TOPIC: AGRIBUSINESS

# HOP BREEDING: BRING ON THE BITTERNESS

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Among the most popular hops found in IPAs these days are Mosaic, El Dorado, Galaxy, and Citra. Introduced in 2012, 2010, 2009, and 2008, respectively, these hops are competing with older favorites. Those include Cascade, “CTZ” (Columbus, Tomahawk, and Zeus), Chinook, Centennial, and Amarillo — released in the US in the 70s through 1990. And many hop varieties used in other beer styles are much older.

The most well-known English hops were introduced much earlier than this. Fuggles was introduced in 1875, East Kent Goldings in 1790. Some popular German varieties have also been around a long time. Tettnang was introduced 1844 and at least some variety of hops has been grown in the Hallertau region of Germany since 736. These and many other hop varieties have been around for a long time and are prized for their brewing quality. In this article, we will explain how new hop varieties are bred. But first, it pays to understand why — with so many existing hop varieties — plant breeders are interested in producing more.

**Goals of Hop Breeding**

There are many existing hop varieties with great brewing characteristics, but this doesn't mean there is no room for improvement. The primary bittering compounds in hops are alpha acids (AA) and hop breeders have tried, and succeeded, in bringing higher-alpha bittering hops to market. These include Zeus (average 15.3% AA), Summit, (16.3% AA) and Pahto (18.5% AA). (Pahto, incidentally, is second only to Citra when it comes expanding acreage over the past several years.)

In the past two decades, however, most of the efforts have been focused on producing interesting flavors. For example, Simcoe and Citra — both bred in the US — have a distinct pine and citrus character, respectively. Heull Melon, from Germany has a melon-like characteristic, as the name implies. And Nelson Sauvin, from New Zealand, has a white wine-like fruit character.

However, performance in the brewhouse isn't the only characteristic sought by brewers. Hops are harvested once a year and need to be usable until the next harvest arrives. The hop storage index (HSI), a measure of how quickly alpha acids degrade, is important for brewers and hop merchants. As such, new varieties must meet some standards in this regard. In general, the HSI of hops released in the past two decades have been superior to older, "classic" hop varieties.

Hop breeders also breed new varieties for their agronomic qualities. In particular, they look for varieties with higher yields, faster establishment times, more disease resistance, and better drought resistance. In addition, the plants must be able to work with the existing hop harvesting machines that cut the vines from the trellises and the separating machines that separate the hop cones from the bines and leaves.

**Hops**

The hop plant (*Humulus lupulus*) is a flowering plant in the Order Rosales. Rosales comprises roses and their relatives — including apples, strawberries, peaches, and others. There are nine families within Order Rosales with the hop plant belonging to the Family Cannabaceae. This family includes hops, hackberries and — of course — hemp and cannabis. There are three species within the genus *Humulus* — *H. yunnanensis*, *H. japonicus*, and *H. lupulus* — the last of which is the species used in brewing.

Hop plants are either male or female. Commercially grown hops are all female, but male hops exist in the wild and at breeding facilities. Growers try to exclude male hops from commercial hop yards as their pollen will cause the female cones to bear seeds, which reduces their brewing value.

Although hops are flowering plants, they do not produce showy flowers with large petals. Instead, hop flowers are small, spiky-looking structures. Wild hop varieties have two sets of chromosomes — one inherited from the mother and one from the father. A few commercial cultivars have three sets of chromosomes. One set of hops chromosomes is 10 chromosomes, nine of which are autosomes ("regular" chromosomes). The final chromosome is the sex-determining chromosome. As in humans, hops have sex chromosomes labelled X and Y and an XX individual is female and an XY is male. (Note: Although labelled as X and Y chromosomes, hop chromosomes are not homologous to human chromosomes.)

In the wild, hops reproduce sexually. Wind-borne pollen from the male plant — carrying one copy of each of its chromosomes — lands on the female cone and fertilizes an egg. The egg, of course, carries one copy of each of its chromosomes. The fusion of the pollen and the egg creates a zygote that contains two copies of each of its 10 chromosomes. This diploid zygote is encapsulated in a seed and the seed grows into a seedling and the cycle continues. Hops also produce rhizomes (underground storage stems) that can sprout both roots and stems. This allows hop plants to spread asexually via lateral rhizome growth.

**Commercial Hop Propagation**

Commercially, hop plants are not planted from seeds. Instead, they are propagated through breaking up rhizomes — the underground storage structure of the plant — and planting those. Once established, hops will sprout each spring from these rhizomes. In a commercial setting, the first set of bines is cut back each spring, and the second set to emerge is trained to trellis wires when they are tall enough. A bine is a type of vine that lacks tendrils. Trellised hop plants can grow up to 30' vertically. In the late summer they will flower and then produce cones. Typically, the density of cones is greatest at the top of the bine. It generally takes three years for a newly planted hop clone to begin yielding a worthwhile crop of cones.

When standing in a hop yard where a single variety is being grown, you are surrounded by clones of single female plant that emerged from a single seed many years ago. The entire variety consists of one plant. No male version of this variety exists. And, this plant may never reproduce sexually unless it is incorporated into a breeding program.

New hop varieties are bred beginning with the cross of a female hop plant — which is almost always an established brewing variety — to a male plant with some desirable characteristic. When the female flowers emerge, they are bagged to block airborne pollen. Pollen from male flowers is swabbed and applied to the female flowers, which results in seeds being produced. These seeds are planted in small planters — usually in a greenhouse — and germinated. None of the seedling of these crosses match either of the parents exactly. For example, if a Cascade female was crossed with a male — even a male with some Cascade genetic material — none of the seeds would grow into a Cascade plant. Hops have enough natural genetic diversity — what geneticist call heterozygosity — that each seed contains a novel mix of alleles. And, although all the seedlings are obviously hops, each is a unique hop variety. (Interestingly, the same thing occurs when apples are bred.)

**Seedling Evaluation**

First year seedlings are grown in a greenhouse. Plants with poor growth characteristics are discarded and the remaining seedlings are then moved outdoors. After two years of outdoor growth trials, the hop plants are evaluated for yield, vigor, and disease resistance. An initial assessment of their brewing chemistry (alpha acid levels, etc.) is also made.

**Multi-Hill Evaluation**

Plants that advance to the next stage have their rhizomes broken up so that 15–30 clones of the seedling are produced. The rhizomes are planted in a mound of soil that is called a hill. These plants mature and are evaluated as before to ensure the performance of the single seedling wasn't a fluke. Analysis of the plants' properties is continued and those that perform well are planted to successively larger plots.

**Commercial Scale Trials**

If any of the cultivars make it to this final stage, they are planted in a 2-acre plot. This size plot can yield enough hops to cover the bottom of an oast — the hop drying "oven" that commercial growers use. The grower can go through picking, cone separation, drying, and packaging to see if this hop candidate is compatible with the machines and methods of hop growers. It's also possible at this stage to cor commercial-scale brewing trials. If everything works out, then the breeder needs to decide whe release the cultivar or not. Given the large number of existing hop cultivars, a new hop variety nee something to set it apart from other cultivars in order to compete.

**Comparison to Other Plant Breeders**

The goals of hop breeders and of other plant breeders are in many ways the same. Both want to breed varieties with increased disease resistance, increased yield (for crop plants), better storage potential, etc. They also want to produce plants that are more enticing to both growers and consumers. However, there are also some notable differences.

Most crop plants, and commercially grown flowers, are annuals. They grow from seed, flower, and produce seed — and fruit or other edible plant parts in crop vegetables — in one growing season. A breeder working on beans or petunias can cross two plants and evaluate the outcome of the cross several months later. With a well-equipped greenhouse, the breeder could grow and evaluate at least a couple generations of an annual plant per year. (Recall that hops are perennial and don't generally flower in their first year.)

Most plants that breeders work on do not grow to 30' and require large trellises to grow. A lot of crop plants and flowers can be bred in relatively small greenhouses, and field tested in comparably small outside plots without any infrastructure. For crop plants bred to be grown commercially, some large-scale testing with harvesting equipment is needed.

Most plant breeders work from plant varieties that "breed true." For example, seeds from any variety of tomato plant yield seeds that of that same tomato variety. Hops do not breed true. However, since they can be propagated by cloning (breaking up and planting rhizomes), a field of any given hop variety will consist of (nearly) identical plants with consistent growing and chemical properties.

**A Long Process**

Hop breeding entails crossing two highly heterozygous parent plants and sifting among all their offspring for one or more promising seedlings. Initially promising seedlings will be repeatedly cloned until they can undergo a full-scale test — with machine harvesting and cone separation. By the time a hop variety is ready to be released, a decade may have passed since the initial seedling was produced and the number of clones of that seedling may easily be into the tens of thousands. Each acre of hops, when planted with the standard spacing, has 889 hills. For every new variety released, 80,000 hybrid seedlings were not. So the next time you lift a pint of IPA, know that a lot of work — in fields, greenhouses, and labs — has gone into the hop profile.

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