Hemp sex-ed

A primer on pollination

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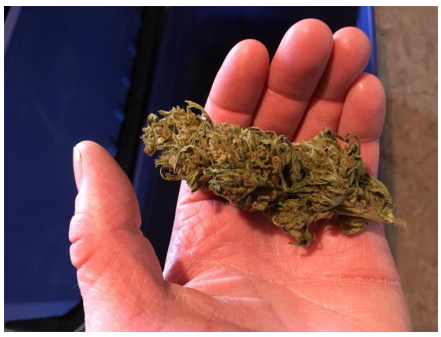

An unfertilized female hemp flower after harvest and drying.

Photo: Richard Roseberg, © Oregon State University

About this publication

Industrial hemp may only be grown in compliance with applicable state and federal law. The following information is provided for educational purposes only to inform licensed growers operating in compliance with applicable state and federal laws. Consult your local authorities, Department of Agriculture representatives, or personal attorney for questions regarding the legality of growing industrial hemp in your jurisdiction.

Introduction

Hemp production has faced significant market ups and downs in recent years. Regardless of farm size, understanding hemp's unique growing needs is essential for success. In intense production areas, such as the Willamette Valley, the Rogue Valley, and Central Oregon, one grower's hemp fields are often planted near another grower's hemp fields, increasing the potential for unintended pollen transfer. To fully understand why pollen transfer is such an important issue in hemp production, we must first review hemp flowering anatomy, pollen dispersal and field-management practices.

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Hemp anatomy

Hemp (*Cannabis sativa* spp.) is an unusual plant for many reasons. One reason is related to how it flowers and produces seed.

Flowering plants are known as angiosperms, which means “covered seed.” Angiosperms are important horticultural and agricultural crops and include everything from apples to zucchini.

Flowers are the reproductive organs for angiosperms. Plant sexual reproduction occurs when genetic information from pollen produced in the male flower parts, known as the stamen, is transferred to ovules in the female flower parts, known as the pistil.

Botanists estimate that 90%–95% of all flowering plants have male and female flowers on the same plant. In these cases, a single plant is capable of sexual reproduction. Plants with both male and female flowers are known as monoecious plants, from the Greek words for single (mono) and house (oikos). A common example of a monoecious crop plant is corn, where the stamen on the top of the plant (commonly called tassels) produces the pollen, which moves by gravity and the wind to the silk tubes and then to the ovules. Fertilized ovules eventually become the corn seed.

Hemp is different. In its natural state, Cannabis sativa produces two separate plants — one with male flowers and one with female flowers. This makes it dioecious — from the Greek words for two (di) and house (oikos). Only a few agricultural crops are dioecious, including hops, asparagus, spinach, mulberry, currant, dates and persimmon.

Although hemp is naturally dioecious, humans have been selecting and crossbreeding Cannabis spp. for around 10,000 years to produce seed, seed oil, fiber and essential oils, such as cannabinoids and terpenes. In this long history, some monoecious hemp types have been developed, but these are mainly used for edible seed and seed oil production and tend to have low concentrations of essential oils. Since the current interest in essential oil production (cannabidiol, CBD) is based on dioecious types, the remainder of this publication will focus on hemp’s dioecious types.

Figure 1. Unopened sepals on a panicle of male flowers.

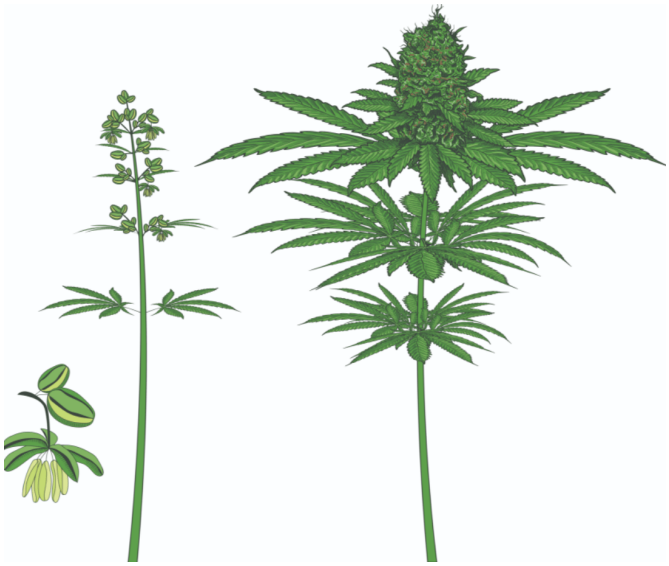

Figure 2. The difference between a male flower (center) and a female flower. The image on the far left shows the male flower in close detail.

Illustration: Nackley Lab, © Oregon State University

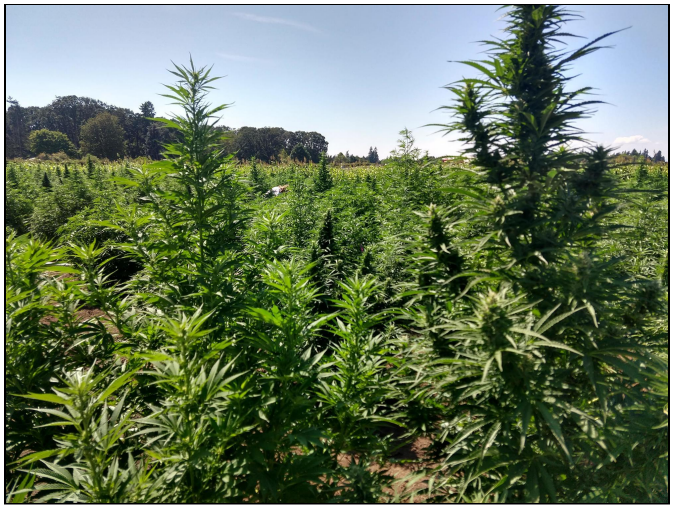

Figure 3: A field with 100% flowering female plants being grown for the production of CBD.

Photo: Lloyd Nackley, © Oregon State University

Characteristics of male and female plants

Vegetative male and female hemp plants are visually indistinguishable before flowers form. Once flowering begins, the differences between male and female plants become evident. Male plants become slender with elongated internodes at the top (Figure 1). This stretching is thought to be a mechanism to improve the plant's chance of spreading pollen on the wind. Male flowers are borne on slender stalks called panicles (pronounced panik-uhls). The male flowers appear as five enclosed sepals dangling like small ornaments on a tree. When the sepals open, the stamens are exposed and pollen grains can be carried away on the wind. Female flowers develop as dense, candle-like clusters of flowers commonly known as "colas" and scientifically known as a raceme (pronounced ray-seem) (Figure 2).

Hemp genetics are flexible, and sexual expression can respond to environmental stresses. Thus, one complication when managing hemp is that genetically female plants (XX chromosome) can spontaneously produce viable male flowers at any point during the growing season. Pollen produced by male flowers on genetically female plants (XX chromosome) is known as X-pollen. This sexual reversion, sometimes called hermaphroditism, can also be induced by applying plant growth regulators like gibberellins, silver nitrate and silver thiosulfate to female plants.

The opposite reversion occurs when plant hormones, such as auxins, ethylene and cytokinins, are used to promote female flowers on male plants. The ability to produce male pollen on a genetically female plant is used to produce "feminized seed." When the feminized seed is planted, the goal is to produce 100% female flowering plants. This is in contrast to seed produced in open-pollinated fields, which will typically result in about about 30% to 50% male plants.

For growers seeking to produce high concentrations of essential oils such as CBD, the ability to plant a field of female plants with few or no male plants is a great advantage (Figure 3, page 2). However, "feminized seed" costs more because of the high market value for female flowering plants.

Because the genetics of hemp and seed production methods are complex compared to some other crops, growers must understand the identity and parentage of the seed they are buying. Seed lots of varieties can have radically different genetic compositions, and the ideal seed type depends on whether the grower's goal is to produce fiber, various combinations of essential oils, or edible hemp seed. Historically, hemp breeding and seed production were unregulated; buyers had to trust that seed genetic trueness to variety, germination quality, and purity were what sellers claimed. The Oregon State University Seed Certification Service was authorized to certify seed beginning in 2015 and is working with other states and federal agencies to set uniform seed-certification standards and criteria for hemp. Increased transparency and uniformity in the seed production market should result in more market transparency regarding hemp seed genetics and seed quality. Similarly, the Oregon Seed Laboratory and private seed-testing laboratories provide services using nationally accepted rules for testing seed germination viability and purity from weed seed and inert material contamination of seed lots.

Figure 4: A field of hemp being grown for essential oil production near Medford, Oregon.

Photo by Richard Roseberg, © Oregon State University

Figure 5: In this field of grain hemp, produced for the seeds, the interspersing of males and females is acceptable. It increases pollen transfer and ultimate seed yield. The photo also demonstrates the sexual dimorphism between male and female flowers. The two panicles of the male flowers are slender compared to the dense raceme of the female flowers.

Photo: Lloyd Nackley, © Oregon State University

Figure 6: A 4-foot male flowering plant was discovered growing in weeds near a 100% CBD production field. To prevent it from spreading its pollen, the plant was bagged in plastic, cut off at its base and then carefully destroyed. Female plants had not yet begun full flowering, so there is a chance that the crop was unfertilized.

Photo: Lloyd Nackley, © Oregon State University

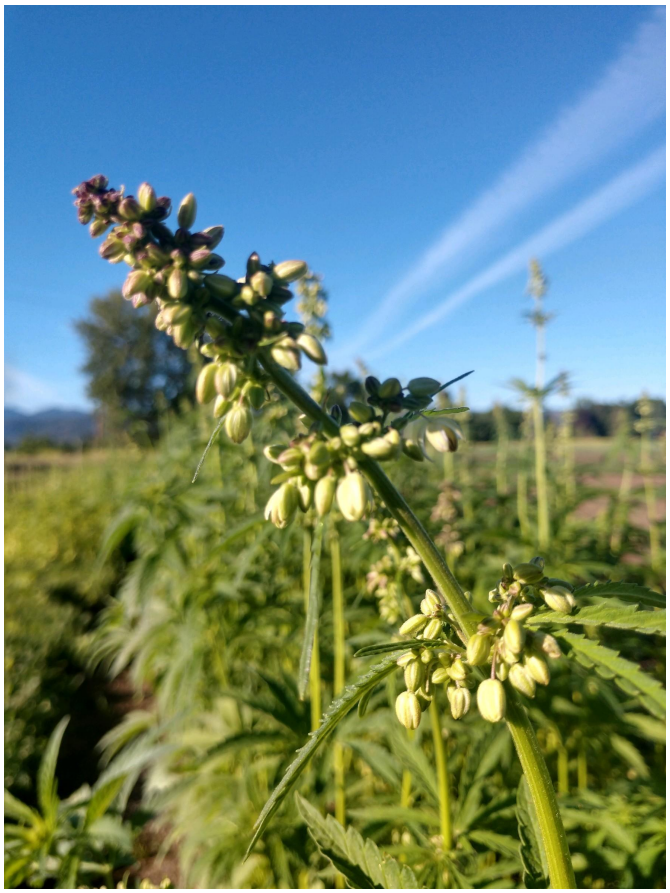

Figure 7: A male hemp plant flowering near Medford, Oregon.

Photo: Jake Hoyman, © Oregon State University

Pollen dispersal

Understanding hemp dioecy (male and female structures on separate plants) is critical when hemp is grown for medicinal and pharmaceutical essential oil extractions. That's because cannabinoids such as cannabidiol (CBD) and other essential compounds are concentrated in female flowers. Cannabinoids are most abundant in the trichomes, the resinous plant hairs coating the female flower buds and to a lesser extent the stems and leaves. When female plants receive pollen, the flowers decline as the plant sets seeds. The science of pollination and pollination's effects on the relationship of cannabinoid type and their concentration associated with pollination is still ambiguous. To reach a market for smokable or usable hemp flowers, growers have favored the production of 100% unfertilized female flowers (Figure 4). Current production methods for the flower market, followed by essential oil extraction, attempt to limit pollen originating from both within the field or from outside sources.

Hemp pollen can be moved by insects, wind, or mechanically transferred such as when physically removing male plants from a field. Wind dispersal is a common method of pollination in many other crops as well.

There is no known distance that will completely eliminate the chance of pollination via wind dispersal. Wind direction and velocity, and the size and weight of pollen determine how far pollen is carried. However, growers with open-pollinated crops (Figure 5) have reduced cross-pollination concerns by carefully separating their fields from nearby hemp crop fields, timing their planting dates to avoid conflicts with the time of flowering and when viable pollen is present, and coordinating with neighbors to avoid having fields close to one another to increase the chances of pollen contamination.

Many types of insects transport pollen effectively. The Oregon Department of Agriculture estimates there are about 500 species of native bees within the state, many of which are common pollinators in crop systems. Managed honeybee colonies can have a range of more than two miles for foraging distances, depending on food and water resources available.

The mechanical movement of pollen is also a significant concern. When highly managed hemp fields are scouted for male plants, pollen sources are identified throughout the season, and male plants and those containing pollen structures are removed from the field (Figure 6). If the goal is to produce unfertilized female flowers, any male plants must be carefully removed to minimize pollen spread when removing. Scouts should cut unwanted plants at ground level, bag and seal the plant, and remove any clothing or gloves that might have pollen before continuing to scout.

The length of time that pollen is viable (able to fertilize a female flower) is also a factor when managing male-plant pollen. A study showed that each pollen grain is more than 75% viable for only a few days, with viability rapidly dropping to less than 10% by the ninth day. While an individual pollen grain is only viable for a short time, unmanaged male plants can continue to produce new pollen for weeks during the growing season (Figure 7). However, because some hemp varieties form flowers at different times during the growing season than others, it may be possible for late-flowering female plants to escape pollen contamination if a nearby male type finished its pollination earlier in the season.

Field management

Many growers strive to maximize market opportunity by producing only unfertilized female flowers. These growers do not want pollination sources in nearby locations at any level. Some growers have tried to “spot the males” by differentiating leaf shape or stem characteristics, using multispectral cameras to detect pigment variations associated with male plants, or by using drone or satellite imagery to identify male plants. Aerial surveillance has been unsuccessful in preliminary tests, and there are no reliable visual methods to identify vegetative phase sexual dimorphism. To determine the sex of hemp before flowers are present, tissue samples must be sent for DNA testing.

Within the hemp field, growers attempt to exclude male plants by:

- Removing male plants before pollen develops.
- Using hormonally “feminized seed” resulting in mostly female plants, with scouting and removal of any X-pollen-producing plants.
- Cloning from known female plants.

Many hemp growers scout weekly for male or hermaphroditic plants. Workers walk through the fields and visually inspect each plant. Males tend to differentiate before females and can be visually identified from several feet away. Female plants can spontaneously produce pollen structures at any point in the season, a situation that may be caused by environmental plant stress. Throughout the season, workers must walk between each row to look into the dense foliage for signs of yellowing or branch elongation that may signify stressed plants that are more likely to produce male flowers and pollen. Spontaneous production of pollen reproductive structures is most problematic near harvest when canopies are dense and female plants have many flowers. Growers aiming for the highest essential oil concentration and crop value have crews scouting every three to four days as the crop nears harvest.

Perhaps the greatest cross-pollination concern is from male plants growing outside the production field. This includes hemp in nearby poorly maintained fields, small-scale residential plantings or feral "weedy" hemp growing wild in noncrop areas. To protect a hemp field from unwanted pollination by wind or insects, many growers recommend physical separation distances between hemp fields, often referred to as crop isolations in other seed production systems. For example, the specialty seed industry in western Oregon helps growers and companies plan crop locations and avoid seed-field conflicts, referred to as the "pinning" system.

Canada's isolation distances for certain hemp seed varieties can be as much as three miles for registered seed and a half mile for certified seed. However, pollen contamination thresholds for seed/grain production may not be equivalent to isolation required to prevent all pollination, as is currently desired for useable flower production. While hemp seed production requires pollen transfer, growing hemp for seedless production seeks to exclude pollen from the unfertilized female flower; these two production systems are likely incompatible in nearby fields without mitigating pollen transfer. More research is needed to develop compatible hemp production systems.

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