

SOIL AND PRODUCTION ENHANCING COVER CROP AND LIVING MULCH SYSTEMS

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THE EROSION PROBLEM

Before the introduction of terracing, contour farming, strip tillage, minimum-tillage or no-till crop production, soil losses from tilled and cultivated cropland in Pennsylvania amounted to 9 to 13 tons per acre each year. Because only 4 to 5 tons of soil is produced annually from parent materials, the annual net loss was 5 to 8 tons.

Soil erosion is a natural process that is greatly accelerated by human activity, specifically when vegetation is destroyed or plant residues buried through tillage. At present, the Pennsylvania Clean Streams Law requires growers who till the soil to have conservation plans. Growers who receive USDA benefits are also required to have a conservation compliance plan that should have been fully implemented by 1995. Such plans are intended not only to reduce soil erosion and protect water quality, but also to retain long term soil productivity.

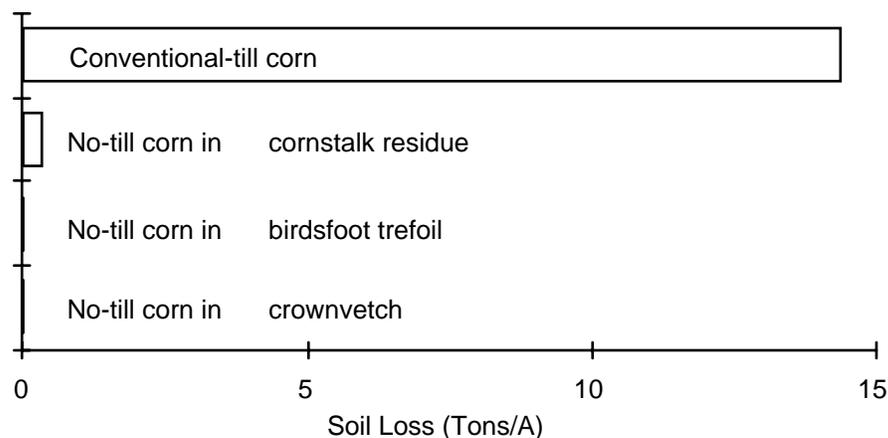
Practices such as contour strip cropping, diversions, grassed waterways, and cropland terraces, promoted during the 1940s and 1950s, reduced soil losses by 50% or more. With the arrival of 2,4-D in 1946 and the rapid adoption of herbicides for weed control in the fifties and sixties, it became possible in the seventies and eighties to control weeds with less tillage. Some crops, such as corn and soybean are now grown without any tillage at all. Because of the plant residues left on the soil surface in no-till, reductions in soil losses of 90% or more are not unusual compared to those of conventional tillage.

Even with such practices, however, many farmers may not be able to grow as much corn or soybean as they would like and still satisfy their conservation compliance plan. An alternative soil-conserving practice is to use a permanent living groundcover into which corn, soybean, small grains, and forages can be planted using minimum-or no-tillage cropping practices. Research on crownvetch as a living mulch has been conducted at Penn State since 1975, and its use for this purpose may be the ultimate soil conservation practice of this century. Further research has shown that birdsfoot trefoil also can be used. These cover crops prevent surface water runoff from ever getting started, virtually eliminating soil erosion and nutrient and pesticide runoff from even the steepest slopes. At the same time, farmers still have the freedom to grow the crops they want in the amount desired with equipment designed for large fields.

BENEFITS OF COVER CROPS

- **Erosion control** - Farmland is most susceptible to erosion when there is no vegetative ground cover or plant residue on the soil surface. A cover crop provides a vegetative cover during those periods when a crop is not present to cushion the force of falling raindrops, which otherwise would detach soil particles and make them prone to erosion. It also slows the rate of runoff, thus improving moisture infiltration into the soil. The goal is to reduce soil erosion to something less than 4-5 tons/A per year (see Figure 1). You'll notice that the soil loss was so little from corn planted into birdsfoot trefoil and crownvetch that it didn't register on the graph.

Figure 1. Soil loss from corn planted on a 14% slope during the 1977 growing season with 17.5 inches of rainfall.



• **Reduce Surface Water Pollution** - Due to the almost total elimination of surface water runoff from the continuous presence of ground covers, the loss of nutrients and pesticides by this route is almost eliminated (Table 1).

Table 1. Average water, soil and cyanazine^a (Bladex™) runoff losses from a 14% slope planted to conventional and no-till corn with and without a birdsfoot trefoil or crownvetch living mulch from May through October for 3 growing seasons (1977-79). Hall et al. (1984)

	CT ^b	NT-CSM	NT-BFT	NT-CV
Water run off (gal/A)	61,000 ^c	6,270 (90%) ^d	2,670 (96%)	2,000 (97%)
Eroded soil (lb/A)	12,690	375 (97%)	50 (99.6%)	18 (99.9%)
Cyanazine loss in runoff water (% of appl.)	2.4	0.31 (87%)	0.12 (95%)	0.12 (95%)
Cyanazine loss in sediment (% of applied)	0.2	0.01 (95%)	0.0 (100%)	0.0 (100%)
Total cyanazine loss (%)	2.6	0.32 (88%)	0.12 (95%)	0.12 (95%)

^a Cyanazine pre emergence @ 2.0 lb a.i./A on CT, 4.0 lb a.i./A on NT.

^b CT = conventional tillage-rototilled, NT-CSM = no-till in corn stover mulch, NT-BFT = no-till in CSM + birdsfoot trefoil living mulch, NT-CV = no-till in CSM + crownvetch living mulch.

^c Data collected from seeding to harvest of corn.

^d Reduction relative to the CT cropping system which received half the cyanazine rate.

• **Added Organic Matter** - Cover crops as well as manure or crop residues, add organic matter to the soil which increases soil tilth and productivity. At one time, prairie soils of the corn belt contained 8-10% organic matter. After 100 years of crop production, the average organic matter content is now less than 6%. The average organic matter content of most agricultural soils is even lower so any increase in organic matter will benefit these soils even more. In no-till crop production, the organic matter becomes concentrated at the soil surface which greatly improves soil tilth right at the surface.

• **Improved Soil Structure and Tilth** - Organic matter can act as a cement to bond soil particles into aggregates. Also, the breakdown of plant residues by soil microbes produce gums

that glue larger aggregates together into peds. This process results in greater soil permeability and aeration, which eases crop emergence and promotes root growth. Tilt thus is improved. Tillage and planting (even when no-till) is easier in a soil with good tilt.

- **Fixing of Atmospheric Nitrogen** - Any legume has the ability to fix nitrogen from the atmosphere which can reduce the need for nitrogen fertilizer. Stem, leaf and root residues left in the field from legumes are higher in nitrogen than grasses. The breakdown of legume plant residues commonly releases some of this nitrogen for use by the next and succeeding crops. Corn or small grains that require external sources of nitrogen can benefit from nitrogen released by a previous legume crop or cover crop.

- **Recycling of Unused Soil Nitrogen** - Unused soil nitrogen left over at the end of the growing season tends to leach out during the fall, winter and spring and may end up in the ground water. Some of this nitrogen is used by cover crops, whether legume or grass, if they can grow after the primary crop slows or stops its nitrogen uptake. These cover crops need to be adapted to relatively cool fall or spring conditions to be effective in removing unused nitrogen from the soil. Some of the nitrogen ultimately is recycled for use by future crops as plant residues are broken down by soil microbes.

- **Greater Soil Productivity** - All of the above practices improve soil productivity. If an ever growing population is to be fed, productivity will have to increase, making it necessary in the future to farm marginal soils whose productivity is already low. Such soils benefit most from cover crops, but cover crop use on better soils will also reverse the downward trend in productivity as a result of losses in organic matter, nutrients and topsoil.

- **Weed Control** - Cover crops provide competition against weeds just as crops do. In addition, cover crops such as winter rye and ryegrasses produce their own chemical herbicides that help to suppress or control weeds.

CHOOSING A COVER CROP

Which cover crops to plant depends on many factors. Is the crop being grown to provide nitrogen for the next crop, to control erosion, to prevent nitrate leaching, or some combination thereof? Is the cover crop compatible with, or does it fit, the crop rotation? For summer-annual crops, such as corn or soybeans, cover is needed in fall, winter, and spring. For winter-annual crops, like winter wheat or barley, cover is needed in late summer or fall. Regardless of the cover crop, most must be killed or suppressed so they don't interfere or compete with the primary crop.

Summer-annual groundcovers - Oats probably are the best summer-annual groundcover. Volunteer oats that come in after harvest make excellent growth and may even head out before frost. If the volunteer oats are spread more evenly with a straw spreader at harvest time, no additional groundcover may be needed.

If oats are seeded as a groundcover, seeding should be done as early as possible, at least six weeks before the first killing frost. This allows for the production of sufficient biomass to provide a good groundcover and to absorb excess nitrate from the soil. If extra forage is needed, the oats may be harvested for silage in the fall. Although this reduces the groundcover, the oat stubble still controls erosion. Since oats are killed by frost, no herbicidal control is necessary.

Winter-annual groundcovers - Winter rye and hairy vetch are the two most common winter-annual groundcovers in Pennsylvania. They have been used with various degrees of success for the last 50 years or more.

Winter rye is planted more commonly today in southeastern Pennsylvania where the longer autumn allows a little more time for establishment. Winter rye should be seeded between early September and early October to allow for the production of enough biomass to provide a good groundcover and to absorb excess nitrate from the soil. Seedings have been broadcast by helicopter and other methods into standing corn, but if the soil is dry, as it often is, stands tend to be poor and competition from corn is too great unless the corn is harvested for silage.

The best stands are achieved when rye is broadcast on tilled ground and lightly worked in or drilled in with a grain drill after the main crop is harvested. Winter rye normally cannot be established after corn or soybeans harvested for grain since harvest of these crops is too late in Pennsylvania. Winter rye must be harvested for silage in the spring if the full nitrate removal benefit is to be realized. Unfortunately, whether winter rye is removed for silage or killed and left as a dead mulch, it will have tied up available nitrogen and extra nitrogen must be applied to corn planted into it to prevent a yield loss. This may not be a problem if there is excessive nitrogen-rich manure to dispose of anyway.

Hairy vetch should be seeded a month earlier than winter rye, making hairy vetch virtually impossible to seed into or after corn. The best hairy vetch stands are achieved by no-till or min-till seeding after small grains in August. A good hairy vetch stand fixes enough nitrogen so that no additional N is required for a succeeding corn crop. Hairy vetch normally is not harvested for forage, although it could be. If it were, however, much of the nitrogen that would be available to the corn crop would be removed with the forage.

Both winter rye and hairy vetch, if seeded early enough, produce enough growth to smother out winter-annual weeds and suppress some summer annuals the following spring. Also, winter rye and hairy vetch will regrow if harvested just before corn planting; thus an effective herbicide program is required for complete kill and for weed control since weed control by the cover crop does not last long enough. Anything less than complete cover crop kill usually results in corn yield losses from competition. Use normal herbicide treatments for this purpose.

BENEFITS OF CROWNVETCH AS A LIVING MULCH

Crownvetch (*Coronilla varia* L.) is a perennial legume adapted to the temperate climates of the northern two-thirds of the United States. It is native to central and southern Europe, North Africa, and the Near East. Crownvetch was most likely introduced in the late 1800's and early 1900's as a contaminant in alfalfa and other legume seed. From these chance introductions, the variety Penngift was named from a selection in eastern Pennsylvania. Crownvetch is a hardy, deep-rooted plant that has proven its value for soil stabilization and erosion control for roadsides, steep banks, strip mine sites, and other non cropland areas.

Contrary to information found on the internet and espoused by plant ecologists, state and governmental experts and local activists, crownvetch is not invasive by my definition. To be invasive, a plant has to spread on its own, establish itself in cropland and non-cropland environments with relative ease, and be able to compete with other native and non-native vegetation already established at the site. After growing crownvetch for use as a living mulch for corn and agronomic crop production for 30 years, I have never seen it spread more than 10 or 20 feet on its own. This spread was by growth of underground root stocks and not by seed. Crownvetch seedlings are so non-competitive that they can only survive where there is little or no competing vegetation. Once established, crownvetch is competitive and this characteristic along with its ability to spread and fill in via growth by underground root stocks is why it is ideally suited to soil stabilization and erosion control for roadsides, steep banks, strip mine sites, and other non cropland areas. Unfortunately, it's not quite competitive enough to totally prevent invasion of other weeds and woody perennials but it is still one of the best and one of the prettiest ground covers presently available for sites that commonly have such poor soil that little else will grow. Its use as a living mulch for cropland use is only possible with the help of herbicides to control competing vegetation and for suppression of crownvetch itself so it won't compete with the primary crop.

Establishment is very slow but after 2 to 3 growing seasons, you should have a good stand. Initially glyphosate, atrazine, simazine, dicamba, or 2,4-D cannot be applied to crownvetch without killing it. Crownvetch can never be moldboard plowed or it will be lost. Even min-tillage with a chisel plow or heavy offset disk more than once every 2 or 3 years will severely thin the crownvetch stand. Crownvetch recovers from winter dormancy late in spring and only begins to make significant growth by corn planting time, so there is little early competition. After it is well established, crownvetch can be chisel plowed, disked and harrowed every second or third year with minimal damage because it recovers from buds on the rootstocks. All tillage operations should be accomplished in a week or less to prevent excessive thinning of the crownvetch stand however. Mechanical suppression normally is not enough to prevent it from competing with corn, soybeans or small grains, so additional suppression with herbicides will be needed. Herbicide treatments listed in the following tables can be applied to crownvetch for suppression and for weed control.

A perennial crownvetch living mulch reduces water runoff, soil loss, and pesticide loss from sloping land by 98% or more. By increasing the amount of water that permeates into the soil, a crownvetch living mulch often improves moisture availability. In 1983 and 1988, both dry years, corn was found to suffer less from moisture stress when planted into crownvetch and as a result yields were greater. However, when a drought starts in April, as was the case in 1991 and 1997, there is greater crownvetch competition for moisture because the corn never has a chance to develop a root system deep enough to tap into the subsoil moisture. If the drought does not begin until two or three weeks after corn planting, corn root development gets below the crownvetch and taps into subsoil moisture. As a result, corn in crownvetch usually yields more than corn planted without crownvetch or corn following rye (see Figure 2).

The summer of 1995 and 2002 proved an exception to this theory in many parts of Pennsylvania. Moisture availability was very good until early July but then came a period of prolonged drought lasting 6 to 12 weeks. The top 6 feet of soil were depleted of moisture so the depth of rooting did not save the corn from severe drought stress. Under these conditions, a living mulch competes for moisture and can reduce corn yields up to 20% or more. During the drought of 1999, in some parts of Pennsylvania corn was stunted so bad that farmers mowed off the cover crop and corn, put it into a silo or made round bales for hay in mid-summer before the corn dried up completely.

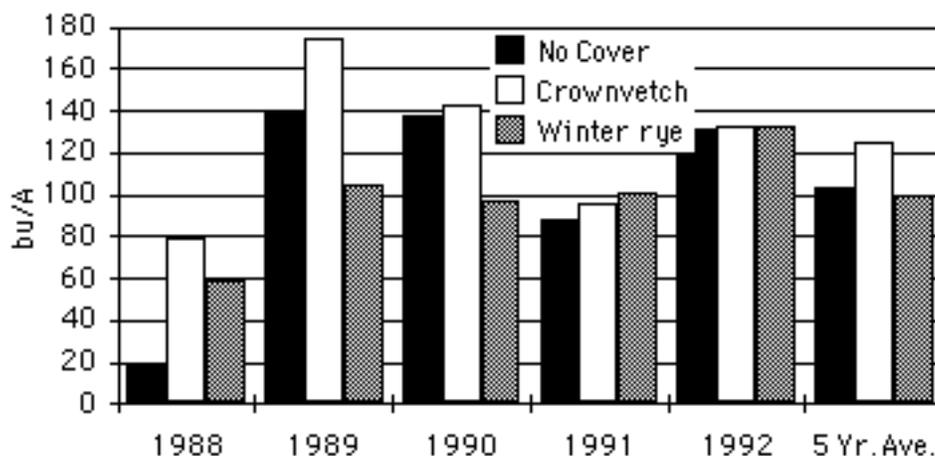


Figure 2. Corn yields with no cover, a crownvetch living mulch and following winter rye. The 1988 and 1991 growing seasons were very dry.

The real problem is to fine-tune the management system to suppress the crownvetch and weeds enough to avoid important competition with the row crop while retaining the crownvetch in viable form so it will come back late in the season and make good fall and spring growth. Herbicides are the key elements in the strategy. Research in Pennsylvania shows that with proper herbicide use it is now possible to obtain corn yields on no-till crownvetch comparable to those on no-till corn residues (Figure 3).

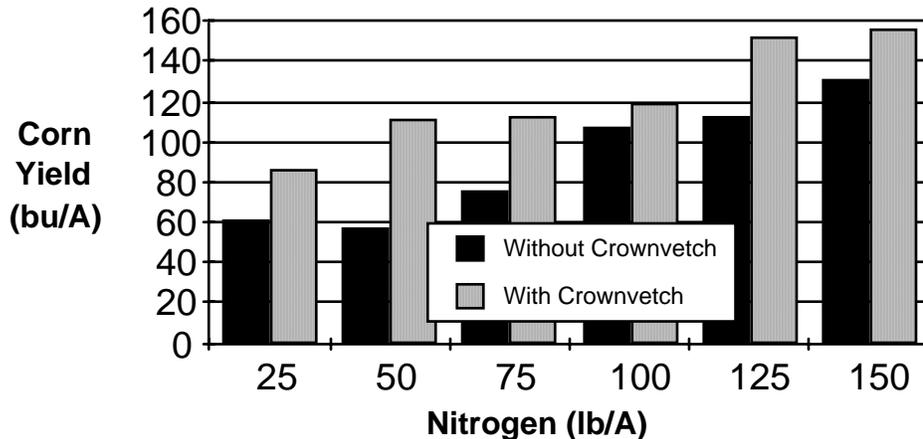


Figure 3. No-till corn yields with and without a crownvetch living mulch at different levels of nitrogen in 1984. (Mayer and Hartwig, 1986)

A crownvetch living mulch aids soil fertility by stopping nutrient loss in surface runoff. In addition, because crownvetch is a legume, it fixes nitrogen from the air. Research at Penn State indicates that yields of 100 bushels per acre are possible without any added nitrogen for corn planted into fields that were crownvetch seed fields or conservation reserve acres having a crownvetch cover. For each additional bushel of potential yield, add about 1 pound of nitrogen per acre in the form of manure or fertilizer. Some farmers have gotten good yields with no additional nitrogen, but 10 to 20 pounds applied in the row at planting time is usually required to obtain maximum yields. This row fertilizer gives the corn a faster start, enabling it to compete better with the crownvetch. When small grains or alfalfa and/or forage grasses are planted into crownvetch, they usually follow corn in the rotation, and normal fertilization required for that crop should be followed.

Crownvetch doesn't contribute any nitrogen the first year when seeded into corn and probably doesn't contribute more than 40 to 50 pounds of nitrogen per acre to second-year corn. Even so, this amount represents a savings of \$10 to \$12.50 an acre when nitrogen is 25 cents per pound. By the third and successive years, crownvetch contributes about 40 pounds of nitrogen each year. Fertilization with phosphorus or potassium beyond what is needed to produce a good corn crop is not necessary unless the crownvetch is pastured or removed for haylage.

Removing the crownvetch and crop residue for feed or bedding does not reduce its soil-erosion-controlling benefits since the root system is still intact and the ground cover is regenerated from root stocks the following growing season. A surface residue of 500 lb/A is all that is needed to control soil erosion. This is about what you get after a 95% suppression from tillage and/or herbicides. If crownvetch is allowed to make any more growth than this, it starts to compete with the primary crop. When suppressed sufficiently, crownvetch will never flower. If crownvetch starts to flower, it's an indication it has not been suppressed enough and if possible it should be treated immediately with Basis plus Banvel. If suppressed to late, the corn will likely suffer from crownvetch competition from which it will never totally recover. Most of the suppression should be accomplished from treatments at or before planting time.

The presence of crownvetch will help control escape weeds and may prevent or slow the invasion of new weeds that otherwise might become a problem. Yellow nutsedge has been controlled very nicely by competition from a crownvetch ground cover. It appears that competition from well established crownvetch will reduce dandelion problems as well. The idea of using crownvetch or some other ground cover as a "designated weed" and learning to live with it is very appealing compared to the constant battle of fighting an ever-changing weed spectrum.

BENEFITS OF BIRDSFOOT TREFOIL AS A LIVING MULCH

Birdsfoot trefoil (*Lotus corniculatus* L.) is a perennial that is not nearly as persistent as crownvetch. It was an alien plant found growing along the Hudson River in New York State. It tolerates less well-drained and lower-pH soils than most other legumes and is a desired source of food and cover for small game. Birdsfoot trefoil is seeded with crownvetch to provide quick cover until the slower establishing crownvetch has a chance to fill in. Unsuppressed birdsfoot trefoil will be competitive with crops, so herbicides are needed to provide weed control and enough suppression that it doesn't bloom when used as a cover crop. Between 0.5 and 0.75 lb/A of atrazine is needed to suppress birdsfoot trefoil in corn and should be used starting the very next year after establishment. Other herbicides applied separately or in conjunction with atrazine will be needed to control any weed problems you might have. (See Table 4)

ESTABLISHING BIRDSFOOT TREFOIL OR CROWNVETCH AS A LIVING MULCH

General Information - Crownvetch seedling growth is very slow, normally requiring 2 to 3 years to produce a well-established, vigorous stand. Birdsfoot trefoil, on the other hand, establishes more quickly, so it is seeded with crownvetch to provide quick cover until the crownvetch becomes well established. The conversion from birdsfoot trefoil to crownvetch may take 3 to 5 years. Normally the crownvetch seeding rate is 5 pounds per acre at a cost of \$50 to \$60 if seeded alone; but if crownvetch is seeded with birdsfoot trefoil, as little as 1 pound per acre of crownvetch seed can be used with 3 pounds per acre of birdsfoot trefoil, reducing the seed cost to about \$20 per acre. Few growers can afford to take a field out of production while the cover crop is being established. Thus, seedings are best made in fields free of perennial difficult-to-control weeds, with IT or Clearfield corn and the Pursuit plus Basis herbicide mixture (Treatment 1, Table 2) for control of weed seedlings.

Perennial weeds, especially thistles, hedge and field bindweed, hemp dogbane, horsenettle, common milkweed and woody perennials are hard to control without legume cover crops and even more difficult with them. If perennial weeds are a problem, try to clean them up with Roundup or Touchdown and/or dicamba (Clarity) when no crop is present, typically in August or September the year before cover crop seeding. This usually is only possible after small grains or on conservation reserve land. Accent, Basis and Lightning have been found to be safe on crownvetch and birdsfoot trefoil and help control some of these problem weeds in corn.

A year before seeding the cover crops, apply lime to raise the soil pH to 6.2 to 7.0, and apply phosphorus and potassium to nourish both the crop and the cover crops. In the absence of a soil test, apply 200 pounds per acre of 10-30-10 starter fertilizer in the row or broadcast at the time of cover crop seeding. Make seedings with a broadcast seeder to the soil surface. Crownvetch and birdsfoot trefoil stands seem to be best when the seed is broadcast on the soil surface, but seedings may also be made with a drill or seeder in the same way any other legume is seeded. The birdsfoot trefoil should provide at least 75% ground cover by the end of the first growing season. A crownvetch stand of one plant per square yard after the first winter should be considered a success. Once the crownvetch becomes the dominant species, it should last indefinitely if treated properly.

If it is necessary to destroy the crownvetch stand, apply dicamba (Banvel or Clarity) or 2,4-D for 2 or 3 consecutive years while growing corn.

Conventional seedings - Conventional seedings following plowing or chisel plowing, disking, and harrowing have been the most successful. Prepare a seedbed as you would for any

other legume seeding and don't plant the cover crop seed more than 1/4 inch deep or it won't emerge. It is better to broadcast the seed on the soil surface than to bury it too deep. If something like a Brillion seeder without disks or spring tooth tines is used, seedings can even be made after corn planting. Otherwise, make the seeding before corn planting so the disk openers of a normal drill don't disturb the corn. Pursuit + Basis (Treatment 1, Table 2) is the best herbicide mixture for most annual weeds in IT corn underseeded to crownvetch and birdsfoot trefoil. Don't, however, let the weeds get taller than 3 to 5 inches before application.

No-till seedings - No-till seedings can be made with any no-till drill that places the seed about 1/4 inch deep. No-till seedings are preferred where soil erosion is likely before the cover crop becomes established. The best cover crop stands have been obtained when seeded into soybean or silage corn stubble where there is little crop residue. The more weed and crop residue there is, the more difficult it is to get a good cover crop stand.

If winter-annual or other weeds have invaded the field, clean them up with Roundup or Touchdown at 1 quart per acre before planting the cover crop. Doing this may require a delayed seeding, since the weeds should be 6 to 8 inches tall before they are treated with Roundup or Touchdown. Cover crop seedings using a no-till drill are best made before the corn is planted because there is less harm done by disturbing the cover crop seeding when planting corn than by disturbing the corn planting when seeding the cover crop.

Broadcast seedings - Make seedings with a broadcast seeder to the soil surface. Some commercial applicators can spray a slurry of water, liquid fertilizer, herbicide and cover crop seed all in one trip. Seedings are best when broadcast to a well prepared seedbed and pressed in afterwards with a cultipacker. On steep slopes where soil should not be tilled, it would be best to make frost seedings onto fields with little plant residue such as soybean or silage corn stubble. Too much weed and crop residue is even more detrimental to broadcast seedings than for no-till seedings made with a no-till drill. Broadcasting the cover crop behind the corn planter using the insecticide box as a seed metering device is possible when an insecticide is not used. Ideally, the seed should drop onto a splash plate so it doesn't drop in a narrow band over the row. The cover crop will emerge in a wide band and will take a little longer for the crownvetch to spread and fill in, but this saves a trip over the field.

Establishing in corn - Crownvetch and birdsfoot trefoil seedling survival is probably best in corn because corn does not produce as dense a shade as soybeans or small grains. Corn may be planted conventionally or minimum- or no-till. The herbicide choice, however, is rather limited (see Table 2).

At the moment, the safest and probably the best method of establishment is to use Pursuit with Imidazolinone-Tolerant (IT or Clearfield) corn hybrids. Pursuit-resistant corn hybrids now are readily available in almost all maturities. Birdsfoot trefoil and crownvetch seedlings are more tolerant to Pursuit after emergence and Pursuit is most active when applied to the weeds early postemergence. Choose one of the recommended herbicide programs from Table 2.

Pursuit is weak on common ragweed, common lambsquarters and most annual grasses except the foxtails. Basis or Permit may be tank mixed with Pursuit to improve the weed control or a cleanup treatment of Accent, Basis or Permit may be applied postemergence to the corn. Permit may be used the year of seeding or anytime thereafter for common ragweed and yellow nutsedge control. All of these herbicides are known to be safe on both crownvetch and birdsfoot trefoil seedlings.

Upright-leafed varieties of corn that permit greater light penetration or corn harvested for silage allow crownvetch seedlings to build up more energy reserves for winter survival than if corn is allowed to go for grain. Harvesting corn for grain is not discouraged however.

Corn, soybeans, small grains, or forages may follow in rotation. See “First-Year Rotations” for weed control recommendations and tillage practices.

FIRST-YEAR ROTATIONS

General Information - Crownvetch seedlings are sensitive to herbicides and crop competition for the first year after seeding. Also, you should avoid tillage during the first year after seeding; otherwise, your crownvetch and birdsfoot trefoil seeding will be lost. Only after crownvetch is well established can you chisel plow, heavy disk, or use other minimum-tillage tools without hurting the crownvetch stand too much. Tillage of any kind will reduce the birdsfoot trefoil stand since it can't recover from underground root stocks. Moldboard plowing can never be done without virtually wiping out both the birdsfoot trefoil and crownvetch.

No-till corn: No-till corn is perhaps the best crop to plant the year following a birdsfoot trefoil/crownvetch seeding, since there are more herbicide choices for good weed control, and corn doesn't exert excessive competitive pressure on the cover crop. Don't use Roundup, Touchdown, 2,4-D, or simazine (Princep) on 1-year-old crownvetch. A mixture of Gramoxone Max (if it is needed for burndown) plus Lightning and Basis Gold; or Gramoxone Extra plus Basis and Bicep with either Lasso MT, Dual II, Harness, Topnotch, Frontier, or Prowl at one-half the labeled rate for your soil type may be used safely without severely injuring birdsfoot trefoil or crownvetch the first year after seeding. Choose one of the suggested herbicide programs in Table 4. If crownvetch should ever appear to be making too much growth (more than 6 inches of growth when corn has less than six leaves), suppress it with Banvel or Clarity mixed with Basis (Treatment 16, Table 4). For crownvetch/birdsfoot trefoil mixtures, substitute Basis Gold for Basis in the same treatment. The goal is to suppress the cover crop 95 to 98% for the first 4 to 6 weeks and then let the birdsfoot trefoil and/or crownvetch recover. If these cover crops are sufficiently suppressed, they will never bloom except around the edge of the field where they get more sunlight.

Soybean - Soybeans should not be planted into a 1-year-old stand of crownvetch and birdsfoot trefoil, since the cover crop is too difficult to manage with present soybean herbicides. Traditional residual herbicides don't suppress the cover crop enough, and Roundup on Roundup Ready soybean will wipe out a crownvetch cover crop. Birdsfoot trefoil will tolerate Roundup but with the addition of Sencor (metribuzin) applied before soybeans are planted or emerge will help suppress BFT. See [Table 6](#) for treatments that can be used on a well-established cover.

Small grains - Among the least competitive crops to follow a crownvetch seeding are no-till small grains. Whether they are sown in fall or spring makes little difference as long as only Harmony Extra or MCPA is used for weed control the first year ([Table 7](#)).

ROTATIONS IN ESTABLISHED CROWNVETCH

Soybean after Corn

Soybeans are best planted into birdsfoot trefoil and crownvetch only when the cover crop will tolerate a chisel plow or some tillage without being wiped out. Roundup plus Sencor is the only effective herbicide mixture for suppression of birdsfoot trefoil and crownvetch in soybean and the soybean must be planted with a corn planter in wide (30-inch) rows in order to prevent a dense soybean canopy from smothering the cover crop. Traditional soybean herbicides with residual activity will be needed at planting time to provide some early season weed control and to reduce the need for Roundup as a post treatment. Ideally Roundup or Touchdown should be part of the preemergence treatment so the cover crop isn't clobbered twice with a pre treatment followed by a postemergence Roundup. Use any of the herbicides suggested for use in the Penn State Agronomy Guide. None of the residual soybean herbicides effectively suppress healthy

crownvetch, so without some tillage or Roundup + Sencor, crownvetch quickly can become a weed in soybean. Classic, Lorox, Sencor or Lexone are very hard on birdsfoot trefoil but without their use birdsfoot trefoil may very well be too competitive also. See [Table 6](#) for weed control recommendations.

Forages after Corn or Small Grains

Established crownvetch competes excessively with a new legume or legume-grass seeding unless the crownvetch is severely suppressed before seeding. Corn usually provides sufficient suppression of crownvetch to allow a new legume or legume-grass seeding afterwards. When following small grains however, additional crownvetch suppression may be necessary by min-tillage, harvesting, grazing, or application of Roundup, Touchdown or Gramoxone Max.

After the newly interseeded legume or grass reaches the second- or third-leaf stage, apply 2,4-DB to suppress crownvetch further and to control seedling broadleaved weeds (Table 8). Manage the forage mixture according to the dominant species, ignoring the presence of crownvetch. You may use any herbicide labeled for the forage mixture without fear of losing the crownvetch. Crownvetch persists throughout the life of the forage stand and will still be there, although in minimum amounts when the field is rotated back to corn.

Corn after Forage

When rotating from hay back to corn, be careful not to eliminate the crownvetch, which has all but disappeared from view. In research trials at Penn State, crownvetch persisted through three years of alfalfa and alfalfa-grass mixtures, and was still present when the field was rotated back to corn. Whether crownvetch can survive four to five years in a hay stand is not known.

Since quackgrass usually invades hay stands in Pennsylvania, Roundup or Touchdown is recommended when rotating out of a forage to corn the first year (Table 4). If applied when dandelions are in full bloom, Roundup or Touchdown will not severely injure crownvetch, because crownvetch is just breaking dormancy at this time and has little foliage.

If dandelion is a major problem, a mixture of Lightning + Basis Gold on IR/Clearfield corn 3 weeks after the Roundup or Touchdown application is the best choice (Treatment 11, Table 4). Crownvetch will be very weak the first year and may appear to be killed completely, but in Penn State research trials it has always come back.

Corn after Corn

Corn can probably be grown after corn forever in a birdsfoot trefoil/ crownvetch living mulch. The goal is to suppress the cover 95 to 98% for the first six weeks after planting and then let it recover. The herbicide program for cover crop suppression and weed control can be any of those listed in Table 4. If corn is planted late and birdsfoot trefoil or crownvetch should appear to be making too much growth (more than 6 inches), suppress it with a burndown treatment of Gramoxone with dicamba (Banvel or Clarity) plus Basis or Basis Gold. If the cover crop gets out of hand after the corn is planted (more than 6 inches of growth before corn has six leaves), suppress it with a normal rate of dicamba (Banvel or Clarity) + Basis or Basis Gold (Treatment 16, Table 4). Basis or Basis Gold reduces activity of dicamba on crownvetch so as not to kill it.

Small Grains after Corn

Most weeds should be under control after a year or more of corn in crownvetch. Herbicide residues should not be a problem if treatments recommended in Table 4 were used the year before rotation to a small grain. If weeds were not controlled adequately in corn, use glyphosate (Roundup or Touchdown) at 1 to 2 pints per acre to control annual and perennial weeds before small grain seeding. Roundup or Touchdown should also be used in fall to control perennial weeds before spring oat seeding.

Birdsfoot trefoil and crownvetch (well established) will tolerate up to 1 quart/acre of Roundup or Touchdown. Once the small grain is seeded, use any of the treatments in Table 7 for normal weed

control and suppression of birdsfoot trefoil or crownvetch. One of these treatments will almost always be needed to suppress the crownvetch if small grains are planted no-till without a preplanting treatment of Roundup or Touchdown; otherwise, crownvetch will overtop the small grain before harvest. If the small grain is harvested for forage, excessive growth of crownvetch is highly desirable because it contributes protein to the mixture.

Table 2. Preplant, preemergence or early post herbicides for establishing birdsfoot trefoil and crownvetch in conventional or min-tillage corn.

• See Pursuit and other product labels to determine activity on various weed species.

GENERAL INFORMATION:

- Pursuit can only be used on Pursuit tolerant (IT/Clearfield) corn varieties.
- Basis should be tank mixed with Pursuit to improve annual grass and common lambsquarters control.
- Permit may be tank mixed with Pursuit to improve common ragweed and yellow nutsedge control.
- Pursuit tank mixed with Lasso MT, Frontier, Surpass/Harness or Prowl are too hot on birdsfoot trefoil.
- Pursuit + Dual II, Lasso MT or Prowl is safe on crownvetch when seeded without birdsfoot trefoil.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Conventional or Min-Till					
Pursuit ECO-PAK plus Basis ¹ plus nonionic surfactant plus Nitrogen solution.	1	0.72 oz plus 0.125 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.0315 lb plus 0.0058 lb This is about a half rate of each.	<i>Read the label.</i> Plant Pursuit resistant corn varieties only. Works best on emerged weed seedlings 1 to 2 inches in ht. Some stunting of emerged crownvetch or birdsfoot trefoil seedlings is expected.	Annual grasses and broadleaves, TR pigweed and lambsquarters; suppression of shattercane and yellow nutsedge
Pursuit ECO-PAK (imazethapyr) if post add nonionic surfactant or Crop oil plus Nitrogen solution.	2	1.44 oz and if applied post add 1 qt/100 gal. or 1 gal/100 gal plus 2 gal/100 gal	0.063 lb	<i>Read the label.</i> Plant Pursuit tolerant corn varieties only. May be applied preplant, pre or post to the corn but after most weeds have emerged. E.post treatments are safer on emerged crownvetch or birdsfoot trefoil seedlings.	Annual grasses and broadleaves; shattercane and yellow nutsedge suppression; weak on common ragweed and lambsquarters
If yellow nutsedge is a problem, use the following treatment with Permit. Permit can also be applied as a post cleanup treatment for yellow nutsedge. (Treatment 20)					
Pursuit ECO-PAK ¹ plus Basis ¹ plus Permit plus nonionic surfactant plus Nitrogen solution.	3	0.72 oz plus 0.125 oz plus 0.533 oz. plus 1 qt/100 gal. plus 2 gal/100 gal	0.0315 lb plus 0.0058 lb plus 0.025 lb	<i>Read the label.</i> Plant Pursuit resistant corn varieties only. Must be applied post to yellow nutsedge. Works best on emerged weed seedlings. Post treatments are safer on emerged crownvetch or birdsfoot trefoil seedlings.	Annual grasses and broadleaves, shattercane and yellow nutsedge; plus common ragweed, TR pigweed and lambsquarters
The following treatment should only be used when seeding crownvetch alone.					

Pursuit ECO-PAK ²	4	1.44 oz	0.063 lb	<i>Read the label.</i> Plant corn at least 1.5 inches deep to avoid Prowl injury. Do not incorporate. Must be applied after planting. Delaying application until spike stage reduces the risk of injury from Prowl. Use only when seeding crownvetch alone.	Annual grasses, broadleaves, TR pigweed and lambsquarters; weak on common ragweed
plus Prowl 3.3E ²		plus 1.8-3.6 pt	plus 0.75-1.5		
if post add nonionic surfactant		if post add 1 qt/100 gal.	<u>Do not use</u>		
or Crop oil		or 1 gal/100 gal	<u>Prowl on birdsfoot</u>		
plus Nitrogen solution.		plus 2 gal/100 gal	<u>trefoil.</u>		

¹ Use Basis, not Basis Gold; they are different products. The atrazine in Basis Gold will kill the cover crop seedlings.

² Pursuit Plus is a prepackage mix of Pursuit and Prowl (0.2 + 2.7#ai/gal -- enough for 3.2 acres).

Table 2 cont. Burndown herbicides for establishing birdsfoot trefoil and crownvetch in no-tillage corn.

For no-till, apply Gramoxone Max, Roundup or Touchdown before the corn or cover crop has emerged, and tank-mix with treatments **1, 2, 3** or **4** above.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Gramoxone Max 3S (paraquat) plus nonionic surfactant	5	1 to 2 pt plus 1 pt/100 gal	0.375 to 0.75 lb plus label rate	<i>Read the label.</i> Use flat-fan nozzle with 20 to 30 psi pressure for best results. Weak on established biennial and perennial weeds.	Annual grasses and broadleaved weeds plus top kill of biennial and perennial weeds
or					
Roundup 4S (glyphosate) or Touchdown IQ (sulfosate) plus nonionic surfactant if needed	6	1 qt. or 1 qt. plus 1 qt/100 gal.	1.0 lb or 1.0 lb plus label rate	<i>Read the label.</i> Use flat-fan nozzle. Annual weeds may be any size. Established weeds should have 6 to 8 inches of leafy growth. Apply at least four days before tillage or seeding in 5 to 10 gal water.	Above weeds plus top and root kill of most established biennial and perennial weeds

Early postemergence herbicides for establishing birdsfoot trefoil and crownvetch in conventional, min-tillage or no-tillage corn.

Post Emergence Herbicides - Cleanup treatment for TR lambsquarters and grasses

Pursuit ECO-PAK plus Basis ¹ plus nonionic surfactant plus Nitrogen solution.	7	0.72 oz plus 0.125 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.0315 lb plus 0.0058 lb This is about a half rate of each.	<i>Read the label.</i> Plant Pursuit resistant corn varieties only. Works best on emerged weed seedlings 1 to 2 inches in ht. Some stunting of emerged crownvetch or birdsfoot trefoil seedlings is expected.	Annual grasses and broadleaves, TR pigweed and lambsquarters; suppression of shattercane, and yellow nutsedge
Basis ¹ plus nonionic surfactant plus Nitrogen solution.	8	0.125 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.0058 lb	<i>Read the label.</i> This is 4/10 of the label rate; higher rates kill birdsfoot trefoil. Apply when weeds are 1 to 2 inches in height and corn from spike to 4 leaf stage.	Annual grasses and broadleaves including TR lambsquarters

Post Emergence Herbicides - Cleanup treatment for some perennial grasses and thistle or dewberry.

Accent 75DF + nonionic surfactant or Crop oil plus Nitrogen solution May be used on IT tolerant corn varieties even with the insecticide Counter	9	0.67 oz + 1 qt/100 gal. or 1 gal/100 gal plus 4 gal/100 gal	0.03125	Read the label. Applications should be made when shattercane, seedling or rhizome johnsongrass is 8 to 16 inches tall. Corn should be between 4 and 20 inches in height. Some corn varieties will be stunted for a few weeks. Do not use on non-IT corn that has been treated with the insecticide Counter.	Shattercane, seedling and rhizome johnsongrass, fall panicum, quackgrass, C.thistle, and dewberry. Very weak on common ragweed.
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¹ Use Basis, not Basis Gold; they are different products. The atrazine in Basis Gold will kill the cover crop seedlings.

Table 3. Herbicide effectiveness on common weeds for establishing birdsfoot trefoil and crownvetch in corn.¹

Cover Crops	Treatment no. from Table 2						
	1,3,7	2	4	52	62	8	9
Crownvetch	5	5	5	-	-	N	5
Birdsfoot trefoil	6	5	6	-	-	6	7
Summer annuals							
Barnyardgrass	8	8	8	10	10	7	8+
Black medic	?	?	?	9	10	?	?
Buckwheat, wild	?	?	?	10	9	?	?
Burcucumber	7	6	6	9	9	?	7
Chamomile, mayweed	?	?	?	9	10	?	?
Cocklebur, common	8	8	8+	10	10	9+	7
Crabgrass, large or smooth	8	7	9	9	10	9	6
Foxtail, giant	9	8	8	9	10	8	9
Foxtail, green	9	8	8	10	10	8+	9
Foxtail, yellow	9	8	8	10	10	8+	9
Galinsoga, hairy	9	9	9	10	10	?	?
Goosegrass	9	6	9	9	10	9	?
Jimsonweed	8	8	8+	10	10	6	7
Johnsongrass (seedling)	7	8	8	-	10	7+	9+
Ladysthumb	9	9	9	10	10	?	8
Lambsquarters, common	10	7+	8	10	10	9	6
Lambsquarters, common TR	10	7+	8	10	10	9	6
Morningglory, ivyleaf	7	5	5	10	10	7	7
Morningglory, tall	7	5	5	10	10	7	7
Mustard, wild	9+	9	9	10	10	?	?
Nightshade, eastern black	8	8	8	10	10	N	?
Panicum, fall	9	7	9	9	10	5	9
Pigweed, redroot	10	9+	9+	10	10	9+	9
Pigweed, smooth TR	9+	9+	9+	10	10	9	9
Purslane, common	9	9	9	10	10	?	?
Radish, wild	8	8	8	9	10	?	?
Ragweed, common	7	7+	7	10	10	5	5
Ragweed, giant	5	5	5	9	10	N	N
Shattercane	8+	8	8	9	10	8+	9+
Smartweed, pennsylvania	9	8+	8+	10	10	8	8
Velvetleaf	9	8+	8+	10	10	8+	7
Witchgrass	9	7	9	9	10	9	9
Biennials							
Burdock, common	?	?	?	9*	8	N	N
Carrot, wild	?	?	?	9*	9	N	?
Fleabane, rough	?	?	?	9*	9	N	?
Parsnip, wild	?	?	?	9*	9	N	?
Rocket, yellow				9*	9	?	?
Thistle, plumeless	?	?	?	9*	9	N	?

- 1 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present. Above ratings are for average conditions; results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH.
- 2 Effectiveness on emerged weeds only; no residual weed control from Gramoxone, Roundup or Touchdown alone. (*=Top kill only)

Table 3. Herbicide effectiveness on common weeds for establishing birdsfoot trefoil and crownvetch in corn.¹

	Treatment no. from Table 2						
	1,3,7	2	4	52	62	8	9
Perennials							
Bedstraw, smooth	N	N	N	9*	9	N	?
Bindweed, field	N	N	N	9*	8+	N	?
Bindweed, hedge	N	N	N	9*	8+	N	?
Blackberry	N	N	N	9*	8	N	?
Chamomile, corn	N	N	N	9*	9	N	?
Chickweed, mouseear	N	N	N	9*	9	N	N
Cinquefoil, sulfur	N	N	N	9*	9	N	?
Cockle, white	N	N	N	9*	8+	N	?
Dandelion	N	N	N	9*	6	N	?
Dewberry, northern	N	N	N	9*	7	N	8
Dock, broadleaf and curly	5	N	N	9*	8	N	?
Dogbane, hemp	N	N	N	9*	7	N	7+
Garlic, wild	N	N	N	8*	7	N	?
Goldenrod	N	N	N	9*	8	N	?
Groundcherry	N	N	N	9*	8	N	?
Horsenettle	N	N	N	9*	7	N	?
Johnsongrass (established)	7	6	6	9*	9	N	9
Milkweed, common	N	N	N	9*	5	N	?
Nutsedge, yellow	7	7	8	9*	9	N	6
Plantains	5	N	N	9*	8	N	?
Poison ivy	N	N	N	9*	7	N	?
Pokeweed, common	N	N	N	8*	8	N	?
Quackgrass	8	N	N	9*	8	N	9
Rocket, yellow	9	?	9	9*	9	N	?
Sorrel, red	N	N	N	9*	8	N	?
Thistle, Canada	N	N	N	9*	7	N	5
Wirestem muhly	6	N	N	9*	9	N	7

¹ 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present.

Above ratings are for average conditions; results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH.

² Effectiveness on emerged weeds only; no residual weed control from Gramoxone, Roundup or Touchdown alone. (*=Top kill only)

Table 4. Herbicides for corn after any crop in a birdsfoot trefoil/crownvetch cover.

- See specific product label to determine correct rate for the soil type and weed species found in individual fields

GENERAL INFORMATION:

- Pursuit tolerant (IMI/IT or Clearfield) corn is needed only if imazethapyr (Pursuit), Pursuit Plus or imazethapyr + imazapyr (Lightning) herbicides are used.
- Gramoxone Max provides only 2 or 3 weeks suppression of birdsfoot trefoil and crownvetch.
- 1 to 2 pt./A of Roundup 4S, Touchdown IQ or any other glyphosate herbicide applied when dandelion are in full bloom with any of the following treatments should suppress well established crownvetch about the right amount. **Glyphosate is weak on birdsfoot trefoil.**
- **Atrazine @ 0.5 to 0.75 lb/A is needed to suppress birdsfoot trefoil.**
- Be ready to suppress the birdsfoot trefoil and crownvetch with post treatments if they have grown more than 6 inches before the corn is in the 6-leaf stage. If birdsfoot trefoil or crownvetch begins to bloom, they're not suppressed enough.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Gramoxone Max 3S (paraquat) plus nonionic surfactant; Can be Tank mixed with treatments 12, 13, 14, or 15 when applied before corn emergence.	10	1 to 2 pt plus 1 pt/100 gal	0.375 to 0.75 lb plus label rate	<i>Read the label.</i> Use flat-fan nozzle with 20 to 30 psi pressure for best results. Weak on established biennial and perennial weeds including dandelion. Safe on 1-year-old birdsfoot trefoil and crownvetch.	Annual grasses and broadleaved weeds plus top kill only of biennial and perennial weeds
Roundup 4S (glyphosate) or Touchdown IQ (sulfosate) plus NIS if needed. Can be Tank mixed with treatments 12, 13, 14, or 15 and applied before corn emergence if burndown is needed.	11	1 pt or 1 pt plus 2 qt/100 gal.	0.5 lb or 0.5 lb plus label rate	<i>Read the label.</i> Apply when dandelion are in full bloom. Use flat-fan nozzle. Annual weeds may be any size. Established weeds should have 6 to 8 inches of leafy growth. Apply at least four days before planting in 5 to 10 gal water. Safe on 1-year-old birdsfoot trefoil but crownvetch must be well established.	Top and root kill of most established biennial and perennial weeds; provides good suppression of crownvetch but poor suppression of birdsfoot trefoil.

Pre or Early Postemergence treatments to the weeds and/or cover crop and corn; don't include Roundup, Touchdown or Gramoxone if corn has emerged.

Lightning 70DG	12	0.768 oz	0.0336 lb	<i>Read the label.</i> Plant Pursuit tolerant IT corn varieties only with relative maturity greater than 88 days. May be applied pre or early post (spike stage) of corn. Add dicamba for common burdock, Canada thistle, curly dock or goldenrod after they have 4-6" of new growth	Annual grasses and broadleaves; TR pigweed and lambsquarters, dandelion, and most other broadleaved perennials; suppression of yellow nutsedge.
plus Basis Gold		plus 5.6 oz	plus 0.3131 lb		
plus nonionic surfactant		plus 1 qt./100 gal	This is about a		
plus Nitrogen solution for Per. broadleaved weeds add		plus 2 gal/100 gal	half rate of each.		
Banvel or Clarity		add 0.5 pt.	add 0.25 lb		

Table 4. Herbicides for corn after any crop in a birdsfoot trefoil/crownvetch cover cont.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Bicep II or Bicep Lite II plus Basis plus nonionic surfactant plus Nitrogen solution. For Perennial broadleaved weeds add Banvel or Clarity	13	1 qt. or 2 qt. plus 0.25 oz plus 1 qt/100 gal. plus 2 gal/100 gal add 0.5 pt.	1.475 lb or 2.45 lb plus 0.0117 This is less than a full rate of each. add 0.25 lb	<i>Read the label.</i> Plant any corn variety with relative maturity greater than 88 days. Apply preemergence or early post. Basis works best on emerged weed seedlings 1 to 2 inches in ht. Add dicamba for common burdock, Canada thistle, curly dock or goldenrod after they have 4-6" of new growth	Birdsfoot trefoil and crownvetch suppression; annual grasses and broadleaves, TR pigweed and lambsquarters; no control of perennial broad-leaved weeds without Banvel or Clarity.
Pursuit Plus plus Bicep II or Bicep Lite II plus Basis plus nonionic surfactant plus Nitrogen solution. For Perennial broadleaved weeds add Banvel or Clarity	14	1.25 pt. plus 1 qt. or 2 qt. plus 0.25 oz plus 1 qt/100 gal. plus 2 gal/100 gal add 0.5 pt.	0.453 plus 1.475 lb or 2.45 lb plus 0.0117 add 0.25 lb	<i>Read the label.</i> Plant Pursuit tolerant IT or Clearfield corn varieties only. Plant corn at least 1.5 inches deep. Apply late preemergence or early post to reduce the risk of injury from the pendimethalin in Pursuit Plus. Add dicamba for common burdock, Canada thistle, curly dock or goldenrod after they have 4-6" of new growth	Birdsfoot trefoil and crownvetch suppression; annual grasses and broadleaves, TR pigweed and lambsquarters; no control of perennial broad-leaved weeds without Banvel or Clarity.
Pursuit ECO-PAK (imazethapyr) plus Basis Gold plus nonionic surfactant plus Nitrogen solution. For Perennial broadleaved weeds add Banvel or Clarity	15	0.72 oz plus 5.6 oz plus 1 qt./100 gal plus 2 gal/100 gal add 0.5 pt.	0.0315 lb plus 0.3131 lb This is about a half rate of each. add 0.25 lb	<i>Read the label.</i> Plant Pursuit tolerant IT corn varieties only with relative maturity greater than 88 days. May be applied pre or early post (spike stage) of corn. Add dicamba for common burdock, Canada thistle, curly dock or goldenrod after they have 4-6" of new growth.	Annual grasses and broadleaves; TR pigweed and lambsquarters, common burdock and curly dock; suppression of yellow nutsedge, Canada thistle and goldenrod.
Postemergence Treatments - For broadleaf weed control and suppression of the cover crop. Should be tank mixed with treatments 12, 13, 14 or 15 if crownvetch already has 3-6" of growth when sprayed.					

Banvel or Clarity (dicamba) plus Basis plus nonionic surfactant plus Nitrogen solution Use only on crownvetch that is well established.	16	0.5 pt plus 0.125 oz. plus 1 qt/100 gal. plus 2 gal/100 gal	0.25 lb plus 0.0117 lb	<i>Read the label. If used post to corn, do not apply dicamba when air temperature is above 85°F and do not apply with surfactant or nitrogen solution unless tank mixed with at least a 4/10 rate of Basis to prevent excessive crownvetch suppression.</i>	Use for control of TR pigweed, lambsquarters, other broadleaved weeds and/or BFT and crownvetch suppression.
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Table 4. Herbicides for corn after any crop in a birdsfoot trefoil/crownvetch cover cont.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Postemergence Treatments - Cleanup treatment for TR pigweed and lambsquarters and grasses.					
Pursuit ECO-PAK plus Basis plus nonionic surfactant plus Nitrogen solution.	17	0.72 oz plus 0.125 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.0315 lb plus 0.0058 lb	<i>Read the label.</i> Plant Pursuit tolerant corn varieties only. Works best on emerged weed seedlings 1 to 2 inches in ht.	Annual grasses and broadleaves, TR pigweed and lambsquarters; suppression of shattercane, and yellow nutsedge
Basis or Basis Gold plus nonionic surfactant plus Nitrogen solution.	18	0.25 oz 5.6 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.0117 or 0.358 lb	<i>Read the label.</i> This is less than the label rate. Higher rates are generally unnecessary. Apply when weeds are no more than 1 to 2 inches in height and corn from spike to 4 leaf stage.	Use Basis for annual grasses and broadleaves including TR lambsquarters; Basis Gold for BFT suppression
Post Emergence Treatments - Cleanup treatment for some grasses.					
Accent 75DF + nonionic surfactant or Crop oil plus Nitrogen solution May be used on IR corn varieties even with the insecticide Counter	19	0.67 oz + 1 qt/100 gal. or 1 gal/100 gal plus 4 gal/100 gal	0.03125	<i>Read the label.</i> Applications should be made when shattercane, seedling or rhizome johnsongrass is 8 to 16 inches tall. Corn should be between 4 and 20 inches in height. May be applied with drop nozzles if corn is too tall. Do not use on non-IR corn that has been treated with the insecticide Counter.	Shattercane, seedling and rhizome johnsongrass, fall panicum, quackgrass, C.thistle, and dewberry. Very weak on common ragweed.
Post Emergence Treatment - Cleanup treatment for yellow nutsedge and other weeds listed here.					
Permit plus nonionic surfactant. May be tank mixed with any of the above treatments for control of target weeds.	20	2/3 to 1 oz. plus 1 qt/100 gal.	0.0312 to 0.0468	<i>Read the label.</i> Apply when corn is spike to 2 ft. stage. Works best on emerged but small weed seedlings. Post treatments are safer on emerged crownvetch or birdsfoot trefoil seedlings.	Yellow nutsedge velvetleaf, common ragweed and suppression of TR pigweed

Table 5. Herbicide effectiveness on common weeds in corn planted into established birdsfoot trefoil/crownvetch cover.¹

Cover Crops	Treatment no. from Table 4									
	10 ²	11	12	13,14	15	16	17	18	19	20
Crownvetch	9+	9	6	8	5	8+	5	N	5	6
Birdsfoot trefoil	9	5	6	8	5	8+	6	6	5	6
Summer annuals										
Barnyardgrass	10	10	8	9+	8+	N	9	8+	8+	N
Black medic	9	10	?	10	9	9	?	?	?	?
Buckwheat, wild	10	9	9	10	9	10	?	?	?	?
Burcucumber	9	9	6	5	?	6	7	?	6	6
Chamomile, mayweed	9	10	?	9+	5	8	?	?	?	?
Cocklebur, common	10	10	9	8+	9	9+	10	9+	7	9
Crabgrass, large or smooth	9	10	8	9+	8	N	8	9	7+	N
Foxtail, giant	9	10	9	9	9	N	9	8	9	N
Foxtail, green	10	10	9	9+	9	N	9	8+	9	N
Foxtail, yellow	10	10	8	9+	9	N	9	8+	9	N
Galinsoga, hairy	10	10	10	10	9	10	9	?	?	?
Goosegrass	9	10	9	9+	7	N	9	9	?	N
Jimsonweed	10	10	8	9	9	9	8	6	7	N
Johnsongrass (seedling)	-	10	9	7	8	N	7	7+	9+	N
Ladysthumb	10	10	8+	9	9	10	9	?	8	8
Lambsquarters, common	10	10	8	9	9	9	10	9	7	N
Lambsquarters, TR	8	10	8	7	9	9	10	9	7	N
Morningglory, ivyleaf	10	10	8	10	5?	10	10	10	9	6
Morningglory, tall	10	10	8	10	5?	10	10	10	9	6
Mustard, wild	10	10	10	10	9	10	9+	?	9	?
Nightshade, eastern black	10	10	8+	10	9	10	9	N	?	6
Panicum, fall	9	10	8	9	7	N	9	5	9	N
Pigweed, redroot	10	10	10	9	9+	9	10	9+	9	9
Pigweed, smooth TR	10	10	10	8+	9+	9	10	9	9	9
Purslane, common	10	10	10	10	9	10	9	?	?	?
Radish, wild	9	10	?	9+	8	9	8	?	?	?
Ragweed, common	10	10	9	10	9	9	9	5	5	9
Ragweed, giant	9	10	8+	9	7	9	?	N	6	8
Shattercane	9	10	9	6	8+	N	7	9+	9+	N
Smartweed, Pennsylvania	10	10	8+	9	9	10	9	8	8	8
Velvetleaf	10	10	8+	8+	9	8	9	8+	7	9
Witchgrass	9	10	9	9	8	N	9	9	9	N
Winter annuals										
Brome, downy	9	10	?	8	5	N	6	?	?	N
Brome, Japanese	9	10	?	8	5	N	6	?	?	N
Cheat	9	10	?	8	5	N	6	?	?	?
Chickweed, common	10	10	?	10	9	7	9	?	?	?
Deadnettle, purple	9	10	?	10	9	8	?	?	?	?

Fleabane, rough	8	10	?	10	?	9	?	?	?	?
Henbit	9	10	?	10	9	8	9	?	?	?
Horseweed	8	10	?	10	N	9	5	?	?	?

1 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present.

Table 5. Herbicide effectiveness on common weeds in corn planted into established birdsfoot trefoil/crownvetch cover cont.1

	Treatment no. from Table 4									
Winter annuals cont.	10 ²	11	12	13,14	15	16	17	18	19	20
Lettuce, prickly	9	10	?	10	?	9	?	?	?	?
Mustard, birdsrape	?	10	?	9	8	9	8	?	?	?
Pennycress, field	9	10	?	10	9	10	9	?	?	?
Pepperweed, field	9	10	?	10	9	10	9	?	?	?
Shepherd's purse	9+	10	?	10	9	10	9	?	?	?
Woodsorrel, yellow	10	10	?	10	?	8	9	?	?	?
Biennials										
Burdock, common	9*	8	?	5	N	8	N	N	?	?
Carrot, wild	9*	9	?	9	N	9	N	N	?	?
Fleabane, rough	9*	9	?	9	?	9	?	N	?	?
Parsnip, wild	9*	9	?	7	N	8	N	N	?	?
Thistle, plumeless	9*	9	?	7	N	8	N	N	?	?
Perennials										
Bedstraw, smooth	9*	9	?	?	N	5	N	N	?	?
Bindweed, field	9*	8+	5	N	N	7	N	N	?	?
Bindweed, hedge	9*	8+	5	N	N	7	N	N	?	?
Blackberry	8*	8	?	N	N	5	N	N	6	?
Chamomile, corn	9*	9	?	9+	N	8	N	N	?	?
Chickweed, mouseear	9*	9	?	9+	9	7	?	N	?	?
Cinquefoil, sulfur	9*	9	?	9	N	8	N	N	?	?
Cockle, white	9*	8+	?	5	N	7	N	N	N	?
Dandelion	9*	6	5	5	N	7	N	N	8	?
Dewberry, northern	9*	7	?	N	N	5	N	N	9	?
Dock, broadleaf and curly	9*	8	?	5	N	9	N	N	?	?
Dogbane, hemp	9*	7	5	N	N	7+	N	N	7+	?
Garlic, wild	8*	7	?	7	N	8	N	N	?	?
Goldenrod	9*	8	?	N	N	8	N	N	?	?
Groundcherry	9*	8	?	5	N	8	N	N	?	?
Horsenettle	9*	7	?	N	N	6	N	N	?	?
Johnsongrass (established)	9*	9	7	N	6	N	N	N	8+	N
Milkweed, common	9*	5	5	N	N	6	N	N	?	?
Nutsedge, yellow	9*	9	7	9	7	N	7	N	6	9+
Plantains	9*	8	?	7	N	8	5	N	?	?
Poison ivy	9*	7	?	N	N	5	N	N	?	?
Pokeweed, common	8*	8	5	N	N	5	N	N	?	8
Quackgrass	9*	8	6	7	N	N	5	N	9	N

Rocket, yellow	9*	9	?	9	9	9	9	N	?	?
Sorrel, red	9*	8	?	7	N	9	N	N	?	?
Thistle, Canada	9*	7	5	5	N	8	N	N	6	?
Wirestem muhly	9*	9	N	7	N	N	N	N	6	N

1 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present.

Above ratings are for average conditions; results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH.

2 Effectiveness on emerged weeds only; no residual weed control from Gramoxone, Roundup or Touchdown alone. (*=Top kill only)

Table 6. Preplant or preemergence herbicides for weed control in no- or min-tillage soybean in a birdsfoot trefoil and/or crownvetch cover crop.

- See specific product label to determine correct rate for the soil type and weed species found in individual fields.

GENERAL INFORMATION:

- Weeds and unsuppressed cover crops are a chief cause of low soybean yields.
- Many perennial weed problems can be controlled with Roundup or Touchdown before tillage or planting of soybeans. **Glyphosate rates should not exceed 0.5 lb/A pre or post to the soybeans to avoid excessive crownvetch suppression. Because of the reduced rate and suggested early treatment, a residual herbicide treatment will always be needed for both no-till and min-till soybeans. Pursuit is one of the better herbicides for dandelion suppression but almost any other residual herbicide could be used for annual weed control.**
- Glyphosate or sulfosate will not suppress birdsfoot trefoil enough.
- Post emergence glyphosate is safe only on Roundup Ready soybeans.
- Preplant tillage will suppress both crownvetch and birdsfoot trefoil but also greatly thin the stand.
- Maintaining a cover crop is almost impossible in drilled soybeans because of excessive competition from the beans.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
No-Till – To suppress the cover crop, apply treatment 21 when dandelion are in full bloom or at least a week before the soybeans are planted. Roundup or Touchdown can be tank mixed with treatment 22 and applied preplant or preemergence.					
Min-Till - Use treatment 21 for control of perennial weeds not controlled by tillage. Apply 5 days before planting to allow time for translocation to weed roots and rhizomes. Follow with treatment 22 .					
Roundup 4S (glyphosate) plus Sencor 75DF (metribuzin) plus nonionic surfactant if needed. Can be Tank mixed with treatment 22 and applied before planting or emergence of soybeans.	21	1 pt or 2.1-4.2 oz. plus 2 qt/100 gal.	0.5 lb or 0.1 -0.2 lb plus label rate	<i>Read the label.</i> Best when applied after dandelion are in full bloom. Use flat-fan nozzle. Annual weeds may be any size. Established weeds should have 6 to 8 inches of leafy growth. Apply at least five days before tillage or planting in 5 to 10 gal water. Birdsfoot trefoil and crownvetch must be well established.	Top and root kill of most established biennial and perennial weeds; provides good suppression of crownvetch but poor suppression of birdsfoot trefoil. Weak on dandelion.
Pursuit ECO-PAK plus Prowl 3.3E ¹ for dandelion suppression and residual annual weed control	22	1.44 oz plus 1.8-2.4 pt	0.063 lb plus 0.75-1.0	<i>Read the label.</i> May be used on regular or Roundup Ready soybeans. Apply preemergence in min-till. Tank mix with treatment 21 and apply preplant or preemergence in no-till.	Annual grasses, broadleaves, TR pigweed and lambsquarters; suppression of dandelion.

Postemergence Roundup – Can be used for cleanup of any weeds missed by tillage and/or the preplant or preemergence treatment and for further suppression of the cover crop on Roundup Ready beans only.

¹ Pursuit Plus is a prepackage mix of Pursuit and Prowl (0.2 + 2.7#ai/gal -- enough for 3.2 acres).

Table 7. Herbicides for weed control in min-till small grain in crownvetch.

- See specific product label to determine correct rate for the soil type and weed species found in individual fields.
- Don't plant a small grain into crownvetch until it is well established (3-4 yrs. old) and can tolerate Roundup or Touchdown or some form of minimum tillage.
- Min-tillage will suppress the crownvetch sufficiently to get the small grain established but herbicide treatments will usually be necessary to suppress the crownvetch regrowth.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Harmony Extra plus nonionic surfactant	23	0.33-0.66 oz. plus 1 qt/100 gal.	0.014-0.028 lb label rate	<i>Read the label.</i> For use on fall-seeded wheat and barley (growth stage 1 to 7) or oats (growth stage 2 to 5). If applying in liquid fertilizer, reduce surfactant to 0.25-0.5 qt/100 gal liquid fertilizer to reduce injury potential to small grain.	Excellent wild garlic and broadleaved weed control with some crownvetch suppression.
MCPA amine - Use only on crownvetch that is more than 2 to 3 years old.	24	0.5 to 1 pt	0.25 to 0.5 lb	<i>Read the label.</i> Apply in the spring after small grains are well-tillered (growth stage 3 to 6), in 5 to 10 gal water. Use low-pressure (10 to 20 psi) or flood-jet nozzles. Use at temperatures between 60° and 80°F.	Annual and winter annual broadleaved weeds in all small grains in established crownvetch.
MCPA - amine or ester - Use only on crownvetch that is more than 2 to 3 years old.	25	0.25 to 0.5 pt	0.12 to 0.25 lb	<i>Read the label.</i> Apply in spring; (growth stage 3 to 6), in at least 10 gal water when weeds are small. Use MCPA amine when temperatures are between 60° and 85°F. Use ester formulation between 50° and 70°F. Add dicamba at 0.12 pt/A for hard-to-kill weeds and greater crownvetch suppression.	Canada thistle, mayweed, corn chamomile, pigweed, corn cockle, wild buckwheat, smartweed, knawel and crownvetch suppression.
Buctril (bromoxynil) May be applied with liquid fertilizers. Use only on crownvetch that is more than 2 to 3 years old.	26	1 pt	0.25 lb Apply when air temp. is above 60°F.	<i>Read the label.</i> Apply fall or spring; (growth stage 1 to 9), when weeds are in 2- to 4-leaf stage, in 10 to 20 gal carrier. Kills species resistant to 2,4-D and MCPA.	Winter annuals such as corn chamomile, mayweed, groundsel, henbit, and knawel

Table 8. Herbicides for no-till legume or grass seeding into birdsfoot trefoil and/or crownvetch after corn or small grain harvest.

- See specific product label to determine correct rate for the soil type and weed species found in individual fields

GENERAL INFORMATION:

- Graze or harvest birdsfoot trefoil, crownvetch and weeds down to the ground or
- Suppress the cover crops with Roundup, Touchdown or Gramoxone if you cannot graze or harvest.
- Plant legume or grass with any no-till drill that will place the seed at a 1/4-inch depth, no later than August 15 when following small grains in central Pennsylvania. (First frost is approximately September 20.)
- Further suppress crownvetch and control broadleaved weed seedlings with Pursuit or Buctril if necessary after new legume seedlings reach the second trifoliolate leaf stage.

Herbicide	No.	Product/A	lb ai/A	Remarks	Weeds controlled
Roundup 4S (glyphosate) or Touchdown IQ (sulfosate) plus nonionic surfactant if needed	27	1 pt or 1 pt plus 2 qt/100 gal.	0.5 lb or 0.5 lb plus label rate	<i>Read the label.</i> Use flat-fan nozzle. Annual weeds may be any size. Established weeds should have 6 to 8 inches of leafy growth. Apply at least four days before seeding in 5 to 10 gal water.	Top and root kill of most established biennial and perennial weeds
Gramoxone Max 3S (paraquat) plus nonionic surfactant	28	1 to 2 pt plus 1 pt/100 gal	0.375 to 0.75 lb plus label rate	<i>Read the label.</i> Apply at planting time in 20 gal or more carrier. Use flat-fan nozzle with 20 to 30 psi pressure for best results. Weak on established biennial and perennial weeds.	Annual grasses and broadleaved weeds plus top kill of biennials, perennials, and crownvetch
Pursuit 2S or Pursuit ECO-PAK plus nonionic surfactant plus Nitrogen solution.	29	3-6 fl oz or 1.08-2.16 oz plus 1 qt/100 gal. plus 2 gal/100 gal	0.047 lb to 0.094 lb	<i>Read the label.</i> For pure alfalfa seedings only. Apply after alfalfa has 2 trifoliolate leaves. Works best on emerged weed seedlings 1 to 2 inches in ht.	Annual grasses and broadleaves; shattercane and yellow nutsedge suppression; weak on common ragweed and lambsquarters

Buctril (bromoxynil)	30	1.0 to 1.5 pt	0.25 to 0.375 lb	<i>Read the label.</i> Apply after alfalfa has 4 trifoliolate leaves. Works best on emerged weed seedlings 1 to 2 inches in ht. May be used on both fall or spring seedings. Do not apply when air temperature is above 70°F to avoid alfalfa injury.	Suppression of crownvetch and control of broadleaved weed seedlings, including corn chamomile, mayweed, groundsel, henbit, and knawel
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Table 9. Herbicide effectiveness on common weeds in small-grain and new forage seedings.¹

	Treatment no. from Tables 7 and 8						
Cover Crops	23	24,25	26	27 ²	28 ²	29	30
Crownvetch	9	9	8	9+	6	N	N
Birdsfoot trefoil	?	5	5	9	6	N	N
Summer annuals							
Barnyardgrass	N	N	N	10	9	8	N
Black medic	?	7	?	10	9	?	5
Buckwheat, wild	8	8	9	9	9	?	6
Burcucumber	?	5	N	9	5	6	5
Carpetweed	?	9	9	10	9	?	9
Chamomile, mayweed	?	5	N	10	9	?	6
Crabgrass, large or smooth	N	N	N	10	9	8	N
Fleabane, annual	?	8+	?	10	9	?	7
Foxtail, giant	N	N	N	10	8	8	N
Foxtail, green	N	N	N	10	8	8	N
Foxtail, yellow	N	N	N	10	8	8	N
Ladysthumb	9	6	9	10	9	9	6
Lambsquarters, common	9	9	9	10	9	7	8+
Morningglory, tall	?	9	8	10	9	5	9
Mustard, wild	9	10	9	10	9	9	10
Nightshade, eastern black	?	?	?	10	9	8	?
Panicum, fall	N	N	N	10	9	7	N
Pigweed, redroot	9	9	7	10	9	9+	8+
Pigweed, smooth	9	9	7	10	9	9+	8+
Pigweed, tumble	9	9	7	10	9	?	8+
Radish, wild	9	7	6	9+	9	?	7
Ragweed, common	6	9	8+	10	9	7	9
Smartweed, Pennsylvania	9	6	9	10	9	8+	6
Speedwells	?	5	?	10	9	?	5
Velvetleaf	9	8+	8	10	9	9	9
Witchgrass	N	N	N	10	8	7	N
Winter annuals							
Brome, downy	N	N	N	10	-	6	N
Brome, Japanese	N	N	N	10	-	6	N
Cheat	N	N	N	10	-	6	N
Chickweed, common	9	5	6	10	10	8+	5
Corn cockle	?	N	?	10	9	?	?
Deadnettle, purple	9	5	7	10	-	7	5
Fleabane, rough	?	7	?	10	8	?	8
Henbit	9	5	8	10	-	7	6
Horseweed	7	8+	7	10	9	?	8
Lettuce, prickly	8	9	6	10	9	?	8
Mustard, birdsrape	9	5	?	9	?	?	8
Pennycress, field	9	9	8	10	-	9	9
Pepperweed, field	9	9	8	10	-	9	9

Shepherd'spurse 9 9 8 10 - 8+ 9

1 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present. Above ratings are for average conditions; results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH.

2 Effectiveness on emerged weeds only; no residual weed control from this treatment alone.

Table 9. Herbicide effectiveness on common weeds in small-grain and new forage seedings.¹

Cover Crops	Treatment no. from Tables 7 and 8						
	23	24,25	26	27 ²	28 ²	29	30
Biennials							
Burdock, common	?	?	?	9*	8	?	?
Carrot, wild	?	?	?	9*	9	?	?
Fleabane, rough	?	?	?	9*	9	?	?
Parsnip, wild	?	?	?	9*	9	?	?
Rocket, yellow	9	8	7	10	9	8	?
Thistle, plumeless	?	6	?	9	5	6	?
Perennials							
Bindweed, field and hedge	?	N	N	8+	9*	N	N
Cockle, white	?	?	?	?	9*	6	N
Dandelion	6	8	5	7	9*	7	N
Dock, broadleaf and curly	8+	6	5	8	9*	7	N
Garlic, wild	9	6	N	7	8*	N	N
Groundcherry	?	5	N	8	9*	N	N
Healall	?	5	N	9	9*	?	N
Johnsongrass	N	N	N	9	9*	8	N
Milkweed, common	?	N	N	5	9*	N	N
Onion, wild	9	6	N	7	8*	?	N
Pokeweed, common	?	N	N	8	8*	N	N
Quackgrass	N	N	N	8	9*	N	N
Thistle, Canada	8	6	5	7	9*	N	N

1 10=95-100%, 9=85-95%, 8=70-85%, 7=65-75%, 6=55-65%, 5=less than 55%, N=No control, ?=unknown, - not present.

Above ratings are for average conditions; results may differ with variations in weed size, temperature, rainfall, soil moisture, soil type, and soil pH.

2 Effectiveness on emerged weeds only; no residual weed control from Gramoxone, Roundup or Touchdown alone. (*=Top kill only)

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Crownvetch/Birdsfoot Trefoil Living Mulch Seed Source

Cover Crop Seed for 10 acres (4 lb/A seeding rate)		
Provider	Input	≈ Cost
Ernst Conservation Seeds 9006 Mercer Pike Meadville, PA 16335 1-800-873-3321 calvin@ernstseed.com	Crownvetch/Birdsfoot Trefoil (ratio 1:3) 40# Bag (inoculated)	\$100