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Pollination and seed set of meadowfoam

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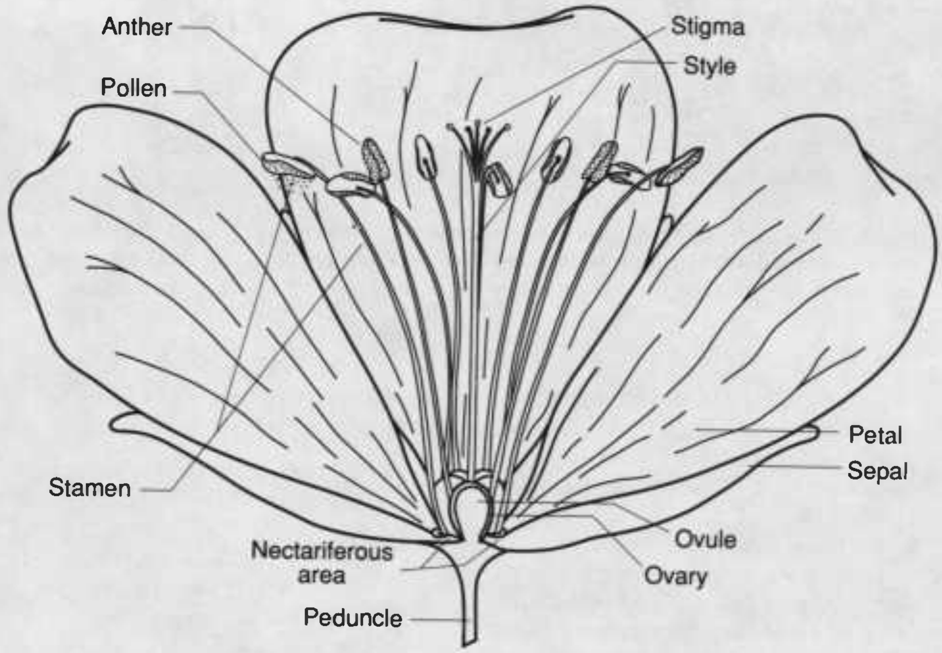

Figure 1.—Longitudinal section of a Mermaid meadowfoam flower with one stamen and two petals removed (X 7).

Meadowfoam (*Limnanthes alba* Hartw. ex Benth. ssp. *alba*, Limnanthaceae) is an oilseed crop that requires insect (primarily honey bee) pollination to set seed. Effective honey bee management will increase meadowfoam yields, which will improve the economic competitiveness of this new resource for Oregon.

The purposes of this publication are:

- to review the flowering characteristics and seed set requirements of meadowfoam, and
- to offer suggestions for increasing honey bee management effectiveness, which will improve meadowfoam pollination and subsequent yield.

The first recorded farm-scale planting of meadowfoam (cultivar Foamore) in Oregon took place in 1975-1976. The Oregon Agricultural Experiment Station released a second cultivar, Mermaid, exclusively to the Oregon Meadowfoam Growers Association in 1984.

Both Mermaid and Foamore are open-pollinated cultivars that require bee pollination to set seed. Mermaid seed yields have ranged from 702 to 1,567 lb/acre in research plots; commercial yields have averaged 770 lb/acre.

Greenhouse pollination studies using hand pollination on selected Mermaid plants have repeatedly produced greater than 4 seeds per flower, but honey bee-pollinated field populations have rarely averaged greater than 2.5 seeds per flower.

The seed set disparity observed between greenhouse and field pollination, as well as yearly yield fluctuations in field research plots, have aroused speculation that inadequate pollination may be limiting seed set. Effective bee management is essential to maximize pollination and seed set.

Flowering characteristics

Mermaid meadowfoam is a short, fleshy-stemmed plant that produces 1 to 12 flowers per stem and 1 to 10 stems per plant under solid stand field production. During peak bloom, it is common for 4 to 6 million new flowers per acre to open each day.

The flowers on each stem develop in a sequential order from bottom to top. Each flower is attached to a stem by a peduncle (figure 1).

Peduncles elongate before flower opening. Each flower has 10 stamens, and each stamen contains a pollen-producing anther, the male reproductive structure (figure 1).

The 10 stamens surround the female reproductive structure (pistil). The pistil is made up of 5 stigmas (female receptors of pollen), a common style, and 5 ovaries, each of which contains 1 ovule (figure 1).

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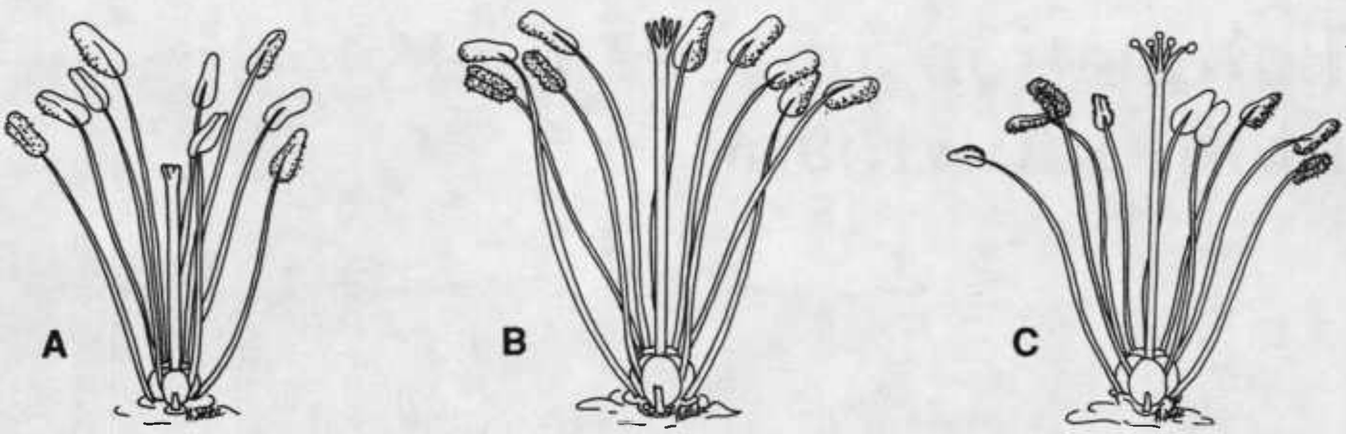

Figure 2.—Sequential reproductive development of a Mermaid meadowfoam flower: **A**. Flower opening with initial pollen availability (dehiscence) and unreceptive stigmas. **B**. Maximum pollen shed with unreceptive stigmas. **C**. Maximum stigmatal receptivity with reduced pollen availability.

The 5 ovaries are located at the base of the style. Each ovary has the potential to produce 1 seed, technically known as a *nutlet*. Before initial flower opening, 5 petals and 5 sepals cover the stamen and pistil.

Once flower opening commences, flower sepals and petals open during the day, exposing the stamens and pistil to potential bee pollinators, and close at night.

Bee visitation is required to start the nightly petal- and sepal-closing mechanism. Flowers on caged plants, lacking pollinator exposure, don't close at night.

Flowers continue to open and close until successful pollination and fertilization; then the petals and sepals permanently close around the reproductive structures.

Meadowfoam pollen is heavy and sticky enough to inhibit wind pollination, thus requiring insects (primarily honey bees) for pollen transport. Within each flower, pollen is shed before the stigmas are receptive (figures 2a and 2b).

This nonsynchronous development of male pollen before the female stigma becomes receptive is called *protandry*, and it can be a period of several hours to 4 days, depending on temperature. Because of protandry, pollen for seed set usually comes from another flower, either on the same or a different plant.

Pollen produced within any given flower is capable of setting seed within the same flower (self-pollination); however, in the field, self-pollination isn't likely because:

- honey bees remove the majority of the flower pollen before stigmatal receptivity; and
- the remaining pollen adheres to stamens that are physically located below the receptive stigmas (figure 2c).

Pollination

The pollination period for meadowfoam ranges from 2 to 4 weeks during May and early June, depending on the weather (figure 3). Individual flowers open for 1 to 4 days, depending on the temperature. Pollination occurs when pollen is inadvertently transferred from the anthers of one or more flowers, by honey bees, onto the stigma or stigmas of a receptive flower.

A study revealed that 1, 6, and 11 honey bee visits to receptive flowers produced an average of 1.6, 2.3, and 3.3 seeds per flower, respectively.

Thus, 6 million flowers per acre X 6 visits per flower = an average demand of 36 million pollination visits per acre during an average day at peak bloom. Therefore, the demand for honey bees is important and warrants close attention.

Pollen germination on a stigma is followed by pollen tube growth down the style into the ovule, where the union of sperm and egg cell results in the embryo formation and potential seed production.

When pollen is abundant, either honey bee pollen foragers or honey bee nectar foragers can successfully accomplish pollination. Pollen-collecting honey bees are most prevalent from about 11 a.m. to 2 p.m., when the majority of available pollen is collected.

Honey bees are found foraging primarily for nectar between 2 and 7 p.m. The daily foraging periods of the pollen- and nectar-collecting honey bees overlap from late morning to early afternoon.

Factors affecting pollination and seed set

Plant

Genetic variability. Individual Mermaid plants in greenhouse and field experiments have averaged from 0 to 5 seeds per flower under adequate pollination. Mermaid plants are genetically variable, resulting in a range of individual plant yield responses within solid stand.

Flower position and timing. Flowering starts at the bottom and proceeds to the top of each stem. The peduncle elongates 1 to 10 inches, pushing the flower bud to the surface of the crop canopy.

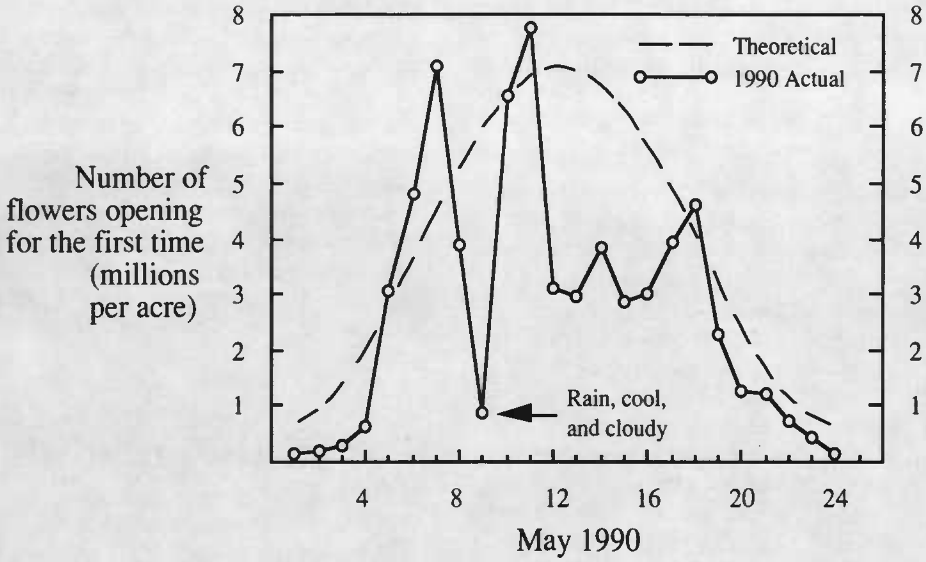

Figure 3.—Mermaid flower opening patterns

The flower then opens and is exposed for pollinator visitation. Younger flowers continually rise above older flowers as the flowering stems and the individual peduncles elongate.

Consequently, throughout the bloom period, the older flowers continually become covered in the canopy of younger flowers. These older flowers are less accessible to honey bees than are the flowers at the top of the canopy. The rate of flower elongation depends on temperature; thus, it's as unpredictable as the weather.

Therefore, it's important to have enough honey bees available, at the proper time, to achieve the desired pollination before large numbers of older flowers are "buried" in the canopy. The first two-thirds of the flowers to open on a stem produce more seeds per flower than the last one-third of the flowers on top of the stem.

Embryo abortion has been observed in individual Mermaid plants. The risk of reduced seed development, by as much as 1 seed per flower over an entire plant, increases with temperatures above 80°F.

Stigmatal receptivity. The stigmas of individual meadowfoam flowers become receptive to deposited pollen at specific times. Pollen deposition before (figures 2a and 2b) or after prime stigmatal receptivity is less likely to maximize seeds per flower than at greatest stigmatal receptivity (figure 2c).

The greater the number of pollinator visitations per flower during the stigmatal receptivity period, the greater the assurance that pollen will be deposited at or near peak stigmatal receptivity, maximizing seed set.

Pollen deposition. The deposition of about 25 viable pollen grains to any or all of the 5 stigmas per flower is required to maximize seed set in Mermaid meadowfoam flowers grown in the greenhouse.

A 2-year field study showed that one honey bee visitation per flower deposited between 15 and 22 pollen grains per stigma, but six honey bee visitations deposited between 43 and 47 grains per stigma.

Though the rate of pollen deposition to maximize seed set in the field hasn't been determined, multiple honey bee visits per flower increase the likelihood of adequate pollen deposition for maximum seed set.

Honey bee

Nutritional requirements. Honey bees require both nectar and pollen to maintain and expand individual hives. The low nectar availability found in Mermaid flowers inhibits honey production, which limits colony maintenance and growth. Pollen for colony growth doesn't appear limiting in meadowfoam.

Canopy penetration. Meadowfoam plants in solid stand grow together, entwining the stems and flowers of adjacent plants. Production practices such as seeding rate, row spacing, and nitrogen fertilization influence the distribution of flower opening over time and flower location in the canopy.

Secondary meadowfoam stem and flower growth may produce a number of flowers below the canopy that have the potential to set seed and increase yield.

The majority of foraging bees don't actively seek out flowers in the depths of the canopy because their movement is restricted by the entwined plants. Increasing the number of foraging honey bees should increase pollination and seed set of these secondary flowers.

Weather

Temperature strongly affects honey bee activity and the day and hour when the plants need to be pollinated. Temperatures below 55°F will hinder flower opening as well as honey bee flight.

In western Oregon, rainfall, low temperature, and low solar radiation typically occur simultaneously. All of these factors contribute to a reduction in the rate of flower opening (figure 3). On a single warm day after inhibited flowering, as many as 8 to10 million flowers per acre may open. The result can be an enormous pollination requirement when those flowers become receptive to pollen.

As temperature rises, there's a tremendous demand for pollen deposition onto the receptive stigma(s) of individual flowers. The prime stigmatal receptivity period may be as long as 24 hours under temperatures below 70°F and as short as 1 hour with temperatures above 90°F.

Wind. At wind speeds greater than 15 to 20 mi/h, honey bee flight and meadowfoam pollination are restricted to areas adjacent to hives.

Managing honey bees

Colony strength and grade

First, if you haven't read PNW 245, *Evaluating Honey Bee Colonies for Pollination: A Guide for Growers and Beekeepers,* do it now!

It explains the critical nature of beehive quality—one Grade A Field colony will pollinate more flowers than two or three weak colonies. Oregon Administrative Rules set the *minimum* standard for pollination colony strength at 25,000 adult honey bees per colony, resulting in about 12,000 total foragers.

Larger colonies are preferred, but they may not be available. Colony strength is often difficult to assess, so using *reputable* beekeepers is highly recommended.

Honey reserves

Honey is the energy source for bee flight. Without adequate honey reserves stored in the hive, pollination deficiencies and colony loss may result. At least 30% of the available frames per hive should contain honey reserves for colony maintenance and pollination strength.

Spacing colonies

Proper hive placement has been shown to increase yields in some crops. During periods unfavorable to foraging, bees tend to work areas close to the hive. On meadowfoam sites greater than 10 acres, a minimum colony spacing of 30 hives every 10 acres should increase pollination and yields, although no data are available to verify this.

Pollination recommendations

Colony numbers

Three hives per acre are recommended to ensure adequate pollination. During long bloom periods with prevalent cool, wet conditions, more than 3 hives per acre may be required to fulfill peak pollination demands.

Timing

Move hives into meadowfoam fields when 5 to 10% of the flowers are in bloom. Introduction at 10% bloom will help to discourage colonies from initially foraging on competing plants, but if you delay introduction past 10% bloom, severe yield reductions may result.

In 1987, caged field studies revealed that 2 days after 10% Mermaid bloom was established, peak bloom occurred. A 1-week delay in honey bee colony introduction would have left 83% of the available flowers opened from 1 to 7 days without pollination.

Because of the way female stigmas age, 50% of the previously unpollinated flowers may not have been able to set seed, a situation that dramatically reduces seed yield.

You can begin removing honey bee hives from the field when less than 5% of the bloom remains.

Competing bloom

Don't plant meadowfoam within 2 miles of commercial acreages of competing crops like crimson clover or a late blooming rapeseed variety. These crops' superior nectar resources will attract honey bees away from meadowfoam—which will drastically reduce pollination.

Weeds commonly in bloom during meadowfoam flowering include the mustards and wild radish. If these plants are present in large numbers, they can directly compete for colony pollination visitations. Cultural or chemical control of these weeds will increase meadowfoam pollination.

Studies in 1981 and 1982 showed that meadowfoam pollen preference within any given honey bee hive dropped off after 2 to 5 days. Pollen collection per colony was increased by replacing existing hives with fresh hives every 5 days. This would be expected to increase pollination and seed set, although it hasn't been tested.

For further reading

Burgett, D.M., Glenn C. Fisher, Daniel F. Mayer, and Carl A. Johansen, *Evaluating Honey Bee Colonies for Pollination: A Guide for Growers and Beekeepers*, Pacific Northwest Extension publication PNW 245 (Oregon State University, Corvallis, 1984). 25¢

Copies of PNW 245, and additional copies of this publication (EC 1360, *Pollination and Seed Set of Meadowfoam*, 50¢), are available from:

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