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Grower's Guide for Hybrid Poplar Plantations for Biomass Production

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Cover Image
A ten-year-old hybrid poplar plantation in central Minnesota.

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Photo 1. A ten-year-old hybrid poplar plantation in central Minnesota.

INTRODUCTION

The goal of this Grower's Guide is to provide practical advice for the establishment and maintenance of hybrid poplar plantations, plantings of trees in rows managed like an agronomic crop to produce fiber and biomass. Hybrid poplar are planted on several continents in a wide variety of applications: examples, in addition to biomass/wood production, include windbreaks, shelterbelts, phytoremediation, mine reclamation, and wastewater treatment. Advice for the establishment of hybrid poplar in these applications should come from other sources, as this guide is focused on growing hybrid poplar in plantation settings. Plantations could be owned by a private landowner or a corporation.

Short-rotation woody crops (SRWC) show promise to fill specific niches in the world's developing bioeconomy. These crops, such as eastern cottonwood, hybrid poplar, and hybrid willow, are receiving increasing interest as plantation crops to provide biomass for renewable energy such as combustion for combined heat and power – CHP, biofuels, bio-based chemicals, and bioproducts. Hybrid poplars have also been grown to produce wood for pulp and paper and oriented strand board (OSB) as well as veneer for plywood manufacturing. The selection of hybrid poplar, cottonwood, or willow depends on the region is which they will be grown and the end use.

An SRWC feedstock has several advantages for manufacturers of these types of products when compared to traditional forest timber or annual herbaceous biomass crops. The production process is

more efficient when using a feedstock with consistent properties, and an SRWC plantation can provide adequate volumes of a uniform feedstock to meet the needs of a processing facility. SRWC can be rapidly scaled up, are harvestable year-round, and, once the canopy closes, require minimal labor and chemical inputs. Harvesting costs are also generally lower than for natural forests.

Hybrid poplars are desirable because of their rapid growth, ease of planting, ability to produce a significant amount of biomass in a short period of time, their high cellulose and low lignin contents, and small environmental footprint. They provide a variety of ecosystems services (environmental benefits) and do not require the high pesticide and fertilizer inputs that some other biomass crops require.

Traditional breeding of poplars began over 100 years ago. Breeding programs across the world have developed varieties with valuable characteristics such as faster growth, increased disease resistance, and attractive wood grain. The hybrid poplar breeding program at the Natural Resources Research Institute (NRRI), University of Minnesota Duluth, will be celebrating its 25th anniversary in 2021.

The typical goal of establishing a hybrid poplar plantation is harvesting the trees at appropriate maturity to generate a profit. Profitability is a complicated equation and involves risk when planting an SRWC. Hybrid poplar plantations are typically established on agricultural lands of lower to average productivity, where the profitability of feed and food crops is questionable. To help producers evaluate the economics of hybrid poplar production systems on this type of land in the midwestern United States, NRRI and the University of Minnesota Extension have developed the *Hybrid Poplar Economics Workbook* (see *Additional Resources*). The workbook was developed in Microsoft Excel using crop enterprise budgets (expected costs and returns) for hybrid poplar and annual crops. It is available at no charge to support producers in their decision-making process. Please see the *Additional Resources* section for download instructions. **Potential growers should be assured of a market before investing in these plantations.** This may involve a partnership between an end user/processor and the grower. In some arrangements, the end user is also the grower. Contracts could involve a crop consultant network funded by the processing company to assist in plantation management. Any contract should include the cost of removing stumps after harvest in the event the field would be returned to traditional agriculture.

NRRI developed this Grower's Guide in partnership with University of Minnesota Extension as part of the Next-Gen Poplars project. This project is a USDA NIFA grant-funded opportunity to advance the genetics, economic analysis, and utilization of hybrid poplars in the midwestern United States.

HYBRID POPLARS OVERVIEW

Plant Descriptions

The focus of this guide is the successful plantation production of hybrid poplar. The typical system includes planting of hybrids of eastern cottonwood and black poplar on agricultural sites managed in much the same manner as many agricultural crops. This includes intensive weed control in early stages, pest control, and fertilization if warranted. Hybridization of eastern cottonwood and black poplar bring together attributes of each species that make them more suitable to fast growth in an agricultural production system.

Populus deltoides, eastern cottonwood (D)

Populus deltoides Bartr., eastern cottonwood, is a wide-ranging native species found across the eastern United States from its borders with Canada and Mexico. Variants or subspecies exist under

more dry or xeric conditions found in areas of the West and Southwest. Eastern cottonwood is a shade-intolerant pioneer species requiring bare mineral soil for seed germination, direct sunlight, and adequate surface moisture, which is characteristic of alluvial soils associated with river systems. Stand establishment in nature is accomplished through the successful germination of large annual seed crops that rely on wind or water dispersal.

Populus nigra, black poplar (N)

Populus nigra L., black poplar, is also a wide-ranging species naturally distributed across Europe, central Asia and extreme northern Africa. Stands of black poplars typically developed along large riverways and water drainages throughout its natural range of distribution. These natural stands have been threatened and pressured by centuries of human activities and domestication practices. Conservation measures and efforts have attempted to identify and preserve natural populations across Europe. High rooting ability from cuttings is a strong trait of this species that hybridization attempts to capture in commercial interspecific hybrid combinations with eastern cottonwoods.

Eastern cottonwoods and black poplars are classified taxonomically within the *Populus* section *Aigeiros*. Cottonwoods and black poplars are both dioecious species; i.e., having male and female flowers on separate trees. Fortunately for the purpose of hybridization and advanced breeding, the two species are compatible and produce hybrid combinations of interest for broadly adapted vigor and commercial utilization. The cross only works with eastern cottonwood as the female parent.

Interspecific hybrids of the DxN taxon types

P. x canadensis Moench. is the nomenclature assigned to the interspecific hybrid combinations between *P. deltoides* (D) seed parents and *P. nigra* (N) pollen parents. These poplar hybrids are commonly the preferred feedstock for establishing windbreaks, pulp and paper plantations, and potential bioenergy plantings. Hybrid poplar clones are selected for improved rooting ability from hardwood cuttings, which is a desired and required characteristic for the purposes of commercial vegetative propagation and plantation establishment.

Planning

Planning should begin by the summer of the year prior to planting. Essential elements of planning include selection of site, determining spacing, pre-planting weed control, and purchasing of planting stock (cuttings). Planting stock from nurseries is often sold out by December of the year before planting, so tree orders should be made before that time. In order to take advantage of cost-share programs (USDA, state agencies, etc.), approval of planting and farming practices should be obtained well before planting. Local USDA and state conservation offices are sources of information on cost-share programs.

An important factor affecting management and harvest efficiency is plantation size. Plantation size can vary depending on a landowner's objectives and the density of plantations on the landscape. Plantations could be small, perhaps one acre in size, or very large depending on landownership and landscape. Things to consider on smaller size plantings are the effects on overall volume, management, and harvest cost. Actual planted acreage in smaller fields will be decreased due to the greater proportion of land consisting of headlands. Also, smaller acreage can result in increased management and harvest cost due to the fixed costs of moving equipment being spread over less acreage. The significance of this impact decreases with larger plantation size and the amount of other plantation acreage in the area.

Planting Stock

Unrooted cuttings

Dormant hardwood cuttings are the planting stock of choice for commercial plantation establishment with hybrid poplars. Vegetative propagation requires establishment of vigorous stool beds (shrubs from which cuttings are made) to provide annual shoot growth and production of one-year-old whips of the improved clones or varieties. These whips are sectioned into cuttings, which have the ability to root when planted in the field with no further treatment. The standard size for hardwood cuttings in the Upper Midwest for hand-planting operations ranges from 9 to 10 inches in length, ¼- to ½-inch top diameter, and ¾- to 1-inch bottom diameter. In the southern United States, cottonwood cuttings can be 12 to 18 inches in length and are commonly planted in subsoil slits for plantation establishment. Unrooted cuttings should be planted with buds facing up and about 1 inch of the cutting above the soil surface. An effective and flexible system is to store unrooted cuttings frozen and keep them frozen until the day of planting.

Rooted cuttings

In some cases, a land manager may have a goal to plant only native species such as non-hybridized eastern cottonwood. In this case, unrooted hardwood cuttings may not be the best choice in cool soils typical of northern sites during spring planting operations. Rather, rooted cuttings can be deployed either as dormant pre-rooted plants which require mechanical lifting and trimming from a nursery bed, or green leafy containerized plants raised in a greenhouse. Survival is typically improved using rooted stock, but unit cost is higher in comparison to unrooted cuttings.

Unrooted whips and poles

Unrooted 1- or 2-year-old whips and poles can be used as an alternative form of planting stock for specialized planting needs, including immediate establishment in weedy situations or sites with deep water tables. Whips are 3 to 6 feet in length; poles can be 6 to 12 feet long. Both are planted deep to develop a vigorous root system that may be required in some environmental services or phytoremediation applications, including streambank stabilization. In some parts of the world, poles are utilized to get early establishment under flooded or irrigated planting operations. In Europe, poles are also used to establish plantations for producing high-valued veneer logs. However, this method of plantation establishment is by far the most expensive of all of the options, and the end-product value must be sufficiently high to justify investing in this method.

Planting Density

The number of trees planted per acre can affect how quickly a crop is ready for harvest, often referred to as “rotation age.” The following harvest expectations assume average growing sites on agricultural soils in Minnesota. Trees planted on a 6 x 6 feet spacing will be ready to harvest between 6 and 9 years of age but will have a smaller tree diameter, typically 4 to 5 inches DBH. (“DBH,” or “Diameter at Breast Height,” is the diameter measured at a point 4.5 feet above ground.) Trees planted at wider spacings such as 8 x 8 feet or 10 x 10 feet can be expected to have larger diameters at their longer rotation ages. Trees at 8 x 8 feet spacing will have a DBH of approximately 5 to 7 inches at 9 to 11 years of age. The DBH of trees spaced at 10 x 10 feet will be about 7 to 9 inches at 10 to 13 years. Trees (cuttings) per acre

are: 1,210, 680 and 436 at 6 x 6 feet, 8 x 8 feet and 10 x 10 feet spacings, respectively. Cost of planting stock is minimized at the widest spacing, but weed control will be needed longer than at closer spacings.

PLANTATION ESTABLISHMENT

Site Preparation

Good site preparation is the key to a successful tree-planting project. Seedlings planted on a well-prepared site will grow faster and have much higher survival rates than seedlings planted on a site with little or no preparation. Site preparation sets the stage for all practices and management options to follow and is one of the most crucial steps (in addition to aggressive weed control) contributing to successful plantation establishment and viable economics. It is far cheaper in both time and money to take the time up front to plan, prepare, plant, and maintain a project than to let it fail and try to replant or inter-plant seedlings into a failed planting. For most landowners, replanting is financially prohibitive.

What is site preparation?

Site preparation is the process of creating soil conditions that will allow planted seedlings to become established, grow, and survive. This means destroying any and all existing woody and herbaceous vegetation as well as sod-forming grasses that will compete with seedlings for growing space, sunlight, water, and nutrients. The destruction of competing vegetation will greatly improve plantation survival and growth. A good example of site preparation is spring tillage that many farmers use to prepare their ground for planting common agricultural crops, breaking up plow pans, and improving soil tilth.

Why is site preparation so important?

Site preparation is important because it creates soil conditions that ensure good root-to-soil contact and allows for the growth of the seedling's root system. The major causes of failure in tree-planting projects are air pockets in the soil (poor root-to-soil contact) and soil compaction. Good site preparation can avoid both of these situations.

The existing vegetation on your site will dictate how you should prepare the site for planting. The following methods should be used depending on the condition of the field, either pasture or recently harvested cropland.

Pasture Sites

The best method for preparing a site where grass or alfalfa is present is to follow these six steps in order. Site preparation starts the year before planting.

1. In late summer, mow or shred the existing vegetation two to three weeks before the herbicide application, typically glyphosate, is made.

2. The best time to apply an herbicide treatment to alfalfa or cool-season grasses such as meadow fescue and Kentucky bluegrass is early fall, any time after September 15 to as late as October 15. Pasture dominated by warm-season grasses such as blue stem and Bermuda grass become dormant earlier. Therefore, herbicide applications on warm-season grasses need to be made in late August or early September.

3. Allow at least two to three weeks for the herbicide application to kill the grasses. Then use a chisel or moldboard plow to break up the dead sod.
4. Disc and harrow or rototill the plowed area to break up soil clods and chunks of sod. Plowed areas may need to be disced more than once.
5. Once the area has been thoroughly worked, allow the area to lay fallow through the winter. The action of freezing and thawing will loosen and condition the soil and help to create an ideal planting site.
6. Disc or harrow the soil again in the spring before tree planting. This will break up any remaining soil clods and ensure that the soil will close back in around the planting stock (unrooted or rooted cuttings) after planting.

Cropland Sites

Compared to pasture, site preparation in cropland is significantly easier than sod-bound sites. However, we recommend that you follow these three steps to prepare a crop land site for tree planting.

1. Disc and harrow or roto-till the crop stubble in the fall after harvesting. It may be necessary to plow heavier soils to break up any deep soil compaction.
2. Allow the area to lie fallow through the winter; the action of freezing and thawing will condition the soil and help to create an ideal planting site.
3. Disc or harrow the soil again in the spring before tree planting. This will break up any remaining soil clods and ensure that the soil will close back in around the planting stock after planting.

Row Markers

An easy setup for a row marker is to use a spring tooth harrow and remove all spring teeth except the ones that correspond to your tree row spacing. For 6 x 6 feet spacing, leave a spring tooth every 6 feet on the harrow. The field should be marked in both directions so that there will be rows of trees in two directions. This will optimize future field maintenance (cultivation, herbicide, and fertilizer applications) and allow subsequent plantings between rows after tree harvest.

Planting

Planting can be done by hand by a planting crew using conventional tree-planting equipment (planting bars, dibble bars) or with a mechanical tree planter. Historically, sites have been hand planted, which provides more flexibility and higher survival in the planting operation. While mechanical planters have the potential to be highly efficient, variations in soil conditions within most fields have been shown to be a problem for mechanical planters, and this method should only be considered in extremely uniform field conditions (i.e., few rocks, even terrain, ideal site preparation). Machine planting is sometimes used for rooted cuttings. After the planting operation is finished, a tank mix of glyphosate and a pre-emergent herbicide should be applied to prevent weed germination in the first few months of plantation establishment.

Photo 2. A two year-old hybrid poplar plantation in central Minnesota.

PLANTATION MANAGEMENT

Cultivation

Of all the plantation management practices, proper cultivation is crucial to the success of poplar plantations. Cultivation should be done when weeds are small and have not developed a sturdy root system or gone to seed, typically 2 to 4 inches in height. Farm equipment used for cultivation includes a spring-tooth harrow, disc, or rotary tiller. In the first year, a wide spring tooth harrow is a good choice, because teeth can be removed that correspond to your spacing. This practice allows for multiple rows to be cultivated at one time until the trees get too tall for overhead clearance. All cultivation should be shallow, 2 inches or less, to prevent damage to the tree roots. It is recommended that cultivators with guide wheels are used to control cultivation depth.

Pesticide Application

Normal agricultural herbicide application equipment works for early treatments before trees get tall enough to interfere with the equipment. At that point, smaller equipment that fits between tree rows is required. Typically, an ATV or small tractor with a spray tank is used. A shielded sprayer can be used to apply herbicides between tree rows if there are concerns about tree damage from herbicide contacting tree leaves or bark or as rescue treatment in a first-year planting. Chemical or biological Insecticide

applications, if needed, typically need to be done by air since most insect infestations happen after tree crown closure. See the list of herbicides and insecticides that are effective in hybrid poplar plantations (Tables 3, 4). Some of these herbicides and insecticides might not be labeled for use in hybrid poplar plantations at this time. If a product is not labeled, an alternative product that is labeled should be used.

Fertilizer Application

Fertilizer applications, if any, should be made soon after crown closure. For plantations spaced at 8 x 8 feet or wider, fertilizer can be applied using fixed-winged aircraft or a small tractor or ATV pulling a fertilizer spreader. Fertilization at narrower spacing will require a fixed-wing aircraft. As is the case with any agronomic crop, a sufficiently high growth response to fertilization must be achieved in order to justify the expense. Research at NRRI, University of Minnesota Duluth (unpublished data), and commercial plantation experience has shown that poplars are highly efficient in using nutrients, and many sites may not show a growth response sufficiently high to justify an investment in fertilization. This research also indicates that nitrogen is the only nutrient limiting growth on most Upper Midwest sites. We strongly encourage landowners or plantation managers to consult with University of Minnesota Extension or other knowledgeable poplar researchers or consultants prior to considering fertilization. The main University of Minnesota Extension contact is listed under *Additional Resources*.

PLANTATION HARVEST

Harvesting

Harvesting hybrid poplar plantations is typically done with conventional logging equipment. The logging equipment used will vary depending on the product specification. At the time of harvest, the equipment used should maximize harvest efficiencies and harvested volumes. In the case of the highest plantation densities, other non-conventional harvest equipment may be needed due to the very small diameter associated with these plantings. Novel prototype equipment is under development to achieve high harvest efficiency in this type of condition.

The harvest schedule is dependent on tree spacing and growth. Typical harvest schedules for average growing sites on agricultural soils in Minnesota: 6 to 9 years of age for 6 x 6 feet spacing , 9 to 11 years for 8 x 8 feet spacing, and 10 to 13 years for 10 x 10 feett spacing. These harvest ages can be adjusted for end-user needs.

POST-HARVEST CONSIDERATIONS

Following stand harvest, landowners have several options, depending on future objectives. These objectives can include replanting, conversion to crops or pasture, and potentially coppice production (re-sprout from existing stumps). To replant the site using new cutting material, herbicide treatment is required to eliminate regrowth of the harvested trees and any newly emergent weeds. This should be done at least two to three weeks prior to planting. Cuttings or seedlings should be interplanted at the midpoint between tree stumps. After planting, the same management procedures used to establish the plantation apply. To convert back to traditional ag crops or pasture, a landowner has two options. One is to kill the tree stumps with an herbicide treatment and allow them to rot in place for two to three years. The second option for conversion to cropping is to remove stumps. It may be possible to establish row

or pasture crops between the tree stumps in the first few years as the stumps rot. More research into the option to coppice from existing stumps is needed, and coppicing is not recommended at this time.

Photo 3. Harvest of a mature hybrid poplar stand in central Minnesota.

SUMMARY

This publication provides a practical guide to the establishment and maintenance of hybrid poplar plantations. It includes an overview of hybrid poplar plants, planning, planting stock, and planting densities. It contains instructions for plantation establishment, including site preparation, row markers, and planting. As well, it lists plantation management recommendations, such as cultivation, and pesticide and fertilizer application. It concludes with a description of hybrid poplar harvesting and post-harvest considerations.

The developing bioeconomy will reduce society's carbon footprint, reduce dependence on fossil fuels, and grow the circular economy. Hybrid poplar is ideally suited as a feedstock for the bioeconomy. When grown as a plantation crop, hybrid poplar offers advantages for the manufacture of biofuels, bio-based chemicals, and bioproducts. It is a consistent feedstock, which simplifies the production process. Hybrid poplar can be rapidly scaled up, is harvestable year-round, and after canopy closure requires minimal labor and chemical inputs.

NRRI developed this Grower's Guide in partnership with University of Minnesota Extension as part of the *Next-Gen Poplars* project. This project is a USDA NIFA grant-funded opportunity to advance the genetics, economic analysis, and utilization of hybrid poplars in the midwestern United States.

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APPENDIX

Table 1. Plantation establishment and maintenance timeline.

Field Preparation for sites beginning with sod

- Late summer – apply a contact herbicide to kill existing plants on site.
- Fall before planting – plow site.
- Spring of planting year – disc site.

Field Preparation for sites beginning with agricultural crops:

- Fall before planting or spring of planting year – plow site if needed; you might not need to plow if field was in soybeans the previous year.
- Spring of planting year – disc site.

Field Marking and Planting

- Spring of planting year – mark field on a grid.
- Spring to early summer – trees are planted at the intersections of the row marks – planting should be done once soil temperatures have reached 50 degrees Fahrenheit.

Post Planting Herbicide Applications

- Spring – spray a tank mix of a contact and pre-emergent herbicide post planting.
- Spring of second year – spray a tank mix of a contact and pre-emergent herbicide before tree bud break.
- Spring of third year if needed – spray a tank mix of a contact and pre-emergent herbicide before tree bud break.

Cultivation

- As needed for weed control until tree canopy closure.

Insecticide Applications

- Insect pests of hybrid poplars are described in USDA Agriculture Handbook 677 (full citation in *Additional Resources*). Apply insecticide at first signs of an insect outbreak severe enough to potentially kill or severely retard the growth of the plantation. One exception is cottonwood leaf beetle. In this case, the plantation should be treated at the first signs of the beetles. See link in *Additional Resources* for description of cottonwood leaf beetle.

Fertilizer Application

- Fertilizer application is dependent on tree spacing and tree nutrient needs. A typical fertilizing schedule is years 4 and 6 for 6 ft x 6 ft spacing, years 4 and 8 for 8 ft x 8 ft spacing, and years 4 and 8 for 10 ft x 10 ft spacing. A common fertilizer rate is 60 pounds of elemental N per acre. This rate can be adjusted depending on the tree nutrient needs.

Table 2. Example timelines for different tree spacings.

6 ft by 6 ft plantation spacing with harvest at age 8								
Years	1	2	3	4	5	6	7	8
Contact Herbicide	■							
Chisel plow	■							
Disc	■							
Mark rows	■							
Plant	■							
Herbicide (post planting)	■							
Herbicide (spring application)		■	■					
Cultivation (as needed)	■	■	■					
Pesticide application (application year will vary)			■					
Fertilizer application				■		■		
Harvest								■

8 ft by 8 ft plantation spacing with harvest at age 10										
Years	1	2	3	4	5	6	7	8	9	10
Contact Herbicide	■									
Chisel plow 2x	■									
Disc	■									
Mark rows	■									
Plant	■									
Herbicide (post planting)	■									
Herbicide (spring application)		■	■							
Cultivation (as needed)	■	■	■							
Pesticide application (application year will vary)				■						
Fertilizer application				■				■		
Harvest										■

10 ft by 10 ft plantation spacing with harvest at age 12												
Years	1	2	3	4	5	6	7	8	9	10	11	12
Contact Herbicide	■											
Chisel plow 2x	■											
Disc	■											
Mark rows	■											
Plant	■											
Herbicide (post planting)	■											
Herbicide (spring application)		■	■									
Cultivation (as needed)	■	■	■									
Pesticide application (application year will vary)				■								
Fertilizer application				■				■				
Harvest												■

Table 3. Herbicides.

Product	Chemical Name	Target Weeds	Application Method	Rate/Acre
Assure II & Targa	Quizalofop	Post-emerge control of annual & perennial grasses	Broadcast & band during growing season.	5 - 10 ounces
Fusilade DX	Fluazifop	Post-emerge control of annual & perennial grasses	Broadcast & band during growing season.	16 - 24 ounces
Glyphosate	Glyphosate	Non-selective control of grasses & broadleaves	Used as a site-prep or as part of a post-plant tank mix burndown.	32 - 64 ounces
LV4	2,4-D	Annual & perennial broadleaves	Used with glyphosate as site-prep treatment.	1/2 pint - 2 quarts
Pendulum Aqua-Cap	Pendimethalin	Pre-emerge - grasses & broadleaves – primarily grasses	Broadcast during dormant season.	25 - 50 ounces
Pendulum 3.3 EC	Pendimethalin	Pre-emerge - grasses & broadleaves – primarily grasses	Broadcast during dormant season.	1 - 3 quarts
Scepter 70 DG	Imazaquin	Pre-emerge - grasses & broadleaves – primarily broadleaves	Broadcast & band during dormant or growing season.	2.0 - 5.6 ounces
SureGuard	Flumioxazin	Pre-emergent control of annual grasses & broadleaves	Used alone or as a tank mix with glyphosate as a post-plant pre-emergent or during the dormant season.	4 - 8 ounces
Transline	Clopyralid	Post-emerge control of selected broadleaves (thistle & ragweed)	Broadcast, band, or spot application during growing season. Can be applied over trees.	8 - 12 ounces
Goal 2XL	Oxyflurofen	Pre-emerge control of annual & perennial grasses	Broadcast or band during dormant season.	4 - 6 pints

Note: Some of these herbicides might not be labeled in your state for use in hybrid poplar plantations at this time. If a product is not currently labeled for that use, then you must select an alternative herbicide or weed control method.

Table 4. Insecticides.

Product	Chemical Name	Target Insects	Application Method	Rate/Acre
Sevin XLR Plus	Carbaryl	Cottonwood Leaf Beetle	Applied throughout growing season or when bugs are present. Apply when blooming plants or bees are not present.	1 - 2 quarts
Warrior	Lambda-cyhalothrin	Cottonwood Leaf Beetle	Applied throughout growing season or when bugs are present. Apply when blooming plants or bees are not present. (Restricted Use)	2.56 - 5.12 ounces
Raven	Bt - bacillus	Cottonwood Leaf Beetle	Applied throughout growing season or when bugs are present.	2 quarts
Spintor	Spinosad	Cottonwood Leaf Beetle	Applied throughout growing season or when bugs are present.	2 - 8 ounces

Note: Some of these insecticides might not be labeled in your state for use in hybrid poplar plantations at this time. If a product is not currently labeled for that use, then you must select an alternative insecticide or insect control method.

ADDITIONAL RESOURCES

Next-Gen Poplars Project website: https://z.umn.edu/hybrid-poplar

The Hybrid Poplar Economics Workbook may be downloaded on the Resources page of the project website: https://z.umn.edu/hybrid-poplar_resources

Ostry, Michael E., Wilson, Louis R., McNabb, Harold S., Jr., and Moore, Lincoln M. 1988. **A guide to insect, disease, and animal pests of poplars. Agrie. Handb. 677**. Washington, DC: U.S. Department of Agriculture. 118 p.

Information on cottonwood leaf beetle: http://cues.cfans.umn.edu/old/cwlb/life.html

Sources of poplar planting stock:

Two midwestern nurseries selling unrooted hybrid poplar cuttings are **Hramor Nursery** (2267 Merkey Road, Manistee, MI 49660; phone 231 723-4846; FAX 231 723-5580) and **Cold Stream Farm LLC** (8585 N. Stephens Road, Free Soil, MI 49411; phone 231 464-5809; info@coldstreamfarm.net). **Schumacher's Nursery & Berry Farm** sells rooted eastern cottonwood cuttings (37806 910th Street, Heron Lake, MN 56137; phone 507 793-2288; FAX 507 793-0025). This is not meant to be a complete list of nurseries throughout the U.S. selling hybrid poplar or cottonwood cuttings.

Contact for further information: Jeffrey Jackson, Extension Educator, University of Minnesota Extension; jeffj@umn.edu; (218) 788-2696; www.extension.umn.edu