



FIELD EQUIPMENT FOR GRAIN PRODUCTION ON MODEST ACREAGES AND DIVERSIFIED FARM OPERATIONS

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Introduction

Interest in growing small grains is increasing among farmers, researchers, and consumers in minor growing regions, such as areas west of the Cascade Mountains and elsewhere (Jones 2012; Brouwer et al. 2016; O’Dea 2014a; Powell and Elkovich 2009; Patzek 2012). This interest is emerging among farmers growing mixed vegetables, berries, or other crops on modest acreages. This includes crop farmers looking for rotation crops or new enterprises, livestock farmers considering growing grain for feed, and entrepreneurs considering growing for emerging artisan baking markets, craft brewing and distilling markets, or for specialty culinary applications, such as cooked grain salads. In some cases, farmers interested in adding grain to diversified farm operations are not experienced with grain production and need access to information on suitable equipment. This Extension manual provides an introduction to grain production equipment appropriate for small- and medium-scale farmers new to grain growing as well as considerations for sourcing affordable and reliable farming implements.

It also incorporates the experience of farmers and tractor mechanics who have grown small grains for many years, worked on small grain equipment, or have direct, recent experience adding grain enterprises to diversified farm operations. Specific data on costs, selection, capacity, and purchasing considerations are based on available literature and feedback from a focus group with grain farmers in western Washington (Thompson et al., personal communication).

Topics addressed in this manual include equipment needed to add a grain enterprise (1), a review of production equipment from field preparation to harvest (2), considerations for equipment selection (3), and sourcing grain production equipment (4). This publication focuses mostly on used and older equipment considering that many diversified farms, and those operating on modest acreages, cannot afford to invest in new and larger-scale grain production equipment. Equipment for storage and post-harvest handling are addressed in a second Extension manual in the series, *Post-Harvest Grain Cleaning, Storage and Other Equipment Needs for Smaller-Scale and Diversified Farm Operations*. Farmer profiles provide specific examples of western Washington farms that have added small grains to existing operations.

Considerations When Starting a Grain Enterprise

Successfully adding a small grain enterprise to an existing farm operation is facilitated by access to equipment and knowledge, an existing network of grain growers, and access to good markets. Typical reasons for adding a grain enterprise include production for livestock feed, adding a new product (such as wheat for flours, or hullless oats or barley for cereals) to farm stands and farmers' market outlets, seed production, and accessing emerging local grain markets. Minimum requirements include sufficient acreage to justify the investment in equipment, production equipment as described below, a tractor with hydraulics and greater than 30 horsepower, potential capacity for cleaning and drying grain, and covered space for equipment and crop storage.

Depending on the existing equipment of the farm operation, the expense of adding a grain enterprise may be modest or substantial (approximately \$20,000 to \$300,000 for an enterprise with no existing field equipment, \$5,000 to \$10,000 with basic tilling and seeding equipment, or \$1,000 and greater to add a combine only) (Thompson et al., personal communication). Cost will depend on many factors including the quality, scale, and features of the equipment. For detailed crop-specific enterprise budgets, see [Washington State University Extension Economics](#) and [Oregon Agricultural Enterprise Budgets](#).

The experience of producers in communities where farmers are adding grain enterprises indicates that this transition is enabled by several conditions and strategies:

- Equipment is shared when possible and feasible.
- Local mechanical expertise is available and utilized, which increases opportunities for equipment sharing and repair.
- Custom hiring is utilized, such as for combining, when crop values are high enough to justify service fees.
- New grain farmers integrate themselves into networks of existing small grain farmers for

mentorship and for finding and repairing equipment.

- Access to low-cost fertilizer sources are available, such dairy or fish waste, which can support relatively lower-value per-acre crops, like grain.
- Premium, local small grains markets are emerging or exist (O'Dea 2014a), such as consumer direct sales at farmers' markets, certified seed production, craft baking, craft malting, brewing and distilling operations, and organic livestock feed buyers.
- Reliable access to grain cleaning, drying, transport, storage for equipment, and infrastructure are available.

Equipment Needed to Grow Small Grains

This section describes a range of equipment appropriate for small- and medium-scale production as well as considerations for sourcing implements. Knowledge of this equipment will help the interested farmer anticipate costs, make well-informed selections, develop an understanding of equipment operation, and integrate grain production with other farm enterprises.

Equipment in grain production is utilized for primary and secondary tillage to prepare the seedbed, fertilize and add soil amendments, seed, manage weeds, and harvest (Table 1). For farmers already equipped with field-scale equipment to seed cover crops and perform other necessary tillage operations for annual crop production, weed management, harvesting, cleaning, and storage of equipment are the only specialized additions needed to add a grain enterprise to an existing farm. For additional information on small grains production in western Washington see *Growing Wheat in Western Washington* (Miles et al. 2009), *Producing Milling Oats in Western Washington* (Winkler and Murphy 2017), the [WSU Bread Lab](#), [OSU Barley World](#), and *Resources on Growing Small Grains in the Northeast* (O'Dea 2014b). For information on larger-scale grain production in eastern Washington see the [WSU Wheat and Small Grains](#) program.

Table 1. Equipment utilized for small grain production.

Field operation	Equipment
Primary and secondary tillage	Moldboard plow, chisel plow, rototiller, sweeps, spaders, disks, harrows, cultipacker
Fertilizer and amendment application	Drop spreaders, broadcast spreaders, liquid slurry reels and guns, slurry manure tankers, manure spreaders, lime spreaders
Seeding	Grain drills, no-till grain drills, broadcast seeders
In-crop weed management	Tine weeders, boom sprayers
Harvesting	Self-propelled and Power Take-Off (PTO)-driven combines, while smaller market, garden-sized operations may employ hand-harvesting with equipment such as scythes, hand sickles, and stationary threshers

Primary and Secondary Tillage

Primary tillage refers to the first pass of equipment through a field after the previous crop to break up sod and incorporate a cover crop or residue.

Moldboard plows are generally inexpensive and widely available but have largely been replaced by chisel plows and other combination tools that are more favorable choices for soil conservation and maintaining soil health. See Simmons and Nafziger (n.d.) for information on chisel plows and other conservation tillage options.

Moldboard plows (Figure 1), are useful for converting pasture land to annual crop production, for burying large volume of crop residue, burying weed seeds, or for burying pathogen inoculum on crop residue. Overuse of a moldboard plow at the same depth creates a plow pan and reduces root penetration (Magdoff and Van Es 2010), which can result in wind and water erosion. For fields that are already in annual crop production, or have been plowed already, off-set or cone disks (Figure 2) may be sufficient to incorporate residue and, where crop rotation is used strategically, to reduce soil surface weed seed loading.

Lower-disturbance implements, such as chisel plows, can be used to reduce compaction and maintain soil physical quality (Figure 3). Spring-loaded shanks on

some chisel plows limit their use to more recently worked or less compacted soils, and shallow tillage, while rigid shanks are suitable for hard soil conditions and deeper tillage. A rigid and specific shank angle helps maintain a set penetration depth and can be adjusted for optimum pulling performance. Refer to the *Tillage Alternatives* (WSU Center for Sustaining Agriculture and Natural Resources, n.d.) for an extensive list of publications detailing conservation tillage alternatives, and *Keep the Weeds Guessing with Crop Rotations* (Schonbeck 2010) for more information on crop rotation strategies to reduce weed seed populations without moldboard plows or herbicides.



Figure 1. Three-bottom, 16-in. moldboard plow.

Secondary tillage breaks up large soil aggregates, creating a smooth seedbed. Secondary tillage implements include spike-tooth harrows (Figure 4), spring-tooth harrows, disk harrows, and shank harrows (Figure 5). A rototiller can be used for primary and secondary tillage but is generally not necessary and will have a negative impact on soil quality if used frequently. Shank harrows are sometimes referred to as seedbed conditioners and can be used to work in fertilizers as well as bulky soil amendments, such as manure or compost. Spike-

tooth harrows are particularly useful for final seedbed preparation. They can be dragged behind shank harrows before seeding, as illustrated in Figure 5, or pulled behind a drill after seeding to cover wheel tracks and improve seed-to-soil contact. However, a cultipacker (Figure 6) is the preferred implement for packing the seedbed following a grain drill. Cultipackers come in varying widths and are typically pulled in a separate, final pass after seeding.



Figure 2. Cone disks for primary tillage. The term “cone” refers to the deep bowl of these disks, which throws more soil laterally, resulting in greater soil disturbance. The outer disks in the set are not bowled as deeply in order to reduce soil movement at the outside of the tillage pass.



Figure 3. Chisel plow for reducing soil disturbance during tillage.



Figure 4. Small-scale, spike-tooth harrow for secondary tillage. The upright levers, when adjusted, rotate the tooth bars to which the spikes are attached. This determines the depth of soil that is worked.



Figure 5. Vibra-shank harrows are used for breaking up large soil aggregates. When pulled in-line with spike-tooth harrows, as pictured here, the combination results in a well-worked seedbed. By attaching implements to a common set of tool bars and equipping with wheels and hydraulics, this arrangement can be readily moved from field to field.



Figure 6. A cultipacker firming up a seedbed following spring barley seeding. Selecting a wide cultipacker allows for coverage of large acreages quickly after seeding.

Amendment and Fertilizer Application

Appropriate equipment for applying amendments for small grain production will depend on the type of amendment and the scale of operation. Cost and availability of amendments should be considered prior to selecting equipment. Fertility application for grain production can include power take-off (PTO)-driven manure spreaders, which distribute solids

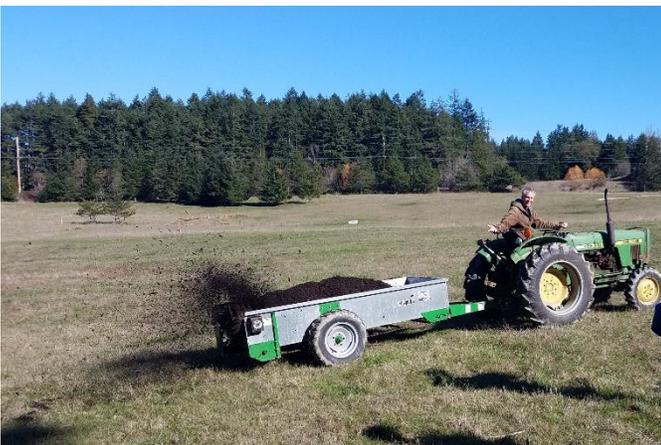


Figure 7. Rear-discharge box manure spreaders can be PTO-driven or entirely axle-driven. This is a small-scale, modern axle-driven type. PTO-driven spreaders can be operated while the tractor is stationary, which is helpful if the spreader will be used to mix feedstock for composting, in addition to field spreading of manure or compost.

from the side or rear of the box, ground-driven manures spreaders (Figure 7 and Figure 8), or V-bottom type spreaders (Figure 9) that utilize vertical or horizontal beaters. Wide tires help reduce compaction.

Manure spreaders with vertical beaters require more horsepower and maintenance due to heavy wear on gear boxes and drive shafts (Post Equipment 2015). Typical box-type spreaders with horizontal beaters (Figure 7 and Figure 8) are less expensive and require less horsepower, but distribution is limited to the rear width of the spreader. Rear-discharge spinner spreaders distribute solids more widely (Rahman and Wiederholt 2012). Cone spreaders (Figure 10) are useful for spreading pelletized fertilizer.

Drop spreaders are used for lime applications. With large volume applications, contracting local supply companies to spread lime and fertilizer using a fertilizer wagon (Figure 11) is advisable. Dry boom spreaders may be appropriate for larger acreage. Amendments can also be placed during seeding operations if grain drills are equipped with fertilizer application boxes.



Figure 8. This manure spreader is old, but still serviceable and in use on a 75-acre vegetable farm with 30 acres of production in grain. Older spreaders are entirely axle-driven and must be moving for the conveyor chains, welded together by angle iron, to advance material to the beaters to distribute the load out of the back of the wagon. This machine can be tested by hitching it up and moving it forward to evaluate the condition of the chains, welds, axles, and beaters. Rotten boards can be replaced, as the top two courses are here. Angle iron broken from the conveyor chains can be readily welded back together with the right tools.



Figure 9. Side-discharge, V-type manure spreader. This PTO-driven spreader utilizes a roughly 20-in. diameter cross auger at the base of the spreader box to advance material to a distribution mechanism, on the side of the machine. Wide tires help distribute the load and minimize soil compaction. Compost, manure and biosolids, among other materials, can be spread with this equipment. This machine has hydraulic controls for adjusting the flow of the materials.



Figure 11. This PTO-driven, rear-discharge fertilizer spreader can hold several thousand pounds of fertilizer and uses a conveyor mechanism to advance material to rotating distributors, pictured in the lower left. A table displayed on the rear of the machine provides guidance for manually setting the application rate. Fertilizer spreaders may be available for rent from farm supply businesses.

Seeding

Broadcast seeding is fast, and can be done with very basic equipment, but typically results in less uniform stand establishment, higher seeding rates to achieved desirable results, and other losses of efficiency and precision and are not recommended if one is targeting a high-value grain market. However, some large-scale and well-established grain operations in western Washington do broadcast seed and achieve good stands.

On a very small scale, seed can simply be hand broadcast or distributed using a hand-crank spreader. On a larger scale, cone spreaders (Figure 10) can be used such as those discussed above for amendment application. Grain drills are preferable for acreages of greater than one to two acres and can be calibrated to deliver seed at a specific rate, spacing, and depth (Figure 12, Figure 13, and Figure 14). Seed is fed from the seed hopper, through a metering unit, and into a series of cups and chutes. From these, the seed is placed in rows behind a furrow opener, such as a set of disks which usually also cut and clear residue out of the way. Furrow closers, chains, or packing wheels are sometimes used to close the furrow, firm up the seedbed, and improve soil contact with the seed.



Figure 10. Cone spreaders used for pelletized fertilizer fit in the bed of small pick-up truck. Application with this equipment is limited to several hundred pounds of fertilizer before refilling is required. Depending on soil fertility needs, this is typically enough for one to two acres using a conventional nitrogen fertilizer, such as ureasul (33-0-0), or half to three-quarter acres using an organic fertilizer such as feathermeal (12-0-0).



Figure 12. Basic grain drill with a riding board. The tractor operator engages and disengages the disk openers and seeding mechanism by pulling ropes at the beginning and end of seeding passes. A second person can make sure the disks drop as intended and that seed is flowing properly. A stick or small broom should be used to remove blockages and distribute seed, as fingers can get drawn into the seed metering unit.



Figure 13. Eight-ft Minneapolis Moline model P36 grain drill. Inspection of drills should include examination of the connection between seed box and seed chutes, rotation of coulters, welds, and any other wear. When seeding, it is useful to have a second person ride on the wooden platform, pictured, to prevent seed blockages and bridging that can be caused by straw lodged in the seed cups and chutes.

Controls for adjusting seeding rate, and to engage and disengage the seeding mechanisms on grain drills, vary some but are fairly similar from drill to drill (Figure 15 and Figure 16).

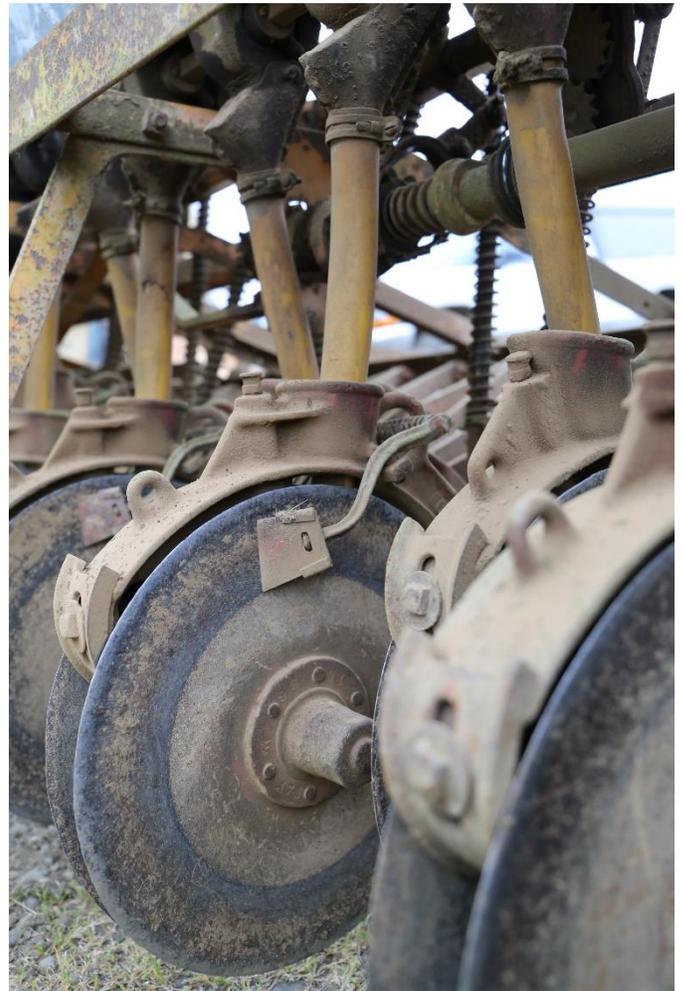


Figure 14. Double-disk openers are visible on this drill, which are used widely for large-sized seed (e.g., wheat, barley, and oats) and small-sized seed (e.g., grass seed and buckwheat). Single-disk openers are fine as well but do not place small-sized seed at as consistent a depth. At seeding, a stream of grain will be seen flowing into the cups from the seed box, at top. Disk cleaners are also visible here to prevent soil and crop residue from building up.

See Further Reading for information on grain drill calibration, and *Conservation Tillage Systems Information Resource* (WSU STEEP 2018) for information on no-till/direct grain drills for reduced tillage operations. No-till/direct grain drills (Figure 17) are typically heavier and have more aggressive furrow openers and residue cleaners for cutting through surface crop residues and into an untilled soil surface.



NOTCH ON DIAL PLATE	LOW GEAR										HIGH GEAR									
	2	4	6	8	10	12	15	20	10	12	15	20	25	30	40	45	50	55	60	
BARLEY												37	50	63	81	114	132			
CRACKED WHEAT GRASS					5	7	10	15												
WHEAT					23	33	46	61	32	62	74	87	107							
RYE					21	34	47	73	49				88	123						
PEAS								49	61											
SOY & COMMON BEAN								38	48											
FLX								19	26	36	53									
MILLET					5	10	17	23	33	46	57									
VEITCH								17	23	30	43	77								
ALFALFA & CLOVER					6	10	14	20												
KUDAN GRASS					4	7	10	12	19	26	32									

Figure 15. Seeding rate is adjusted by a lever on the operator side of the drill and is sometimes creatively held in place. A corresponding table provides estimates of seeding rates, which can be checked by seeding across a hard-packed service over a measured distance, gathering the seeds, and weighing them.



Figure 16. The vertical engagement mechanisms, looped together with rope, can be seen on this single-disk, eight-ft McCormick-Deering drill. The spring-loaded disks allow the seeding mechanisms to recoil in the event of hitting a rock or other object to minimize damage and maintain seeding consistency over uneven terrain.

In-Crop Cultivation and Spraying Equipment

Equipment for weed management after grain has been planted includes mechanical cultivation implements and spraying equipment for application of herbicides, pesticides, and fungicides (whether organic or conventional), compost teas, biodynamic preparations, foliar feeding, or other products. In-crop cultivation equipment includes spring-tine harrows (Figure 18 and Figure 19). Tine harrows have a large numbers of narrow, spring tines that



Figure 17. A no-till range drill, which are sometimes available for rent from conservation districts.

dislodge weed seedlings while minimizing damage to the grain crop. Harrows can be used prior to crop emergence, or at the stage of growth when plants have two to three leaves. Shallow-seeded grain, or grain seeded into an uneven seedbed with large soil aggregates, have been observed to yield less (when harrowed) than not harrowed. Successful mechanical weed management in small grain crops requires careful attention to many conditions, such as soil moisture, seed date, weed pressure, and other factors.

Power harrows (Figure 20), while uncommon, may find use in a farmer’s equipment fleet. For more information on organic grain cultivation see *Steel in the Field* (Bowman 2001). Refer to *Using Conservation Tillage in Organic Systems* (WSU Wheat and Small Grains, n.d.) for use of sweeps, rotary harrows, and rotary hoes for pre-plant, post-harvest, and in-crop weed management in organic



Figure 18. Fourteen-ft tine weeder for cultivation.

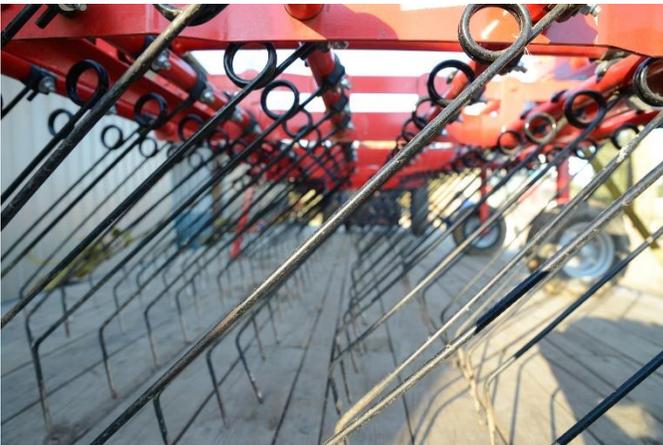


Figure 19. Support wheels allow consistent depth for six rows of tines on this weeder. Tine diameter for post-emergence cultivation equipment is typically between 6.5–8.0 mm. A search for a used tine harrow may turn up implements with thicker gauge tines. Be careful using these more aggressive harrows, which could cause significant damage to the crop. They may be better suited for weed cultivation before emergence, as compared to the two to three post-emergence tine harrowing passes customary in organic or no-spray grain production. (Photo credit: Swaying Trees Photography.)

grains. See Further Reading for several publications on mechanical weed control.



Figure 20. Power harrows are uncommon in small grain production but may find use in seed-bed preparation and pre-emergence weed management. Their numerous moving parts make these implements prone to mechanical trouble. They also require a PTO-equipped tractor.

Equipment for spray-applied pest control or other products consists of a basic boom spray rig. Simple spray nozzles are unidirectional, as illustrated in Figure 21. These are designed to spray, with some force, directly into the plant canopy to reach weed cover in the understory. The spray direction of newer nozzles can be adjusted, including with the ability to spray backwards, which is suitable for misting canopy coverage when applying fungicides, compost teas, and foliar-feeding products.

Pumps, cracked hoses, leaky gaskets, sprays nozzles, and fatigued steel or welds are the most likely repairs on boom sprayers. Maintaining and regularly calibrating spraying equipment is critical for [appropriate application of pesticides](#). See the [Cornell University Extension Pesticide Application Technology program](#) for further information on spray equipment. Information on this equipment can also be referenced in greater detail elsewhere (Stock and Castagnoli 2015; Hanna and Sawyer 2001).

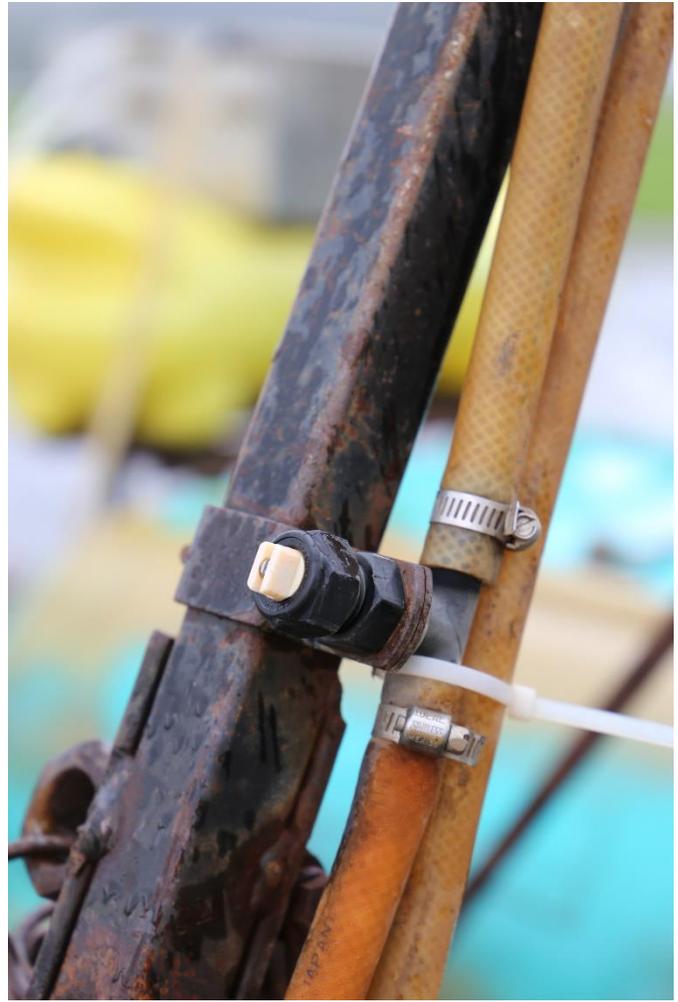


Figure 21. Boom sprayer showing articulating booms, a basic steel scaffold, and inexpensive unidirectional spray nozzles that are readily replaced through farm equipment supply companies. Old spray pumps, in addition to most all grain production equipment, can often be found at regional equipment auctions.

Harvesting

Small grain harvest equipment consists of self-propelled, and PTO-driven (also known as “pull-behind”) combines, as well as pull-behind combines equipped with an engine. These can be pulled by a tractor or well-trained draft animals. PTO-driven combines are not manufactured anymore but can be found on the used market. Users must be ready to deal with the pitfalls of antiquated equipment when it is selected. This can include lack of safety features—such as pulley and belt housing, lack of precision in threshing adjustments, mechanical as compared to hydraulic controls that can be difficult to work, and an absence of enclosed cabs for dust-reduction, shielding from the sun, and air-conditioning. Mechanical adjustments often cannot be made from the cockpit; however, their continued

functionality on 50- to 70-year-old machines has proven their durability, sometimes in contrast to their hydraulic counterparts. On a very small scale, grain can be cut by hand and threshed using stationary threshers.

The PTO-driven, Allis-Chalmers All Crop (Figure 24) with a six-ft header is a low-cost and versatile grain harvesting implement. It is capable of threshing a wide range of crops, from small-seeded quinoa to large-seeded corn and dry beans. The open-cockpit John Deere 105 roughly triples harvest capacity with a 12-ft header (Figure 25), while the closed-cockpit John Deere 6600, with a 16-ft header, increases harvest potential to 15 to 20 acres per day (Table 2). Figure 26 illustrates an International 1440 combine with a pickup header.

A pickup header enables harvest of crops that have been swathed (for drying purposes, and, sometimes,

for pre-harvest weed control) and are lying on the ground. In wet regions (especially) swathing may be

How a Combine Works

The primary components of a combine are the header, thresher, straw conveyers (or straw walkers), cleaners, and bagging area or grain bin into which cleaned grain is augered (Figure 22). Standing grain is cut by a sickle-bar mowing mechanism. The reel (and attached wooden batts, on older combines), coordinated with the combine ground speed, delivers the severed grain and straw to a threshing chamber where a rotating cylinder subjects the crop to sufficient agitation to shatter the seed head and separate the grain from the chaff. Cylinders may have rub-bars, rasp bars, or spiked teeth. All material exits the threshing chamber onto a straw conveyor (Figure 23) where straw raddles vibrate, tossing the straw up and out the back of the combine. Threshed grain falls through this mechanism onto a series of cleaning screens over which air is forced by a metal-vented fan. Fully threshed grain is screened to an auger by which it is delivered to a bagging platform or grain bin. Seed smaller than the desired grain falls through the screens and is directed out of the combine, while oversized material that was not ejected by the straw walkers is recycled to the threshing chamber.

General controls on combines include those for ground speed, header height, reel speed, and others used for making variations to the threshing mechanism. Combines are designed to operate at full throttle. Threshing adjustments are similar across most combines and include controls for cylinder speed, concave clearance, chaffer and sieve openings, and fan speed. The instruction manual for a combine, whether available with the combine or found online, provides specific information on appropriate settings by crop.

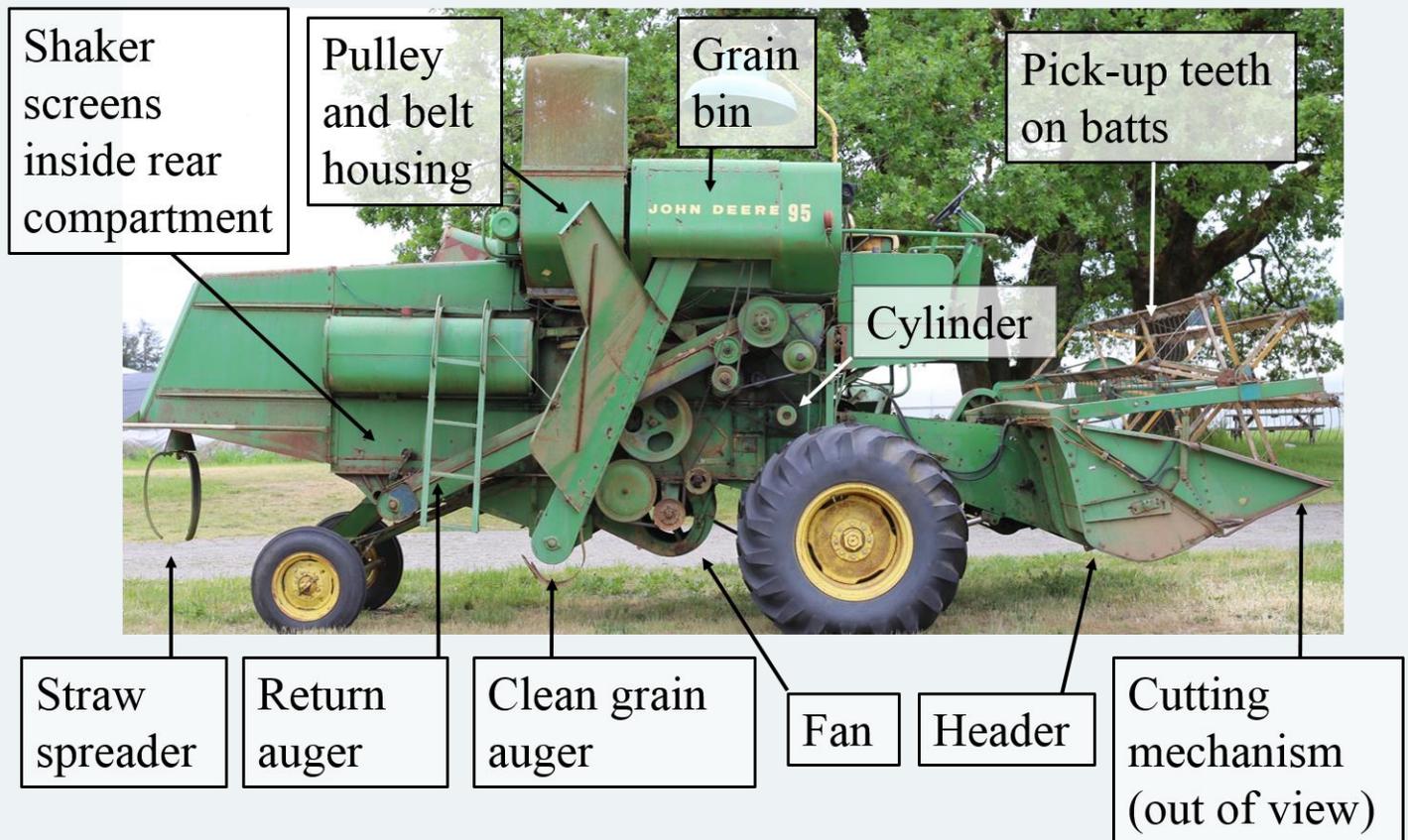


Figure 22. General components of a combine.

critical to achieve uniform ripening in crops such as field peas and buckwheat. Combine buyers should develop a specific sense of their desired equipment

attributes, such as those illustrated here, prior to purchase.



Figure 23. A combined top sieve screen and straw walker removed from an Allis Chalmers All Crop 66 for a repair. Sieves to the left allow for threshed and some un-threshed grain to fall through to a second sieve below. To the upper right, a combination of slats, serrations, overlapping platforms, and notches function to force straw out of the combine while allowing un-threshed grain to pass through and recirculate to the threshing cylinder.

Figure 24. The Allis Chalmers All-Crop is inexpensive and versatile. This All Crop received new reel arms and batts, and has a grain bin as opposed to a grain bagging platform. The unloading auger is at left, the clean grain auger is vertical, while an articulated section at center is the return auger depositing un-threshed grain back to a rub-bar type threshing cylinder.



Figure 25. Open cockpit John Deere 105 combine.

Figure 26. International 1440 combine with pickup header designed for harvesting crops that have been swathed. Any grain, oilseed, or seed crop can be swathed and combined using a pickup header, although this approach is more necessary for some crops than others, including peas and buckwheat.

Table 2. Generalized* daily combine harvest capacity for older, smaller-scale (and typically second-hand market) combines^a.

Model	Header width (ft)	<u>Max</u> harvest capacity (acre/day)
Allis Chalmers All-Crop	6	3–4
Case 600	10	8–10
John Deere 105	12	10–15
John Deere 6600	16	12–20

^aThompson et al., personal communication.

*Aside from specific combines cited, to be noted is the relationship between header width and daily harvest capacity among older combines.

Considerations for Equipment Selection

Key information to consider when selecting equipment is whether to buy used versus new, the size of the equipment, how it fits in the current operation, repair needs, equipment wear-out life, and availability of parts. Individual farm finances, risk management thresholds, mechanical ability and capacity for equipment maintenance and repair, etc., should be considered in determining whether to buy new versus used equipment.

Refer to *Buying Farm Equipment* (Rumsey 2012) for detailed information on equipment wear-out life, tips to identify different types of damage, and pitfalls associated with specific equipment. When purchasing used equipment, the buyer is only purchasing the remaining hours of life on that equipment. Getting to know local grain farmers nearing retirement can help new farmers acquire reliable equipment.

New versus Used versus Renting

New grain enterprises are more likely to utilize used equipment out of necessity, whereas established businesses develop focused needs that justify or require new equipment. The price of new combines, combined with the absence of new smaller-scale combines on the domestic market, makes it practical for start-up operations to purchase used. Imported equipment should be considered with care due to difficulties with the importing process, and cost and availability of parts. Research plot combines, though perhaps tempting in theory, are typically rare and too expensive.

In regions of historical or current grain production, it is possible to secure a used combine with a 20-ft header in good condition for under \$10,000.

Generally, bigger equipment tends to sell for less than smaller equipment, and many implements are available used at very affordable prices (Table 3). The most affordable equipment is available to those able to make repairs or those who have access to a knowledgeable and cost-effective mechanic. For additional information on equipment costs including ownership and operation, see *Costs of Owning and Operating Farm Machinery in the Pacific Northwest* (Painter 2011).

Table 3. Estimated price ranges for grain-specific equipment most likely to be purchased used^a.

Equipment	As-is cost, repairs needed (\$)	Field-ready cost (\$)
Small field tractor (e.g., Ferguson 35)	3,000	4,500 - 6,000
Self-propelled combine	1,500–5,000	3,000–8,000 (and up)
Allis Chalmers All Crop	1,000	1,000–2,000
Grain drills	300	500
Wind screen seed cleaners	700	2,000
Cone fertilizer spreader	500	500
Manure spreader	600–700 (not less)	2,500 (good condition)
Tine weeders	500–1,000	1,000–4,000 +

^aThompson et al., personal communication.

When selecting equipment, it is important to distinguish between equipment that is ready for operation versus equipment in need of repair. New farmers and those unfamiliar with grain production should seek assistance from experienced mechanics, grain farmers, and employees at local agricultural supply stores. A knowledgeable individual can help distinguish level of repair difficulty, while a set of general guidelines (Table 4) should be followed by anyone evaluating used equipment.

In addition to purchasing new or used equipment, some equipment may be available for rent from local input dealers as well as conservation districts. Equipment at the latter is sometimes restricted to equipment for conservation practices such as no-till drills, but can also include lime and fertilizer spreaders, and other equipment. In some instances, it

may be more cost-effective to hire a custom operator to complete fieldwork requiring specialized equipment. See Hanna (2010) for information on inspecting used combines and implements, Jarrett (1995a), and Jarret (1995b) for typical inspection checklists for evaluating used tractors and implements.

Grain Equipment Size

Suitable equipment size is determined primarily by budget and daily harvest goals combined with local climate patterns that set seasonal and daily harvest limitations. Table 2 provides some generalized, older, smaller-scale combine harvest capacities. These capacities may decline depending on local conditions. This can include conditions such as morning dew in coastal climates, which reduces the

Table 4. Inspecting used equipment^a.

Information to consider	Age of the equipment, availability of warranty, maintenance and use records, hours on the equipment, diesel- versus gasoline-powered, cost in comparison to similar equipment, damage from accidents such as collisions, fire, flooding, and roll-overs, fresh paint concealing damage, engine oil analysis
Parts to inspect	Welds for cracks, presence of new welds, condition of hydraulic lines, gear boxes for leaks, frame alignment, zerk plugs, crankshaft seals, belt condition, tire condition

^aInformation compiled from Thompson et al., personal communication; Rumsey (2012); Jarrett (1995a); and Jarrett (1995b).

daily harvest window by necessity of waiting for grain to dry to appropriate levels for combining (between 13 and 16 percent; see Miles et al. 2009).

Matching tractors and implements is determined by a number of factors, including tractor size, soil type and condition, field speed, and implement pull requirements, among others (Grisso et al. 2012). Basic calculations are available that take into consideration implement width and draft, soil type, and desired ground speed (Edwards 2017). These calculations, in Farm Machinery Selection, are readily applied to all disks, harrows, drills, chisel plows, and other implements (Table 5). A rule of thumb for draft requirements to pull a moldboard plow is determined by total inches in the ground, with a general recommendation of ten horsepower per foot of plow. However, tractor weight and four-wheel drive capability influence draft requirement. Other factors being equal, heavier tractors, and those with four wheel-drive, can pull more. A tractor with a properly matched implement should be able to travel between three and eight mph, but not more (Grisso et al. 2012). Refer to *Managing Machinery and Equipment* (Kyme 2017) for more information concerning equipment cost, size, and power considerations.

Tractor size is of less concern for implements with low draft requirement, such as drills, rotary hoes, harrows, and rollers. In these cases, working condition, price, and availability are more important than size.

Sourcing Grain Production Equipment

Sourcing affordable grain production equipment is greatly assisted by effective networking. Some mechanics and employees at fertilizer application companies visit dozens of farms annually. They may have intimate knowledge of potentially available used equipment on properties they service, and they may be able to connect a prospective buyer with the landowner. Similarly, buyers can utilize legitimate channels to contact landowners individually to inquire about derelict and stored equipment. Options for sourcing used grain production equipment include:

- Personal relationships
- Windshield surveys
- Online classified postings
- Local auctions
- Regional agriculture newspapers
- Historic grain production regions where production has declined
- Other countries (when imports are allowed)

Table 5. Draft requirements of various implements used in grain production^a.

Implement	Speed (mph)	Draft (lb per unit width)	Estimated horsepower required (hp)
2-bottom, 16-in. moldboard plow (7-in. deep) in medium soil	5	600	35
Four-shank chisel plow	5	500	44
Double-tooth subsoiler in medium soil	4.5	2,000	79
10-ft grain drill	5	70	15
Heavy off-set disk	4	300	42
Spike-tooth harrow	6	50	8
Rotary hoe	7.5	84	28

^aCalculations from Edwards (2017).

Farm Profiles

Farmer Profile 1: Kirsop Farm, Rochester, WA

Operator: Colin Barricklow and Genine Bradwin

Grain produced: Barley, wheat, triticale, and oats

Operation grains were added to: Mixed vegetables. An initial overgrown cover crop inspired the farm owners to harvest it for seed. Concurrently, they became interested in growing grain for poultry and hog feed and decided to experiment with grain production.

Acreage of farm:

Current: 75 acres total, 30 acres in grain production.

Initial grain production: 2 acres.

Equipment obtained to grow grain: All Crop combine (\$1,000 bagger unit), followed by a second Model 66 All-Crop (\$1,000) with a 25-bushel tank and unloading auger. The farm owned regular field implements used for vegetables: plow (three-bottom, 16-in. kvernland), disk (8-ft double gang Ford Series J), spike-tooth harrow, and grain drill (8-ft McCormick-Deering), which were all used for cover crop seeding.

Source of fertility: Lime per soil test, and dairy solids and liquids traded with a neighboring dairy in exchange for cover crop that Colin grows and the dairy cuts for silage.

Estimated investment in grain equipment: \$2,000 for two All-Crops, \$600 for a hammer mill from craigslist, and \$500 for a roller mill. Total: \$3,100.

Upcoming changes and goals: A transition to a bigger combine, as current production of 20–30 acres harvested with an All-Crop pushes the limit of the machine. The owners also would like to expand acreage to grow peas to complement the cereal grains currently produced for livestock feed.

Equipment tip for success: Cultivate relationship(s) with experienced grain producers and mechanics who a person can call for equipment questions and other advice for grain growing.

Nearby operation that modifies equipment needs: Access to a dairy next door allows for access to relatively inexpensive fertility, while avoiding the need for acquisition of application equipment, which the dairy owns.

Farmer Profile 2: Hidden River Farms, Montesano, WA

Operator: Evan Mulvaney

Grain produced: Barley, peas, wheat, and triticale

Operation grains were added to: Organic hog operation. The farmer was introduced to the idea of growing feed grain through other local grain farmers. He invested two years talking with grain farmers to become familiar with equipment and address other questions that he was unable to find answers to online.

Acreage of farm:

Current grain production: 105 acres

Initial grain production: 55 acres

Equipment obtained to grow grain: Several plows of varying sizes, tillage and finishing disks, an Einboch tine harrow for seedbed preparation and weed cultivation. For tractors, the farmer started with a 50-hp Massey Ferguson 65, followed by a 74-hp Massey Ferguson, and then a 200-hp John Deere 6210R. Other implements include a John Deere 800 Swather (utilizing a draper-style suitable for grain, but not for hay), an International 1440 axial-flow combine, a 14-thousand-lb-capacity flatbed trailer, and a bailer for straw.

Source of fertility: Currently cover crops, dairy and hog solids, and liming per soil test. The farmer is working on an NRCS Environmental Quality Incentives Program grant for liquid manure storage and application equipment to close nutrient loop with hog operation.

Estimated investment in grain equipment: \$300,000

Upcoming changes and goals: Equipment for bulk grain handling: high-volume cleaner, grain dryer, more augers for transfer, grain bins, grain wagon, dump truck, and ration mixing tub.

Equipment tip for success: To match equipment selection with the proportion of grain in the farm system, while still providing room to grow. The farmer suggests that maintenance and attention to operate a \$1,000, heavily-used machine, may require maintenance beyond what a person can handle in the first few years.

Nearby operation that modifies equipment needs: Custom-hired services from a neighbor for bailing straw, before a bailer was purchased.

Farmer Profile 3: Nash's Organic Produce, Sequim, WA**Operator:** Sam McCullough**Grain produced:** Barley, wheat, triticale, rye, peas, vetch, buckwheat and vegetable seed (carrots, kale, spinach, beets, cauliflower, corn, sunflowers, camelina, beans, peas, cilantro, parsley).**Operation grains were added to:** Mixed vegetables and poultry. Grain was added as a way to grow feed (barley) to incorporate animals into a vegetable operation, and cover crop and vegetable seed production followed.**Acreage of farm:**

Current grain production: 80 acres

Initial grain production: 10 acres

Equipment obtained to grow grain: For combining, a Massey-Harris 90 was initially obtained, followed by a 1970 John Deere 95, and then a 1973 John Deere 6600. Implements include a Lely tine weeder, 16-ft, 4-gang offset tillage disk, 10-ft International #10 grain drill with 7-inch spacing, a cultipacker, and a vibra-shank harrow.**Source of fertility:** Heavy cover cropping consisting of vetch seeded at 200 pounds per acre, which yields on average 2 to 2.5 tons per acre. Other fertility options utilized include Perfect Blend 4-4-2 and 4-4-3; however, return on investment has been marginal. Dairy solids and liquids have been available, but expensive to haul. The farmer believes that a nearby poultry operation would be ideal.**Estimated investment in grain equipment:** Not available.**Upcoming changes and goals:** No current updates to grain production equipment are planned, but the farm continues to make adjustments to grain handling and processing equipment.**Equipment tip for success:** Look for opportunities where different parts of the whole farm can complement one another, such as producing grain for livestock or human-grade consumption for an existing customer base (1), growing vegetable seed for vegetable operations (2), and producing cereal grains for diversifying vegetable crop rotations (3).**Nearby operation that modifies equipment needs:** Crab meal from a nearby cannery has been utilized as a protein source in hog feed that utilizes grain grown on site. This has reduced, somewhat, the attention on equipment needed for higher volume production of pulse crops, such as field peas.

Summary

Starting or adding a grain enterprise to an existing farm operation requires specialized equipment, much of which is available used at reasonable prices. Before making purchases, consider equipment sharing (1), existing networks of grain farmers for advice and assistance locating used equipment (2), neighbors with whom trades for animal manure and other resources that may modify equipment needs (3), and the status of small grains markets (4). A combine, and covered storage for it, is the minimum specialized production equipment required to add a grain enterprise to those existing farm operations with field-scale tillage and cultivation equipment. For grain harvests greater than a few acres, operations without existing equipment will need a minimum 30-hp tractor, and implements for primary and secondary tillage, fertilizer and soil amendment application, seeding, weed management, and harvest.

Considerations prior to investing in equipment are numerous. Those pertaining to site planning include the scale of the enterprise, crop selection, fertility needs, and environmental factors, such as rainfall, humidity and temperature.

Some practical equipment factors to consider include the availability of parts, the remaining life on a piece of equipment, and honest assessment of one's own skills, and available time, for repairs. Finally, prospective equipment buyers should consult equipment inspection checklists, identify specific daily productivity goals, and match tractor power to the draft requirements of the implements selected.

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