

The Theory and Operation of a Moldboard Plow, Simplified

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FORWARD

As I write this commentary for my friends with compact garden tractors, some who are reliving a bit of their past themselves, I think often of my Dad and my grandfather, both who were blacksmiths and who both, in their times were expert in the use of a moldboard plow on their farms. My accounting of their knowledge is not meant in terms of an engineering paper, rather it's meant for those who aspire to learn the basics of how a plow works and apply the knowledge through repeated experience.

“Thank you Dad and thank you Grandpa, for giving me this wonderful gift of knowledge”. I dedicate this passage to both of you who were instrumental in my understanding and applied experience of “setting up a plow and tractor”.





THE PLOW

The purpose of a plow is to expose nutrient enriched, fresh soil in which to till with a disc or harrow, plant, and encourage seed germination. Tilling the soil the hard way by hand is as old as man's own existence. But not as productive as when the Industrial Revolution conquered the harnessing of iron horses to the invention of the moldboard plow!

Early North American farmers used a single or two-bottom plow behind a horse or team of horses. If the plow was not hitched and adjusted properly, horses could not pull it straight. And therefore it overworked the horse and the farmer who, were both struggling with each other to counteract the uncontrollable side forces that tore ligaments and muscles of both man and beast. The wise farmer depicted in the opening illustration above, knew that time spent in preparation of proper hitching to the horse(s) and implement adjustment, made the plow just glide in a straight line across the field.

Though some may get the urge to hop on a tractor and go "plow", many rush paying little to no attention to plow adjustment. And, that's all fine, but not for long. More likely, the plow will probably just chisel up some soil in some form of an undesirable result that looks like the field was hacked open with a spade. However, if you want to achieve good results and you passionately want to strive to be a good plowman in the U.S., or a ploughman in a similar vernacular in Canada, you must understand the theory behind the secret of making a plow work effectively.

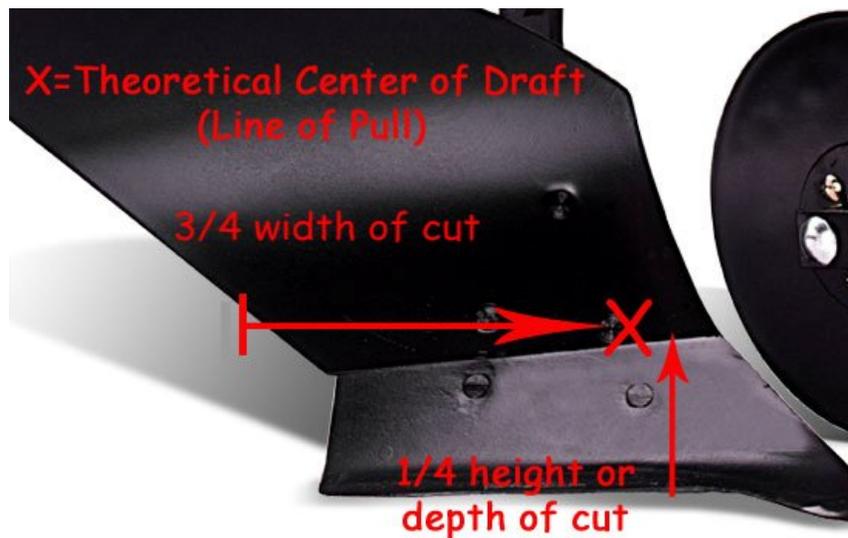
The plow is in effect a sliding wedge. A wedge that rolls a furrow on its side. A wedge that should "slip" through the ground with precision and ease. Improper adjustment will make it buck and jerk, and you won't be able to control it. The plowed furrow should turn up and over, and lay nearly like a ribbon if you set your tractor/plow up correctly and soil conditions are not harshly dry, excessively wet, or heavy clay based.

We could go on about soil types, but as a rule of thumb a good soil conducive to good plowing will "clump" and break off in $\frac{1}{2}$ to $\frac{3}{4}$ " (12-18mm) pieces as you roll and squeeze it out between your thumb and forefinger. Heavy, wet, or clay soils will not clump as readily. Instead, clay will break off in longer pieces, as will very wet soil. Soil moisture is most optimum for plowing using the above guideline.



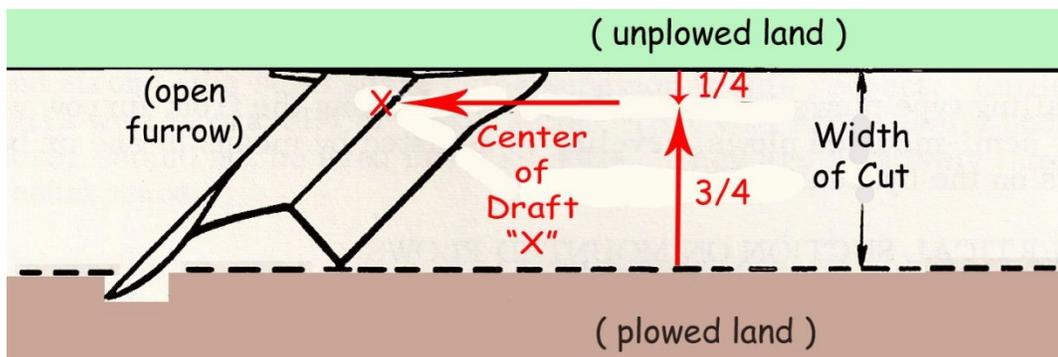
THE THEORY

A moldboard plow has a "center of draft", or center of pull. This is an imaginary point on the face of the moldboard which suggests that, if you were to attach a line to that point, the plow would pull perfectly straight in the ground. If not, then a condition known as "sidedraft" could occur, which means the plow would wander erratically off course from a straight line of pull down the field, similar to the horse and farmer fighting to keep the misadjusted plow on an even keel.



The above frontal view of a moldboard shows this point "X", an intersection of the horizontal and vertical plane. It is about 3/4 the width of the stated "width of cut" designed in a plow with each pass or furrow. And it is about 1/4th the depth of cut of the plow and is measured plumb, straight up the moldboard. The intersection of the horizontal and vertical draft planes is the exact "center of draft".

Next, we look at the center from a different perspective, for clarification, below:



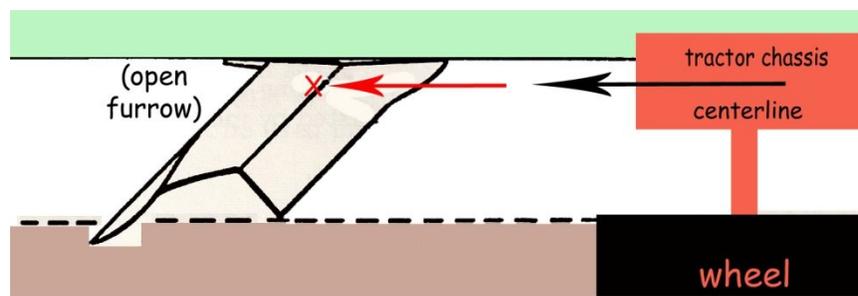
For example in the preceding illustration, if a plow is a "Twelve Inch Width of Cut" (12), then the horizontal line of draft is measured 9" from the right side of the moldboard edge. (Or, you can also measure it as a quarter the width of cut starting from the left side of the moldboard because it is harder to determine where on the moldboard wing edge where to start from).

Also note: Left and right always refers to standing BEHIND the plow looking forward in the direction of travel, even though the views shown is in FRONT looking back.

Now, below we look at the center line of draft as it applies in use. Seen from the side, this shows the relationship of the plow to the tractor as a complete unit. Notice the line begins at the axle center, passing through the lift linkage pins and finally to the imaginary "X" point on the moldboard. When these three coordinates are in perfect alignment, is when the plow will slide its way through the ground.



Now this all sounds technical and truly it is, but equally important. Because the imaginary center of draft must align with the center of the tractor powertrain. If not, the tractor will pull one side left or right depending on the misalignment of the plow draft center to the tractor center. Much like the struggling horse and farmer with a misaligned hitching set up, the tractor experiences the same difficulties in overcoming the tendencies of "side draft".

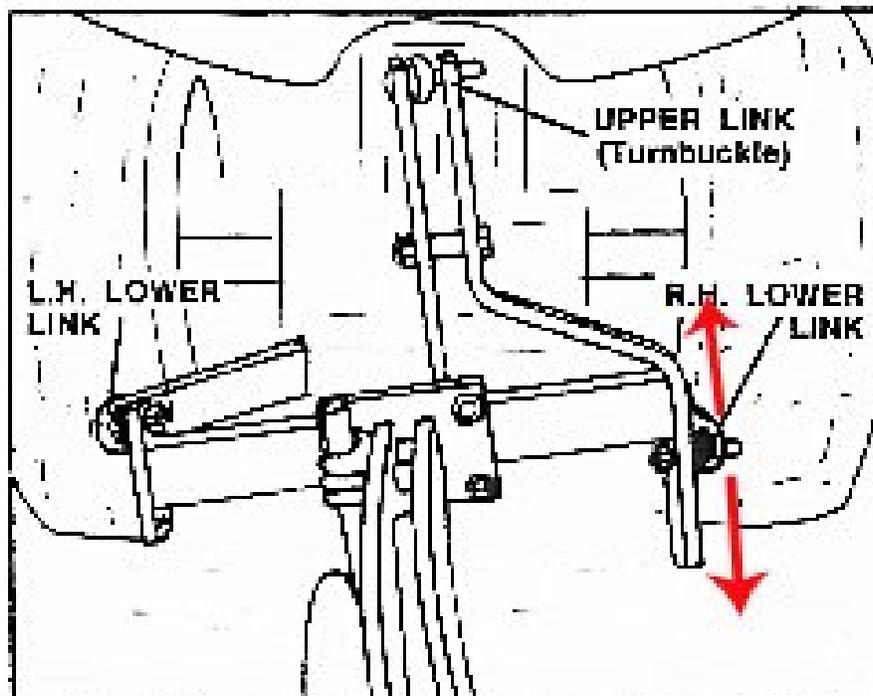


Case “high wheel” tractors have a distance of eleven inches, as measured from tractor center to the inside of the right tire. Assuming a twelve inch plow with a centerline of draft being nine inches, the extra two inches allow for tire flex and squat, and for a little side slippage of the tire while pulling. The plow draft center will align with the tractor in working conditions. Your plow manual will discuss how to fine tune the side to side width of cut if needed, by moving the plow frame left or right along its drawbar. Or, in the case of the sleeve hitch, by using a different hole.

While we’re examining this in theory, in reality there are other influencing factors such as variations in soil texture, moisture content, ground speed, and lay of the land. These greatly influence the plow’s behavior. But, the variances must be countered with a baseline tractor-to-plow relationship in achieving proper centering. This is to bring the plow back around to a normal and smooth, default line of pull as soil conditions change during forward travel.

OPERATIONAL PRE-ADJUSTMENT

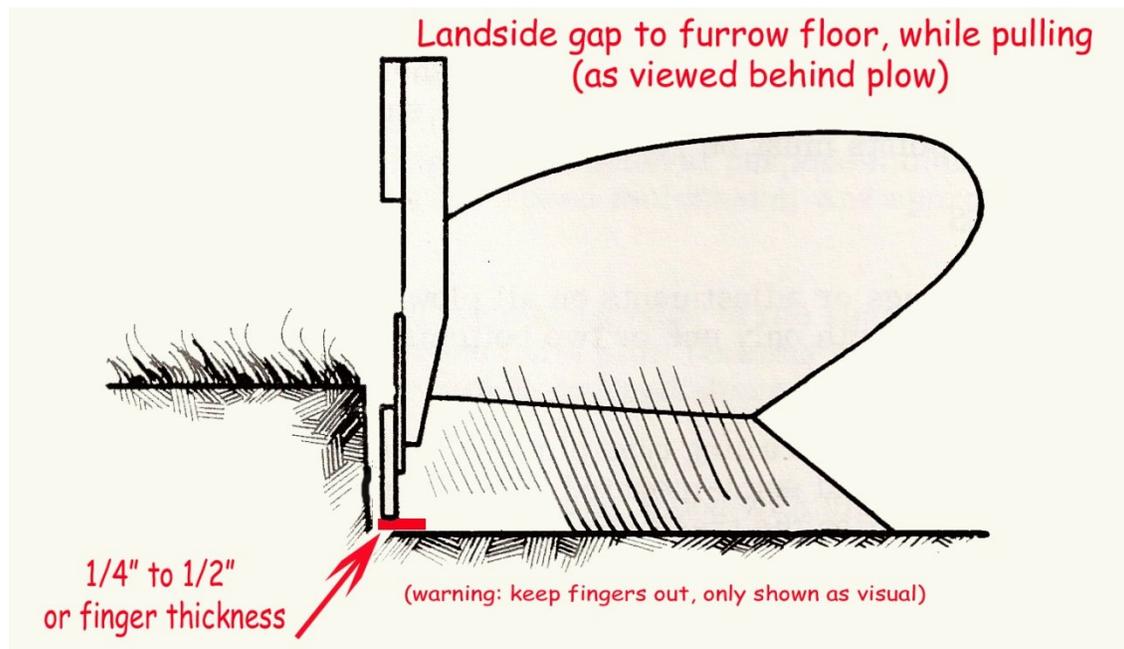
The first consideration in adjustment is the side to side leveling of the plow, needed while the tractor wheel is in the furrow. If you have a 12" plow, the maximum depth you should be going in is 6". Or, if a 10", it is 5". Once in the furrow, the plow must be level from side to side across its drawbar, or from wheel to wheel. Its easy to see. When the tractor and plow sits on the driveway, you notice the tilt of the plow, slightly raised on the right side.



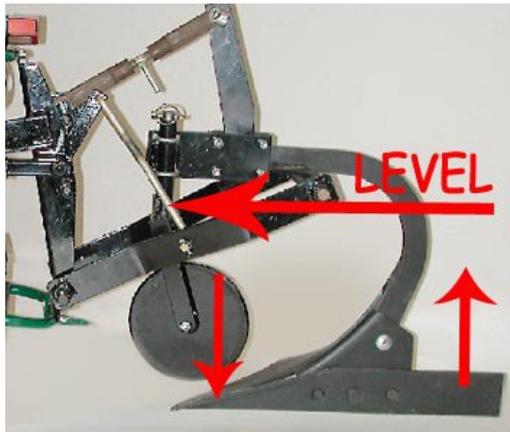
If you notice on 3 point hitches in the example above, the drawbar right attaching pin is usually vertically offset from the left one. This automatically accounts for the wheel being lower, in the furrow, assuming both left and right tractor lift links are equal height. You can fine tune the leveling if the tractor lift link has a turnbuckle adjustment as shown by the red arrows in the preceding illustration. You won't find this adjustment on a sleeve type hitch because the hitch clevis has the pre-determined angle built into it.

The second consideration is the fore-aft leveling adjustment. In either extreme of an out of level condition, the plow may either nose, or dig in erratically or, the plow won't dig in much at all and most of the digging is stopped by the rear edge of the landside riding "on it's heel". Think again of the plow and tractor together sitting on a concrete floor. When properly adjusted, the plow will rest level on its landside, fore to aft.

As the plow travels, there should be a slight gap under the rear landside, or about a index finger's thickness. This gives the plow bottom a slightly biased attitude to "dig in", but not too much. Otherwise, the plow will "chop" up and down across the land like a stone skipping across water. You'll know it when it happens. Your tractor won't pull it when the plow sinks in too deep. In this event, the corrective action is to lengthen the top link or the turnbuckle of the garden plow. Do this in increments until the plow bottom slides through the ground with no pressure on the heel of the landside.



When in the field, this relationship is the same. Then once in the ground, you notice a turnbuckle either on the garden plow and/or the top link of the 3 pt. hitch. You may in some soils have to decrease the length of the turnbuckle slightly to give the plow a "nose in" attitude, or what is referred to as "suck". You can see this relationship below. The plow should pull through the ground level, but... notice the up/down arrows are what favor "suck".



(Note: On some garden tractor plows, the plowshare, or “point” has an extended nose that dips below the landside bottom edge. This provides for additional penetration because these plows don’t have the frame weight to help push the plow into the ground, once moving. As part of pre-adjustment before heading to the field, you’ll have to stick a board under the landside to shim the plow bottom up enough to really level it to the driveway.)

A plow works to turn a furrow upside down, almost 3/4 the way over. The turned furrow will cover the ground residue and when adjusted right, each succeeding furrow will adjoin the previous one and "seal in" the residue underneath, encouraging the decomposition of the residue, vital to soil composition.

You have to admit, plowing with a garden tractor won't look this perfect, but...if you're like me and most perfectionists who strive to do the best, you can do a pretty nice job in preparation for a disc harrow to level out the soil and prepare a quality seedbed for planting. And, there is a distinction between soil and “dirt”. One of my teachers used to say, “Dirt is what you sweep off the floor”. By contrast, the same high school agricultural teacher used to say, “Soil is what enables us to feed ourselves and, the world”

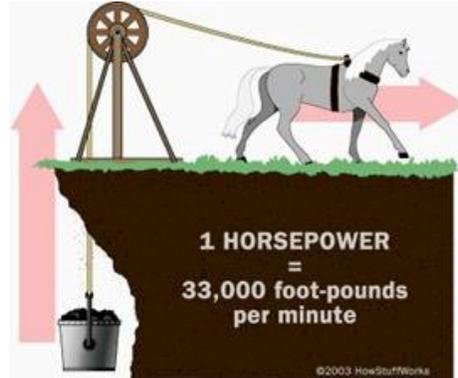


Setting Up and Properly Weighting Your Tractor

Notation: These principles apply to any tractor, not just garden tractors

When It Comes To Weight, It's Usually a Good Thing

It's said that one horse can do a lot of work, and many horses can do a lot more work. Yet many horses working in unison versus many horses working in disarray can be an interesting comparison when it comes to the measurement of work output. That's what we know as taming raw HP and finding a way of optimizing by, "putting the power to the ground". As illustrated, just look at what ONE horse can do.



Your tractor is no different. Think of that team of horses pulling a single bottom, hand controlled plow back in the early days of agriculture. Now, compare that team of four beautiful horses to your team of 12, 14, or 16 horses and beyond. All of those living, breathing horses neatly packaged under the hood of your shiny garden toy.



The point is, unless you harness your horses effectively to transmit power to the ground wheels, then you can have many, many horses doing very little work, costing a lot of fuel, and creating much frustration in lost work.

Weighting Theory

The key to effective pulling, is the end product of your tractor set up, which means,

1. The rear wheels should just “break” the soil surface as the wheel turns over under load pulling the plow, and the frame and wheels are properly weighted to do so.
2. Secondly, to keep the wheels in a constant state of effective pull, overcoming the load exerted by the plow’s natural resistance to work (like some of us), or to varying soil pressure, the tractor weight relationship from front tractor frame to back frame must be proportionately balanced.

For example, if the front wheels come off the ground, counterweighting may be the solution. A fair weighting ratio to use is 3 for 1. That means for every extra one unit of weight on the front of the tractor as the plow is working, there are three effective units returned to the traction wheels under a full pull. Why? Because of the mechanical advantage of the lever, or “torquing” as some say. Or effective, dynamic “weight transfer” of the tractor’s chassis is another expression.



How do these two issues affect performance?

First, is the reduction of wheel slippage. Be it weighting by either cast wheel weights, or liquid tire ballast, I prefer cast weights because they allow the flexibility of reducing rear axle weight when plowing season is over. Liquid tire fill does not offer this flexibility. *Caution: (A liquid filled tire should never exceed the top of the rim level or a tire could rupture from ground impacts in wheel travel if completely filled.)*

Second, is tractor instability. If you have an adequately weighted rear axle and yet when pulling the plow, you lose control of steering (light front end), the tractor will react to uneven soil loads by raising the front end off the ground. Therefore, front end weighting is essential for safety and weight transfer

to the rear. Also, do not assume a heavy front end will reduce the need for rear wheel weights. Balance the front and rear proportionately to get the right combination for the job. It sometimes requires trial and error. Generally, start with the rear wheel weights or tire fill to rim level, as a baseline.

Caution: There is a great temptation to overload the tractor with all types of ballast. This not only makes the tractor a “dog”, it puts extra strain on drive components, and... increases soil compaction.

A built-in amount of wheel slip is desirable, typically around five to ten percent is desirable. As a properly weighted tractor pulls, you’ll notice on agricultural type tires that wheel slip will be equal to about one half to one full width of the distance between traction lugs on agricultural tires. On turf tires, it’s a little tougher to see it, unless chains are used. Turf tires do not offer the pulling power of agricultural tires. Chains are usually a must on turf tires.

Most garden tractors have a favorable power to weight ratio and thus, don’t require a huge amount of ballasting. It all depends on the texture, depth of cut, and moisture of the soil you’re plowing in.

So, garden tractors usually pull a load quite nicely without much effort if the plow is properly adjusted to the tractor. Where trouble begins is in heavy soil, low moisture types, clay based, and of course wet ground.

I would not expect anyone to become plow proficient overnight. But once acquainted with plowing concepts, you can even eyeball it from a distance,... a tractor putting effective power to the ground without much loss of efficiency. You develop the skills to have the eye and experience and in no time you’ll be ready for your garden, better yet plowing competition!

Take it from Canada, they’re quite well known for their ploughing contests.

Preparing the Plow For The Field

An experienced farmer will tell you, “be sure to oil up those plow bottoms before you put it away for the winter”. Well my Dad used to tell me that too. As a teen, I could care less. Until Spring. And that’s when the moldboards were all rusted and the surfaces had to be scrubbed of corrosion. A very nasty, time consuming job.

Well, we who’ve done that know we now listen to our mentors. Dad was right. A plow can NOT work if the bottoms are fouled up. Why? Because the soil must slide across the bottom smoothly. With rust, it will clog up and clump off and make a mess of your field. Try it sometime. You’ll get the idea. Once.

“Scouring” the moldboards is an on-going process during plowing. Most soils have some abrasive quality and will scrub the steel moldboard, making it shiny and smooth. Some soils are sticky and less able to scour off the moldboards, so you have to have a clean, shiny moldboard to start off with. The moldboard must be able to allow soil to slide off it, not stick to it.

The disc coultter which slices the ground is desirable in use as it provides a square, clean furrow wall. There are conditions which make it less effective. Such as, gravely soil and hard ground. The disc will actually prevent the plow from penetrating in hard conditions. In gravely soil, the disc may encounter rocks which force the plow up out of the ground. Use your judgment, and refer to the plow manual for proper adjustment.

Assuming you already listened to your Dad like I did, attach the plow to the tractor, while sitting on a level floor, or preferably concrete or good level driveway. As the unit sits in tandem, notice the level of the plow when it is sitting on the ground.

Reviewing again, proper level includes the fore-aft attitude of the point and landside heel. It also includes the side to side level (as viewed from rear of plow looking forward to tractor. The plow, if a sleeve hitch install will show the right side higher than the left. It's the built in angle to account for right wheel drop in the furrow.

If you have a 3 point hitch, you can cheat a little before hand and place a six inch block of wood under the left rear wheel, which simulates furrow depth. Then level the plow to the floor. This will get you close for field operation, and then fine tune the level later in the field.

Think of the plowshare as being like an old style pocket pencil sharpener. The knife slices off the pencil end like a veneer cut. The plowshare does the same. It slices the soil and the moldboard flips the slice over. What you're looking for is in the furrow. The result of good adjustment is viewing a clean cut furrow floor. Level. Square. Clean.

Now you have your plow set up, you're almost ready to show off your work!

How to "Open a Field"

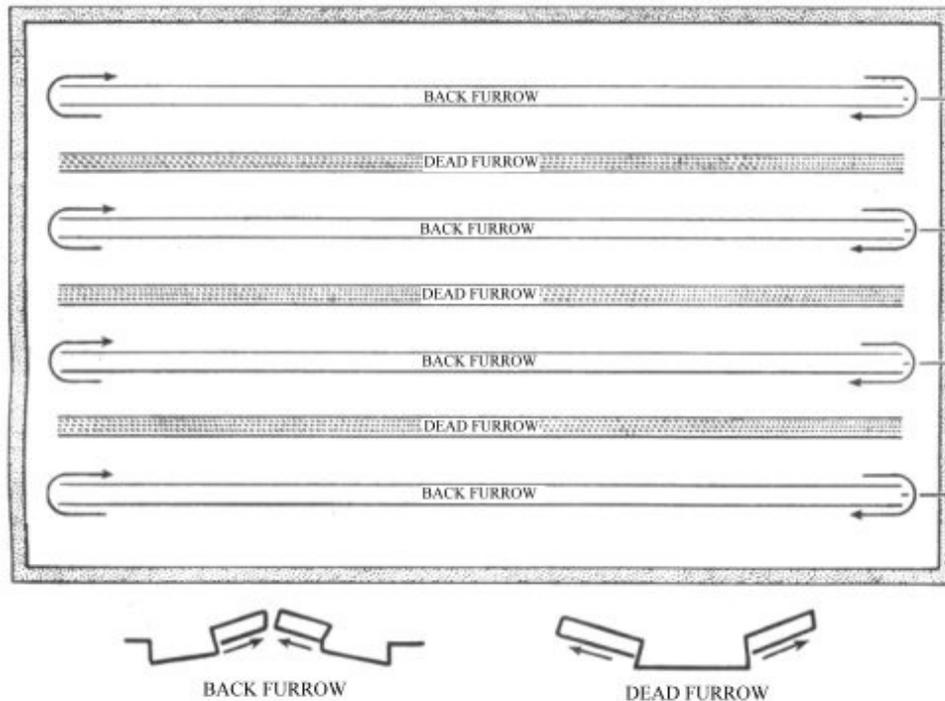
The test of application comes when you drop the plow in the ground and attempt your first pass across. Like many of us, we rush to get the tractor going, throttle wide open, and horses churning. It's thrilling isn't it? Raw horsepower!

Not for the first pass. This one is most critical. Not only are you attempting to scribe a straight line in the soil, your plow must "open" the unplowed ground and create a furrow for the next time around. Once an open furrow is created, let her rip!

First, drop your plow in and create the "ditch" or furrow at say half throttle. Take your time. Get it right. You may not see your first furrow lay properly, but that's ok. You opened the land.

Now after the first pass, come back down alongside plowing the other direction. Throw the furrow against the first, in the same careful manner. What you have just done, is create what is called a "backfurrow". I'll explain later.

Now if you decide to open the land by plowing the outer perimeters of the field, not only are you opening a furrow, eventually you'll come to the middle of the field and create a "dead" furrow. A dead furrow is simply two furrows opposing each other. And for that, you've created a bigger ditch.



To counter this ditch, many farmers will sight a field first, before opening it. They look for the dead furrow of the previous year. And once located, now they create a backfurrow on top of the old dead furrow.

Why go to this trouble? Because in time, you'll end up with a lot of displaced soil in mounds and ditches. So the goal is to keep those to a minimum and not expose a lot of "hardpan" (the layer of thicker soil sitting underneath the nutrient – rich, topsoil).

Draft (Depth) Control

On larger tractors of about 20 horsepower and up, there is a feature which enables the automatic raising and lowering of the plow while engaged with the ground to compensate for changes in soil toughness and depth changes from terrain inconsistencies (not perfectly flat). This feature is designed into the tractor's top link attaching point and usually there is a heavy coil spring behind it. The tendency for the plow to wander in and out of the ground causes a movement in the spring and thus, this signal is transmitted to the hydraulic system to raise or lower the plow a micro amount.

Garden tractors of this type do not have this feature. However, the rear gauge wheel found on Brinly plows accomplishes the same thing, by maintaining constant soil depth. If the plow is in tough ground, you may have already found that a very slight shortening of the top link will increase penetration. Use this gingerly, a half turn of the turnbuckle at a time, as an extreme adjustment to the top link will cause the plow to nose down and create a choppy furrow.

Some smaller tractors of the diesel variety have a similar feature called "Position Control". It is not the same. It merely places the lift links in a fixed position which is related to the location of the raise/lower control lever. You can use this feature only if you have a gauge wheel and you lower the control lever all the way down.

Conclusion

I hope you've gained some simple insights into plowing that the manual doesn't tell you. I've enjoyed sharing my thoughts with you and listening to yours. An operator's manual for your specific plow gives more details on the actual adjustments. I've just given a high level view of how the plow works. With some applied learning, you can plow expertly in no time and achieve the satisfaction that comes with a job well done.

For me, memories are vivid of the days with my Dad, riding the tractor, watching the plow turn the ground, listening to the tractor engine, smelling the fresh soil, and the watching seagulls tracking close behind for their Thanksgiving feast. Plowing is one of the most rewarding things you can take pride in. And your crops, vegetables, and soil will thank you too.

Now, go have some supper and get a good night's rest! Your neighbor will be begging you to do his garden tomorrow...

