balance must be struck between soil churn and energy used. Also plant residues are often tough and have the potential to cling to and block soil engaging parts such as hoe blades, especially those with low sweep angles. The optimum solution for these issues is a knife blade with 15° rake and 60° sweep angles, as used on the 4 Wheel Hoe's, T hoes (see http://orgprints.org/6673/1/OF0312_2234_FRP.pdf) .

In contrast the 'stirrup' / oscillating / 'Swiss' hoes, popular on modern one wheel hoes, fail practically all hoe blade design requirements. For example, with stirrup and other low sweep angle hoe blades the hoe needs to be endlessly pushed and pulled backwards and forwards to clear weeds and plant residues from the blade. No farmer would accept a tractor mounted hoe that has to be constantly edged forwards and backwards to clear it of weeds and plant residues. Imagine how little work could be achieved with a tractor mounted hoe that required such an action? So why put up with such an approach in a pedestrian hoe? The 60° sweep angle of the 4 Wheel Hoe blades ensures effective self cleaning so it can be just pushed forwards so there is no need for the endless pushing and pulling required with stirrup hoes. With the stirrup hoe the rake angle changes as the blade oscillates and as the user moves the handles, plus the concave shape means that the blade depth varies across the hoe's width, all of which reduce the hoe's effectiveness. The 4 Wheel Hoe has its blades set at the optimum rake and sweep angles which are maintained by the hoe not the user resulting in maximum effectiveness.

Rather than using traditional L blade hoe, like the Nicholson Webb hoe blade (Figure 3), as used on other wheel hoes (Figure 1) T hoes (so-called because they are shaped like an inverted capital letter 'T') have the leg positioned well clear of the crop so the blade can slide underneath crop foliage. This means the horizontal blade position only has to be altered when the plants' stems grow larger, rather than the foliage. In comparison an L blade hoe has to be moved away from the crop as the foliage grows to avoid damaging it. This means that a T hoe can hoe more of the soil surface at larger crop sizes than an equivalent L hoe so killing more weeds for longer into the crops life. It also means that one width setting for the blades can accommodate a wide range of crop sizes, and only small width adjustments will accommodate all crops thereby minimising the need to adjust the hoe between different crops - essential for the small scale producer with a wide range of crops.

4.6. How mini-ridgers work

The blade height of mini-ridger blades determines the maximum size of the ridge they can create, even if they are placed too deeply in the soil, as excess soil simply flows over them. By correctly matching blade height to the crop size it is almost impossible to bury the crop as long as a suitable tilth and soil conditions (e.g., not too wet) are present.

Therefore, with both the T hoes and mini-ridgers working together on the 4 Wheel Hoe, 100% control of small weeds in one pass, both in the interrow and intrarow, is now possible. This represents as big an advance, if not more, in manual weed control as the invention of the wheel hoe itself.

However, optimum blade design is only part of the 4 Wheel Hoe concept…

4.7. Easily accommodate different intrarow and interrow widths

Crops fill the row space as they grow and they can be sown in single, double and triple bands. This all means that the distance between the tips of the hoe blades (the crop gap) has to be altered to fit the crop’s size and the number of seed bands. The 4 Wheel Hoe achieves this using a turnbuckle system which moves the two sides of the hoe closer or further apart rather than adjusting the hoe blades and other implements individually. This means that the width of the blades can be adjusted completely independently of the depth, so eliminating the highly frustrating situation found on other hoes (especially tractor mounted hoes) where the width and depth of a blade are adjusted at the same time - often resulting in one position being lost while the other is changed. Central width adjustment also means that all tools are adjusted at the same time, which is a particular boon where many tools are attached to the toolbars in precise positions as changing them individually would be very time consuming. In addition the mini-ridgers can also be adjusted independently so ensuring that the optimum size soil ridge can always be formed regardless of the T hoe crop gap.

Another significant advantage of the T hoe, is that it needs to be adjusted both less frequently and by smaller amounts that an L blade hoe. This is because the L hoe leg is positioned right next to the crop, so as the crop grows or the hoe is moved between different sized crops, the leg position has to be continually adjusted. In comparison the T hoe has the leg in the center of the blade and therefore close to the center of the interrow area, i.e., as far from the crop as it is possible to get. As the leg is far from the crop the T hoe only needs to be adjusted if the ends of the blades would hit the crops roots - a far smaller target than spreading foliage. This means the 4 Wheel Hoe needs much less adjusting compared with an L blade hoe when changing among different types and ages of crops.

With the centralised width adjustment system the 4 Wheel Hoe can be set up to fit down a wide range of interrow widths from as little as 15 cm / 6” upwards, although 20 cm / 8" is considered a more practical minimum width, with 25 to 30 cm / 10" to 12" considered optimum.

4.8. Ergonomics

Any physical job that has to be undertaken regularly, especially for hours at a time, can be made much easier by good ergonomic design. The 4 Wheel Hoe has incorporated the best ergonomics from the start of the design process. Removing the need for the operator to control hoe blade depth and no longer push and pull the hoe, as described above, are very substantial ergonomic improvements in and of themselves. In addition the hoe travels over the crop row, rather than beside it so the operator walks squarely behind the machine so they don't have to twist their body to sight the hoe up with the crop. The long handles give a clear view of the tool which allows for upright posture and the sight guide takes the guesswork out of accurately guiding the hoe. The handle’s weight is supported by the hoe so removing the need to continually lift the handles (the hoe will stand upright without any assistance). The ability to change (both vertically and horizontally) where the handles attach to the hoe along with the handles quick and simple height adjustment (via the handle clamp) means that an optimum weight transfer can be achieved for a wide range of soil conditions, so that the force of the user pushing the hoe is balanced by the weight of the machine, thereby ensuring as much of the users effort goes into pushing the hoe blades through the soil and nothing else.

The handle grips have the optimum diameter for the average human hand grip and for any ‘Incredible Hulks’ the size can be increased by slipping a piece of water pipe or hand grips over the handle ends. The hand grips are also in the correct vertical orientation for human hands, i.e., if you leave your arms loose at your side and then bring them up to the handles no rotation of the wrist / forearm is required. The variable height system also means that the wrists are kept straight, rather than bent, when pushing the hoe. The handles are the same width as an average persons shoulders, so keeping the arms in a neutral alignment. This all aims to minimise fatigue in hands, wrists, arms, shoulders and back.

The long arms also allow a more natural ‘pushing position’. Whether the upper arms are by the users sides and lower arms pointing forwards at 45° or if the user prefers to lock their arms out straight, the handles can be positioned so the user can maintain a healthy upright posture, rather than being bent over to put their ‘weight’ into propelling the hoe. This all adds up to reduced fatigue, lower risk of injury, especially chronic strains, and therefore happy healthier staff as well as higher work rates. For those that prefer to have a horizontal hand grip, there is the opportunity to hold the hoe using the cross bar. This is also handy when moving the hoe between jobs as pushing down on the cross bar lifts the hoe onto its rear wheels thus keeping the blades clear of the ground for easy transport and manoeuvring.

4.9. Usability

There can be few things as frustrating and annoying as spending a load of time heading out to the field to do a job, only to find that an adjustment is required or something needs fixing and the tools you need are back in the shed. The 4 Wheel Hoe, only requires a single 19 mm / ½" spanner / wrench to make any adjustment or change. Such a tool is easily carried in a pocket, or hung from the hoe.

4.10. Flexibility

The standard toolbars, clamps and tool-legs allow a very wide range of weeding and other tools to be attached to the weeder, including user-designed equipment, making it exceptionally flexible. This makes the 4 Wheel Hoe more like its tractor mounted brethren than other wheel hoes with their proprietary tool attachment systems.

The wheels also have multiple attachment points and tools can be clamped anywhere along the toolbars (except where the wheels are of course!). The spare wheel attachment points can also be used as a means of attaching tools to the 4 Wheel Hoe.

4.11. The highest build quality

The 4 Wheel Hoe is designed and built for exceptional strength and durability. As much of the materials are off the shelf standard steel parts. It is a professional machine designed and built for decades of use by professional growers.

4.12. False seedbeds

The 4 wheel hoe is also an excellent tool for tilling (cultivating) false seedbeds (see http://www.bhu.org.nz/future-farming-centre/information/bulletin/2015-v4/false-and-stale-seedbeds-the-most-effective-non-chemical-weed-management-tools-for-cropping-and-pasture-establishment).

5. The Caveats

Few designers tell of their machines limitations up-front, but PhysicalWeeding prides itself on its honesty. We are farmers and growers ourselves so understand the importance of not overselling equipment. Having said that we also pride ourselves on designing and building the best machines conceivable so our caveats are few and far between and in most cases they are not unique to our machines but apply equally to machines sharing the same principles.

5.1. Weeding crops grown on the flat vs. ridges

The 4 Wheel Hoe is not designed, and is unsuitable, for use on ridge cropping systems, e.g., potato ridges. It is only for use where crops are grown on flat ground, typically the vegetable bed system (either raised or flat beds) or any system where the soil surface immediately surrounding the crop is flat. While the 4 Wheel Hoe can travel over or between ridges, and it may appear that the weeding requirements of both ridges and flat ground are similar, they are in fact dramatically different. For example, a flat bed (if it has been properly tilled / cultivated) is effectively a smooth two dimensional surface, while a ridge (regardless of how careful soil preparation was) is a very variable three dimensional surface. It is therefore considerably more difficult to precisely follow the entire soil surface of a ridge compared to flat soil, so therefore, ridges are much harder to precisely weed than flat soil. There are also many other problems manually weeding ridges, such as needing to walk in the furrow while having the weeder run on top of the ridge resulting in off-center draft forces and skewed line of sight. Beds and ridges therefore require quite different approaches and tools to effectively weed them. For example, tractor mounted weeding tools (not tool frames) designed for one system are rarely capable of weeding the other, e.g., a horizontal axis brush hoe can not be used on ridges and a potato ridger would destroy crops grown on a bed. The same goes for pedestrian weeders: either you have a tool that is optimally designed for one system that achieves the best possible results; or you have a jack-of-all-trades machine that accomplishes average results in both systems. The 4 Wheel Hoe is an example of the former, one wheel hoes an example of the latter. At the same time, ridge crop systems are only an optimal production approach for a small number of crops.

5.2. Suitability for different soil types and stones

The 4 Wheel Hoe is not suitable for all soil types: Stones larger than about 5 cm / 2” across can significantly hamper the effectiveness of the hoe, as they will any precision horizontal knife blade hoe. Soils with significant amounts of large stones will be difficult to impossible to hoe. Similarly, the soil tilth needs to be fine and level. Lumpy, uneven cloddy soils and those with high levels of plant residues, will prevent the hoe working effectively.

Soils that set hard will also be a serious impediment to effective weeding as the effort required to push a hoe through such soils is more than most humans can manage. This equally applies to trying to weed tractor wheelings - they are too hard and compacted to be weeded by a hoe designed for precision weeding of vegetables. You will be better off getting a cheap old toolbar to go on the back of a tractor, with a set of spring tines with duck’s feet sweeps to clear wheelings of weeds, because accuracy is not an issue, but speed, brute force and aggressive soil penetration are the ‘name of the game’.

5.3. Effect of soil moisture and weather on weeding effectiveness

Horizontal knife blade hoes won't work nearly as well in wet soils or wet weather as the soil does not flow, and weeds have a better chance of re-establishing themselves post-hoeing. This equally applies to the T hoes on the 4 Wheel Hoe. However, as long as the soil is not so wet that forming a good mini-ridge that effectively buries weed seedlings is still possible, then weed kill with the ridgers will still be good, because this means of killing weeds is less affected by soil moisture or weather conditions as the weeds are killed by light deprivation not desiccation.

5.4. Width adjustment and row spacing limits

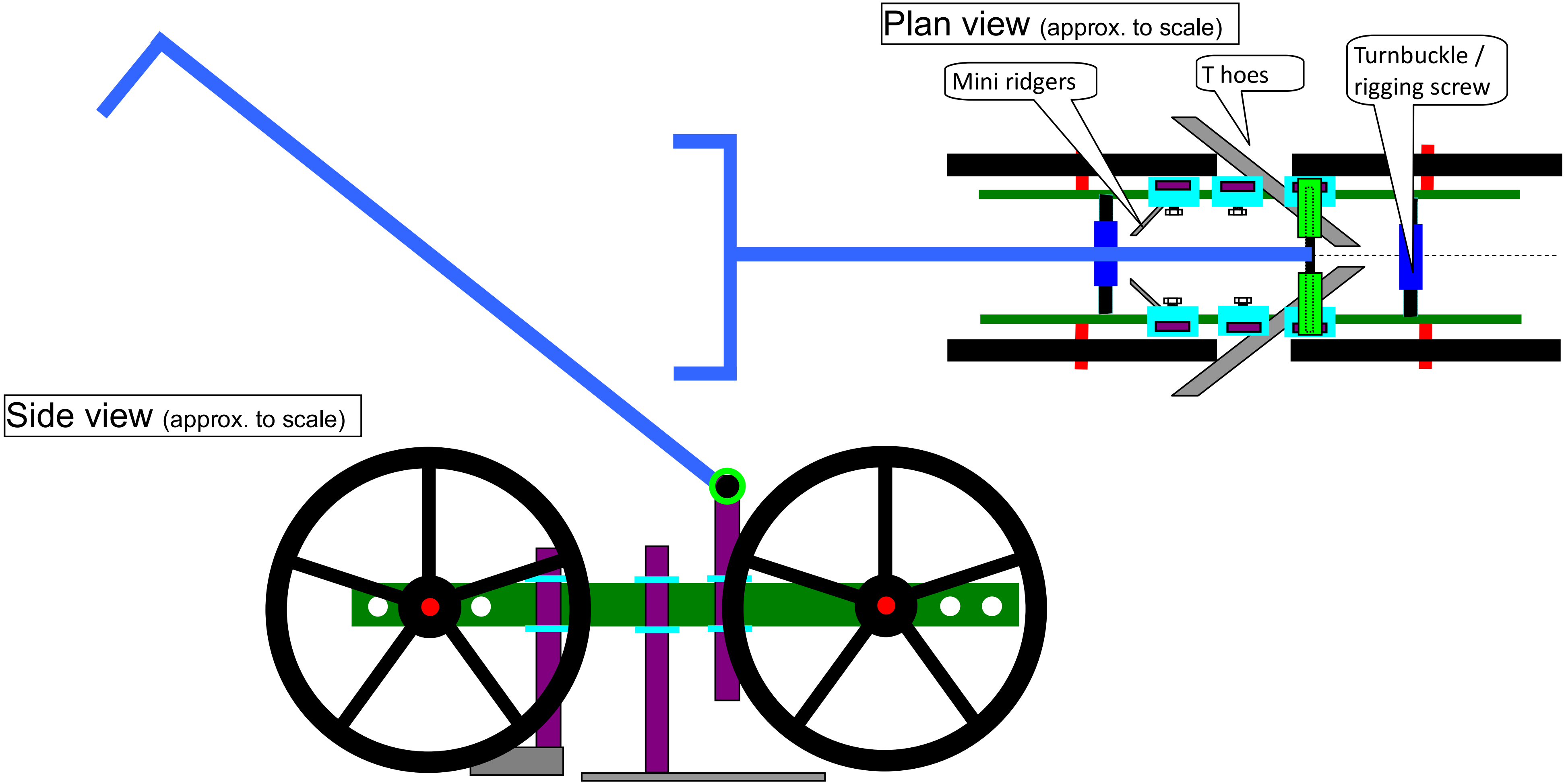
There is a trade-off between adjusting the 4 Wheel Hoe for different intrarow and interrow spacings. While the 4 Wheel Hoe can accommodate row widths (interrow) as small as 15 cm / 6” and it can be quickly adjusted to deal with different crop gap sizes (intrarow) the fixed length of the T hoe blades means that it cannot be so quickly swapped between widely differing intrarow and interrow sizes at the same time. This limitation applies to all horizontal hoe blade designs. The solution requires the use of different length T hoes and potentially mini-ridgers. While this may appear an undue restriction for growers used to hand-hoeing, it is an inevitable constraint faced by growers using tractor mounted hoes. For growers using tractor mounted hoes it is often simpler and more economic to have just one row spacing for every crop, such is the time and hassle involved in altering hoe settings. It is therefore recommended that as small as possible range of interrow spacings are adopted for use with the 4 Wheel Hoe, with ideally just one spacing used. However, if widely varying interrow widths are essential then swapping different length hoe blades and changing the 4 Wheel Hoe width only takes a handful of minutes, much less than for tractor mounted machines.

While the 4 Wheel Hoe can get down 15 cm / 6” rows, it’s a tight squeeze, and the outside of the wheels are right next to the adjacent crop rows. Therefore, there is no margin of error, e.g., for the interrow distance to vary or room for crops to grow sideways. Interrow spacings of at least 20 cm / 8” for very upright crops and 25 cm / 10” for most crops are recommended. While it is possible to reduce the width of the 4 Wheel Hoe (by having smaller bottlescrews) so it could effectively fit down 15 cm / 6” rows there would be such a loss of lateral stability (greater side to side wobble) that its effectiveness will be hampered. However, if it is essential to grow crops in such narrow rows, the hoe width could be set so it straddles two crops rows rather than one. This will however, require custom hoe blades and a different way of attaching them to the 4 Wheel Hoe.

While there is no mechanical upper limit on the row spacings the 4 Wheel Hoe can be used on, there are practical limits to the effective width of a horizontal knife blade hoe. This is due to variation in soil height (undulations) which mean that the longer the blade, and/or the further the blade is from the depth wheel, the greater the likelihood that some parts of the blade will be too deep and others too shallow. This will depend on soil conditions, especially how level tillage implements leave the soil, so it will therefore vary between farms. A maximum blade length of 60 cm is suggested as an upper practical limit on beds that are exceptionally flat and uniform. For rougher tilths, shorter lengths will be required.

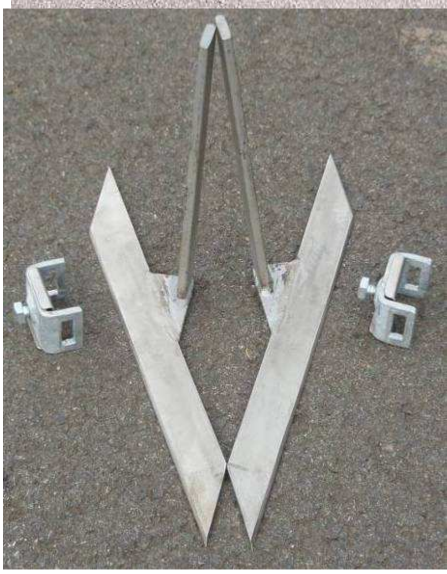
This is the thinking and purpose of the 4 Wheel Hoe. Happy weeding!

4 Wheel Hoe Design Plans



The 4 wheel hoe consists of two main longitudinal toolbars called the ‘main frame’ (dark green) connected and braced by two rigging screws (dark blue), and the handle clamp system (light green). The four wheels bolt into the main frame. The handles and all tools are attached to the main frame by adjustable clamps which fit a ‘standard leg’. All fasteners (bolts / screws / nuts) to be M12 with 19 mm heads and nuts or 1/2” for USA. This means only a single 19 mm / ½” spanner is required for assembly and adjustment of all components apart from the set screws which are adjusted by hand.



NB. Photos for illustration only as there are a small number of design changes to the hoe in the photos - (no clamp shims) please work from the plans not photos.

1. Notes on sizes and dimensions

The dimensions in this plan are based on the most commonly available metric steel and components sizes. **However**, despite international standardisation the exact sizes of steel and fasteners available in different countries, their tolerances, etc., all vary. Therefore the measurements should not be accepted blindly and if in doubt the design principles should be referred to, to determine what the design intent is and then adjust the dimensions to satisfy the design intent rather than just following the sizes given. All measurements are in millimetres.

In non-metric countries, i.e. USA, the sizes of non-metric components are not exact metric equivalents, so the sizes of dependent parts will have to be adjusted to match. Most components have a close non-metric size, e.g. 50 × 10 mm = 2 x 3/8".

There are three types of measurement:

- **Critical** measurements that impact the effective construction and/or performance of the hoe, for example the size and location of the slot in the frame clamps. Some of these critical measurements are affected by manufacturing, e.g., how the clamps are folded, factors that can not predicted in the design process due to differences in manufacturing and therefore require extra re-consideration as part of the construction process. Where measurements are described as **critical** in this document please ensure that they are given careful consideration, especially if they could be affected by construction. Many critical measurements are dependent on the size of other parts, e.g., the internal diameter of the handle clamp is dependent on the external diameter of the bar that goes into the handle clamps. It is possible to vary such critical measurements if all components involved are changed as long as they meet the design objectives;
- **Standard** measurements, that are important in terms of quality of construction or the overall design but not critical if there are small inaccuracies, e.g., the length of the legs, in that small errors will not effect the construction or use of the hoe to any significant amount;
- **Approximate** measurements are those that can be varied by a considerable amount without affecting the hoe, e.g., the outside diameters of the handle clamps. These are marked as 'approximate' and/or use the '~' symbol to indicate that this measurement can be changed, for example, to facilitate the production and construction process by being able to use standard sized materials, rather than custom made parts.

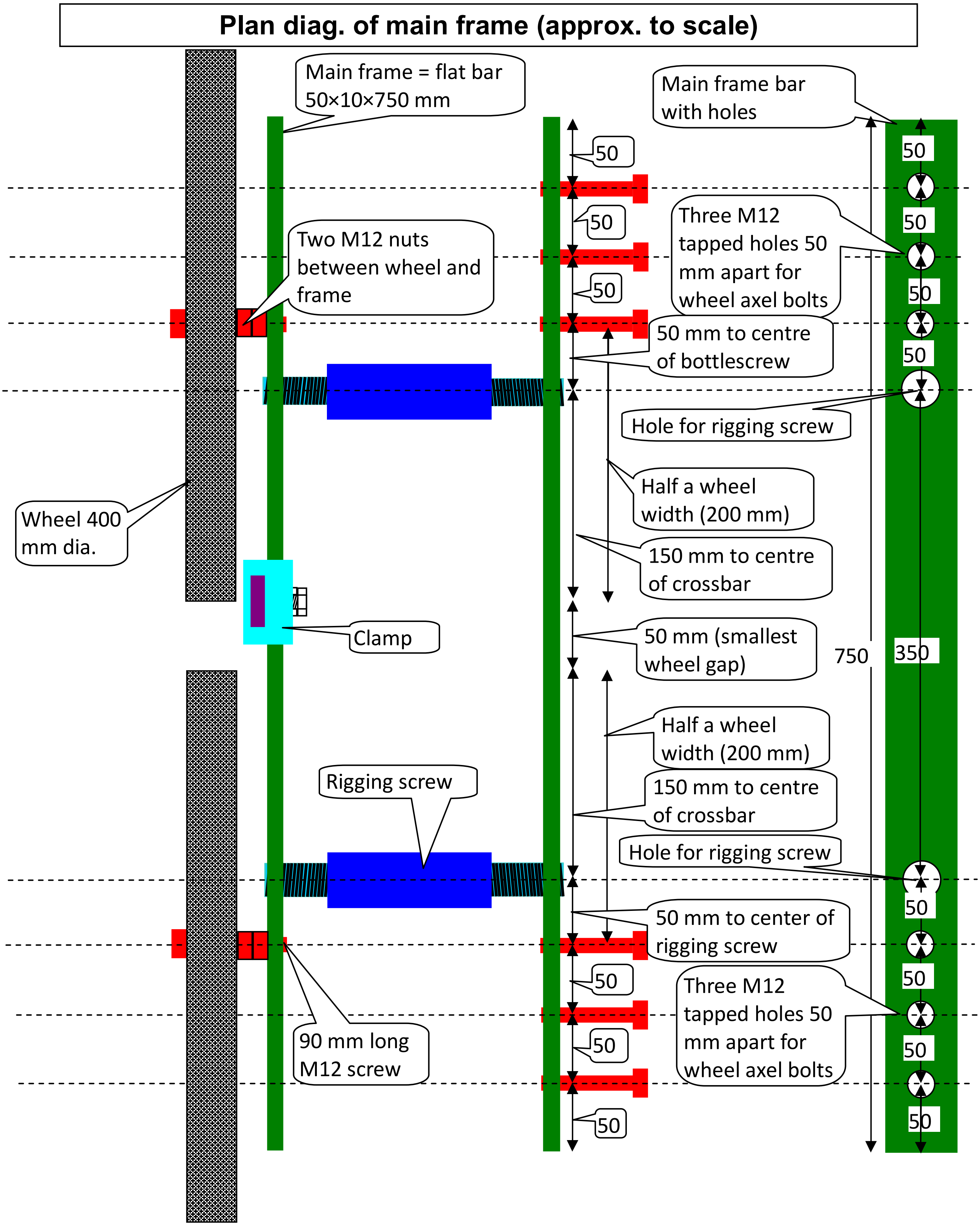
2. Fasteners: Bolts vs. set screws and head sizes

Commonly the word 'bolt' is often used to describe both 'true' bolts where there is an un-threaded length of shank next to the head and also 'set screws' where the entire shaft is threaded. In these plans the words 'bolt' and 'screw' are used in their technical meaning.

In Australia and New Zealand, M12 bolts and nuts do **not** use the international standard 19 mm head size except for Nylex nuts. Either standard 18 mm sized nuts and bolts can be used, or industrial fastener suppliers are able to supply 19 mm M12 fasteners, overseas supplies may also be cheaper, even when posted to NZ. The aim of having all nuts with 19 mm is so only one spanner is needed.

3. Zinc electroplating and stainless components

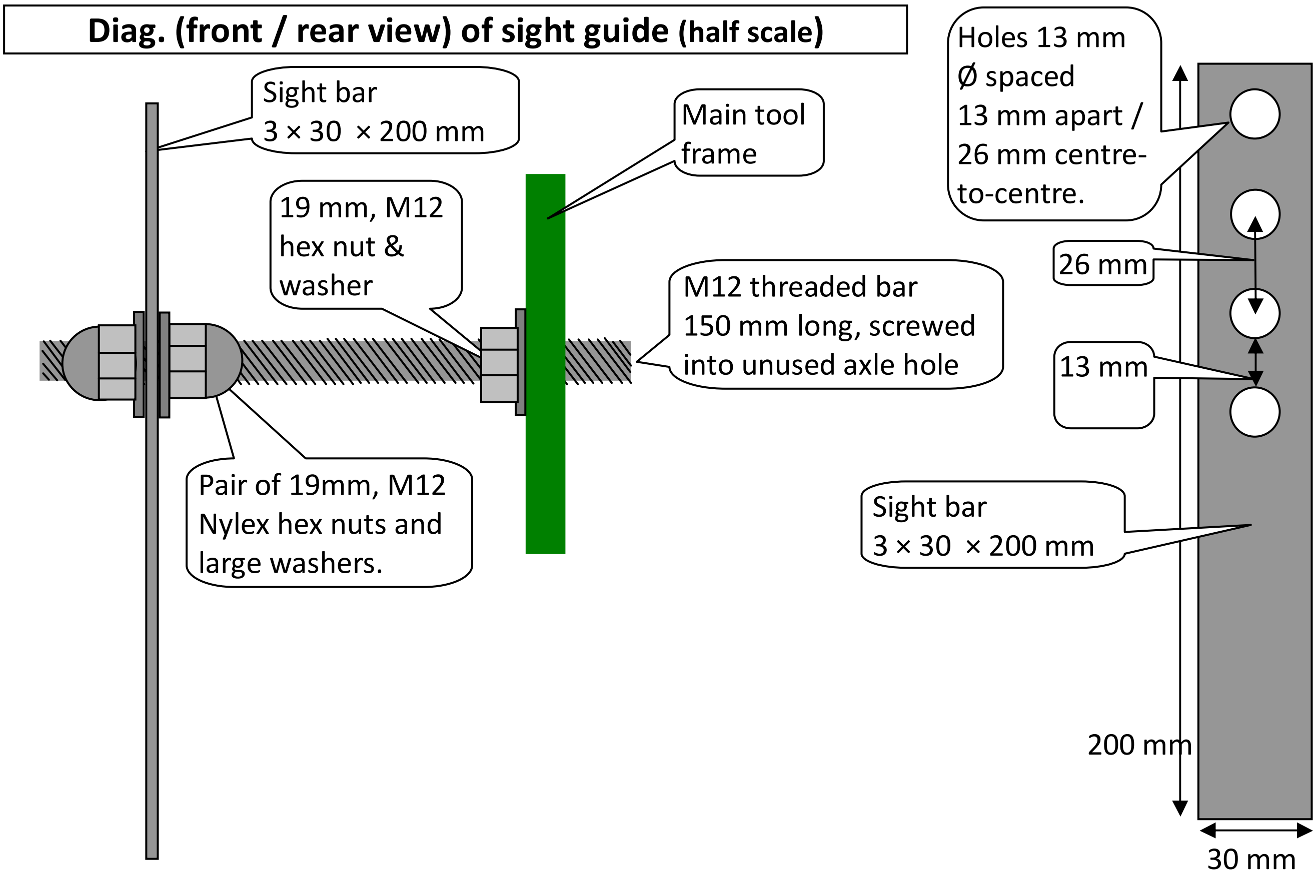
The blades for the T hoes and mini-ridgers are best made from stainless steel. Other components, can be made from mild steel or stainless as desired. Note that drilling holes and tapping threads in stainless is challenging. It is recommended that all the mild steel used should be zinc electroplated after manufacture. This is considered superior to galvanising (hot zinc dipping) as galvanising adds significant extra thickness to the steel, effecting critical measurements, and the finish is often poor, requiring cleaning up and the rust protection for electroplating is often superior due to better coverage. Zinc electroplating is often no more expensive than galvanising . Painting is considered a poor alternative to zinc plating or galvanising, but is better than nothing.



- The two main frame bars are made from 50 × 10 mm flat bar 750 mm long and are identical.
- Holes for wheels to be tapped / threaded to take M12 bolt, **ensuring hole & thread is accurately cut at 90° to frame so wheels and sight guide are square to frame. Best use a drill press for drilling and starting tapping**.
- M12 screws **90 mm long** are used for the wheel axles with 1.6 mm washers on both sides of the wheel and **two** 19mm nuts between the wheel and frame as packing and to lock the screws in place.

4. Sight guide

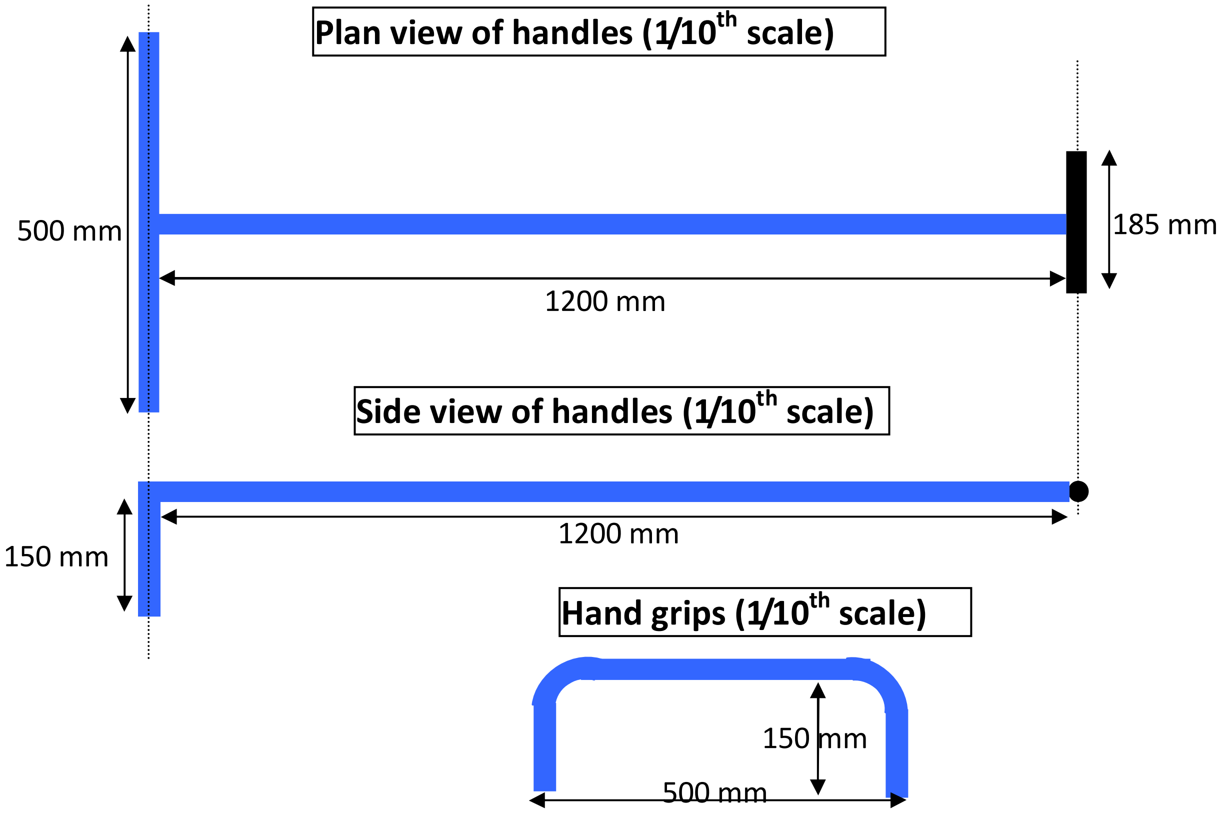
The purpose of the sight guide is to have a thin vertical bar that hangs below the level of the main frame, placed down the centre line of the hoe / between the hoe blades so that the user has something to line up ‘sight’ against the crop, as the ends of the T hoes will not be visible to the user as they will be under the soil. As the hoe width is altered the position of the sight guide needs to be able to adjust accordingly.



- The sight bar is a piece of flat bar 3 × 30 mm × 200 mm.
- One end / half to have four 13 mm holes cut starting 7 mm (half a hole width) from the end of the bar with 26 mm between hole centres.
- The sight bar holder is a piece of 150 mm long M12 threaded bar.
- The sight bar is kept in position on the threaded bar by two M12 Nylex nuts and large washers. A standard M12 hexagonal nut and washer is used to lock the threaded bar to the frame to provide the necessary resistance against which the Nylex nuts can be turned.

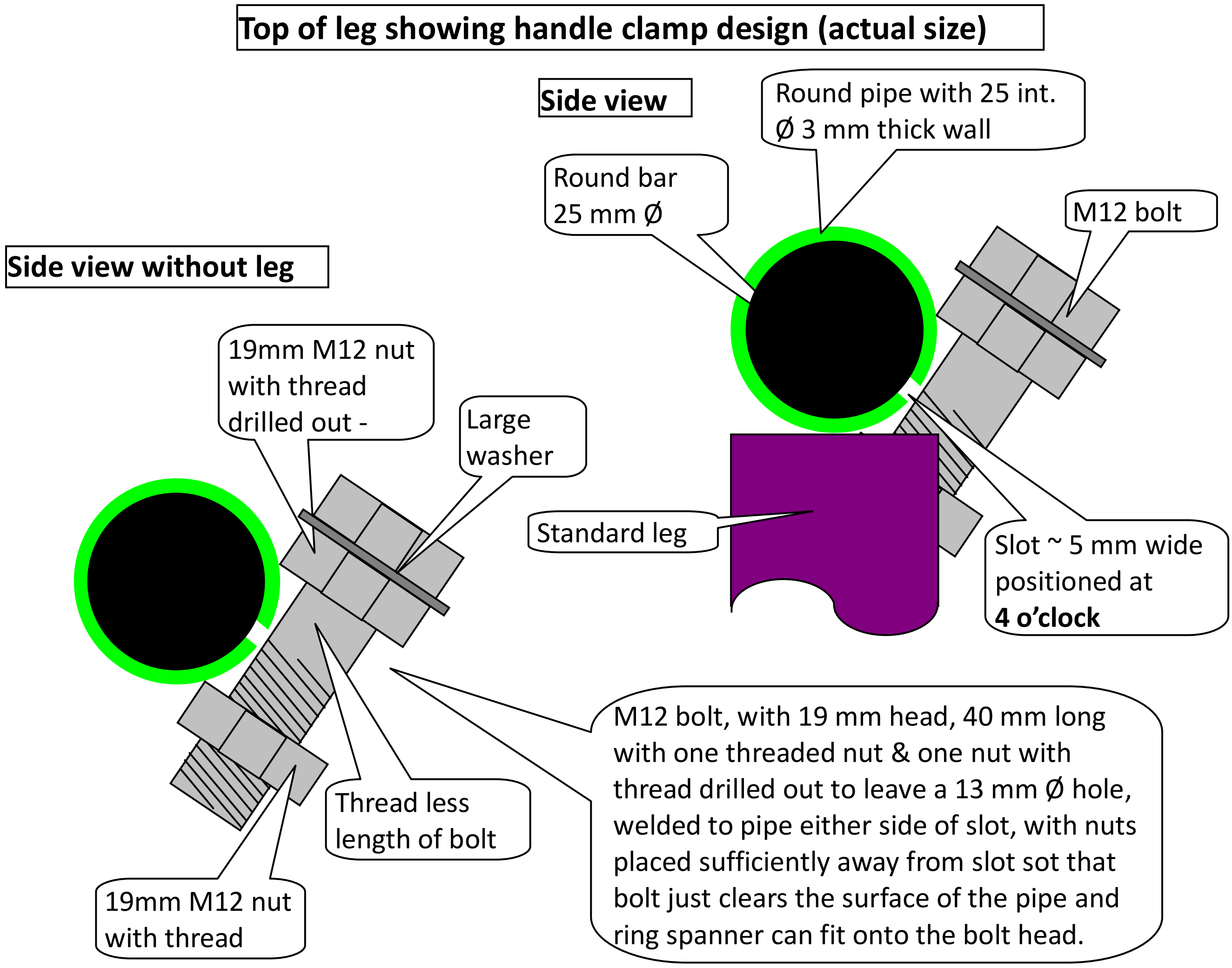
5. Handles and handle clamp system

- Handles to be made out of lightweight tube approx 25 mm diameter (1”), wall thickness approx. 1.6 mm, e.g., exhaust tube.
- Handles consist of one long central arm and hand grips which are similar to ‘sit up and beg’ style bicycle handle bars.
- The hand grips are formed from a single piece of pipe: The ends are bent at 90° to form a long shallow U shape in a single plane (i.e., bent pipe will sit flat on a bench) with the hand grips approx. 150 mm long and total width 500 mm. Else the pipe can be cut at 45° at and welded.
- The central arm is a straight length of pipe 1200 mm long welded to the center of the hand grips at one end and at the other end to the 25 mm diameter round (solid) bar 185 mm long that fits into the handle clamps (see below)



5.1. Handle clamps

- The 185 mm long round bar on the handles fits inside two clamps made of round pipe with an **internal** diameter of 25 mm, i.e., the 25 mm ext. Ø round bar needs to fit 'snugly' inside the pipe.
- The wall thickness of the pipe needs to be close to 3 mm to achieve a balance of strength vs. flexibility.
- An approximately 5 mm wide slot is cut down the length of the clamps. **NB** Where the pipe has a weld ridge the slot must be cut down the weld leaving the rest of the inside of the pipe smooth.
- The clamps are tightened by means of a 50 mm long M12 bolt passing between an M12 nut, and a M12 nut with its thread drilled out (13 mm Ø drill), welded to either side of the slot. The nuts should be welded onto the clamp slightly away from the slot so the bolt passes close to the surface of the clamp.
- A washer is required between the head of the bolt and the drilled out nut to facilitate firm tightening.
- The end of each clamp pipe is welded to the top of a standard leg with the slot just above the leg (as per diag., below) i.e., at **4 O'clock**. Also see diagrams on pages 21 and 24 and photos on page 14.
- One of the legs should be shortened by ~50 mm to facilitate putting the handles into the clamps when they are on the main frame, i.e. so one leg can be inserted first, then the second, rather than simultaneously trying to line up two equal length legs in the clamps.



6. Standard leg

The hoe blades, mini-ridgers, handles and all other pieces of equipment are attached to the main frame by a 'standard leg' and 'standard clamp' (below).

- The standard leg is 30 × 8 mm flat bar, 250 mm long.

This is a standard mild steel flat bar size, however, the manufacturing tolerances on flat bar is often 1-2 mm (especially on cheaper steel) which means that the legs have to be ground to the correct size to fits through the clamps. It may well be better to have the bars profile cut, as the thickness tolerance of the sheet from which the bars are cut is higher than bar, and, the cutting is highly accurate, so the width will be constant / the same for all bars.

7. Rigging screws

The two sides / toolbars of the hoe are connected by two custom made rigging screws (also incorrectly called turnbuckles (which have an open middle)). Every conceivable means of joining the two main bars of the 4 Wheel Hoe together have been tried, including pins, sliding bars, multiple holes and more. Much effort has gone into finding off-the-shelf turnbuckles and rigging screws to do the job. In the end all of these have been found wanting and this custom version has proved the best solution as it allows the screws to turn even if the main frame bars are slightly out of alignment as the M16 threaded bar has 'extra space' inside the barrel.

The rigging screws will need to be turned in a lathe, to ensure that the holes and threads are straight / true. Either round bar can be used or if heavy walled pipe (line pipe) e.g. OD 30 mm and ID >13 mm can be found that can also be used.

It is **critical** that the holes in the two sides of the main frame are exactly opposite so that all four wheels sit squarely on the floor when the hoe is assembled.

It is also **critical** that the M16 threaded hole in the frame is tapped at exactly 90° to the frame bars otherwise the rigging screws will not accurately align and jam when turned and the wheels won't sit flat on the floor. Use a pedestal drill to cut both the holes and at least start tapping the thread, turning the chuck by hand.

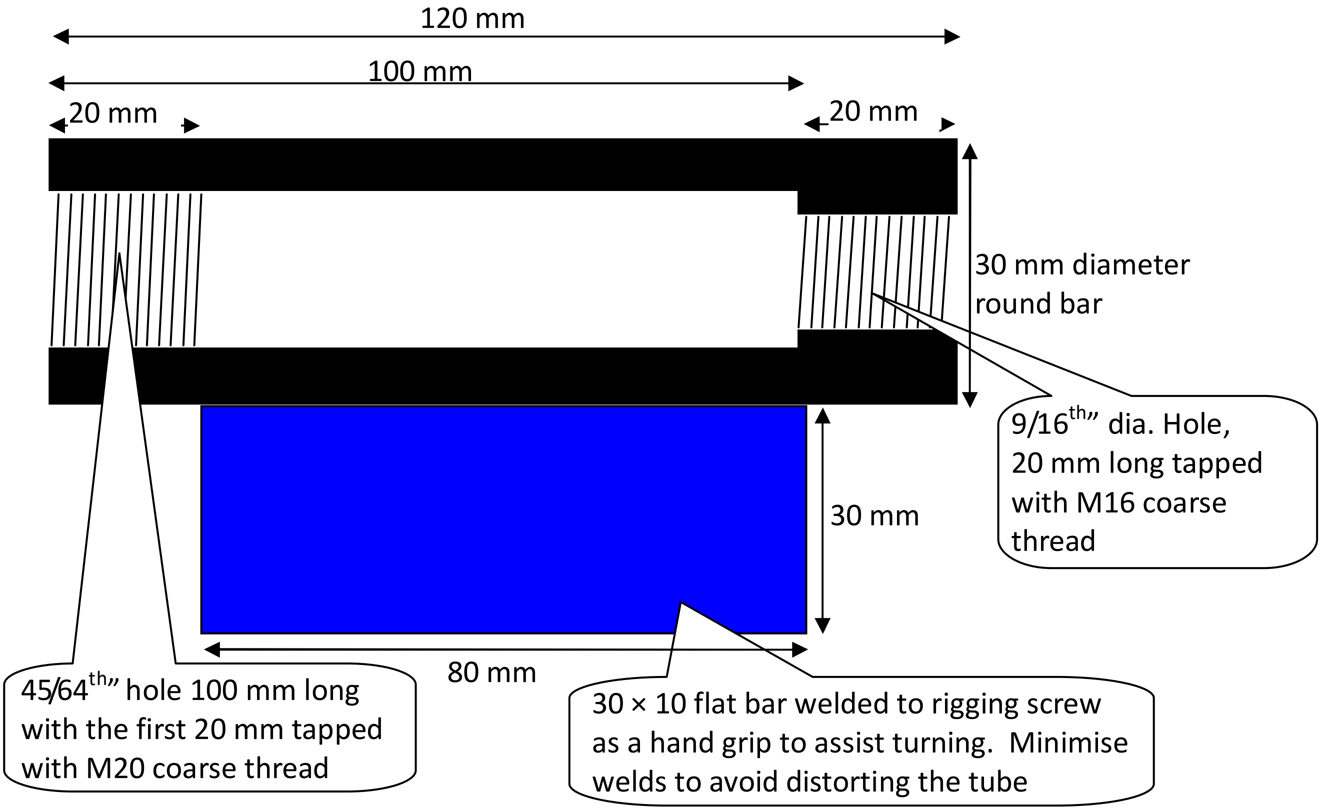
If however lathe work is a barrier then **modifying** an off-the-shelf rigging screw or turnbuckle is a viable option. Good off-the-shelf options are the rigging screws / turnbuckles from the three point linkage stabilisers on small tractors. Turnbuckles have the advantaged of reduced threads in contact with the threaded bar such that there is reduced chance of jamming if things are out of alignment. Many aftermarket tractor part suppliers carry a wide range of these, as well as second hand as an option.

Below are examples of rigging screw used on previous versions of the 4 Wheel Hoe (Figure 5). The best design for a workshop with limited tools was to weld two M16 nut onto / into a length of pipe, as this reduced the length of thread in contact with the inside of the rigging screw so allowing it to still turn when there is moderate misalignment (Figure 5, right photo). To ensure both nuts are aligned, screw them onto a piece of threaded rod (or a very long bolt or set screw). This can also be useful to keep them tight if they are sitting on the ends of the tube not inside it, while welding them. As long as the nuts are aligned it is not vital to have them absolutely perfectly centered on the tube.

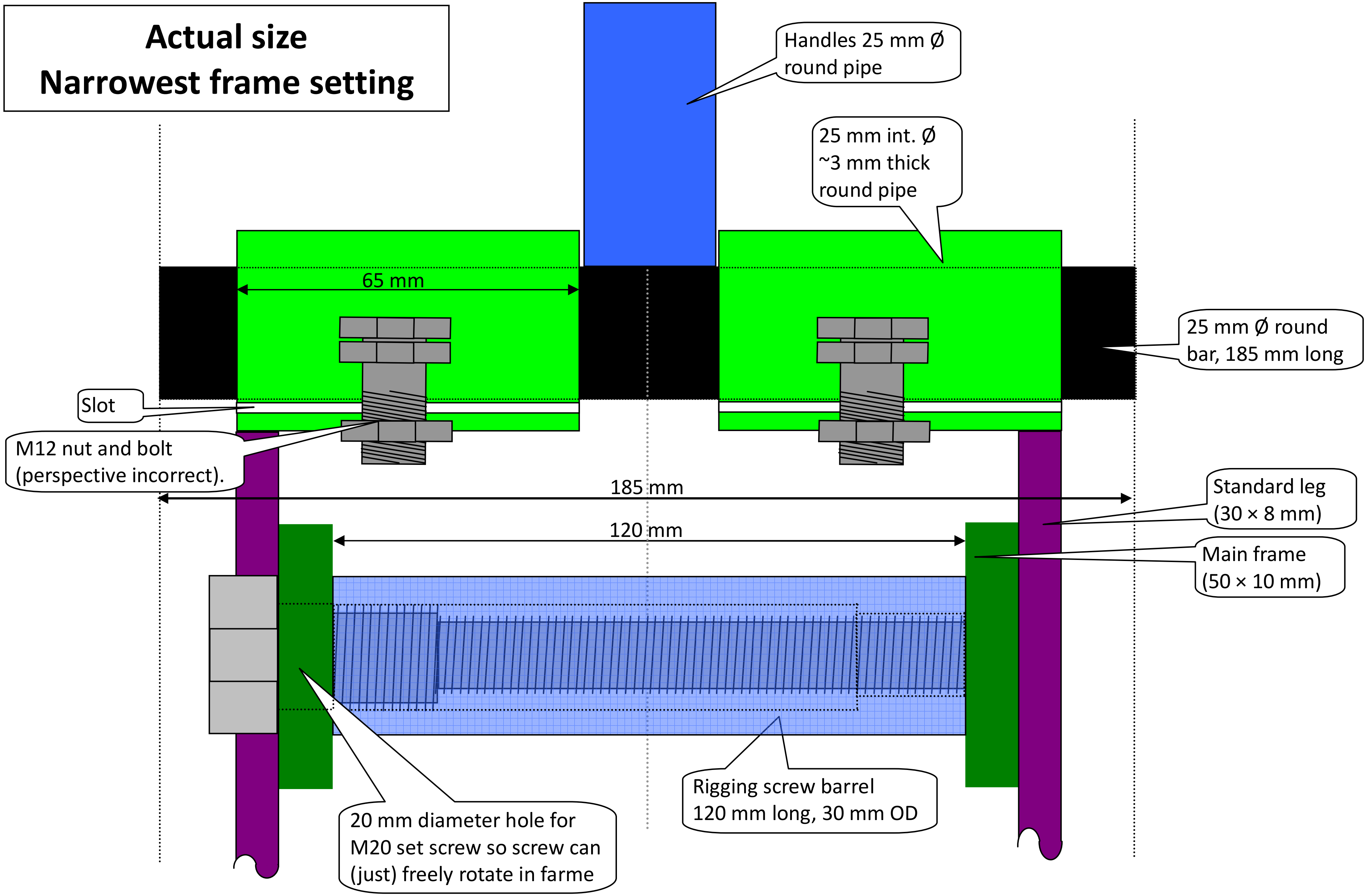
The left photo in Figure 5 is a piece of pipe that has been drilled out and tapped on a lathe.

Figure 5. Examples of rigging screws from previous versions of the 4 Wheel Hoe.

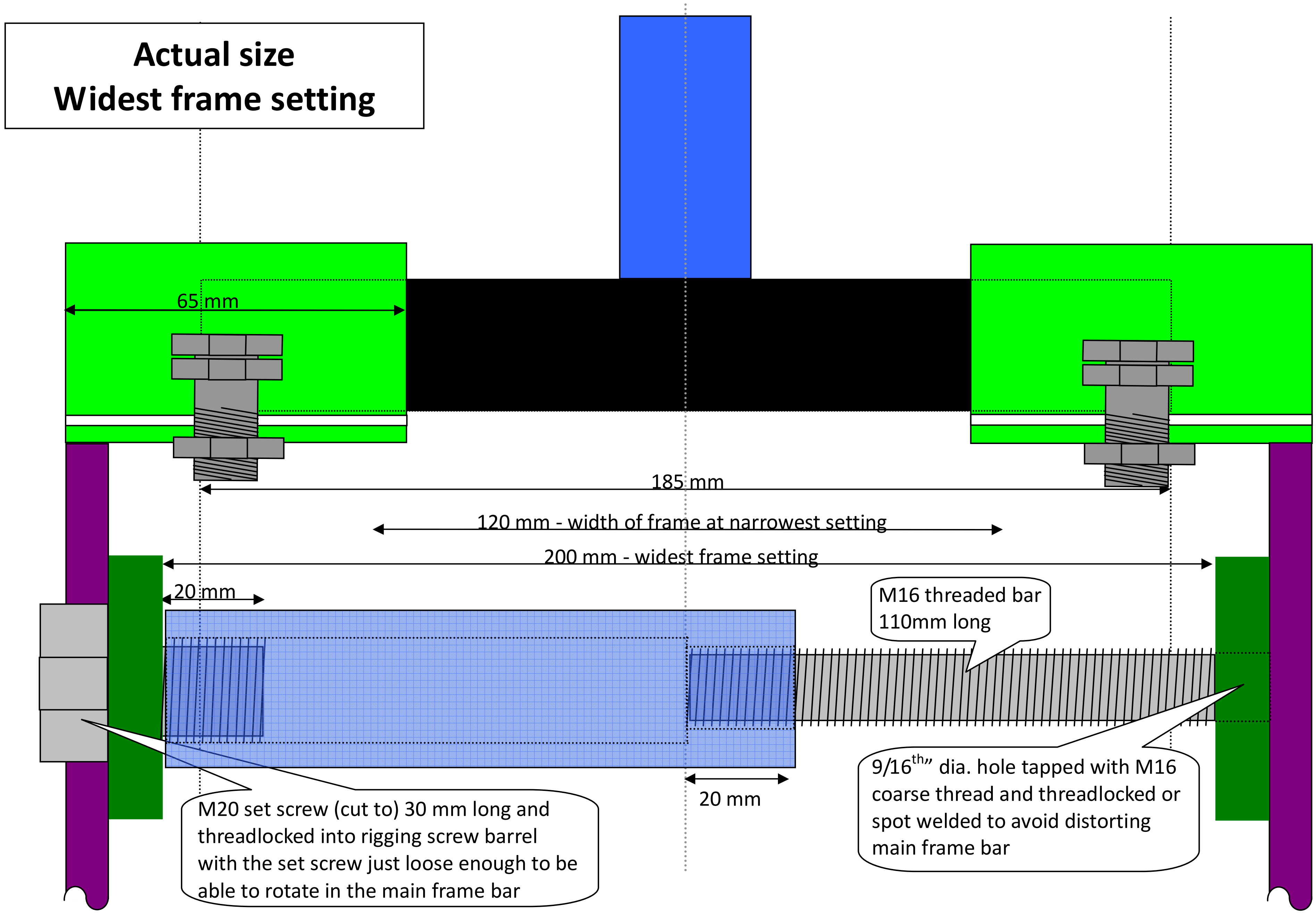
Rigging screw, barrel



See the diagrams on the next two pages for details of the M20 set screw and M16 threaded bar used in the rigging screw. The M20 set screw is threadlocked into the rigging screw barrel while the M16 threaded bar is threadlocked into the main frame. Turning the rigging screw barrel results in the M20 set screw 'freely' rotating in the main frame while the M16 threaded bar winds in and out of the rigging screw barrel thereby increasing or decreasing the distance between the main frame bars.



Actual size
Narrowest frame setting
Handles 25 mm Ø
round pipe
25 mm int. Ø
~3 mm thick
round pipe
65 mm
25 mm Ø round
bar, 185 mm long
Slot
M12 nut and bolt
(perspective incorrect).
185 mm
Standard leg
(30 × 8 mm)
120 mm
Main frame
(50 × 10 mm)
Rigging screw barrel
120 mm long, 30 mm OD
20 mm diameter hole for
M20 set screw so screw can
(just) freely rotate in farme


Actual size
Widest frame setting
65 mm
185 mm
120 mm - width of frame at narrowest setting
200 mm - widest frame setting
20 mm
M16 threaded bar 110mm long
9/16th" dia. hole tapped with M16 coarse thread and threadlocked or spot welded to avoid distorting main frame bar
20 mm
M20 set screw (cut to) 30 mm long and threadlocked into rigging screw barrel with the set screw just loose enough to be able to rotate in the main frame bar

8. Standard clamp

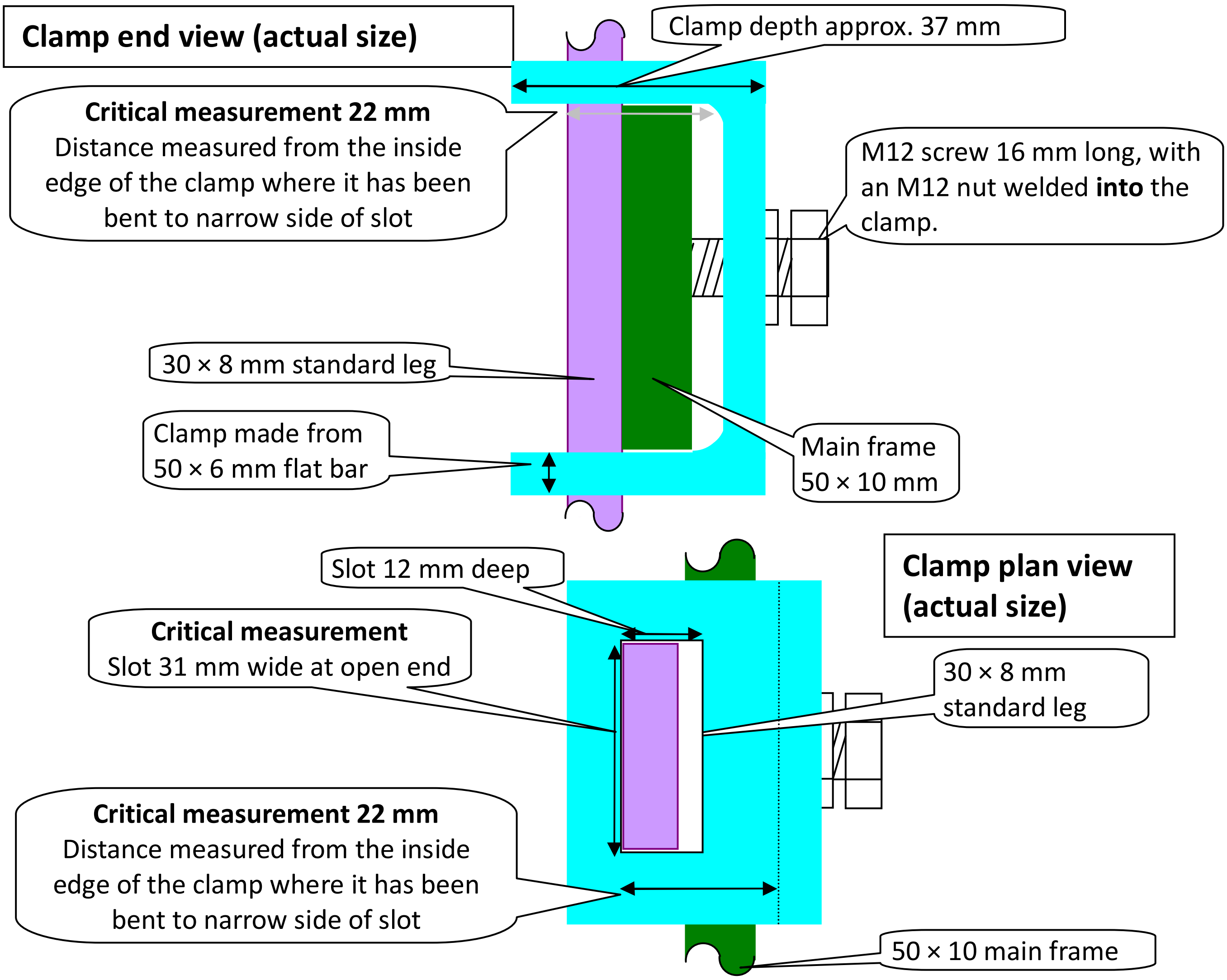
Design as per diagram below, made to take the 30 × 8 mm standard leg. Clamps to be made from 50 × 6 mm flat bar, folded into a rectangular '**C / U**' shape, **or** if accurate folding is not possible then the clamp can be made in three parts and welded together, **or** if channel is available that fits snugly on the main bars that can also be used. It is **critical** that the clamps dimensions are accurate, if they are to keep the legs exactly vertical / at 90° (both front to back and side to side) to the main frame.

The critical sizes are:

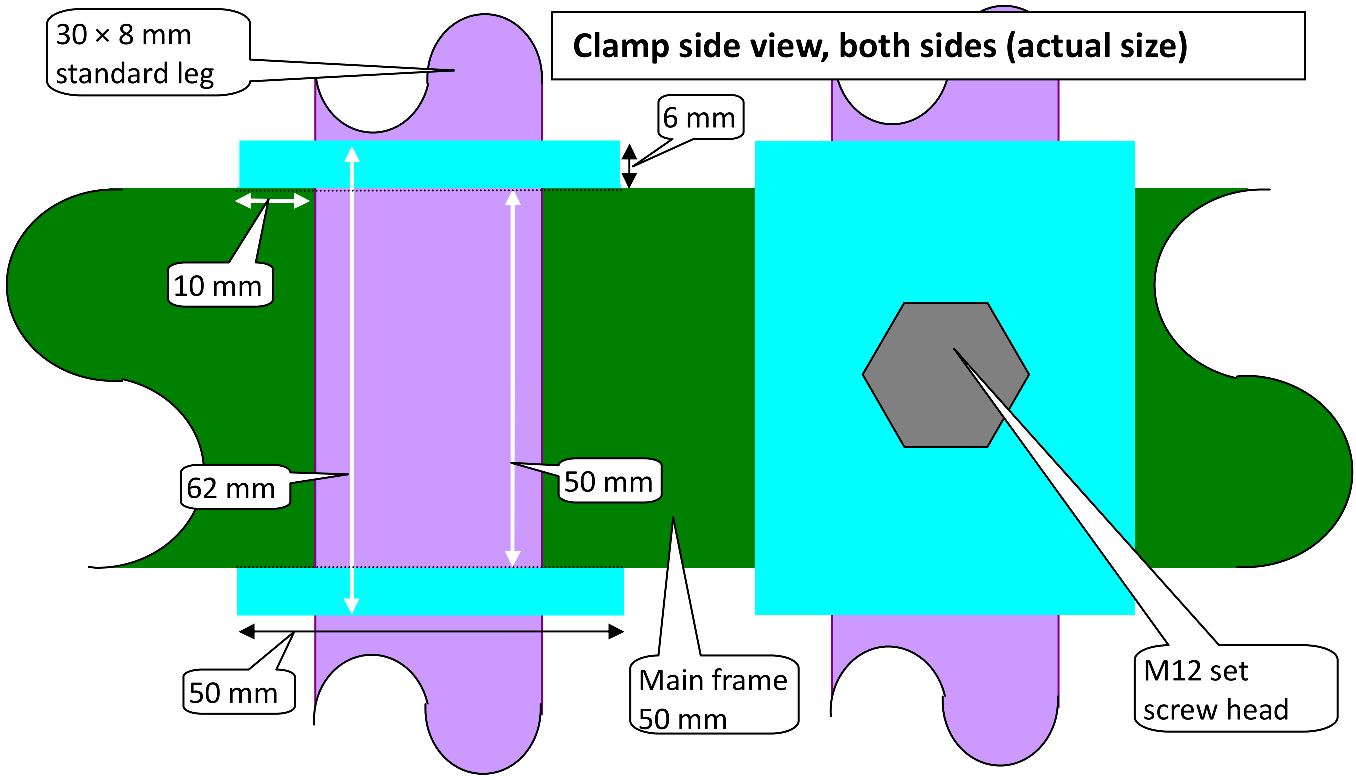
- **the length of the slot - so it is just big enough for the standard leg;**
- **that both slots are exactly opposite each other;**
- **that the slot is far enough towards the end of the clamp arms that when placed on the main frame that it is easy to get the legs in and out;**
- **that the clamp arms are exactly parallel;**
- **that the clamp fits snugly onto the main frame.**

as these control the front / rear and left / right angle of the legs. However, the depth of the slot is not as critical as the length as has to be to be sufficiently wider than the leg is thick to allow the leg to be easily inserted, removed and adjusted.

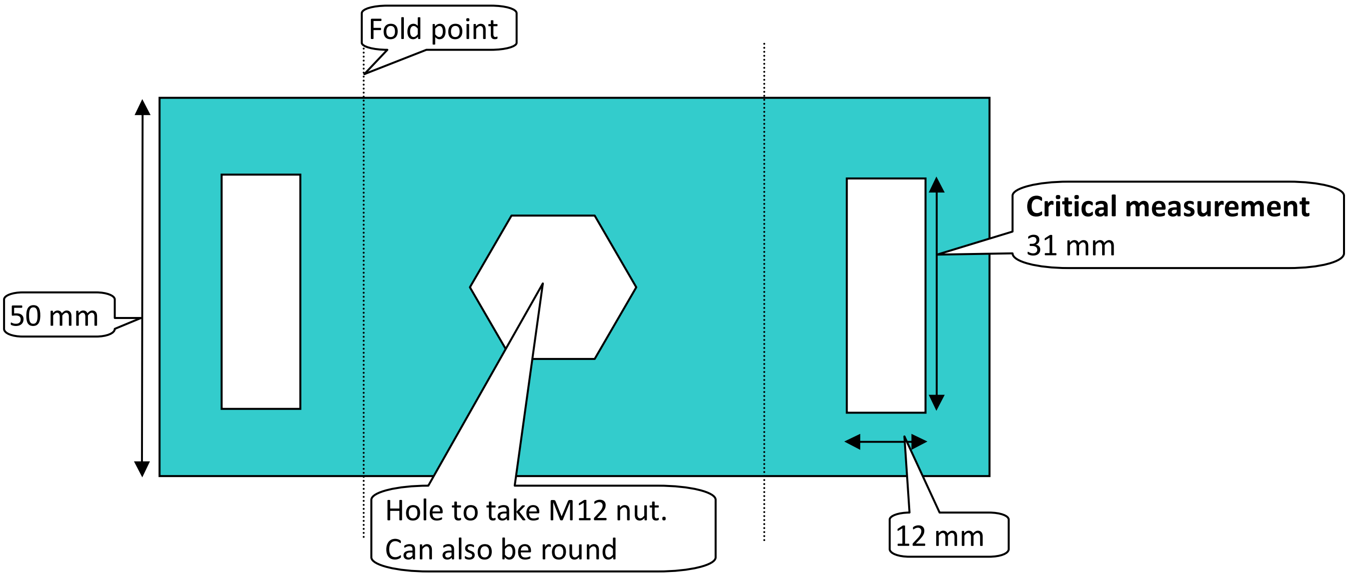
A hexagonal or round hole into which an M12 hex nut will fit is cut into the center of the clamp, so the nut can be welded **into** the clamp, with the nut flush to the inside of the clamp, i.e., protruding on the outside. M12 screws with 16 mm long with the **ends of the screws ground flat** to reduce the amount the end of the screw cuts into the main frame as they are tightened.



Clamp side view, both sides (actual size)

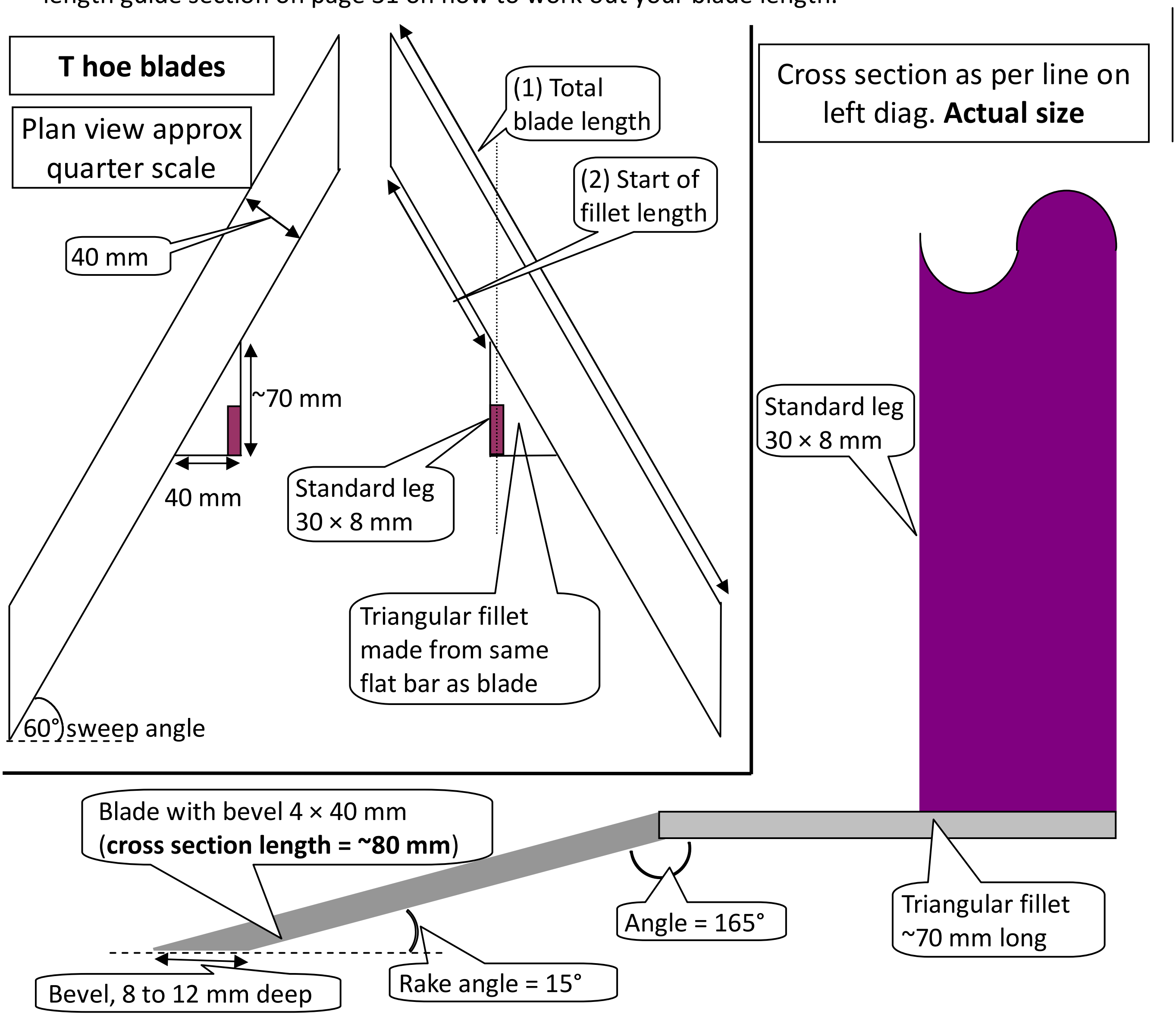


Clamp cutting plan **(approx. actual size) final dimensions dependent on amount taken up by fold**



9. T hoe

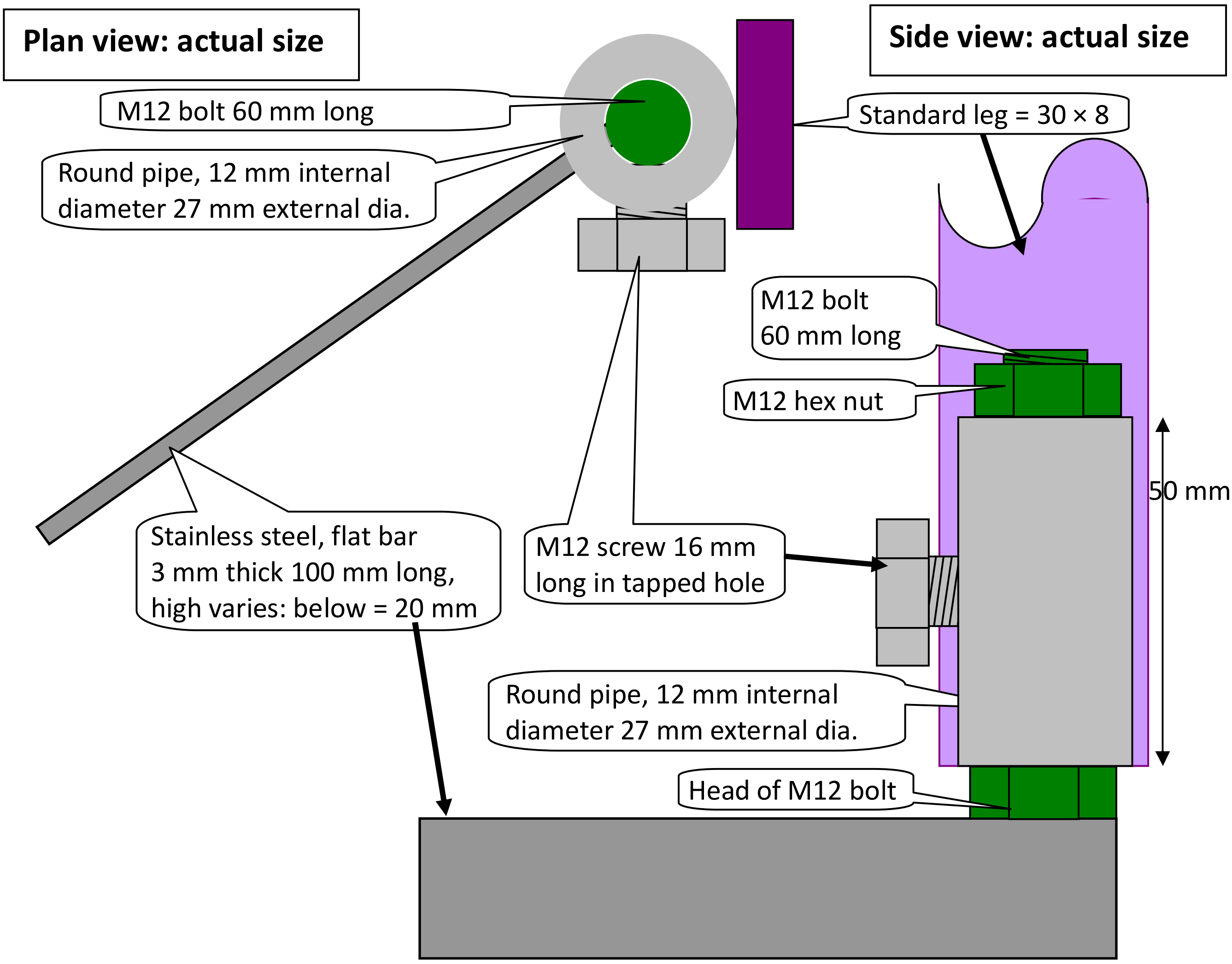
- The blade of the T hoe should be made from stainless due to its rust-resisting properties and also hardness compared with mild steel. The alternative is to use a second hand cutting bar from a reel mower, which are cheap as they are scrap, and the steel is hard, flexible, weldable, and ideal size.
- T hoe blade is made of flat bar 40 × 4 mm.
- The blade needs a sharpened (bevelled) front edge, with the bevel on the **bottom**, with a minimum bevel angle of ~30° (8 mm deep) or **ideally** ~20° (12 mm deep).
- The blade is angled 60° towards the direction of travel (sweep angle) from a line at 90° to travel direction (see diagram below). Both ends of the blade need to be cut at 60° across the bar so the cut edges are parallel with the direction of travel.
- To allow soil to flow as freely as possible long the front edge of the blade a triangular fillet made from the same steel as the blade (the fillet is the same size as the off-cut produced from cutting the bar at 60° to make the blades) is welded flat to bottom of the leg.
- Next the blade is welded to the fillet at an angle of 15° forward tilt (rake angle), i.e., the front edge is lower than the back edge of the blade. For a 40 mm wide blade this equals a 10 mm lift at the back edge of the blade. This means the fillet and blade are welded at a 165° angle to each other (i.e., 180° - 15° = 165°)
- The blade length depends on user requirements. There are two measurements (1) Total blade length (2) Start of fillet length. The default sizes are (1) = 540 mm (2) = 190 mm. See the blade length guide section on page 31 on how to work out your blade length.



10. Mini-ridgers

Mini-ridger blades are made from 3 mm thick stainless steel flat bar in two different standard heights (widths): 20 and 40 mm. Smaller and bigger ridgers can be made if desired. Ridgers are all 100 mm long.

- The blades are welded to the head of a 60 mm long M12 bolt.
- The bolt fits inside a 50 mm length of thick walled round **line** pipe, internal dia. 12 mm external 27 mm.
- The above pipe has a threaded hole to take a **16 mm long** M12 screw halfway along its length.
- The pipe is welded to a standard leg with the lock bolt parallel to the leg and pointing towards the rear of the hoe. This means that left and right handed pairs are required, see photo on page 14.



11. Wheels

The wheels for the 4 wheel hoe are 400 mm / 16" in diameter and about 40 mm wide. Larger and smaller diameters have been tried and don't work as well. It is essential to get high quality wheels, e.g. wheelchair rated (40 kg), with twin bearings. Lower quality wheels have been tried and broken.

Ideally the wheels would have a non-pneumatic tyre which are puncture proof, however, there are few supplier of such wheels e.g., www.urathon.com in the UK. Pneumatic tyres can be filled with an anti-puncture compound to give similar puncture resistance. Choose as smooth a tread patten as possible, i.e. avoid mountain bike / off road treads as these collect, rather than shed mud.

The ideal wheel would have agricultural semi-pneumatic tyres as used on seed drills and interrow hoes.

The axle hole size needs to fit 19 mm / ½” bolts, that are used as standard on the hoe. If the wheels have different axle hole sizes, the size of the tapped holes in the main frame will have to be changed to match.

12. Manufacturing information

12.1. Steel ordering list

Account has been taken of cutting loss, by having excess bar where length is **critical**, or where part size is not critical by excepting cutting loss. Steel type is mild unless otherwise stated

Type	Size mm	Length mm	Parts	Cutting loss notes
Flat bar	50 × 6	800	Clamps	10 mm cutting allowance
Flat bar	30 × 10	1500	Legs	Shorter by cutting loss
Flat bar	50 × 10	1500	Main frame	Shorter by cutting loss
Flat bar	30 × 3	200	Sight guide	Single part - no cutting
Stainless flat bar	40 × 4	500 - 1200	T hoe blades and fillets	Depends on blade length
Stainless flat bar	40 × 3	200	Ridgers	20 mm cutting allowance
Stainless flat bar	20 × 3	200	Ridgers	Shorter by cutting loss
Round pipe	12 × 25*	100	Ridger clamps	Shorter by cutting loss
Round pipe	25 × 35*	135	Handle clamps	5 mm cutting allowance
Round pipe	23 × 25*	2100	Handles	Shorter by cutting loss
Round bar	25	185	Handle clamp bar	Single part - no cutting
Bright mild round bar	30	250	Rigging screws	5 mm cutting loss

* Pipe size refers to internal × external diameters.

12.2. Bolt / screw, nut and washer ordering list

12.2.1. M12

N.B. 16 mm and 90 mm M12 set-screws are uncommon lengths so they may need to be specially ordered. All M12 bolts and screws should ideally have 19 mm heads i.e. the international standard size.

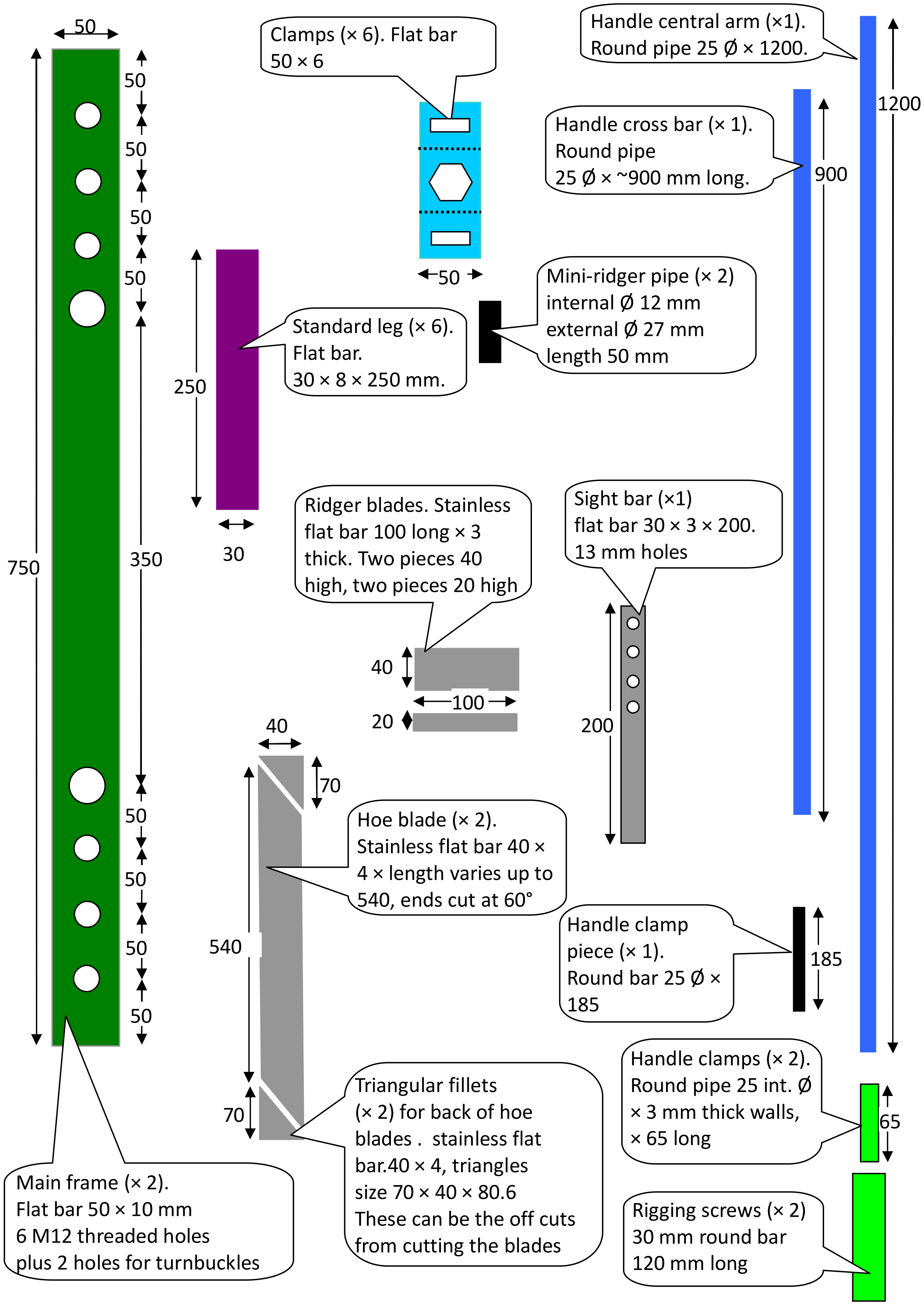
M12 / bolts/set screws, nuts and washers required per machine:	Count	Length mm	Nuts	Nylex nuts	Washers 1.6 mm
Wheel axle **set screws**	4	90	8	0	8
Site guide **threaded bar**	1	150	1	2	3
Leg clamps and mini ridger clamps	8	16	6	0	0
Handle clamps	2	50	4	0	2
Bolts for mini ridger blades .	4	60	2	0	0
Total	**19**	**N/a**	**21**	**2**	**13**

12.2.2. M16 and M20

225 mm of M16 threaded bar (inc 5 mm of cutting allowance for the rigging screws)

Two M20 30 mm long set screws for the rigging screws (these can be made by cutting down longer set screws).

12.3. Component cutting list **(individual parts roughly to scale)**



4 Wheel Hoe Blade Length Guide

1. Introduction

This document explains how blade lengths are determined for interrow hoes and therefore what T hoe blade length you will need for your crops. This is required because it is impossible to supply a standard length hoe blade that will suit everyone, as not only do row widths vary, but so do the size of the crop gap crop types and interrow width consistency, all of which can affect the length of the hoe blade.

If you have a diverse range of crops growing on very different sized row widths, more than one pair of hoe blades may be required. This could also apply if you have narrower crop rows but would also like to use the hoe for the false seedbed technique on larger areas of soil, in which case a second larger pair of hoes would be required.

The rest of this guide outlines the issues that need to be considered when working out the optimum blade length. It may appear rather complicated, especially for such an apparently simple machine, but the underlying principles are relatively straight forward, and they apply to all knife blade hoes.

1. Terminology

For clarity there are a few terms to define.

- **Blade tip**, is the front most part of a T hoe blade i.e., the part closest to the crop row being currently hoed.
- **Blade heel**, is the backmost part of a T hoe blade, i.e., the part closest to the crop row adjacent to the row currently being hoed.
- **Blade length**, is the length of the blade measured along its edge (front or back), i.e., this differs from the interrow width the blade will hoe. For a hoe blade at 60° (as the T hoe is) blade length is twice the interrow width it will hoe.
- **Crop gap**, is the width between the tips of a pair of hoe blades that the crop must fit through. Crop gap is also used to refer to the distance between the blade heel and the adjacent crop row. The minimum size of crop gap that is practically possible to hoe is about 3 cm or just over an inch.
- **Interrow width**, also called row spacing, is the width (measured at 90° to the crop row) between the center of one crop row and its adjacent crop row.
- **Consistent interrow width**, means that the interrow width always remains exactly the same to less than a centimetre / ½" i.e., rows have been marked out using a 'marking out bar' or put in with a multi-row seed drill or planting machine.
- **Variable interrow width**, is the opposite of a consistent interrow width, in that the interrow width frequently varies by more than a centimetre / ½", e.g., each row has be marked out individually.
- **Overlap**, the area of soil between two adjacent crop rows that is hoed twice as the hoe passes down the first row then up the second. Maximising overlap is valuable to maximise weed kill.

2. Ready reckoner

The ready reckoner (Table 1) gives the maximum hoe lengths for a range of interrow widths for small (3 cm) and large (6 cm) crop gaps and the position of the leg along the hoe (see Figure 6).

Table 1. 4 Wheel Hoe, blade length ready reckoner. The widths are illustrative as the 4 Wheel Hoe is continuously variable for interrow widths above 15 cm. See the following sections and Figure 6 for a full explanation of factors that determine blade length. * = See the detailed information about hoe and frame size limitations in the sections below.

	Max possible blade length		Leg position length	
Interrow width	**3 cm crop gap**	**6 cm crop gap**	**3 cm crop gap**	**6 cm crop gap**
15 cm / 6” *	24 cm	18 cm	11 cm	8 cm
20 cm / 8”	34 cm	28 cm	14 cm	11 cm
25 cm / 10”	44 cm	38 cm	16 cm	13 cm
30 cm / 12” *	54 cm	48 cm	16 cm	13 cm

Blade length is calculated by taking the row width, subtracting the crop gap and then multiplying by two. This assumes an equal sized crop gap at the hoe tip and heel, which would not normally be used in practice, see section 2.1 for an explanation.

Leg position is only indirectly affected by crop width as they are dependent on the hoe width, which varies from 14 cm to 22 cm (measured to the outside of the frame). The leg positions for the 30 cm row are the same as the 25 cm row because room for adjustment of the hoe’s width is required, so all of the additional length is added to the back end of the hoe blade.

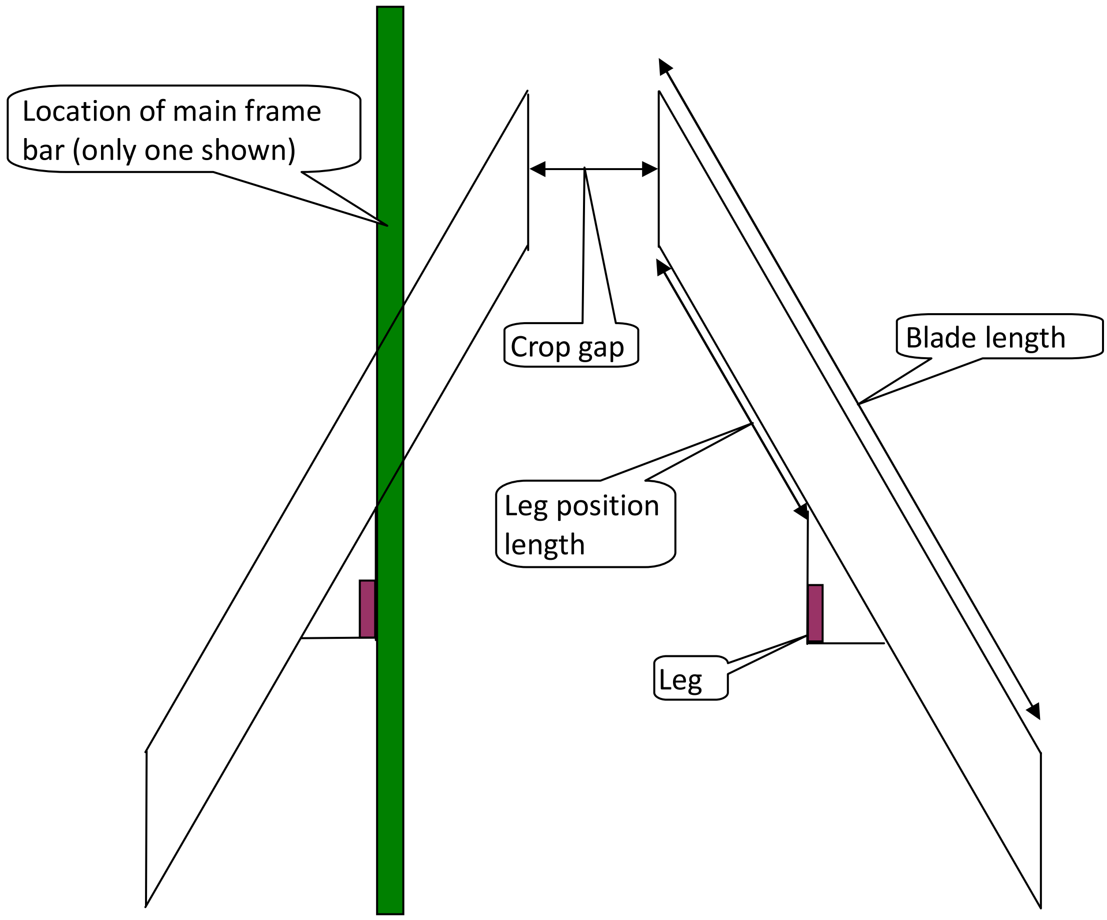


Figure 6. Diagram of pair of T hoes showing how ‘blade length’ ‘leg position length’ and ‘crop gap’ are measured.

All the measurements in Table 1 are based on mounting the hoe leg on the outside of the main frame, which is the standard location. This means that moving both pairs legs to the inside of the frame will reduce the crop gap by 3.6 cm / 1 ½”, which can facilitate using the blades to till the entire soil surface for the false seedbed technique or to give an alternative means of changing from a larger to a smaller crop gap without changing hoe width.

2. Interactions between crop gap, interrow and blade widths

2.1. Crop gaps at the blades tip and heel

As the length of T hoe blades are fixed, as are all hoe blades (i.e., they are not telescopic!), each blade can only hoe a fixed width of soil. Therefore the only way to change the size of the crop gap is to move the hoe blades towards or away from the crop row. The 'problem' with this is that moving the blade away from one row, to increase that crop gap, moves the blade towards the adjacent crop row, decreasing its crop gap. The blade length therefore has to be short enough, so that the distance from the crop row to the blade tip at the widest desired crop gap, is the same as, or less than, the distance from the heel of the hoe to the adjacent crop row Figure 7.

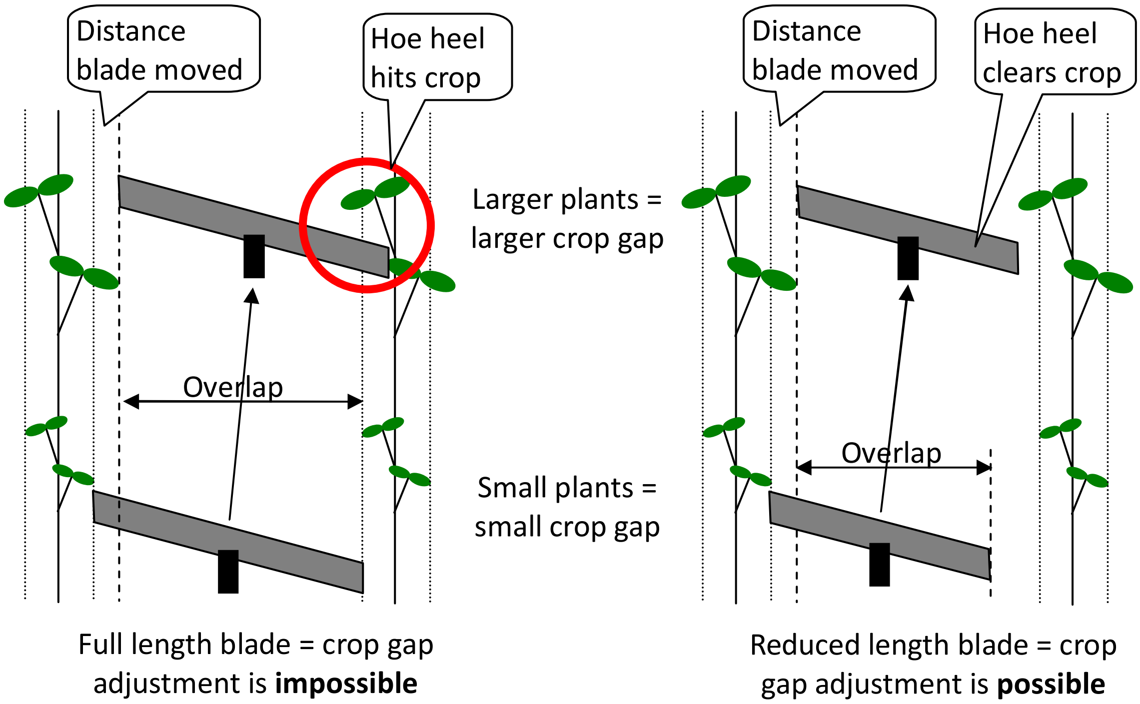


Figure 7. The effect of full or reduced blade lengths on the ability to alter the crop gap.

Generally the crop gap at the blade's heel needs to be larger than at the tip for two reasons: (1) because soil flowing off the blade heel can bury small crop plants; (2) as long as the crop gap at the hoe's heel is bigger than at its tip, if the crop passes through the crop gap at the tips it will pass through the crop gap at the heels.

2.2. Interrow width: consistent or variable

Consistent and variable interrow widths are related to the crop gap issue. If the interrow width is always exactly the same, a hoe that covers the full interrow width can be used without any risk of the hoe heel killing plants in the adjacent crop row. If the interrow width varies, then a full length hoe will hit the plants in the adjacent crop row when the interrow width decreases too much. Therefore, where there is a variable interrow width, such as where rows are marked out individually, for example, using string, or between bouts of tractor mounted equipment, a reduced length hoe blade is required. The optimum length for such a blade is ⅔ of the full length hoe. This gives the optimum balance between ensuring maximum overlap on successive passes while minimising the chance of killing crop plants in the adjacent row as shown in Figure 8. Clearly a ⅔ length hoe blade must not be placed centrally in the crop gap but must be positioned towards the center of the hoe to work correctly.

2.3. The practical method to work out your optimum hoe length

Perhaps the most practical approach to cutting your blades to your optimum length is to fit the blades to the hoe but lift them clear of the ground by several centimetres and set the hoe frame to the minimum width you wish to use. Then use a marker pen to draw on the blade at the estimated place to cut them off, both at the tip and the heel, based on the information in Table 1. Then offer the hoe up to a range of crops of different sizes with the hoe set to both minimum and maximum crop gaps to make sure the estimated cutting places are correct. If not, redraw the positions of the cutting lines and then offer the hoe up to the crops again. Repeat until the optimum size is determined. If in doubt cut less off rather than more to start with, and test the hoe for real, as the blades can always be shortened further by cutting off a bit more but it's a rather harder to lengthen a blade by welding bits back on! Always cut the blade parallel to the original ends which are 60° to the blade's edge.

If you have crops grown on significantly different interrow widths, need a wide range of crops gaps, and/or want to hoe crops when their leaves have spread far into the row, one hoe length may not meet your needs and two or more pairs of different lengths and/or leg positions may be required.

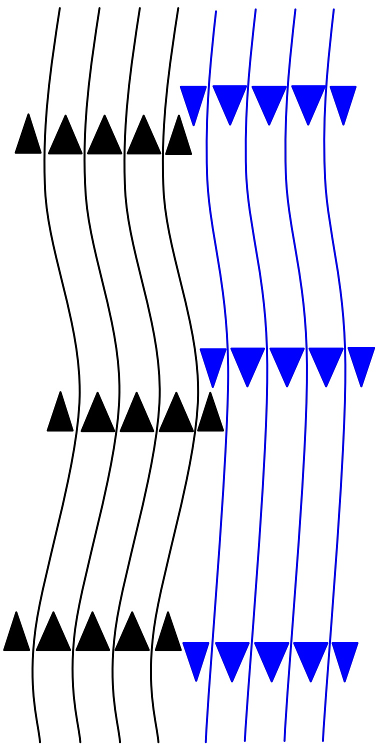


Figure 8. Diagram of how a 1⁄3 width weeder outside the last row of a bout ensures full ground coverage with a varying inter-bout gap between the black and blue bouts.

2.4. Specific interrow / crop width issues

2.4.1. Fifteen cm / six inch interrow

While it is possible to hoe 15 cm / 6" wide crop rows with the 4 Wheel Hoe, this is the absolute minimum row size it can fit down while straddling a single crop row, i.e., the smallest width of the 4 Wheel Hoe, from outside tyre-wall to outside tyre-wall, is 13 cm / 5", which leaves only a 3 cm / 1" gap between successive tyre tracks for adjacent crop rows. Therefore, at such interrow widths there is no possibility of increasing the hoe frame width to increase the size of the crop gap, as making the hoe wider means that the wheels will run over the adjacent crop row.

To reduce the width of the hoe that little bit more, one nut from each of the wheel axle bolts between the wheel and main frame can be removed, although this will reduce the locations clamps can be attached to the toolbars as they will hit the tyres on the wheels. Therefore, if different crop gaps are required for 15 cm crop rows, then multiple pairs of T hoes, cut to the required length, will be required for each crop gap size. The exception to this is if one pair of hoes are alternatively clamped on the inside or outside of the toolbar, it will change the horizontal position of each hoe by 1.8 cm / ¾" so altering the crop gap width by 3.6 cm / 1 ½". In addition, if only one blade is moved finer adjustment can be achieved, although the crop gap, and therefore the sight bar, will no longer be in the centre of the hoe which may be confusing when steering.

An alternative approach is to have the hoe straddle two crop rows, however, the standard T hoes and legs will not fit such an approach so custom made hoe legs would be required to reach the central crop interrow. The ancillary benefit of such this approach is that two crop rows are hoed at once so halving the number of passes required. You will have to design this attachment system yourself.

2.4.2. Twenty to 25 cm / 8 to 10" interrow widths

Twenty and especially 25 cm / 8 and 10" interrow widths are recommended as the optimum for the 4 Wheel Hoe and are also considered the best 'all round' row widths for vegetable production, especially on smaller production scales with lots of different types of crop. At these interrow spacings the maximum amount of width adjustment is available in the 4 Wheel Hoe frame, which means for any one blade length the largest range of crop gaps is possible.

2.4.3. Thirty centimetre / 12” and wider row widths

With long enough blades the 4 Wheel Hoe can in theory weed any interrow width, even one meters wide! However, practical issues such as human strength and maintaining optimum blade depth mean that a single blade length of 50 cm which will weed a 25 cm wide strip of soil is probably the realistic maximum for a normal strength person to attempt (two 50 cm blades will be weeding a half meter wide strip of soil which is a considerable amount of draft!). For crops that have to be grown in rows larger than 30 cm / 12” especially very large rows e.g., 150 cm / 5’ such as pumpkins, it is better to use shorter blades to precisely hoe next to the crop and then longer, overlapping blades, to hoe the interrow area between the crop, which can be done more quickly due to less need to steer precisely. For crops such as brassicas that require intermediate spacings e.g., 40 to 60 cm / 16 to 24”, it is almost certainly better to use narrower interrow widths e.g., 25 - 30 cm / 10 - 12” and increase the intrarow (along the crop row) spacing to maintain the correct field populations, rather than trying to grow on, and therefore, hoe, wider crop rows in one pass. For crops that have wider intrarow spacings than interrow spacing, if they are planted on the diamond (i.e., plants in adjacent rows, are planted halfway along the row) the crop is actually planted on the square, it is just the square rows run diagonally across the beds.

A critical issue for wider interrow widths is not to set the frame at its maximum width at the minimum crop gap, as the crop gap cannot therefore be increased. Decide on the maximum crop gap required, then with the hoe frame at its maximum width, cut the blades to fit that crop gap, so that the crop gap can be decreased to whatever is required. If the largest crop gap is less than 8 cm, then the crop gap can be decreased to zero, or even ‘negative size’ i.e., the blades overlap, especially if the blades are clamped to the inside of the main frame, which allows them to be quickly changed to hoe a continuous area of soil, e.g., for use in large interrow spaces such as for pumpkins.

2.5. Conclusions

If the above all seems rather confusing, don't panic! Build the longest hoe blades, fit them to your hoe, and follow the advice in section 2.3, and remember, cutting your hoe blades to the right length is something you only have to do only once, not daily!

4 Wheel Hoe Instruction Manual

1. Introduction

While the 4 Wheel Hoe is straight forward to use, to get the best out of it requires an appreciation of how knife blade hoes and soil ridging kills weeds, the design concepts behind the hoe and how to set it up for your farm / holding. So time spent reading this manual to ensure the 4 Wheel Hoe is best set up for you, will be well rewarded.

2. Fitting farm and hoe to each other

Any form of mechanisation, even a hand hoe, imposes restrictions on farming systems. If all weeding is done by hand pulling, crop plants can be placed in any position, as they often are in ornamental gardens, as people have the flexibility to work around the plants. In comparison, if a hand hoe is used the space between plants must be larger than the width of the hoe blade, otherwise it will not be possible to hoe in-between the plants without killing some of them. As the size and complexity of machinery increases, it imposes ever greater restrictions on the layout of crops plants, otherwise machines cannot function efficiently. The 4 Wheel Hoe is no different. To be the most effective, crops must be planted in straight rows, with each row the same distance apart as this makes it easy to steer the hoe. If the crop rows are bendy following them is much harder and the crop is more likely to be accidentally harmed. Equally and consistently spaced rows also mean that there is minimal risk of hoeing the crop in the adjacent row or leaving a gap between rows. As for any blade hoe, accurate depth placement is essential for maximising weed kill, so if the soil surface is uneven then optimum depth control will not be possible. Similarly lots of plant residues, soil clods and a rough tilth will hamper effectiveness. For best results a level and fine surface-soil-tilth is required that is free of plant residues large enough that they may bind and/or block the weeding tools. Stones larger than 5 cm / 2" may also significantly impede progress and should ideally be removed.

To ensure that crop rows are straight and evenly spaced, it is recommended to make a row 'marking out bar' (Figure 9). This can be as simple as a wooden batten with pegs, big nails or similar, sticking out of it to mark the rows, and a handle to drag it up the planting bed as straight as possible. This is preferable to using strings or the bout marking bars that can be found on some seed drills. If a tractor is available, then making a marking out bar that can go on the tractor's three point linkage is highly recommended as this will produce the straightest rows more quickly and accurately than a hand-pulled marker bar (Figure 9).

Figure 9. Hand drawn marking out bar (left), tractor three point linkage marking out bar (right).

3. Adjusting your 4 Wheel Hoe – Gear spanner

It is strongly recommended to get a combination gear spanner (Figure 10) to adjust your 4 Wheel Hoe. This makes adjusting the hoe much quicker and easier than a standard combination spanner. Ideally get spanner with a ‘cap stop’ in the ring end so that the bolt head cannot slide through the gear ring (Figure 10) as this makes using the spanner even easier. As there are only 19 mm nuts on the whole machine one gear spanner will thus adjust everything except the bottle screws which are moved by hand.

Figure 10. Combination gear spanner (left) and cap stop ring (right).

3.1. 4 Wheel Hoe components

There are four main parts of the 4 Wheel Hoe: (1) main frame, (2) wheels, (3) handles and (4) the sight guide. The tools that attach to the hoe are covered in section 4 on page 42.

The main frame consists of two identical ¾ meter long ‘toolbars’ connected to each other by two bottle screws (also called turnbuckles) (Figure 12). The wheels bolt directly into the main frame, two at the front and two at the rear, with a choice of three mounting positions at either end (Figure 12).

The handles attach to the main frame by the ‘handle clamps’ which allow the handles to pivot up and down, which are in turn attached to the main frame by a ‘frame clamp’ (normally just called a ‘clamp’ except when needing to differentiate between them and the handle clamps) (Figure 13). The ‘sight guide’ (Figure 13) bolts into an empty hole in the front of the main frame (Figure 13). Figure 11 shows a fully assembled 4 Wheel Hoe.

It is recommended to put a drop of oil or grease on all the bolt threads prior to assembly. This is good engineering practice as it allows them to be more firmly tightened and will reduce the chance of them coming loose. It also makes doing them up quicker and easier!

Figure 11. Fully assembled 4 Wheel Hoe.

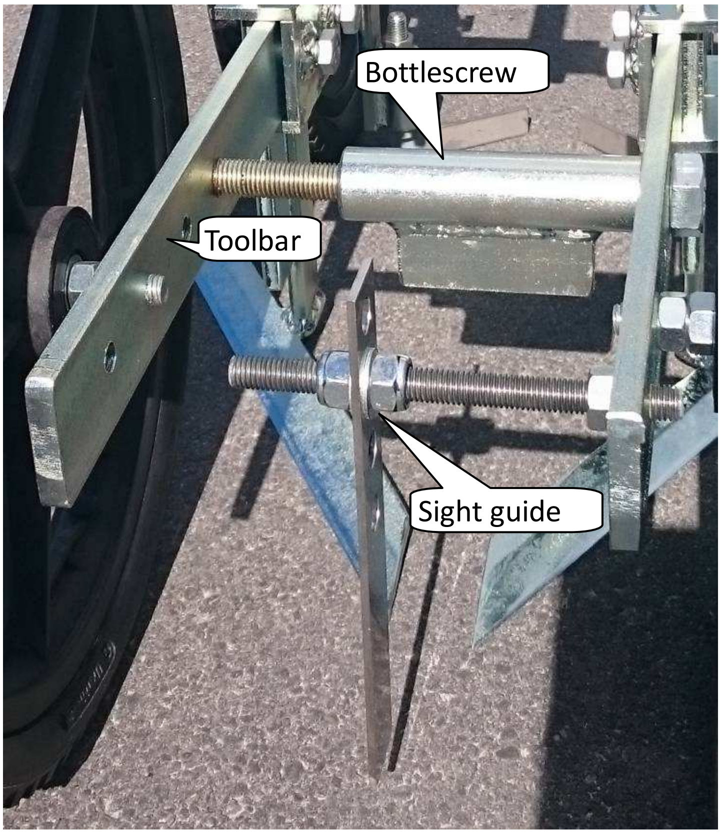


Figure 12. Main frame: Two long 'toolbars' connected by two bottle screws, and the sight guide.

3.1.1. Main frame

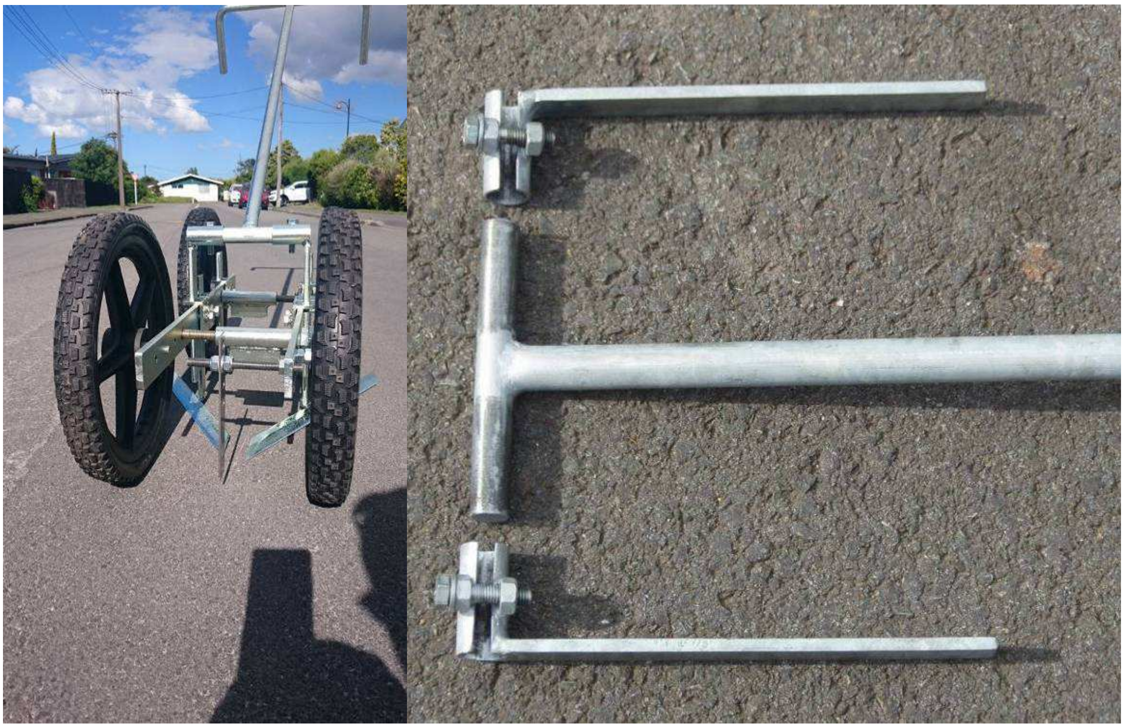


Figure 13. Handles and handle clamps: Left, handles attached to the main frame by a pair of 'frame clamps' and right handle clamps disassembled.

3.1.2. Wheels

Bolt the wheels into the threaded holes at either end of the main frame using 90 mm long fully threaded set screws (aka bolts), use flat washers on either side of the wheel axle hole and use two nuts to lock the bolt to the wheel (this acts as a spacer). Then screw the bolt into the frame, making sure the nuts and attachment to the frame are not so tight that it stops the wheels freely rotating, but tight enough so the wheels do not wobble or otherwise feel loose (Figure 12 and Figure 14). It is suggested, to start with, that the rear pair of wheels are fitted to the center pair of holes at one end of the main frame and the front wheels are bolted to the inner most pair of holes (Figure 15). Having the rear wheels further towards the end of the frame helps when manoeuvring the hoe on its rear wheels as it creates greater clearance between the hoe blades, mini-ridgers and the ground.

Figure 14. Axle bolts for wheels showing washers on either side of the wheel, with two nuts on the bolt.

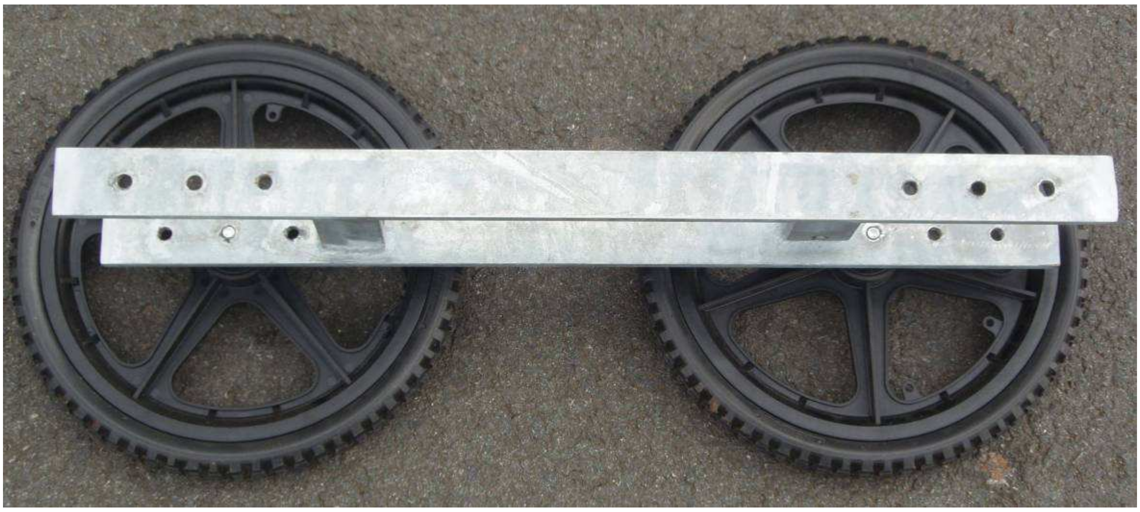


Figure 15. Main frame with two wheels attached, the left wheel is bolted into the middle of the three holes, the right is bolted to the innermost of the three holes making the left end the rear of the hoe.

3.1.3. Sight guide

The sight guide consists of a 150 mm long M12 threaded bar, two Nyloc nuts and washers, the sight bar (which has four holes at one end) and a plain nut and washer to lock to the frame as shown in Figure 16. It screws into one of the unused wheel bolt holes at the front of the main frame. For the narrowest frame width the bolt has to be screwed all the way through the frame with the nut between the frame and wheel (Figure 16). For standard or wider settings the nut is placed on the inside of the frame for ease of access.

Figure 16. Sight guide screwed into the main frame, with the locking nut on the inside of the frame.

3.1.4. Handles

1. Place the frame with wheels attached on some flat ground.
2. It is essential to lubricate the thread and head of the handle clamp's **bolts** with a good quality grease so that they can be very firmly tightened. Do **NOT** put any form of lubrication on the inside of the clamps as this will allow the handles to move. If this happens clean all traces of grease and oil from the inside of the clamps and the round bar on the bottom of the handles that fits into them.
3. Fit the handle clamps to the short round bar at the bottom of the handles, with the legs to the outside, but don't tighten the bolts yet (Figure 13). It does not matter which ways the bolts face, but pointing towards the handle grips / rear of the hoe probably looks 'better'.
4. Take a pair of frame clamps, and place them one on either side of the main frame with the bolts inwards unless you are using the hoe on the widest settings, in which case put the bolts to the outside. As a suggested starting position put the clamps just behind the front wheels as shown in Figure 11. Then, putting the hand grips of the handles on the ground (so you don't have to lift them up), slide the legs of the handle clamps into the slots in the frame clamps (if you have bolted the front and rear wheels in different positions, make sure you put the handles on so they are at the rear of the hoe).
5. Once both handle clamp legs are fully in the frame clamps, check the handles are inline with the hoe frame, i.e., straight, then lift the handle clamp legs to the desired height (about ⅔ of the clamp leg above the main frame is a good starting position), and then tighten the frame clamps so that the handle clamps are both the same height above the frame, i.e., the handle clamp bar is horizontal.
6. Lift the handles off the ground to the desired operating height, and then tighten the handle clamps, very tight.
7. The 4 Wheel Hoe is now assembled! All that remains is for the desired tools to be bolted on…

3.2. Adjusting the hoe

The wheel hoe has been designed so that it can accommodate a wide range of tools and a wide range of users. At the same time as providing this high level of flexibility it has been designed so that once set up it requires the minimum amount of adjustments. This section explains the adjustments that can be made to the hoe itself, tool adjustments are covered in later sections.

3.2.1. Wheels: longitudinal positions

There are three holes / positions for the wheels at both ends of the 4 Wheel Hoe. It is expected that most users will find the wheel positions recommended in section 3.1.2 perfectly adequate and will never need to change them. However, should the need arise, considerable flexibility has been built in from the start.

A key point regarding wheel positions is that the closer the front and rear wheels are to each other the better the depth control, i.e., wheels with a larger space between them will not follow uneven ground as accurately as closely spaced wheels. Therefore for best operation the wheels should be closer rather than further apart.

3.2.2. Handles: vertical and longitudinal positions

Handle height and longitudinal position is a personal choice, i.e., there is no set handle height for people of a given height, it depends how you like to hold the hoe and what feels the most comfortable. Some users prefer to have their arms out straight, others close to their chest or stomach. If the handle position is comfortable for you then its correct. The height of the handles is adjusted by loosening both handle clamps just sufficiently that the handles will move up and down, then pick the desired height and re-tighten the handle clamps. **Always be aware that the handles can suddenly drop as the handle clamps are loosened so never leave them unsupported when making adjustments, e.g., hold them up with a free hand.**

The longitudinal position of the handles along the main frame changes the ‘center of gravity’ of the hoe. If the handles were attached right at the very back of the hoe, it would tend to rear up at the front when pushed, and vice versa, if the handles were attached right at the front the rear wheels would tend to lift off the ground. Therefore, in-between is a ‘sweet spot’ for the handles where the force applied to push the hoe is equally distributed to all four wheels when the hoe is in use, which will result in the best performance. The location of the sweet spot is affected by the height the handles, the type and the number and depth of tools that are being used, so no detailed guidance can be given due to the many possible setups of the hoe. However, having said all of that, the exact position to attach the handles is not particularly critical, i.e., the sweet spot is reasonably big, and for most situations a good all-round position is to attach the handles just behind the front wheels as shown in Figure 19 and the photo on the front of the manual. When adjusting the height and/or longitudinal position it is often easier to loosen the handle clamps and lower the handles to the ground. **Always be aware that the handles can suddenly drop as the handle clamps are loosened so never leave them unsupported when making adjustments, e.g., hold them up with a free hand**. Once the handles are on the ground, loosen the frame clamps and slide them to the desired position. Then re-tighten the frame clamps and then the handle clamps

3.2.3. Hoe width

To adjust the width of the 4 Wheel Hoe, first loosen the handle clamps, sufficiently that the handles can descend to the ground. **NB when adjusting the handles always support them so they don't fall to the ground.** The handle clamps must be loosened because they serve two purposes, to lock the handles in the operating position, and second as an additional cross brace for the hoe’s frame ensuring its complete rigidity and strength. Once the- handles are on the ground, then turn the bottlescrews to increase or decrease the width of the hoe as desired. It is important to turn both bottlescrews by the same amount at the same time because otherwise they will jam because the two main frame bars wont be parallel, and therefore the bottle screw threads wont be aligned. If one bottlescrew starts to become hard to turn, twist it back the other direction a little and then turn the other bottlescrew. Keeping the threads well oiled or greased also helps! If in doubt that the frames are square measure the distance between the main bars at the front and back.

For every three or so complete turns of the bottle screws it may be necessary to wiggle / lift the handles up and down a bit so that the handle shaft can move inside the handle clamps. If this is not done the bottlescrews will become impossible to turn.

Once the hoe is at the required width, return the handles to the desired height and re-tighten the handle clamps.

3.2.4. Sight guide

When the width of the hoe is changed, the sight guide will also have to be adjusted, as it will no longer be down the centreline of the hoe / exactly midway between the T hoe blades. For small / fine adjustment, loosen the standard nut locking the threaded bar in the frame and turn the threaded bar into or out of the frame to the required location and retighten the nut. For larger adjustments the two Nyloc nuts will need to be moved along the threaded bar.

The height of the sight bar is adjusted by un-screwing the end Nyloc nut and washer off the threaded bar, sliding the sight bar off the threaded bar and placing it back on the threaded bar through the desired hole, replacing washer and Nyloc nut.

Different height users may benefit from having the sight guide mounted in different holes in the main frame so they can see it more clearly.

4. Tool attachment, setup and adjustment

4.1. Attaching tools

A key aim in the design of the 4 Wheel Hoe was to make it exceptionally flexible so that users can design and attach their own tools. To this end the main frame bars are equivalent to toolbars on a tractor mounted hoe, in that they have been designed so that anything that could be practically used on a pedestrian hoe can be easily attached. The holes that the wheels bolt into also provide an additional means of attaching further tools or other components to the hoe, as is done with the sight guide. You are only limited by your imagination!

Tools are attached to the main frame using the 'leg and clamp' system which is commonly used on tractor mounted hoes. The leg and clamp system is based on a leg of a standardised size (a standard leg, 30 × 8 mm flat bar, 250 mm long), to which the required tool, e.g., hoe blade, is attached (permanently e.g., by welding or by bolting it on). The leg is then attached to the main frame by a 'standard clamp' (Figure 17) (normally just referred to as a 'clamp') which allows both its longitudinal and vertical position to be easily altered.

Clamps are normally placed on the frame with the bolt to the inside (Figure 13), as it is easier to access the bolt head in this position, thought they can also be mounted with the bolt to the outside if required. The leg of the required tool is then slid into the slots in the clamp from the underneath. This normally requires the hoe to be lifted up, typically onto its back wheels or laid on its side. For ease of use, it is recommended that when inserting tools into clamps with the hoe on its side or back wheels, that all the tools be placed in their approximate position, the clamps tightened just sufficiently to keep the tools in place (i.e., by hand), and then final adjustments be made when the hoe is in the working position, ideally on a flat surface as described below (section 4.1.1) and then tightened with a spanner.

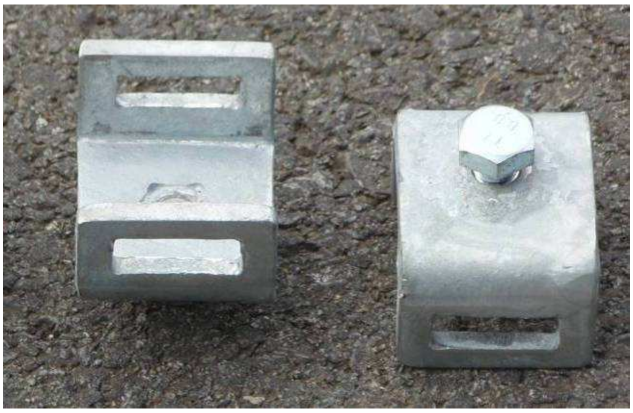


Figure 17. The 'standard' clamp, used to attach the handles and all tools to the main frame / toolbars.

4.1.1. Tool setup: flat floor or a 'depth setup board'

To facilitate setting the tool depths quickly and accurately, it is highly recommended to use a dead-flat and smooth area of floor or make up a dedicated flat 'stand' e.g., a piece of thick plywood sheet. Attempting to set the 4 Wheel Hoe (or any hoe) up in the field can be frustrating, as soil is uneven, meaning that what's right for the place the hoe was set up is wrong for other parts of the field. Once the hoe is set up then making minor field adjustments is easier.

The best initial setup position is to have both the blades and mini-ridgers flat on the floor or board. This ensures the hoe blades are not tipped up or down. If soil conditions are hard, which means the wheels wont sink into the ground, the blades and ridgers (weeding tools) need to be set lower. Conversely if the soil is particularly soft the wheels will sink in, so the weeding tools need to be set higher. A simple way of doing this in the shed is to have some thin wood laths or similar thin flat strips, e.g., flat steel bar, of about 5 mm and 10 mm / ¼" and ½" thickness. To set the weeding tools lower, put the laths under the wheels to lift them up so the weeding tools drop down. If the tools need to be higher, put the laths under the tools to lift them up. The hoe blades need to have two pieces of lath, one at the front of the blades and one at the back to ensure they stay level.

A depth setup board has the advantage of being able to be taken to the field and used in-situ between different jobs that require different hoe depths.

2.1.1 Longitudinal position: parallel or staggared?

In addition to setting the vertical position of the tools, the longitudinal position (i.e., the position of the tools along the frame) can have a significant effect on the tools performance. There are two approaches, opposite or staggered. Fairly self-explanatory, opposite is where a pair of tools are directly opposite each other on the frame, and staggered is where they are at different longitudinal positions along the frame. Having tools opposite each other often increases their 'interaction' whereby the area of soil displaced by one tool interacts with the soil area displaced by the second, which normally intensifies the weeding effect. This is particularly true of the mini-ridgers. The biggest benefit of staggering the tools is where there is material in the soil, typically stones and plant residues, that could become stuck between parallel tools, particularly the mini-ridgers, these will more easily flow between staggered tools and thereby reduce or eliminate blockages. Staggering tools is also helpful where the interaction between two parallel tools is also harming the crop, e.g., hoeing young seedlings, as staggering them can reduce crop damage while still maintaining the same hoed area, i.e., the same crop gap is maintained.

Also when using the hoe to till a false seedbed the T hoes should be overlapped as shown in Figure 20 which requires the hoes to have different longitudinal positions, otherwise one blade will be sitting on top of the other resulting in them not being at the correct depth, among a number of other problems.

2.2 T hoes

The T hoe design, with the leg in the center of the blade, means the leg is well clear of the crop row and the crop foliage growing there, which means that it needs far less horizontal adjustment than an L hoe.

4.1.2. Attaching the T hoes

The T hoes are in 'mirror pairs' i.e., one is for the left side of the hoe and the other for the right see Figure 11 Figure 13 and Figure 18. It is essential to put the T hoes on the correct side of the machine otherwise they will not work.

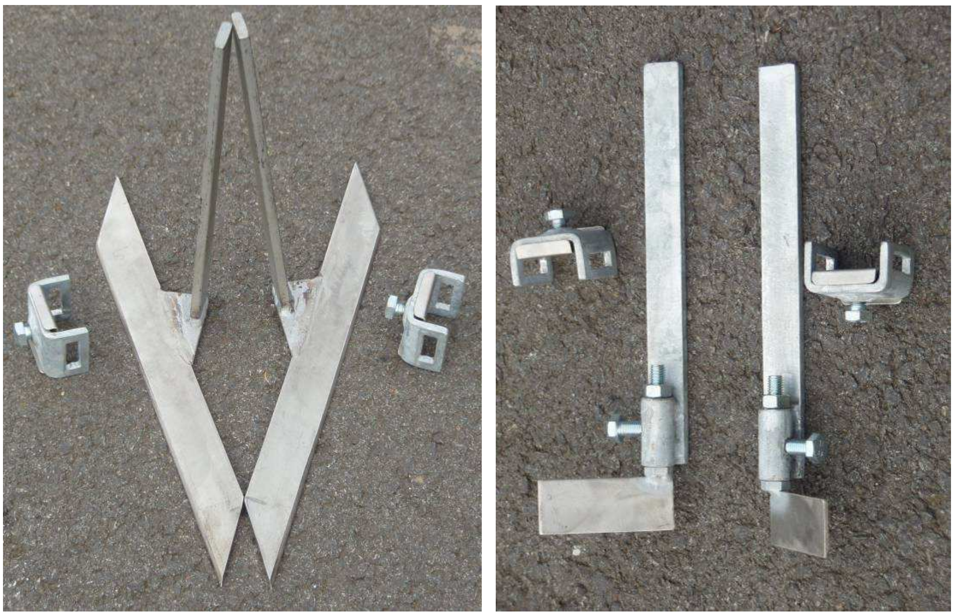


Figure 18. Right and left hand T hoe blades and clamps (left). Left and right hand mini ridgers and clamps (right).

2.2.1 Longitudinal position

As the T hoe blades extend both inside and outside of the frame they can only be positioned between the wheels. It is essential to leave sufficient space between the front wheel and the hoe blade so that the wheel does not block the soil travelling over and along the hoe (Figure 19).

2.2.2 Depth

The optimal depth of the T hoe (and any blade hoe) is just below the soil surface, literally a few millimetres / ¼”. This is because if a weedling is cut through the hypocotyl (the section between the roots and the cotyledon leaves) it cannot survive. Hoeing deeper results in the weeds’ roots being undercut, rather than the hypocotyl severed, which results in lower weed mortality. Clearly the blades will not work when they are out of the soil! So the final depth setting is a compromise between being shallow as possible, to maximise effectiveness, while as deep as needed to ensure that the blade always remains in the soil. This can only be determined by using the hoe in the field and fine tuning the depth. Also the position of the hoes is likely to have to change with changing soil conditions.

Setting the depth of the T hoes is best done on a smooth flat floor or a ‘set up board’ as described in section 4.1.1. Fine tuning may well need to be undertaken in the field.

Figure 19. Suggested starting location of handles, T hoes and mini-ridgers (this is the same photo as Figure 11).

4.1.3. Width / crop gap

The distance between the ends of the T hoes is called the ‘crop gap’ and it is varied by changing the width of the main frame as explained in section 3.2.3 and shown in Figure 20. In addition the crop gap can be altered by clamping the T hoe legs to the other side of the frame bars. This moves each hoe blade by the thickness of the frame + the hoe leg, i.e., 18 mm / ~¾” so moving both blades changes the crop gap by 36 mm / ~1½”. This feature can be particularly useful when the hoe is being used for false seedbeds as moving the hoe legs from the outside of the frame (normal position) to the inside will, for crop gaps of less than 36 mm / 1½” (i.e., the amount the hoe blades position changes) result in the blades overlapping without having to change the width of the hoe .

Figure 20. T hoes at different crop gap spacings: typical width (left) very narrow (center) crossed / over lapping (right) for false seedbed tilling.

4.2. Mini-ridgers

4.2.1. Attaching the mini-ridgers

It is recommended that the mini-ridgers are mounted just behind or in front of the rear bottlescrew, so that when the hoe is tilted up on its rear wheels for manoeuvring and transport they are well clear of the ground (Figure 19). The mini-ridger legs are also mirror pairs Figure 18 and when correctly mounted the locking bolt points towards the back of the hoe, so it does not catch on crop leaves. Normally the legs are clamped to the outside of the frame, however, when using the frame at the widest setting then it may be beneficial to move the leg to the inside of the frame so the blades are at a better angle.

4.2.2. Changing ridger blades and locking in position

To change between different ridger heights there are two options. Make a set of legs for each ridger height, and then swap the whole leg over. Or, if you only made one set of ridger legs, you need to swap the blades out of the legs. First remove the nut on the top of the bolt which the ridger blade is welded to. Then loosen, but don't remove, the locking bolt that screws into the side of the ridger leg and the bolt will slide out of the leg. The ridger blades themselves are not mirror images (i.e., they are ambidextrous) so it does not matter which leg they go in. Once the desired blade is fully inserted into the leg, replace the nut on its top and re-tighten the locking bolt. It is best if the nut is only done up hand tight as this will allow the blade to freely pivot so it can then be easily positioned before being locked in place by fully tightening the locking bolt. The leg height will then have to be adjusted due to the different height ridger blade.

If you regularly change between different height ridger blades, having a pair of legs for each ridger height will make swapping them over much quicker.

4.2.3. Depth and crop gap

The depth and angle setting for the mini-ridgers are not as critical as for the T hoes because their design means if they go too deep soil simply flows over them rather than creating too big a ridge. Also as the effects of the blades extends beyond their ends, i.e., soil flows off them into the intrarow, they don't need to be as close to the crop as the T hoes. Therefore, there are no hard and fast rules for the angle and depth. Clearly there has to be sufficient crop gap between the ends of the blades for the crop to comfortably pass through, and its better to start with a larger gap and make it smaller than the other way round. A space of around 8 cm / 3” between the ends of the blades is suggested as a starting position, until operators are skilled at steering.

4.2.4. When not in use

If the mini-ridgers are not required when weeding, they can be simply lifted up out of the way by loosening the frame clamp, sliding the ridger leg upwards and then tightening the clamp. It is recommended to mark the working position of the leg in the clamp as discussed in section 5 below.

Likewise, if the T hoes are not required but the ridgers are, then the hoes can be raised and the ridgers left in the working position.

5. Using your 4 Wheel Hoe

While the 4 Wheel Hoe is more complex and requires more setting up than other wheel hoes, the reward comes when the hoe is used because the only task for the user is to push the hoe accurately along the crop row, using the sight guide. There is no need to push and pull the hoe, unlike other push hoes, and the 4 Wheel Hoe controls the blade depths, via the four wheel design, so relieving the user of this task.

It is recommended that new users start with a larger crop gap, e.g., 5 cm / 2” or greater, while they gain experience before moving down to the minimum practical crop gap which is around 3 cm / 1”.

As soil conditions vary, e.g., dry to wet, soft to hard, and crops differ in size some fine tuning of tool position may well be required in the field. It is recommended that a line is drawn on the tool legs (e.g., with a permanent marker, tippex, or paint) where they pass through the clamps when they are first setup, to act as a point of reference when making vertical adjustments. The final optimum tool position can only be determined by using the hoe in the crop and checking to see that the tools are doing the job required of them, and making fine adjusting as necessary.

To facilitate moving the hoe between crop rows and around a holding, it can be lifted onto its rear wheels by pushing down on the handles, i.e., ‘doing a wheelie’. An alternative approach, when moving the hoe longer distances ground is to flip it over and balance it on the front wheels, with the frame approximately vertical. Be careful not to catch and bend the site guide when doing this.

6. Maintenance

The 4 Wheel Hoe requires very little maintenance. Any bolts that are adjusted on a regular basis should be kept oiled and/or greased. Good quality wheels will have sealed bearings so they do not require lubrication. While the blades are made of stainless steel they will still benefit from having the soil washed off after use, and if the hoe is being stored for longer periods, e.g., overwinter, then applying a coat of oil to the blades will ensure they are in perfect condition for the next use.

Happy weeding!

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