2025-2026
Cornell Integrated Hops Production Guide

Cornell Cooperative Extension

These guidelines are not a substitute for pesticide labeling. Always read and understand the product label before using any pesticide.

2025-26 Cornell Integrated Hops Production Guide

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Abbreviations and Symbols Used in This Publication

A.......... acre
AS........ aqueous suspension
D.......... dust
DF........ dry flowable
DG....... dispersible granule
EC........ emulsifiable concentrate
F........... flowable
G.......... granular
GPA..... gallons per acre
GPM.....gallons per minute
IPM......integrated pest mangement
L...........liquid
LC........liquid concentrate
ME.......microemulsion
PHI.......pre-harvest interval
psi.........pounds per square inch
REI.......restricted-entry interval
SC.........soluble crystalline, suspension concentrate
SE.........suspension emulsion
SL.........soluble liquid
WDG....water dispersible granule
WP........wettable powder
WSP.....water soluble packet
WSB.....water soluble bag

*........Federal restricted-use pesticide; may be purchased and used only by certified applicators
*NY......Restricted-use pesticide in New York State; may be purchased and used only by certified applicators.
†........Not for use in Nassau and Suffolk Counties

Every effort has been made to provide correct, complete, and up-to-date pest management information for New York State at the time this publication was released for printing (February 2025). Changes in pesticide registrations, regulations, and guidelines occurring after publication are available in county Cornell Cooperative Extension offices or from Cornell IPM Pesticide Safety Education (psep.cce.cornell.edu).

Trade names used in this publication are for convenience only. No endorsement of products is intended, nor is criticism of unnamed products implied.

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The guidelines in this bulletin reflect the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this bulletin does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

Cover photo: *Larry Smart, School of Integrative Plant Sciences, Plant Pathology and Plant-Microbe Biology Horticulture Section*

CHAPTER 7 – CROP MANAGEMENT, HARVESTING, POST-HARVEST PROCESSING *(continued)*

Chapter 1 – Introduction

This publication uses the term Integrated Pest Management (IPM). By definition, IPM is a pest management strategy that uses a combination of methods (such as scouting, thresholds, pest and weather forecasts, as well as biological and cultural controls) rather than relying solely on calendar-based applications of chemical pesticides. When developing a hopyard pest management strategy, growers must consider the following factors: pest biology (life cycle, infection requirements, etc.), varietal susceptibility, IPM strategies currently available, and the economics of implementing these strategies, in addition to the efficacy of available management options.

Since the resurgence of the hops industry in New York State is relatively recent, much of the pest and specific pest management information contained in this publication is based on research conducted in areas outside of New York, primarily the Pacific Northwest. (See Chapter 11 for complete listing of materials used in the production of this publication). While much of the pest information is transferable, it is important to keep in mind the distinct differences in growing-season conditions between the two regions (e.g., timing and probability of rainfall) and the effect that may have on IPM tactics such as thresholds and models for specific target pests. Every effort has been made to provide information that is applicable to hop growing in New York, but the best pest management plan will be based on knowledge developed in local hopyards. This publication has been developed to provide growers with research-based pest management information. It does not cover the entire spectrum of hop pests. Instead it concentrates on those pests which have been shown to be a problem in the Northeastern United States. With the limited number of pest control products available for hops in New York State, a conscientious use of additional IPM techniques such as selecting the proper site, keeping accurate pest history records, and preventing pest outbreaks through the use of sanitation, biological controls, variety selection and planting stock derived from certified, virus-tested sources is essential.

Chapter 2 – Site Selection

For successful, sustainable and profitable hop production, the importance of proper site selection cannot be over-emphasized. Hops are a perennial crop, so decisions made on site selection and improvement prior to planting will impact all aspects of production for many years to come. Once a hopyard is planted it is very difficult to make major changes to improve soil and air drainage, soil tilth, pH, or nutrient status. Improving soil structure or eliminating soil compaction layers in an established hopyard rarely proves successful. Site improvements should be conducted prior to hopyard establishment.

Preparations for hop planting must begin one to two years in advance. Select a site with good air and soil water drainage and have a preplant soil analysis performed on representative soil samples. Access to a good source of water for irrigation is critical. Hops generally require about 6 inches of rain per month during the growing season. In most regions of New York, we average about 3.5 inches/month. Using typical figures of a planting density of approximately 1000 plants/acre, and about 3 gallons of water needed per plant/day, it may require as much as 3000 gallons of water for each irrigation event. Water sources that only collect seasonal surface runoff may not have the capacity to provide the water when it is needed the most. Drip irrigation systems are the most efficient way to provide both water and nutrients to the plants when needed. Growers have found it is very difficult to achieve successful yields without mastering irrigation and fertilization practices. Soils for growing hops should be well drained, fairly deep (ideally, three feet or more of rooting depth), reasonably level, properly limed, and in good tilth (have good structure). Medium-textured soils (sandy to silty loams with good organic-matter content) are generally most satisfactory; well-drained, sandy soils with a slight to moderate southern slope are most favorable for hop.

Pest management should be a consideration in selecting the best site. A site with some slope will help provide air drainage that helps in two ways. A low spot in the topography will collect both cold air, leading to late spring frosts, and humid air that will contribute to downy mildew and other fungal infections.

Surrounding vegetation is also important. Woodlots will reduce air flow and produce shade, both of which will potentially increase fungal infections. On the other hand, some sites may be subject to excess winds which can physically damage both the hop plants and contribute to trellis failure. Therefore there may be sites that would benefit from windbreaks.

In relation to insect pests, potato leafhoppers come up north from the Southeastern US in the spring. They prefer alfalfa fields and when the hay is cut, they will exit the field and enter the hopyard in great numbers. Strip mowing of the hay may reduce the number of leaf hoppers in the hop field. Another insect that has caused significant damage in hops is the adult Japanese beetle. The grubs live in in sod, feeding on the roots of grasses and are especially numerous in sandy soils. Hay fields, pastures and turf may produce large numbers of Japanese beetle adults which will feed on the leaves. See Chapter 9 Hopyard IPM for more information on managing these two pests.

A question that often comes up with potential growers has to do with the direction to plant the rows. All things being equal, rows that run N-S will gain the most sunlight. However, slope and direction of daily air flow may make it more beneficial to plant E-W or some other orientation. Having prevailing winds go up and down the rows will help keep the yard dry and reduce disease incidence. Slope can impact tractor operator safety as well as irrigation system layout.

For a summary of soil types and soil management groups in New York State, please see the general information section of the Cornell Field Crops and Soils Handbook. Detailed soil survey maps are available through local extension and National Resource Conservation Service (NRCS) offices. After determining whether the soil is suitable, check for, and address, perennial weeds and correct pH level before planting.

Soils in good tilth provide a desirable medium for root development, absorb water and air rapidly, withstand erosion, and resist the tendency to crust. Many agricultural practices cause soil structure to deteriorate. Compaction, which results from the use of heavy equipment on wet soils, is particularly damaging. Tillage tools break down soil aggregation; intensive cultivation accelerates loss of organic matter and causes soil to crust. Obviously, all unnecessary operations should be avoided. Prepare the soil only enough to reduce weeds, incorporate soil amendments such as lime, fertilizer, and organic matter, and loosen the area for planting the hops as well as a seedbed for cover between the rows.

Never plow, till, plant, or cultivate soils when they are wet. One mistake can reduce the yield of the planted crop regardless of the level of other inputs.

Chapter 3 – Hopyard Nutrient Management

3.1 Introduction

To produce a healthy crop, soluble nutrients must be available from the soil in amounts that meet the minimum requirements for the whole plant. The challenge is balancing soil fertility to supply the required plant nutrients at the correct time and at sufficient levels to support healthy plant growth.

3.2 Soils and Fertility

Healthy soil is the basis for any successful farming operation. Regular additions of organic matter in the form of cover crops, compost, or manure create a soil that is biologically active; with good structure and capacity to hold nutrients and water (For more information on the use of Manure and Produce Safety see section 3.9). Decomposing plant materials will support a diverse pool of microbes, including those that break down organic matter into plant-available nutrients as well as others that compete with plant pathogens in the soil and on the root surface. The practice of crop rotation to promote a healthy soil should be done in the one or two years prior to hopyard establishment or is limited to row middles in a perennial crop such as hops. Growers must attend to the connection between soil, nutrients, pests, and weeds to succeed. An excellent resource for additional information on soils and soil health is *Building Soils for Better Crops*, 3rd edition, by Fred Magdoff and Harold Van Es, 2010, available from SARE, Sustainable Agriculture Research and Education, Building-Soils-for-Better-Crops-3rd-Edition (www.sare.org/ Learning-Center/ Books/Building-Soils-for-Better-Crops-3rd-Edition). For more information, refer to the Cornell Soil Health website (soilhealth.cals.cornell.edu).

Fertility management is part of an overall soil management program that involves proper tillage practices, crop rotation, cover crops, water management (irrigation and drainage), liming, and weed management. Although it is important in obtaining maximum economic yields, fertilization alone will not overcome shortcomings in the areas mentioned above. Such problems should be corrected first so as to benefit fully from organic and inorganic fertilizer supplements and to sustain high yields and quality over the long term.

Regular soil testing and petiole testing will help monitor nutrient levels. It is recommended that regular petiole testing be incorporated into a fertility management program with soil testing to assist in determining the bines' nutrient status and to make sure that what is in the soil is making it into the bines in the proper amounts. It is recommended that soil and petiole tests be completed in each block/variety a minimum of every three years. Petiole testing is especially critical in getting the information needed to make management decision in problem areas of the hopyard and should be used on a more frequent basis if needed.

3.3 Soil Testing

Fertilizer requirements for best economic yield should approximate the difference between what hop plants take up from the soil for best growth and quality and what the soil can actually supply during the crop-growing period. The supply of essential nutrients in soil cannot be determined without conducting a soil test. Moreover, if pH is not in a desirable range, yields may be poor regardless of fertilizer added or already present in the soil.

Soils on which hops will be grown should be sampled at least once every three years. The pH of most hop soils can change with the removal of crop materials. Testing every year gives a more complete evaluation and is appropriate when significant changes have been made in the fertilizer program (e.g., applying less phosphorus or potassium when the previous year's test showed high levels). In general, when the Cornell-recommended rates of fertilizer are applied, low soil test values for phosphorus and potassium usually increase slowly and steadily in spite of crop removal. Medium soil test values tend to remain constant or increase slightly, whereas high values decrease gradually. The potassium level could decrease much more rapidly, however, if a light sandy soil with relatively low exchange capacity is coupled with a heavy potassium feeder such as hops. In such situations, yearly sampling is appropriate. The purpose of applying nutrients, however, is to benefit crop development, not to achieve a predetermined test result.

Growers interested in obtaining Cornell guidelines for crop management should submit samples to Dairy One (730 Warren Road, Ithaca NY, 14850; 1-800-344-2697) and request the Cornell Morgan test and Cornell guidelines. When submitting samples for hops, use the "F" form from the Dairy One website.

The soil test results provide soil pH, percent of organic matter, and level of phosphorus, potassium, magnesium, calcium, and zinc. Levels of aluminum, iron, and manganese are also listed to identify potential toxicities rather than deficiencies. Other nutrients can be tested for an additional fee. See the nitrogen, phosphorus, and potassium recommendations under each crop to design a fertility program for your farm.

Go to the Dairy One website (www.dairyone.com) to find out more about soil testing services.

3.4 Soil pH

In general, hops grown on mineral soils will thrive at pH 6.0 to 6.8., the closer to 6.8 the better. Hops should not be grown on muck soils as they are prone to frost heaving. When soil pH is adequate, the availability of both major and minor nutrients is maximized, and the accumulation of toxic metals is minimized. Clearly, one cannot expect to

Table 3.7.2. Estimated nutrient content of common animal manures

Type of Animal Manure	N	P_2O_5	K_2O	N_1[a]	N_2[b]	P_2O_5	K_2O
	Nutrient content lb/ton			***Available Nutrients lb/ton in first season***			
Dairy (with bedding)	9	4	10	6	2	3	9
Horse (with bedding)	14	4	14	6	3	3	13
Poultry (with litter)	56	45	34	45	46	36	31
Compost (from dairy manure)	12	12	26	3	2	10	23
Composted poultry manure	17	39	23	6	5	31	21
Pelleted poultry manure[c]	80	104	48	40	40	83	43
Swine (no bedding)	10	9	8	8	3	7	7
	Nutrient content lb/1000 gal			***Available Nutrients lb/1000 gal in first season***			
Swine finishing (liquid)	50	55	25	25*	20+	44	23
Dairy (liquid)	28	13	25	14*	11+	10	23

[a] N1 is the total N available for plant uptake when manure is incorporated within 12 Hours of application,
[b] N2 Is the total N available for plant uptake when manure is incorporated after 7 days.
[c] Pelletized Poultry manure compost. Available in New York From Kreher's.
*= injected
+ = incorporated
Adapted from *"Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops"* by Carl Rosen and Peter Bierman and Penn State Agronomy

3.8 Manure

Most hop operations do not have a ready source of manure, but it can be used when available. Once applied to soil, manure is decomposed by microorganisms, forming humus. Manure provides both major and minor nutrients. When used regularly, it contributes organic matter and helps to alleviate structural deterioration, an important consideration in maintaining the productivity of heavily worked hop soils. One drawback of using manure is that certain weed seeds maintain their viability after passage through animals, so a potential exists for adding a new weed species to a field. This is especially true of horse manure. This threat is more likely with fresh than with composted manure. An excellent, thorough discussion of manure use in crop production is provided in the Cornell Field Crops and Soils Handbook.

Manure contains two forms of nitrogen, the unstable form in the urine and the stable form in the feces. The unstable form may account for 50 percent or more of the total nitrogen in manure. This nitrogen decomposes rapidly to ammonium, which in turn converts quickly to extremely volatile ammonia that can be lost from the system. For this reason, much of manure's unstable nitrogen may never be taken up by crops unless measures are taken to conserve it during the process of collection, storage, and application to the field. In general, about 35 percent of the stable nitrogen becomes available during the year of application, about 12 percent the second year, about five percent the third year, and about two percent the fourth year. Thus, repeated application to the same field results in an accumulation of a slow-release source of manure nitrogen.

Most potassium in manure is available for plant growth during the year applied; whereas, some of the phosphorus is in organic form and must decompose before it becomes available. Moreover, because phosphorus is not very mobile in the soil, broadcasting manure is not an efficient way of applying this element for crop establishment.

A micronutrient deficiency in a field with a history of manuring is rare because manure contains small quantities of these elements. If a deficiency is observed on a nonmanured field, a commercial fertilizer should be added immediately because of the slower availability of micronutrients in manure. If soil pH is acceptable, manuring may eventually solve the problem.

3.9 Manure and Produce Safety

The use of improperly aged or treated manure can increase microbial risks and contribute to foodborne illness. The possibility that fecal matter may come into contact with produce or that water might splash pathogens from the manure onto field produce are both important concerns. Pathogens such as *E. coli* O157:H7, *Salmonella*, and *Campylobacter* can be present in manure slurry for up to 3 months or more, depending on temperatures and soil conditions. Troubling for growers is that *Listeria monocytogenes* can survive in the soil for much longer than 3 months. *Yersinia enterocolitica* may survive, but not grow, in soil for almost a year.

It is important that all farms using manure follow good agricultural practices to reduce any microbial risk that may exist. These include:

- Consider the source, storage, and type of manure
- Store manure as far away as practical from areas where fresh produce is being grown and handled. If manure is

Chapter 4 – Soil Health

4.1 Introduction

Healthy soil is the basis for any successful farming operation and is extremely important when growing a perennial crop such as hops. Regular additions of organic matter in the form of cover crops, compost, or manure create a soil that is biologically active; with good structure and capacity to hold nutrients and water. (For more information on the use of Manure and Produce Safety see Section 3.9.) Decomposing plant materials will support a diverse pool of microbes, including those that break down organic matter into plant-available nutrients as well as others that compete with plant pathogens in the soil and on the root surface. The practice of crop rotation to promote a healthy soil should be done in the one or two years prior to hop yard establishment or is limited to row middles in a perennial crop such as hops. Growers must attend to the connection between soil, nutrients, pests, and weeds to succeed. An excellent resource for additional information on soils and soil health is Building Soils for Better Crops, 3rd edition, by Fred Magdoff and Harold Van Es, 2010, available from SARE, Sustainable Agriculture Research and Education. For more information, refer to the Cornell Soil Health website (soilhealth.cals.cornell.edu).

4.2 Soil Organic Matter

Soil organic matter is much more than the dead leaves, stems, and roots produced by the groundcover. As plant tissues decay, through the activity of soil microorganisms (bacteria, actinomycetes, fungi, algae, protozoa, and nematodes) they produce **humus**, a complex mixture of organic compounds that gives topsoil its characteristically dark brown color. The soil microbes themselves die, contributing to the total pool of biomass that forms humus. In sod-covered soils, humus typically constitutes the bulk of soil organic matter. But humus is not permanent. Its constituents undergo a slow, but continuing process of decay. If soil is kept bare, the major food source for soil microorganisms is eliminated, and humus can then be expected to disappear faster than it is formed.

Humus is a major source of nitrogen, phosphorous, and sulfur. These three essential elements are abundant in biological tissue, the source of humus. Humus also has a controlling influence on the availability of essential micro-nutrients, not because its parent biological tissues were high in micro-nutrients, but because humus can form “chelates” with copper, zinc, manganese, etc. that are released from soil minerals. Chelated micronutrients are held against leaching from the soil, and under the right conditions, are available to plant roots.

Another value of humus derives from its electrostatic attraction for oppositely charged nutrient elements, protecting them against leaching. This property, called cation exchange capacity, is also exhibited by clay particles. Cation exchange capacity, together with chelation, allows soils to hold nutrients until picked up by plant roots. Soils in which these properties are at a low level, as in soils with little clay or organic content, are naturally low in agricultural productivity, because they cannot supply as much mineral nutrition as the crops are capable of using.

Additional benefits of soil organic matter are:

- It increases moisture-retention in sandy soils. Organic matter can hold up to 20 times its weight in water.
- It acts as “glue” to hold very small soil mineral particles together in units called aggregates. Aggregation permits a loose, open, granular condition that aids penetration by water, air, and roots, and resists erosion.
- It has the ability to absorb many organic pesticides, holding them near the soil surface, where they are more likely to be degraded by biological activity and sunlight, rather than leach to groundwater.

Chapter 5 – Cover Crops

5.1 General

Cover crops are close-growing crops planted primarily for protecting and improving the soil. Integrating cover crops into hop production systems offers many benefits, but provides some challenges as well. Since hops are a perennial, cover crops are not used in the row. However, the following information can be useful for preparation in the year before the hops are planted or as an intercrop between the rows. For cover cropping to be successful, it is important to know the intended purposes, consider key management factors, and understand the characteristics of different cover crop species.

Cover crops offer a way to add organic matter to soils; improve soil tilth and remediate compaction; protect soil from wind and water erosion; add or recycle plant nutrients; increase the biological activity of soil; retain soil moisture; and in some cases, suppress weeds and may help control insects diseases and nematodes. No single cover crop can do all of these things. Matching the need and opportunity to the right cover crop requires information and planning.

5.2 Goals and Timing for Cover Crops

Cover crops can play an important role in a hopyard, especially during the years prior to planting through improvement of soil organic matter, breaking up of compaction layers, erosion control and suppression or elimination of weeds. Goals should be established for choosing a cover crop; for example, the crop can add nitrogen, smother weeds, or increase equipment mobility. The cover crop might best achieve some of these goals if it is in place for an entire growing season prior to hopyard establishment.

Cover crops planted in late summer will suppress annual weed growth, improve soil texture, provide organic matter, and may increase soil nitrogen. The cover crop can be incorporated in late fall or in the spring before planting. Certain cover crops (marigold, sudangrass) will either suppress or resist nematode populations. These should be considered where fumigation is not an option. (See Tables 5.2.1 and 5.2.2.) In addition to producing large amounts of biomass that out-compete other plant species, some cover crops (annual rye, ryegrass) can inhibit weed growth through allelopathy, the chemical inhibition of one plant species by another. Rye provides allelopathic suppression of weeds when used as a cover crop, and when crop residues are retained as mulch. Rye residues retained on the soil surface release chemicals that inhibit germination and seedling growth of many grass and broadleaf weed species. Retention of residue on the soil surface can be accomplished by mowing after seed head formation.

Cover crops will perform best under good growing conditions, such as optimal temperatures, sufficient soil moisture, and adequate soil fertility. Practices, such as preparing an adequate seedbed; drilling seed or broadcasting and cultipacking; inoculating seed with the proper *Rhizobium* inoculant if using a legume; planting into sufficient soil moisture; correcting pH or soil fertility problems; and in some cases, controlling weeds with herbicides or mowing the cover crop in midseason, often further enhance cover crop performance. Access to appropriate equipment for incorporating the cover crop is also critical.

To be effective, cover crops should be treated as any other valuable crop on the farm, with their cultural requirements carefully considered including susceptibility, tolerance, or antagonism to root pathogens and other pests; life cycle; and mowing/incorporation methods. See Section 5.3 for more information on specific non-leguminous cover crops.

Use of cover crops in the alleys (row middles) after hopyard establishment can have both beneficial and detrimental impacts, so the choice of cover crop should be carefully considered. Care should be taken in the selection of a cover crop in established hopyards to minimize the competition for water and nutrients. In a four-year study in Western

Table 5.2.1. Non-leguminous cover crops: cultural requirements and crop benefits

Species	Planting Dates	Life Cycle	Cold hardi-ness zone	Tolerances[1]			pH Pref-erence	Soil Type Prefer-ence	Seeding Rate (lb/A)	Comments
				Heat	*Drought*	*Shade*				
Brassicas	April or late August to early September	Annual/ Biennial	6-8	4	6	NI	5.3-6.8	Loam to clay	5-12	• Good dual-purpose cover & forage • Establishes quickly in cool weather • Biofumigant properties
Buckwheat	Late spring-summer	Summer annual	NFT	7-8	4	6	5.0-7.0	Most	35-134	• Rapid grower (warm season) • Good catch or smother crop • Good short-term soil improver for poor soils

Table continues on next page.

Chapter 6 – Variety Selection

6.1 Hop Varieties

There are hundreds of hop varieties being used around the world. Hops are asexually propagated to maintain true-to-type products, similar to other crops like grapes and apples. Hop growers should consult with brewers to research demand. Flavor, yield and disease susceptibility are all factors to consider when deciding what to plant. Cornell University (https://hops.cals.cornell.edu/) and the University of Vermont (https://www.uvm.edu/extension/nwcrops/hops) are conducting variety trials that should help determine which varieties will perform best in the Northeast. Table 6.1.1 is adapted from the Washington Hops Commission, published previously in the "Field Guide for Integrated Pest Management in Hops, 3rd edition" (produced in the Pacific Northwest).

Table 6.1.1. Disease susceptibility and chemical characteristics of the primary hop varieties grown in the US.

		Disease Susceptibility[1]		
Variety	**Usage**	*Powdery Mildew*	*Downy Mildew*	*Verticillium Wilt*
Amarillo®	Aroma	R	R	R
Brewers Gold	Bittering	S	S	MR
Bullion	Bittering	S	S	R
Canadian Red Vine	Aroma	S	MR	U
Cascade	Aroma	R/MS	S	MR
Centennial	Bittering	MS	S	U
Chinook	Bittering	S	S	R
Citra	Aroma	MR	MR	U
Columbia	Aroma	MS	MR	S
Comet	Bittering	R	S	R
Crystal	Aroma	R	S	R
CTZ	Bittering	S	MR	U
East Kent Golding	Aroma	S	S	MR
First Gold	Bittering	R	S	MR
Fuggle	Aroma	MR	MR	S
Galena	Bittering	S	S	R
Glacier	Aroma	S	S	U
Hall. Gold	Aroma	MS	R	S
Hall. Magnum	Bittering	S	R	MR
Hall. Mittelfruh	Aroma	MS	S	S
Hall. Tradition	Aroma	MR	R	MR
Horizon	Bittering	MS	S	MR
Late Cluster	Aroma	S	S	R
Liberty	Aroma	MS	S	U
Mosaic™	Aroma	MR	S	U
Mt. Hood	Aroma	MS/R	S	S
Newport	Bittering	MR/R	R	U
Northern Brewer	Bittering	S	S	R
Nugget	Bittering	S/MR/R	S	S
Olympic	Bittering	S	MS	R
Perle	Aroma	S	R	MR
Pioneer	Bittering	MR	MR	U
Saazer	Aroma	S	MS	S
Saazer 36	Aroma	S	MS	S
Simcoe®	Aroma	MS	U	U
Sorachi Ace	Aroma	MR	MR	MR
Spalter	Aroma	S	R	MR
Sterling	Aroma	S	MR	U
Summit™	Bittering	R	U	U
Teamaker	Aroma	MR	MR	S
Tettnanger	Aroma	MS	MS	S
Triumph	Aroma	R/MS	MR	U
Tolhurst	Aroma	S	S	U
U.S. Tettnanger	Aroma	S	MR	S
Vanguard	Aroma	S	S	U
Willamette	Aroma	S	MR	S

Table 6.1.1. Disease susceptibility and chemical characteristics of the primary hop varieties grown in the US.

[1]Disease susceptibility ratings are based on greenhouse and field observations in experimental plots and commercial yards in the Pacific Northwest as of 2023. Disease reactions may vary depending on the strain of the pathogen present in some locations, environmental conditions, and other factors, and should be considered approximate. For powdery mildew, some cultivars have multiple susceptibility rating that reflect their potential reaction based on region and whether virulent strains of the powdery mildew fungus occur.
S = susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant; U = unknown. (Gent et al, 2015, Woods and Gent, 2016, Gent et al, 2023)

When selecting a hop variety it is important to consider its agronomic capacity and how it will perform in the location where it will be grown. How difficult is it to grow and harvest? Will it produce a competitive yield in the eastern United States or elsewhere? Are brewers interested in brewing with the variety? Look at a variety grown under the best of conditions and then adjust its growth and yield for any shortcomings found on the site where it will be grown. If best production practices are followed and the variety only produces 600 pounds of dry hops per acre, it will be difficult to make a profit unless they are sold for a premium

Chapter 7 – Crop Management, Harvesting, Post-Harvest Processing

7.1 Planting

When purchasing stock for planting, you can choose from either plants or rhizomes. Rhizomes are dug and sold as dormant pieces of root with buds on them. At a minimum, two plants or rhizomes should be planted per hill. Most growers in the Pacific Northwest plant three or more rhizomes per hill because not all will survive, and they want the field to fill in with as many plants as possible. Be careful to never let the rhizomes dry out before they are planted as they will not take root. Plants come in plugs and pots of varying sizes, with 4 inches being average. These are grown in greenhouses from rhizomes or from cuttings taken from stock plants and propagated in a greenhouse. Whether you choose plants or rhizomes, you should always be careful to purchase as clean of stock as possible. At this time, there is no "certified" nursery stock available for hops. This would require constant testing for viruses in all stock materials. The National Clean Plant Network nursery in Washington State sells tested virus-free planting stock to a network of propagators. They may purchase their clean stock cuttings (meaning free from viruses, not diseases) from this USDA-funded nursery and in turn start their stock plants from these. There are no hop propagation greenhouses in New York that are actively producing hop plants for commercial sale. One of the closest propagators is Sandy Ridge Farms in Michigan (https://sandyridgefarmsinc.com/). Orders for those plants are usually taken in the winter with plants available in May and June. To ensure the best start for a hopyard it is important to know where your planting stock comes from. Whether purchasing rhizomes from a grower's field (there are growers in the east who have been growing long enough to have rhizomes ready for collection and sale) or a greenhouse/nursery operation, it is important to know where the planting stock comes from and the conditions in which they were grown. Working with a local supplier during the year prior to purchasing plant material will help to provide information on potential disease and insect problems associated with the variety. Buying locally also offers the opportunity to inspect the plant material before the purchase is complete.

Posts holding the trellis wires are typically space 12 to 14 feet apart, but may be slightly wider depending on equipment. Wider spacing can allow more air movement, which will reduce the spread of disease. Within row spacing can be matched with planned weed control strategy and the number of strings installed per hill, but the final arrangement should result in ~1420 strings per acre. By spacing hills six feet apart and using three strings per hill in a 14 foot trellis system, this approaches the desired number of strings per acre and allows space to mow inbetween hills. Alternatively, within row spacing of 4 feet in a 14 foot trellis system would support two strings per hill.

7.2 Pruning

Once the hop planting is established (usually after year twoor three) pruning is an important agronomic practice for hopyards and is the spring removal of plant and crown material that helps to reduce downy mildew infection and increases hop yield. There are several different methods that growers use to prune away the first shoots in a growing season, commonly referred to as "bull" shoots, and the top of the hop crown. These methods are described on the Michigan State University hop extension web site (https://www.canr.msu.edu/news/pruning-for-disease-management-and-yield-benefits-in-hops).

Crowning – Crowning is typically conducted in early spring in regions with high downy mildew or powdery mildew pressure, like New York State, to reduce inoculum. During crowning, the top of the hop crown (the top 0.75-2 inches of new wood from the last growing season) in addition to new shoots, are removed using a mechanical offset tool. These mechanical offset tools are typically attached to the power take-off (PTO) shaft of a tractor and use one or more rotating discs to cut back plant growth.

Flaming – Flaming is the process of burning back new shoot growth early in the season with a flamethrower and is used to remove bull shoots and reduce disease incidence later in the season.

Herbicide application – Often referred to as "burning back," a herbicide application upon the emergence of new shoots can be used to remove bull shoots and reduce disease incidence. It is critical to avoid excessive herbicide damage early in the season and with newly established hop plants.

Scratching – Scratching is less intensive than crowning and involves removing bull shoots using a mechanical "harrow-like" implement.

The timing of pruning is critical, as you want to prune early enough for the plant to reach the top wire by early July, but pruning too early can significanly hinder hop growth and reduce yield. Typically, it takes three to four weeks from the time hop plants are pruned until the time they have grown enough to be trained.

7.3 Stringing

Stringing provides hop bines with the ability to grow to the top wire during the growing season. One to four strings are typically installed per hill, with two being the most common in the Northeast. Strings are tied to the top wire, typically using a cow hitch knot, and set in the ground using a hop clip applicator or similar tool in a V shape. Strings may be held in the ground using a W clip pushed over the

On a commercial scale, hops are commonly dried using customized dryers with forced air at a temperature between 120 and 140ºF (50 to 60ºC) until they reach the target percent moisture – usually within 24 hours, depending on the depth of the hops and the air current.

A handheld moisture sensor can be used or the percent moisture can be calculated by hand using a food dehydrator or air fryer to determine the target weight after drying. First, follow the method described in 7.6 Picking Window to determine the percent moisture of your freshly harvested hops. Second, weigh a larger sample of your freshly harvested hops that you intend to dry, between 2 to 3 kg (4 to 7 lbs). Third, calculate the target weight of your sample after drying down to 8 to 10 percent moisture using the equation below. Fourth, place your sample in the middle of your dryer along with the rest of your fresh hops to be dried, weighing the sample and continuing the drying process as needed until the target percent moisture and weight have been reached. Once the sample has reached the target percent moisture, the hops should be removed from the dryer and temporarily placed in a location with good airflow and out of direct sunlight for one to two hours so that all of the hops in the batch can reach equilibrium and cool before baling.

Equation 7.8.1 Target Percent Moisture Calculation

$$\text{Target Weight}=\frac{\text{Dry Weight}}{1-\left(\frac{\text{Target Percent Moisture}}{100}\right)}$$

Sample Calculation

$$\text{Dry Weight}=3.1\text{ kg (sample+bag)}-0.1\text{ kg (bag)}$$
$$\text{Dry Weight}=3.0\text{ kg}$$

$$\text{Target Percent Moisture}=8.5\%$$

$$\text{Target Weight}=\frac{3\text{ kg}}{1-\left(\frac{8.5}{100}\right)}=2.75\text{ kg}$$

Baling – Once the hops have been adequately dried to between 8 and 10% moisture, they are ready to be compressed into bales using a hydraulic baler. The size of hop bales range from 20 lbs to 200 lbs. Each hop bale is tightly wrapped in a woven burlap or plastic bale bags to maintain that 8% to 10% moisture content. A properly labeled bale will contain information on the variety, harvest date, and lot number. Baled hops should be stored in a cool, dry location before being shipped to processors or distributors. Baling hops extend their shelf life, reduces storage space, and makes them easier to ship to a processor or distributor.

Figure 7.8.1 HopsHarvester® 100 lb Hop Baler

Pelletizing – Most craft brewers prefer to add hops as dried pellets. Bales must first be broken and milled to reduce the size of the hop cones. That milled material is then fed through a die under pressure to form a pellet. A steel roller is passed over the pellet die, compressing the hop powder into the shape of the pellet die. The pellet mill should be refrigerated so the hops do not lose aromatics by over heating from the pressure of the process. Pellets have greater bulk density than whole cones, making storage and transport easier. Additionally, the small size and consistent shape of hop pellets make them easier to add to the brewing process, allow for increased flow since they take up less space in the fermenter, and have a greater extraction efficiency allowing them to impart notably more flavor and bitterness during the brewing process. Hop pellets are typically vacuum packed in bags with an inert gas, such as nitrogen to reduce deterioration and extend their shelf life.

Chapter 8 – Pesticide Information

8.1 Pesticide Classification and Certification

Pesticides can be classified as general use or restricted use. **General use pesticides** may be purchased and used by anyone. **Restricted use pesticides** can only be purchased and used by a certified applicator or used by someone under a certified applicator's supervision. In some cases, the pesticide label may limit use of a restricted use pesticide to only a certified applicator.

Private applicators use or supervise the use of pesticides to produce agricultural commodities or forest crops on land owned or rented by the private applicator or their employer. If a private applicator wants to use or supervise the use of restricted use pesticides, they need to be a **certified private applicator**. Certified private applicators are also allowed to purchase restricted use pesticides. Certification is not needed if a private applicator uses general use pesticides.

In New York State, a **certified commercial applicator**, **certified commercial technician**, or **commercial apprentice** working under the supervision of a certified commercial applicator is allowed to apply any type of pesticide on property that is not a private application (described above) or is a residential application. (A residential application is the use of general use pesticides on property owned or rented by the applicator, excluding establishments selling or processing food and residential structures other than where the applicator lives.) Certified commercial applicators are allowed to purchase restricted use pesticides.

Information on pesticide certification and classification is available from your Cornell Cooperative Extension office (cce.cornell.edu/localoffices), regional NYSDEC pesticide specialist (dec.ny.gov/about/contact-us/statewide-office-information), the Pesticide Applicator Training Manuals (www.cornellstore.com/books/cornell-cooperative-ext-pmep-manuals), or the Cornell Pesticide Safety Education Program (psep.cce.cornell.edu).

8.2 Use Pesticides Properly

Using pesticides requires the user to protect their health, the health of others, and the environment. Keep in mind "pesticide use" is more than just the application. It includes mixing, loading, transporting, storing, or handling pesticides after the manufacturer's seal is broken; cleaning pesticide application equipment; and preparing a container for disposal. These activities require thoughtful planning and preparation. They also require you to comply with state and federal laws and regulations intended to protect human health and the environment from the adverse effects pesticides may cause.

8.2.1 Plan Ahead

Many safety precautions should be taken *before* you begin using pesticides. Most pesticide accidents can be prevented with informed and careful practices. **Always read the label on the pesticide container before using the pesticide.** Make sure you understand and can follow all label directions and precautions. Be prepared to handle an emergency exposure or spill. Know the first aid procedures for the pesticides you use.

8.2.2 Move Pesticides Safely

Transporting pesticides carelessly can result in broken containers, spills, and contamination of people and the environment. Accidents can occur even when transporting pesticides a short distance. You are responsible for a pesticide accident so take every effort to transport pesticides safely. Be prepared for an emergency.

8.2.3 Personal Protective Equipment and Engineering Controls

Personal protective equipment (PPE) needs depend on the pesticide being handled. **Required PPE are listed on pesticide labels.** Any required PPE is based on the pesticide's toxicity, route(s) of exposure, and formulation. Label-listed PPE are the minimum that must be worn when using a pesticide. You can always use more than what's listed!

The type of PPE used depends on the type and duration of the activity, where pesticides are being used, and the user's exposure. For example, mixing/loading procedures often require more PPE than when applying a pesticide. Studies show you are at a greater risk of accidental poisoning when handling pesticide concentrates. Pouring pesticide concentrates is the most hazardous activity.

Engineering controls are devices that help reduce a pesticide user's exposure. An example is a closed transfer system that reduces the exposure risk when dispensing pesticide concentrates. Consult the product label for more information on using engineering controls in place of PPE.

8.2.4 Avoid Drift, Runoff, and Spills

Pesticides that move out of the target area can injure people, damage non-target areas, and harm the environment. Choose weather conditions, pesticides, application equipment, pressure, droplet size, formulations, and adjuvants to minimize drift and runoff potential. Product labels may have specific application and/or equipment requirements to reduce issues with drift and runoff.

Chapter 9 – Hopyard IPM

9.1 Principles of Insect, Mite and Disease Management

Integrated Pest Management (IPM) is an agroecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, use of resistant varieties and judicious use of pesticides. While hop production may be severely limited by arthropod pests (insects and mite) and plant diseases (fungi, bacteria and viruses), an understanding of the factors involved in their development can aid greatly in effective IPM. The development of disease and arthropod damage is highly dependent on characteristics and conditions of the crop (host), the pathogen/pest population, and the environment. These factors all must be conducive before significant disease development or insect damage can occur.

Characteristics of the host that influence disease and pest susceptibility include the host's vigor, physiology, and variety (genetics). Aggressiveness or virulence, abundance, and physiology are characteristics of the pathogen or pest population that influence their ability to cause disease or damage. At the same time, environmental conditions such as temperature, moisture, light, and soil chemistry can affect both the host and pest and may promote or prevent disease. Moreover, the presence, abundance, and activity of natural enemies can play an important role in determining pest status. To complicate matters further, the most successful disease pathogens and insect pests have coevolved with crop hosts over many years to incite disease and damage at the most opportune times.

To successfully minimize disease and pest damage, the relevant aspects of the host, pathogen/pest, and environment must all be managed within specific timeframes. One of the purposes of this manual is to improve management practices for diseases, insects, weeds and other pests by providing science-based information.

Although individual arthropod pests and plant disease pathogens can be vastly different in their biology, they often have enough similarity in life history strategies to allow successful management under a single set of underlying principles. These principles include avoidance/exclusion, eradication/sanitation, and protection and are defined below.

Avoidance/exclusion: This principle focuses on prevention of pest introduction and minimizing factors that favor the establishment of pests. Several practices that exclude or limit pathogen and arthropod presence include the following:

- Choose sites with good drainage. On heavy soils, tiling of plantings to remove excess water is necessary. Promote air circulation to dry leaves in hop plantings by selection of an open site, removal of dead or senescent plant material, and weed reduction.
- Plant only disease-free planting stock.
- Practice weed management as weeds can be hosts for certain pests. Weeds also raise humidity that can increase downy mildew growth.

Eradication/sanitation: This principle is concerned with the destruction and/or minimization of pathogen/arthropod populations. Typically, complete eradication of a pest is not feasible and difficult to justify for economic reasons. A better goal is to use practices that reduce pest populations to manageable levels. Practices that can greatly reduce pathogen/arthropod populations include the following:

- Sanitation of plantings by removal and destruction of infected/infested plants or plant parts that will otherwise maintain, and increase, pest populations.
- Pheromone traps may reduce insect numbers, they are also primarily used for scouting.
- Several biological products are available to suppress insect populations, including those based on formulated *Bacillus thuringiensis* and insectary-reared predatory mites. Currently, biological control products for disease management are designed to prevent infection at their particular sites of application.
- Applications of effective fungicides, insecticides, and miticides – whether chemical or biological –will (by definition) limit the reproduction of pathogen and pest populations and their resulting damage. It is MUCH easier to obtain and maintain desirable levels of control if such applications are made as soon as possible once the appropriate action threshold has been reached, rather than waiting to respond to an emergency. (See considerations regarding chemical application below).

Protection: This principle is founded on the protection of plants from pathogen infection and arthropod damage. Practices that protect plants by minimizing factors favoring infection and damage include the following:

- Plant hop varieties with significant resistance to important arthropods and diseases. *The selection of varieties with significant resistance is the cornerstone of an IPM program, and is the single most effective measure that can be taken to reduce losses. Decisions on what varieties to plant are especially critical for organic production, where disease suppression is extremely difficult on highly susceptible cultivars with the options available to organic growers.* Certain varieties have certain characteristics that make them far less susceptible to specific diseases or insect damage.
- Mating disruption using pheromones may protect crops by limiting reproduction and growth of insect populations.
- Avoid excessive nitrogen fertilization as many pathogens and insects thrive on succulent tissues.

Table 9.7.1. Downy mildew management options. *(continued)*

Common Name	FRAC Group Code	Trade Name	Formulation[a]	Days to Harvest (PHI)	Restricted-Entry Interval (REI)	EPA Registration Number
Phosphorus acid mono- and di-potassium salts	33	Rampart	L	Up to day of harvest	4 hours	34704-924
	33	Fosphite	L	Up to day of harvest	4 hours	68573-2
	33	*[NY]K-Phite 7LP	L	0	4 hours	73806-1
	33	ProPhyt	L	0	4 hours	42519-22-5905
	33	Phostrol	L	0	4 hours	55146-83
	33	Phiticide	L	0	4 hours	19713-625
Phosphorus acid mono- and di-potassium salts + hydrogen peroxide	33	OxiPhos	L	0	4 hours	70299-22
***Reynoutria sachalinenis* extract**	13	Regalia Biofungicide	EC	0	4 hours	84059-3
***Streptomyces lydicus* WYEC 108**	N/A	Actinovate AG	D	0	4 hours	73314-20
Trifloxystrobin	N/A	Flint[b]	DG	14	12 hours	264-777

[a]Formulation abbreviations: D = dust; DG = dispersible granule; EC = emulsifiable concentrate; F = flowable; L = liquid; P = powder; SC = soluble crystalline, suspension concentrate

[b] Will provide suppression when applied for powdery mildew control.

[c] Use only with a protectant fungicide.

[d] Apply as soil drench after pruning or at first sign of secondary infection.

*[NY] Restricted use pesticide in New York State. May be purchased and/or used by certified applicators.

POWDERY MILDEW is caused by the fungus *Podosphaera macularis*. It is the oldest known fungal disease of cultivated hops. Powdery mildew can occur on all green tissues of the hop bine and can cause severe crop damage resulting in loss of marketable yield due to lost production and reduced cone quality. Powdery mildew appears as white colonies on leaves, buds, stems and cones. During periods of rapid plant growth raised blisters are often visible. *P. macularis* is an obligate parasite (needs a host plant to live) of the hops plant. It grows superficially on hops tissue penetrating only the epidermal cells. Infection of burrs or young cones causes abortion or severe distortion of the cone as it develops. Affected cones may develop a characteristic white powdery fungal growth, although in some cases fungal growth is visible only under bracts and bracteoles and only with magnification. Affected cones become reddish brown as tissues are killed or may turn a medium brown after kiln drying.

Powdery mildew overwinters within dormant infected crown buds. The pathogen also forms a resistant structure called a chasmothecium, which contains overwintering spores that can perpetuate the disease from one season to the next. Chasmothecia release their spores during rain events from early shoot growth until shortly after bloom. Shoots emerging from an infected bud often are rapidly covered with fungal growth and are termed “flag shoots”. These shoots appear white and are stunted with distorted leaves. Infected shoots are rapidly overgrown by uninfected shoots in the hill, so frequent scouting is critical. The disease spreads most conspicuously within hills where flag shoots are present, but air-borne spores (conidia) produced from these infection sites will soon spread the pathogen to nearby rows if not suppressed or eradicated. As minimum nighttime temperatures increase to above 50°F, the rate of spread can increase dramatically. During warm spring temperatures, shoot growth can be faster than fungal growth and bud perennation (the growth from one growing season to the next) results in the infection of only the bract tissue at each node. When this type of growth appears, there is usually rapid and extensive spread within and among hills prior to pruning and training. Initial signs of infection are usually individual colonies located on the undersides of leaves at least 3 inches from the ground. The pathogen spreads as the plant develops moving up the bine in sync with plant growth. Leaves become increasingly resistant to disease as they age, especially when they are produced during hot weather (greater than 85°F). Disease development is favored by rapid plant growth, mild temperatures (47°-82°F), high humidity and cloudy weather. Under ideal conditions at 65°F the fungus can complete its life cycle in as little as 5 days. When temperatures exceed 86°F infection is reduced 50%. The detrimental influence of high temperatures is magnified even further on plant tissues with good exposure to the sun. Burrs and young cones are very susceptible to powdery mildew, arresting development and resulting in reduced crop yield and quality. Infections occurring later in the season are thought to lead to browning and an to ensure that the formulations, recommended adjuvants, and water conditions are compatible. See Tables 9.9.1, 9.9.2, and 10.3 for more information about herbicides registered for use in hopyards. More information about adjuvants can be found at:

- https://www.cropscience.bayer.us/articles/bayer/understanding-herbicide-adjuvants
- https://ag.purdue.edu/department/extension/ppp/ppp-publications/ppp-115-1.pdf

It is important to remember that registered herbicides can still cause crop damage, especially if they are used improperly. The type and amount of damage observed is dependent on the type of herbicide applied (and how it acts in the plant) as well as the hop tissue that is treated and the dose that is received. Auxinic herbicides, such as 2,4-D, can produce upward leaf cupping and other deformations plus abnormal stem twisting. Glyphosate can produce leaf yellowing or whitening symptoms, particularly at the base of leaves or between veins. Leaves and cones can be malformed, and stems can have shortened internodes. Injury can be severe and persist into the following season. Chlorosis and whitening can be a symptom of norflurazon injury, although the symptoms are more transient. Carfentrazone injury can appear as brown, dead (i.e., necrotic) areas which can range from leaf spots to whole tissue damage depending on coverage. Stem cracking has been reported in some varieties. Trifluralin can cause stubby roots and may result in crown and stem thickening. Significant injury is not expected from clethodim itself, as it is a grass specific herbicide, although adjuvants included in spray mixes can sometimes cause burning.

Table 9.9.1. Some herbicides registered for management of hopyard weeds.

Common Name	WSSA Group Code	Trade Name	Formulation[a]	Days to Harvest (PHI)	Restricted-Entry Interval (REI)	EPA Registration Number
2,4-D	4	Various trade names[b]	Various	28	48 hours	Multiple
Bicyclopyrone	27	*[NY]†Optogen	L	30	24 hours	100-1465
Carfentrazone-ethyl	14	Aim EC[b]	L	7	12 hours	279-3241
Clethodim	1	*[NY]Clethodim 2E[b]	F	21	24 hours	42750-72
Dimethenamid	15	*[NY]†Outlook	L	60	12 hours	7969-156
Glyphosate	9	Various trade names[c]	Various	14	4-12 hours	Multiple
Indaziflam	29	*[NY]†Alion	L	14	12 hours	264-1106
Norflurazon	12	*[NY]†Solicam DF	DF	60	12 hours	61842-41
Pelargonic acid; related fatty acids	27	Scythe	F	See label	12 hours	10163-325
Pendimethalin	3	Prowl H2O[b]	Various	90	24	241-418
Pyraflufen-ethyl	14	Venue MAX[b]	Various	30	12 hours	71711-69
Trifluralin	3	Treflan HFP[b]	Various	-[c]	12 hours	10163-363

[a] Formulation abbreviation: DF = dry flowable; F = flowable; L = liquid

[b] See Chapter 12 for more sample trade names. Multiple products may contain the same active ingredient. Always check with the New York State Department of Environmental Conservation website to ensure that products are currently registered for use in New York hop production. Always read herbicide labels carefully to ensure proper mixing, loading, application, and disposal.

[c] Applied at dormancy.

*[NY] Restricted use pesticide in New York State. May be purchased and/or used only by certified applicators.

† Not for use in Nassau or Suffolk Counties.

Table 9.9.2. Herbicides and their basic characteristics for hopyards. (Read the label for potential tank mixes and specific use, rate and timing of each product.)

Common Name	(C)ontact or (S)ystemic	Application Timing and Type					Weeds Controlled[c]		
		Pre-plant	*Pre-emergence*	*Post-emergence*	*Broadcast*	*Directed spray*	*Broad-leaves*	*Grasses*	*Suckers*
2,4-D	S	-	-	x	-	x	C	N	N
Bicyclopyrone[d]	S	-	x	x	-	x	C	PC	N
Carfentrazone-ethyl	C	x	-	x	x	x	C	N	C
Clethodim	S	-	-	x	-	x	N	C	N
Diamethenamid	S	-	x	x	x	x	C	C	N
Glyphosate	S	x	-	x	x	x	C	C	N
Indaziflam	S	-	x	-	x	x	C	C	N
Norflurazon	S?	-	x	-	-	-	C	PC	N

Chapter 10 – Sprayer Technology

10.1 Solutions for Safer Spraying – Engineering Controls

Keeping pesticide exposure to a minimum should be a chief concern of any pesticide applicator. To reduce the risks associated with handling and applying pesticides, devices known as **engineering controls** can be used to reduce or practically eliminate exposure to hazardous chemicals.

10.1.1 Areas of Exposure

1. Loading the Sprayer

Closed transfer systems. Closed transfer systems allow concentrated pesticide to be moved from the original shipping container to the sprayer mix tank with minimal or no applicator contact. Many systems provide a method to measure the concentrated pesticide. Some systems also include a container rinsing system. Currently available closed transfer systems use a probe inserted into the pesticide container, a connector on the container that mates to a similar connector on the application equipment, or a vacuum-type (venturi) system that uses flowing water to transfer the chemical from the container.

Induction bowls. Induction bowls are metal, plastic or fiberglass hoppers attached to the side of the sprayer or the nurse tank that allow pesticides to be added to the mix tank without the applicator climbing onto the spray rig. Pesticides are poured into the bowl and water is added to flush out the bowl and carry the pesticide to the spray tank. Often a rinse nozzle is mounted inside the bowl for rinsing out empty pesticide containers. Typically, induction bowls are raised out of the way during spraying and lowered to about 3 feet above ground when the sprayer is being loaded.

Direct pesticide injection system. Direct pesticide injection systems allow pesticides to be mixed directly with water in the sprayer plumbing system rather than in the main spray tank. The pesticide is pumped from its container and mixed with the water either in a manifold or at the main water pump. Only clean water is held in the main tank of the sprayer. An electronic controller and up to four pumps adjust the amount of concentrated pesticide that is injected into the water stream, allowing for variable application rates.

Container rinse system. Container rinse systems consist of a rinse nozzle and a catch bowl that traps the container washings (rinsate). The empty container is placed over the rinse nozzle and a jet of water cleans the inside of the container. The rinsate caught in the bowl is pumped into the spray tank to be used along with the spray mixture. Often rinse nozzles are installed in chemical induction bowls. Most closed transfer systems also provide a way of rinsing containers and piping the rinse water into the spray tank.

2. Reducing Exposure at the Boom

Boom folding/extending. Manually folding booms can be a source of operator contamination because the boom can be covered with pesticide from drift or dripping nozzles. Consider the use of hydraulic or mechanical folding methods.

Diaphragm check valves. Typically, when a sprayer is shut off and as the system pressure drops, any liquid remaining in the boom piping drips from the nozzles, possibly dripping onto the boom or even the operator. Diaphragm check valves installed at each nozzle prevent this by using a spring-loaded rubber diaphragm to close off the flow of liquid once the system pressure drops below about 10 pounds per square inch. When the sprayer is switched on and system pressure builds up, the valve opens and allows the liquid to flow through the nozzles.

Multiple nozzle bodies. Contamination can occur when operators change or unclog nozzles during an application. Multiple nozzle bodies (or turret nozzles) allow operators to switch between nozzles with a turn of the nozzle body rather than having to unscrew or undo a threaded or bayonet fitting.

Hand wash water supply. Providing adequate wash water is essential (and often required). A simple container with a hand-operated valve can be mounted on the side of the sprayer to provide clean water for hand washing and personal hygiene.

3. Drift and Contaminated Clothing in Cabs

Cab filtration using carbon filters. Carbon filtration systems are used to remove pesticide odor and pesticide-laden mist from fresh air used in a tractor or self-propelled sprayer cab. Carbon filtration systems are often a standard feature on self-propelled sprayers. Many factory installed tractor cabs offer optional filtration systems.

Protective clothing lockers. To prevent contamination of the tractor or sprayer cab interior, protective clothing should be removed before entering the cab. A few sprayer companies offer a simple compartment (or locker) mounted to the side or front of the sprayer where protective clothing can be stored.

4. Controlling Drift

Low-drift nozzles. Low-drift nozzles create larger-size droplets than conventional nozzles. The larger droplet sizes are less prone to drift, reducing environmental and operator contamination.

Air induction nozzles. These nozzles allow air to mix with the spray liquid, creating large, air-filled droplets with virtually no fine, drift-prone droplets. The droplets explode when they contact their target and offer similar coverage to droplets from conventional, finer-spray nozzles.

10.3.1 Travel Speed Calibration

Sprayer travel speed influences spray deposition and is a critical factor in maintaining accurate application rates. Studies to determine the effect of travel speed on average spray deposition agree that the higher the travel speed, the greater the variability in spray deposit. This variability is an important factor where uniformity of spray coverage throughout the canopy is required. Conclusions from research were drawn using travel speeds of 1-4 mph.

Factors affecting travel speed include**:**

- Weight of sprayer to be pulled.
- Slope of terrain.
- Ground conditions traveled over (wheel slippage).

The best way to measure travel speed is to pull a sprayer half full of water over the same type of terrain on which the actual sprayer will be operated.

Using a tape measure, set up a test course at least 100 feet long. Do not pace the distance. The longer the course, the smaller the margin of error.

Run the course in both directions. Use an accurate stopwatch to check the time required to travel the course in each direction. Average the two runs and use the following to calculate the speed in MPH.

Formula $\frac{\text{Ft. traveled}}{\text{Sec. traveled}} \times \frac{60}{88} = \text{MPH}$

Your figures:

Tractor gear___________ Engine revs.___________

$\frac{\_\_\_\_\_\_\text{ft.}}{\_\_\_\_\_\_\text{sec}} \times \frac{60}{88} = \_\_\_\_\text{MPH}$

An alternative to using the above method is to purchase a hand-held GPS receiver. A number of systems are available from electronics stores, hunting equipment suppliers, and online. Cost ranges from $80-150. The small device is portable so can be used in all tractors to determine forward speed in specific tractor gears at known engine RPM.

10.3.2 Airblast Sprayer Calibration

- use clean water

1. Pressure check

Place the pressure gauge on the nozzle fitting farthest away from the pump and turn the sprayer on. If pressure is lower at the nozzle than specified, increase pressure at the regulator.

Pressure at nozzle ______________ psi

Pressure at sprayer gauge _____________ psi

2. Nozzle output

Use a flow meter (obtainable from Gemplers, Spraying Systems, or other sources) attached to individual nozzles OR connect hoses to each of the nozzles and measure the flow from each nozzle into a calibrated jug. Record and total your results using Figure 10.3.1.

Calculate gallons per acre using the following formula.

Formula: $\frac{\text{Total GPM} \times 495}{\text{mph} \times \text{row spacing (ft.)}} = \text{GPA}$

Your figures: $\frac{\_\_\_\_\text{GPM} \times 495}{\_\_\_\_\text{mph} \times \_\_\_\_\text{ft.}} = \text{GPA}$

Replace all nozzle tips which are more than 5% inaccurate.

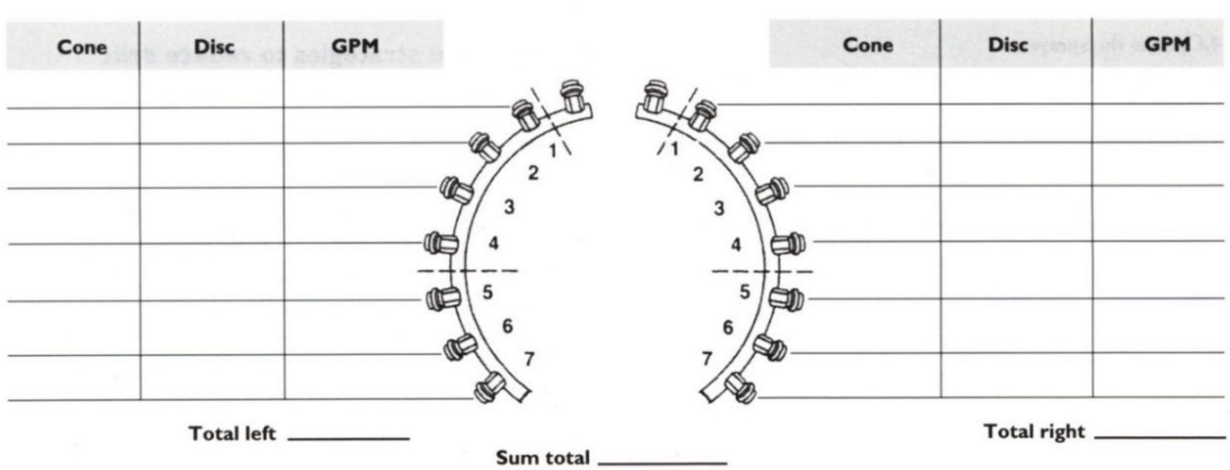

Figure 10.3.1. Airblast Sprayer Calibration

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Chapter 12 – Pesticide Index

Table 12.1. Fungicides registered for use in hops.

Common Name	FRAC Group Code	Trade Name	Formulation[a]	Days to Harvest (PHI)	Restricted-Entry Interval (REI)	EPA Registration Number
Ametoctradin + dimethomorph	45, 40	*[NY]†Zampro	SC	7	12 hours	7969-302
***Bacillus amyloliquefaciens* strain D747**	44	Double Nickle 55	WDG	0	4 hours	70051-108
	44	Double Nickle LC	AS	0	4 hours	70051-107
***Bacillus amyloliquefaciens* strain F727**	N/A	Stargus	EC	0	4 hours	84059-28
***Bacillus pumilus* strain QST 2808**	N/A	Sonata	F	0	4 hours	264-1153
***Bacillus subtilus* QST 713**	N/A	Serenade ASO	F	0	4 hours	264-1152
Boscalid + pyraclostrobin	7, 11	Pristine	DG	14	12 hours	7969-199
Basic copper sulfate	M1	Cuprofix Ultra 40 Disperss	DF	14	48 hours	70506-201
Copper hydroxide	M1	Champ Formula 2 Flowable	L	14	48 hours	55146-64
	M1	Champ WG	G	14	48 hours	55146-1
	M1	Nu-Cop 3L	L	14	48 hours	42750-75
	M1	Nu-Cop 50DF	DF	14	48 hours	45002-4
	M1	Nu-Cop 50WP	WP	14	24 hours	45002-7
	M1	Nu-Cop HB	G	14	48 hours	42750-132
Copper octanoate	N/A	Cueva Fungicide Conc.	F	Up to day of harvest	4 hours	67702-2-70051
Copper oxychloride + copper hydroxide	M1	Badge SC	SC	14	48 hours	80289-3
Copper oxychloride + basic copper sulfate	M1	C-O-C-S WDG	G	0	48 hours	34704-326
Cuprous oxide	N/A	Nordox 75 WG	WG	14	12 hours	48142-4
Cyazofamid	21	Ranman 400SC	L	3	12 hours	71512-3
Cymoxanil	27	Curzate 60 DF	DF	7	12 hours	352-592
Dimethomorph	40	Forum	L	7	12 hours	241-427
Fluopicolide	43	*[NY]Presidio	SC	24	12 hours	59639-140
Fluopyram + trifloxystrobin	7,11	*[NY]Luna Sensation	SC	14	12 hours	264-1090
Flutriafol	3	Rhyme	SC	7	12 hours	279-3588
Fosetyl al	33	Aliette	WDG	24	24 hours	264-516
Hydrogen dioxide+ Peroxyacetic acid	N/A	Oxidate 2.0	L	0	Until spray has dried	70299-12
Mandipropamid	40	Revus	L	7	4 hours	100-1254
Mefenoxam	4	Ridomil Gold SL	L	45	48 hours	100-1202
Metrafenone[c]	U8	Vivando	SC	3	12 hours	7969-284
Mineral oil	N/A	Drexel Damoil	oil	0[b]	4 hours	19713-123
	N/A	Biocover UL	oil	0[b]	4 hours	34704-806
	N/A	Glacial Spray Fluid	oil	0[b]	4 hours	34704-849
	N/A	Suffoil-X	EC	-	4 hours	48813-1-68539
	N/A	Omni Supreme Spray	oil	0[b]	12 hours	5905-368
	N/A	Purespray Green	oil	0[b]	4 hours	69526-9

Tips for Laundering Pesticide-Contaminated Clothing

Pre-Laundering Information

Remove contaminated clothing **before** entering enclosed tractor cabs.

Remove contaminated clothing **outdoors** or in an entry. If a granular pesticide was used, shake clothing outdoors. **Empty pockets and cuffs.**

Save clothing worn while handling pesticides for that use only. Keep separate from other clothing **before, during, and after** laundering.

Wash contaminated clothing after **each** use. When applying pesticides daily, wash clothing **daily**.

Clean gloves, aprons, boots, rigid hats, respirators, and eyewear by scrubbing with detergent and warm water. Rinse thoroughly and hang in a clean area to dry.

Take these **precautions** when handling contaminated clothing:

- Ventilate area.
- Avoid inhaling steam from washer or dryer.
- Wash hands thoroughly.
- Consider wearing chemical-resistant gloves.
- Keep out of reach of children and pets.

Air

Hang garments outdoors to air.

Pre-rinse

Use one of three methods:

1. Hose off garments outdoors.
2. Rinse in separate tub or pail.
3. Rinse in automatic washer at full water level.

Pretreat (heavily soiled garments)

Use heavy-duty liquid detergent.

Washer Load

Wash garments separate from family wash.

Wash garments contaminated with the same pesticide together.

Never use the “sudsaver” feature on your machine when laundering pesticide-soiled clothes.

Load Size

Wash only a few garments at once.

Water Level

Use full water level.

Water Temperature

Use **hot** water, as hot as possible.

Wash Cycle

Use **regular** wash cycle, at least 12-minutes.

Laundry Detergent

Use a **heavy-duty** detergent.

Use amount recommended on package or more for heavy soil or hard water.

Remember to use high-efficiency (HE) detergents in HE and front-loading washers.

Rinse

Use a **full** warm rinse.

Rewash

Rewash contaminated garments **two or three times** before reuse for more complete pesticide removal.

Dry

Line drying is preferable to avoid contaminating dryer.

Clean Washer

Run complete, but empty, cycle.
Use **hot water and detergent.**

Prepared by Charlotte Coffman, College of Human Ecology, Department of Fiber Science and Apparel Design, Cornell University

PESTICIDE EMERGENCY NUMBERS

Poison Control Centers

Poison Control Centers nationwide 800-222-1222

Emergency responder information on pesticide spills and accidents…

CHEMTREC 800-424-9300

For pesticide information…

National Pesticide Information Center 800-858-7378

To Report Oil and Hazardous Material Spills in New York State…

NYS Spill Hotline 800-457-7362

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