SEED DISPERSAL IN WILD CARROT (DAUCUS CAROTA)

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While animals and wind have been proposed as agents of seed dispersal for *Daucus carota*, a common weed, no quantitative data can be found in the literature to support either. This paper presents evidence to support both modes of dispersal. Seeds attach to fur coarser than that of rabbit, and also disperse by wind. Spines appear to facilitate both mechanisms. Wind can disperse seeds locally and over long distances and is probably the more frequent dispersal agent.

In spite of the importance of seed dispersal to weedy plants, little information about dispersal vectors is available for *Daucus carota,* a common species of abandoned fields and other disturbed habitats. Evidence for dispersal by animals comes from seeds that have been germinated from excreta of roe deer (Ridley, 1930) and found in horse dung (Salisbury, 1961) and nests of wrens (Ridley, 1930); however, the number of such observations is unknown. Also, *D. carota* seeds make up 0.5–2% of the diet of Ruffed Grouse, Ring-necked Pheasant, Pine Mice, and Cotton Rats in the northeastern United States and 2–5% of the diet of the Townsend Mole in Washington and Oregon (Martin et al., 1951). Most evidence for animal dispersal comes from observations on fruit morphology. Stebbins (1971) stated that *Daucus* has evolved a fruit with hooks and spines that aid in dispersal by animals, and Salisbury (1961) indicated that because of curved spines on the ribs of the fruit, the seeds of *D. carota* are often spread by animals. The implication is that seeds are unintentionally transported on animal fur and on clothing, although no data support this conjecture. Dale (1974) reported that, in addition to animal dispersal, seeds can be blown for short distances by wind, or long distances over crusty snow, but again no supporting evidence was given. This paper presents observations on fruit morphology and experiments designed to test the efficacy of wind and animals as dispersal agents for *D. carota.*

Daucus carota, commonly called Queen Anne's Lace or Wild Carrot, has spread across the continent in northern United States and southern Canada and as far south as the Georgia Piedmont in the eastern United States since its introduction from Europe. North American populations and some European populations belong to the informal group "subspecies aggregate" *carota* (Small, 1978).

In southeastern Michigan, *D. carota* disperses fruits from late August through the winter. The fruits, which are borne on compound umbels (Fig. 1), usually split into two one-seeded mericarps which disperse separately. The mericarp separates from the carpophore, first in the middle and subsequently from either the base or the tip. (Because each mericarp contains one seed, I will, for simplicity, refer to seed dispersal rather than mericarp dispersal.) Four rows of large spines project from a mericarp, and one to several barbs may be found at the tip of each spine. The number of barbs per spine may vary from one to

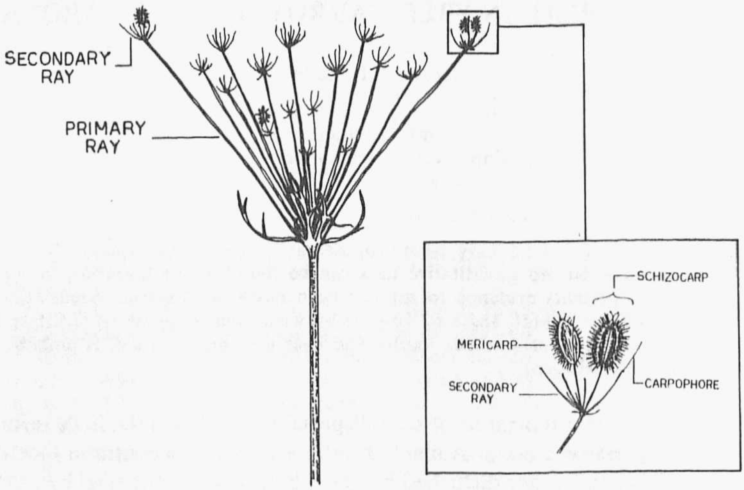

Fig. 1. A compound umbel. (A mericarp is one half of a schizocarp.)

five (Fig. 2–5), and associated with the number of spines is a characteristic angle. The mean angle formed by the barbs and spine is $\leqslant 90°$ for spines with four or five barbs (Fig. 2 & 3). The mean angle for spines with two or three barbs is $\sim 90°$ (Fig. 4) and for spines with one barb $\geqslant 90°$ (Fig. 1). Although plants that I sampled have predominantly one barb per spine, the number varies among individual plants (Table 1). That found in 15 European specimens I examined is lower than the 3–5 barbs per spine reported by Heywood & Dakshini (1971) for European populations.

The presence of barbs, especially more than one per spine, and the presence of spines on mericarps suggest that seeds might be dispersed by animals. To examine the effectiveness of animal dispersal, I dropped seeds onto the fur of live field and meadow mice (*Peromyscus leucopus, P. maniculatus,* and *Microtus* sp.) and a raccoon and also onto prepared skins of badger, skunk, and rabbit to see how well the seeds would stick. Seeds did not stick to the rabbit or mice fur because of the fine and thin nature of the fur. Seeds lodged in the coarse hair of the raccoon, badger, and skunk and could be removed only by deliberately picking them up.

An alternative hypothesis about the function of spines and barbs is that they decrease the rate of fall of seeds through air and that seeds are dispersed by wind. To examine this possibility, I conducted experiments to compare dispersal distances of seeds that were intact, barbless, or spineless. To compare intact and spineless seeds, I selected 60 seeds whose spines appeared to the naked eye to be present and in good condition. The seeds were divided without regard to size or shape into two samples of 30 seeds. One sample was rubbed between the hands to remove all spines, and the other sample was left intact. Independently, I placed each sample on a piece of cardboard directly in front of

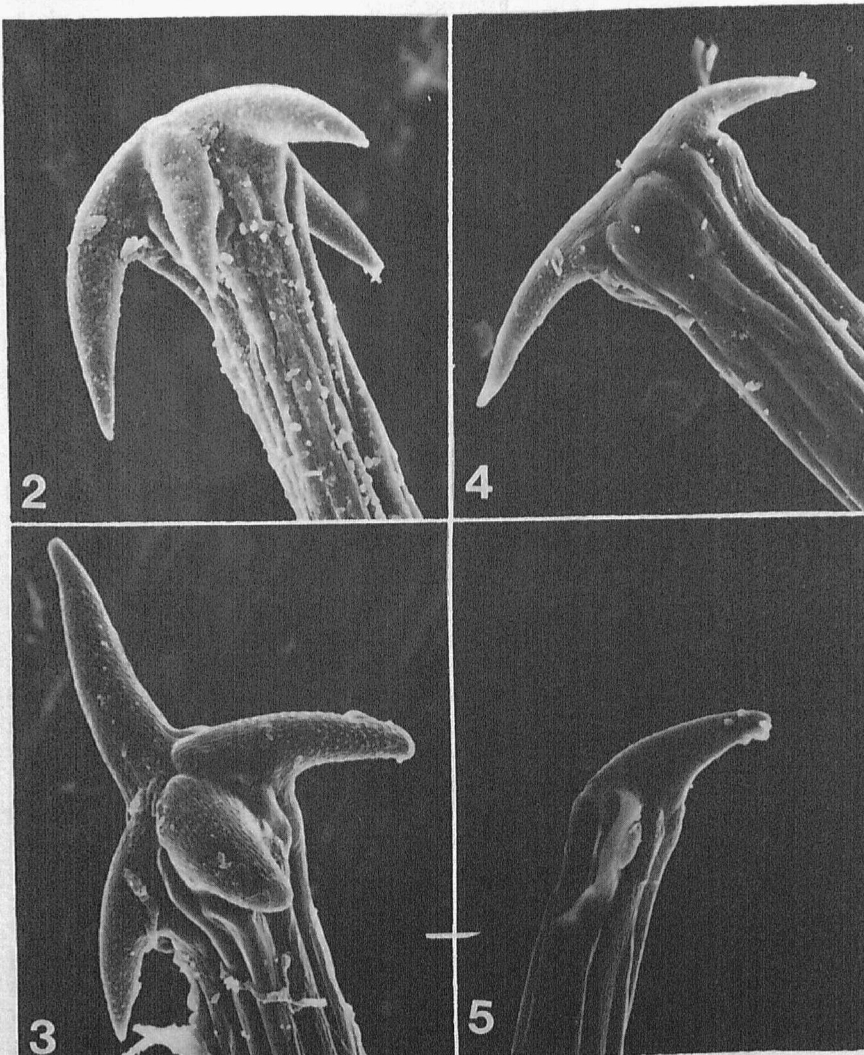

Fig. 2–5. Examples of barb number and orientation on spines of *Daucus carota* seeds. 2–3. Mean angle of barbs $\leqslant 90°$ for 4 or more barbs per spine, $\times 768$ and $\times 664$, respectively. 4. Mean angle of barbs $\sim 90°$ for 2–3 barbs per spine, $\times 676$. 5. Mean angle of barb $\geqslant 90°$ for one barb per spine, $\times 569$.

TABLE 1. Variation in barb number per spine in individuals of *D. carota* from North America and Europe.

	Barbs per Spine			
	1 barb >66%	1–2 barbs >66%	3–5 barbs >66%	intermediate number or highly variable
North America				
United States (Calif., Wis., Mich., N.C.)	12*	8	1	4
Canada (N.S., N.B., Que., Ont., B.C.)	16	2	3	3
Europe				
(France, Belgium, Denmark, Romania, Sweden, Portugal, Italy, Germany)	6	0	2	7

*number of individual plants

a window fan on the floor. I held the cardboard 0.42 m above the floor and initially protected the seeds from the force of the wind (with a velocity of 4 mph) by holding vertically a second piece of cardboard between the seeds and the fan. When I removed the vertical piece of cardboard, the seeds dispersed onto the cheesecloth spread on the floor in front of the fan. I then recorded the distance from each seed to the fan. This experiment was replicated three times. On the average, spineless seeds (mean distance = 0.33 m) went only two-thirds as far as the intact seeds (mean distance = 0.45 m), even though the spineless seeds weighed less (mean weight of intact seeds = 1.12 mg; mean weight of spineless seeds = 1.01 mg). A Kolmogorov-Smirnov test (Siegel, 1956) indicated that the difference in distribution was highly significant ($D = 0.36$, $p < .001$).

To compare intact with barbless seeds, I selected 22 seeds whose spines and barbs appeared to be intact when viewed under a dissecting microscope at high power. Only seeds that had many spines with three or more barbs were chosen. I measured the dispersal distance for the intact seeds in the same manner as in the previous experiment. I then soaked the seeds in water for a few minutes to soften the spines and thus to reduce the damage while removing the barbs. Using the dissecting microscope and scissors I cut off the barbs; although I tried to minimize spine loss, in most cases a bit of spine was removed as well. After letting the seeds dry, I remeasured the dispersal distance. The intact seeds (mean distance = 0.53 m) went slightly farther than the barbless seeds (mean distance = 0.49 m). A Mann-Whitney U-Test (Siegel, 1956) indicated that the difference was just barely significant ($Z = 1.68$, $p = .0465$).

To examine wind dispersal under natural conditions, I conducted outdoor experiments in fall and winter. Information on fall dispersal comes from two experiments in which seeds dispersed from isolated plants stuck in the ground which was covered with blankets and cheesecloth to catch the seeds (Lacey, 1978). Mean distances were 2.06 m and 2.43 m, and no seed was found farther than 6.25 m from the plant even though the material on which the seeds were caught extended at least one meter beyond the farthest seed collected. During the time of dispersal the mean wind speed was 6–7 mph with gusts to 16 mph as measured by a continuously recording anemometer. In fall 1975 I constructed a cage of chickenwire (1.52 X 1.53 X 1.52 m) and set it over several carrot plants to observe seed disappearance in an environment where mammals larger than mice were excluded. (These plants were growing on the George Reserve where a deer population is maintained.) The small number of plants prevented the collection of quantitative data; however, plants inside and outside the cage appeared to lose seeds at a similar rate.

I gathered information about dispersal in winter over snow on three windy days by laying seeds on the snow to observe how far they moved over the surface. I observed seeds moving over both crusty and powdery snow when the wind exceeded 12 mph. On a day of winds 15–25 mph I laid cheesecloth (3.66 X 0.91 m) against an upright fence bordering a softball field and released 300 seeds sixteen meters upwind. All seeds disappeared from my hand as soon as I released them, and 37 were collected in the cheesecloth. Because of shifting winds the other seeds probably were blown out of the range of the cheesecloth and consequently traveled much farther.

Morphological and experimental evidence thus indicates that *D. carota* seeds may be dispersed by wind and on animals. Seeds can be transported on the coat of mammals with fur coarser than that of rabbits. I have also transported seeds myself on wool clothing and occasionally in cuffs of jeans. The spines and barbs undoubtedly facilitate this dispersal. However, spines also aid in wind dispersal by decreasing the rate of fall of seeds in air. The barbs have little effect, if any, on this fall rate. The fact that intact seeds dispersed only slightly farther than barbless seeds might be attributed to the removal of spine material when the barbs were removed.

An aspect of dispersal that is often overlooked is that there may be selection not for just one mode of dispersal but for several modes of dispersal particularly in environments where presence of any one vector may be unpredictable. For example, morphological structures may evolve that facilitate several types of dispersal. The dual role of spines in *D. carota* illustrates this point.

Any conclusions drawn from this study regarding the relative importance of animals and wind as dispersal agents are speculative. Quantitative data on patterns of animal movement through old fields, grooming behavior, and abundance of animal dispersers are lacking. Animals most often encountered in the eight fields where I collected demographic data in 1976 and 1977 were rabbits, deer, and mice; I also saw two badger mounds. Mice and rabbits do not have fur coarse enough to retain seeds for dispersal. No doubt badgers, deer, dogs, and humans pick up seeds; however, the seed number is probably minuscule in proportion to the millions of seeds produced in one carrot population. While I could pick up a few dozen seeds by walking through a dense patch of carrots, one plant can produce from several hundred to more than 15,000 seeds (Lacey, 1978). The few trails that appeared to be made by animals (such as deer) skirted rather than penetrated the dense patches of carrots, which become tough and scratchy on dying. These observations suggest that while animals do disperse seeds, wind is probably the more frequent vector. This is further supported by the absence of differences in seed disappearance from caged and uncaged plants.

Forces favoring a particular dispersal mechanism in *D. carota* may not be the same over its entire range especially because of its recent expansion into North America. Reported evidence for animal dispersal appears to come from observations of European plants; while animal dispersal may be most important in Europe, wind dispersal may be more important on this continent. If this is true, one would predict an eventual decrease in barb number per spine in American populations; my data are consistent with this possibility, though the European sample size is small. It will be interesting to see if in the future dispersal behavior of North American populations diverges from that of European populations.

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