Comparison of Pollen Collected by a Honey Bee Colony with a Modern Wind-dispersed Pollen Assemblage

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Forty-six pollen types found during 1976 in Honey Bee (*Apis mellifera*) pellets from a single hive in southern Ontario showed a seasonal pattern related to pollen availability. Honey Bees collected pollen from both native and introduced plants. They concentrated on anemophilous (wind-pollinated) forest trees, entomophilous (insect pollinated) fruit trees and early-blooming entomophilous herbs in the spring; later in the season they collected from entomophilous forage crops, weeds, and shrubs that grow in disturbed habitats. The pollen assemblage from lake mud was dominated by anemophilous taxa. This assemblage is compared to the local pollen present in bee pellets.

Key Words: pollen, Honey Bees, Ontario, season, entomophily, anemophily, pollen rain.

Honey Bees (*Apis mellifera*) collect pollen as a source of protein for raising broods and to supplement a diet of nectar and honey (Free 1970; Stanley and Linskens 1974). While collecting pollen, Honey Bees pollinate many agricultural crops. They have been associated with agriculture for at least the past 2300 years (Geroulanos 1973) and were introduced into southern Ontario by late 18th or early 19th century settlers (Jones 1946), who also introduced fruit trees, vegetables, forage crops, and weeds (Ontario Agricultural Commission 1881).

In both Europe and North America, general knowledge of insect pollination (entomophily) is enhanced by the study of pollen collection by Honey Bees (Maurizio 1949; Maurizio and Louveaux 1967; Synge 1947; Lieux 1972, 1975; McLellan 1976) and by solitary bees (Heinrich 1976).

We provide here illustrations of pollen collected by Honey Bees in southern Ontario as an aid to future study and we document the seasonal trends of pollen collection observed during 1976. The number of taxa and the percentage of each taxon are compared with the surface pollen assemblage of a nearby lake. To our knowledge, this is the first documentation of seasonal Honey Bee pollen collection in southern Ontario and the first quantitative comparison of Honey Bee collection and the atmospheric pollen rain from a specific area. This comparison requires the distinction between dispersal mechanisms and floral adaptations such as anemophily (wind pollination) and entomophily (Faegri and van der Pijl 1971), since floral adaptation does not limit pollen dispersal to only one vector such as wind or insects.

Methods

The study hive was located in the Campbell Bee Yard near Brantford, Ontario at 43° 10′N, 80° 18′W. Brantford is located in the deciduous forest region (Rowe 1972). The size of a Honey Bee foraging area (Free 1970) is within 1.6 km (1 mi) of the colony. Present land use in the study area is about 75% pasture and cultivated land and 5 to 10% woodlands; 15 to 20% of the area is taken up by urban development and roads (Canada Surveys and Mapping Branch 1974). These percentages are unlikely to have changed appreciably between the date of the survey and that of our study.

Pollen pellet samples were taken from the colony with a pollen trap consisting of a cloth pellet-collecting tray at the base of the trap, two layers of screening with four openings in 2 cm (five meshes per in.) above the tray and a single upper layer of screening with five openings in 2 cm (six to seven meshes per in.). The upper screen removed pellets from the corbiculae or pollen baskets on the bee's rear legs. The lower two layers prevent complete pellet retrieval by the bees, although they are still able to carry 20 to 30% of the pellets into the hive. The entire trap is installed between the standard floorboard of the hive and the upper portion (supers) of the hive so that the trap entrance replaces the original hive entrance (Smith and Adie 1963). The trap was used for one day each week and then removed to allow the bees unimpeded access to the hive. Trapping began 18 April and ended 1 October. Although the bees may have collected pollen before and after these dates, this period is the major collection time. In mid-season at the peak of the pollen flow as much as 500 g of pollen may be collected by one bee colony (Smith and Adie 1963).

Variation in pellet color, size (from 1 to 4 mm diameter), shape, and texture have previously been used to determine the pollen types present and their percentages (Synge 1947; McLellan 1976). We used an alternate method to ensure a representative sample of each day's pellet collection by dispersing a 50-mL pellet sample in 350 mL of water with frequent stirring. A 0.5-mL sample of the resulting suspension was diluted until nearly clear, centrifuged, and decanted. The pollen walls were then chemically cleaned by acetolysis and mounted in silicone oil (Faegri and Iversen 1975) for microscopic examination. For each sample a minimum of 300 pollen grains was identified and counted, and the percentage frequency calculated.

Reference pollen was collected from flowers of plants in bloom within 2 km of the colony. This pollen was also treated with acetolysis and compared to unknowns in the pellet samples. Microscopic examinations were at 400-diameter magnification. Photomicrographs were taken with a Zeiss Ultraphot II using Kodak High Contrast Copy film. All photomicrographs were enlarged to 1000×.

Pollen from the surface mud of Pinehurst Lake at 43°55′N, 81°02′W and 10 km (6 mi) northwest of the bee yard was examined after sediment preparation (Faegri and Iversen 1975) to compare wind-dispersed pollen with that collected by Honey Bees.

Results

Forty-six taxa were found in pellets during the 1976 season. Major components are pollen taxa with 10% or more for at least one day; secondary components range from 1 to 10% and minor components are less than 1%. The major components (Figure 1), include *Acer* (maple),

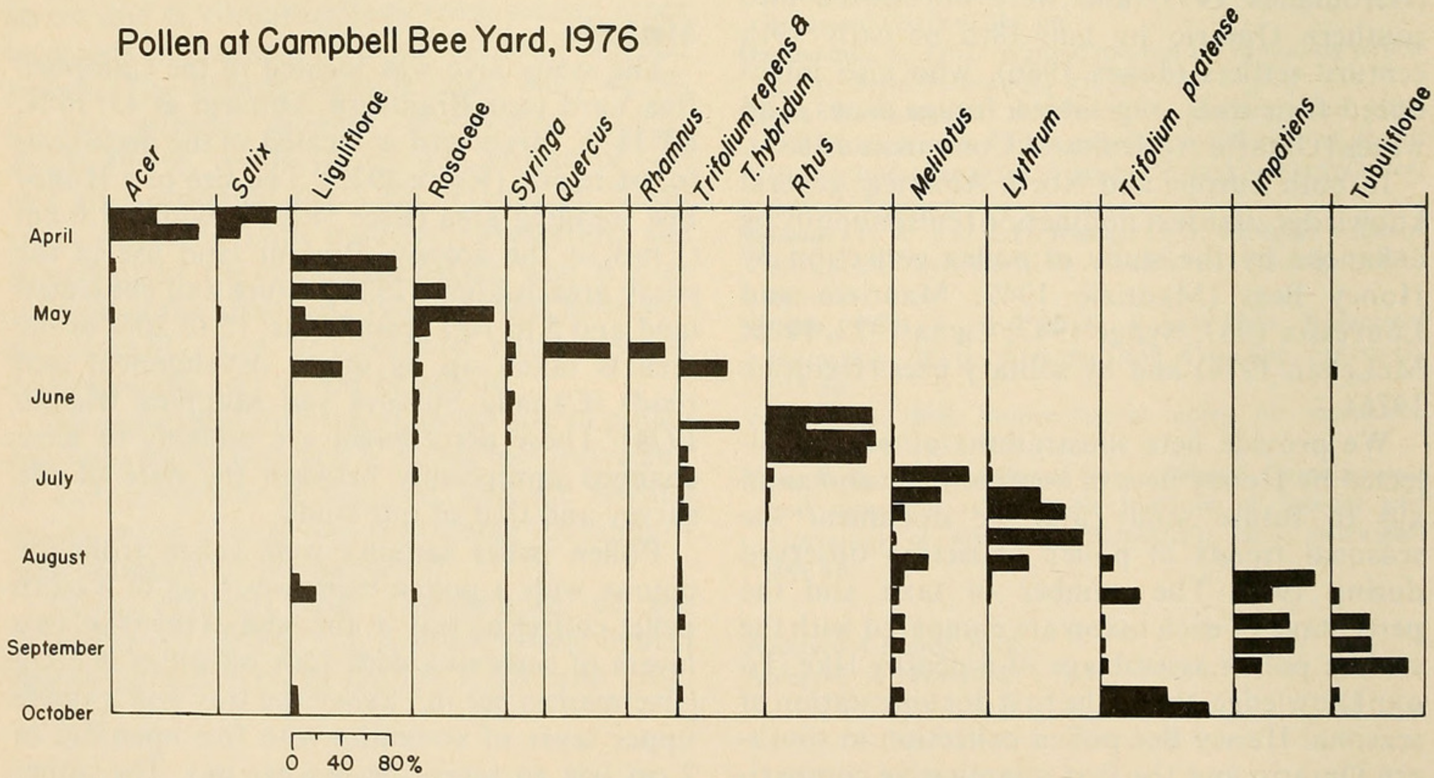

FIGURE 1. Seasonal progression of the major and secondary pollen components in Honey Bee pellets from Campbell Bee Yard, southern Ontario. The shaded areas indicate months.

Salix (willow), Liguliflorae (dandelion, lettuce, chicory), Rosaceae (plums, cherries, hawthorn, apples, pears, and roses), *Quercus* (oak), *Rhamnus* (buckthorn), *Trifolium repens* (White Clover), *T. hybridum* (Alsike Clover), *T. pratense* (Red Clover), *Rhus* (sumac), *Melilotus* (sweet clover), *Lythrum* (loosestrife), *Impatiens* (jewel-weed), and Tubuliflorae (goldenrod, yarrow, etc.).

The secondary components (Figure 1, Table 1) were *Syringa* (lilac), *Symplocarpus* (skunk cabbage), Ranunculaceae (buttercups), *Lonicera* (honeysuckle), *Aesculus* (horse chestnut), *Cornus* (dogwood), *Hamamelis* (witch hazel), Cruciferae (mustards), Liliaceae (lilies), *Sambucus* (elderberry), Umbelliferae (carrots, Queen Anne's lace, etc.), *Medicago* (alfalfa), *Lupinus* (blue-bonnet), Labiatae (mints), and *Arctium* (burdock).

The minor components (Table 1) include Onagraceae (evening primrose, fireweed), *Ribes* (currant), Gramineae (grasses), *Thalictrum* (meadow rue), *Elaeagnus* (Russian olive), *Lotus* (trefoil), *Vicia* (vetch), *Echium* (blueweed), *Lespedeza* (bush clover), *Catalpa* (catalpa or Indian bean), *Saponaria* (soapwort), *Plantago* (plantain), *Echinocystis* (wild cucumber), Caryophyllaceae (pinks, chickweeds), and *Cirsium* (thistle).

Identification of Pollen from Pellet Samples

Useful comprehensive guides to pollen identification and the terms used to describe pollen grains are presented by Faegri and Iversen (1975) and Kapp (1969). An illustrated key to fossil pollen that occurs in lake sediments of the Great Lakes region (McAndrews et al. 1973) emphasizes primarily wind-dispersed pollen rather than those taxa gathered by insects. Some taxa such as *Acer* and *Quercus* appear both in bee pellets and in lake sediment.

Photomicrographs (Figures 2, 3, 4) show the major and distinctive taxa found in bee pellets during 1976. Other taxa that may occur can be tentatively identified with the guides cited above. Collection of reference pollen and records of flowering times for plants growing in the foraging area are also useful in identification of unknowns.

The major characteristics used in pollen identifications are number, position and shape of apertures, wall sculpture, grain shape and grain size. Pollen found in bee pellets may have one to four or more furrows (Figures 2d, e, f, and 4f), furrows with equatorial pores (Figure 3a), a combination of simple furrows and furrows with pores (Figure 2l, m, n) or four or more pores regularly spaced over the surface (Figure 2j). Further, the surface sculpture of pollen grains may be smooth (Figure 2f), or may have radial projections (Figures 3b, and 4f, j), striations (Figure 3l, m), a reticulum or network (Figure 2b, c, n, o), or depressions in the outer pollen wall (Figure 2h). The shape in side or equatorial view varies from spherical, with the polar axis larger than the equatorial diameter or with the equatorial diameter larger than the polar axis. The shape of pollen grains in polar view may be circular, triangular, rectangular, or hexagonal. The combination of such characters provides information for identification of pollen grains to family, genus or even species, eg. Leguminosae (Adams and Smith 1976). Although it is possible to separate Rosaceae into genera and species, we have not done so here. Compositae is divided into two major groups, Tubuliflorae and Liguliflorae, but more refined generic identifications are possible.

Comparison of Pollen Presence and Frequency

At the beginning of each season, the overwintering bees retain the ability to forage from productive pollen and nectar crops. Thus they begin the year's collecting in early spring by exploratory foraging on any potential crop, sometimes erring by collecting small particles such as dust and fungal spores that lack nutritional value (Stanley and Linskens 1974).

Figure 1 shows the seasonal progression of major pollen taxa collected by Honey Bees during 1976. In southern Ontario, the earliest pollen collections are from anemophilous forest trees and early-blooming entomophilous herbs. Pollen of the entomophilous rose family is abundant, as is the early-blooming dandelion (*Taraxacum* of the Liguliflorae). *Rhus* replaces *Trifolium repens* and *T. hybridum* in mid-June; *Trifolium* again dominates pellet collections in late June, with *Rhus* as a minor component.

Trifolium pratense bloomed shortly after *T. repens* and *T. hybridum*, but did not appear continuously in pellets until mid-August along with *Lythrum, Impatiens*, and Tubuliflorae. *Trifolium pratense* was then abundant until the

TABLE 1—Percentages of secondary and minor components of pollen pellet analysis

Collection day	*Symplocarpus*	Ranunculaceae cf. *Caltha*	*Lonicera*	*Aesculus*	*Cornus*	Onagraceae	*Ribes*	Gramineae	*Thalictrum*	*Elaeagnus*	*Lotus*	*Vicia*	*Tilia*	*Viburnum*	*Echium*	*Lespedeza*
April 18	4.1	1.3														
29		5.0														
May 9		2.1														
16		4.4														
22		0.8	1.4	4.4												
29			0.2	1.9												
June 4					0.5											
12					6.8	0.4										
21					2.4	0.4	0.1	0.2	0.4	0.4	0.1	0.1				
28								0.3		0.2	0.2		0.2			
July 4								0.4	0.5				0.4	0.1		
11																
18												0.2			0.2	0.2
25																
Aug 1																
10																
16																
22																0.2
Sept 1																
8																
15																
22																
Oct 1																

Collection day	*Catalpa*	*Plantago*	*Hamamelis*	*Echinocystis*	Cruciferae	Liliaceae	*Sambucus*	Umbelliferae	Caryophyllaceae	*Medicago*	*Cirsium*	*Lupinus*	Labiatae	*Arctium*	*Althaea*
April 18					0.5	10.7									
29															
May 9					2.5										
16					0.9	0.1	12.4								
22					2.6		7.8								
29					4.4										
June 4									0.1						
12					0.5			0.5							
21					1.0			0.5		4.6					
28					0.6		1.1			0.5					
July 4					3.9		0.8			0.5					
11					0.3					5.5	0.5	1.8			
18					1.3				0.2	5.7	0.6	3.0	0.7		
25					3.7				0.2	1.5		0.2	0.3	3.8	
Aug 1	0.3					8.6				1.3		0.3	2.2	5.8	
10						1.8		2.2	0.7					2.3	
16					1.5	0.7		0.3	0.6	5.0				0.2	
22		0.3			0.2			1.0	0.2	3.4		0.5			
Sept 1															
8					0.5					0.2					
15										0.9					
22			1.2			2.4			0.6		0.3	7.5		0.6	
Oct 1				0.2	0.2	0.5						0.9	0.2		0.2

FIGURE 2. Pollen from spring pellet collections: a, *Symplocarpus* (skunk cabbage) equatorial view (ev); b, c, *Salix* (willow) ev; d, *Acer* (maple) ev; e, *Acer* polar view (pv); f, liliaceae (lilies) ev; g, Ranunculaceae, c.f., *Caltha* (marsh marigold) oblique view (ov); h, liguliflorae, c.f., *Taraxacum* (dandelion) pv; i, *Sambucus* (elderberry) ov; j. Cruciferae (mustards) pv; k, Rosaceae, c.f., *Pyrus* (apples, pears) pv; l, Rosaceae, c.f., *Prunus* (plums and cherries) ov; m, Rosaceae pv; n, *Syringa* (lilac) ov; o, *Syringa* pv; p. *Lonicera* (honeysuckle) ov.

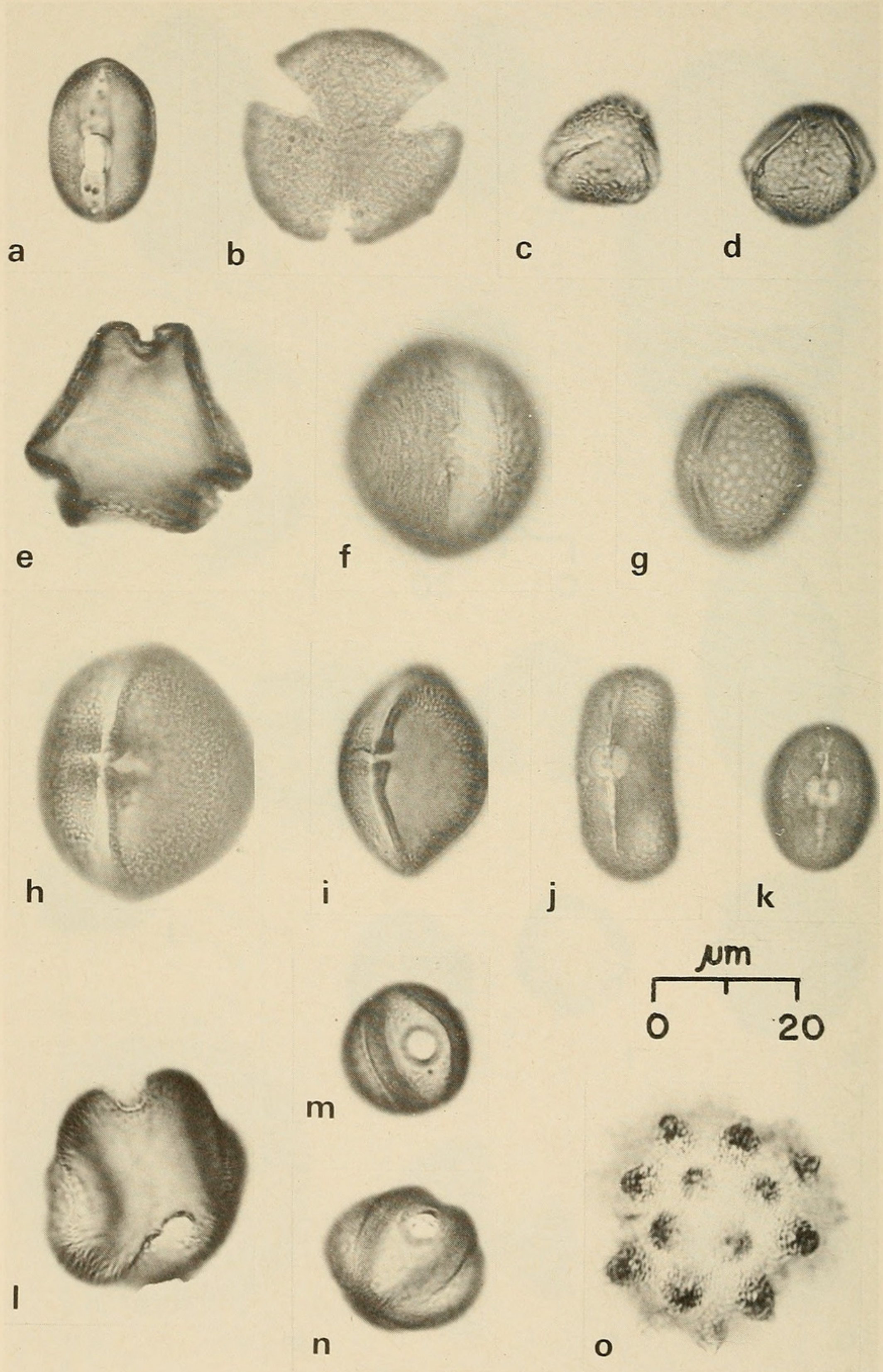

FIGURE 3. Pollen from spring and summer pellet collections: a, *Aesculus* (horse chestnut) ev; *Quercus* (oak) pv; c, *Rhamnus* (buckthorn) ov; d, *Rhamnus* ev; e, *Cornus* (dogwood) pv; f, Rosaceae, c.f., *Crataegus* (hawthorn) ev; g, *Trifolium hybridum* (Alsike Clover) ev; h, *Rhus*, c.f., *typhina* (Staghorn Sumac) ev; i. *Rhus*, c.f., *radicans* (Poison Ivy) ev; j, k, *Melilotus* (sweet clover) ev; l, *Lythrum* (loosestrife) ov; m, n, *Lythrum* ev; o, *Circium* (thistle) pv.

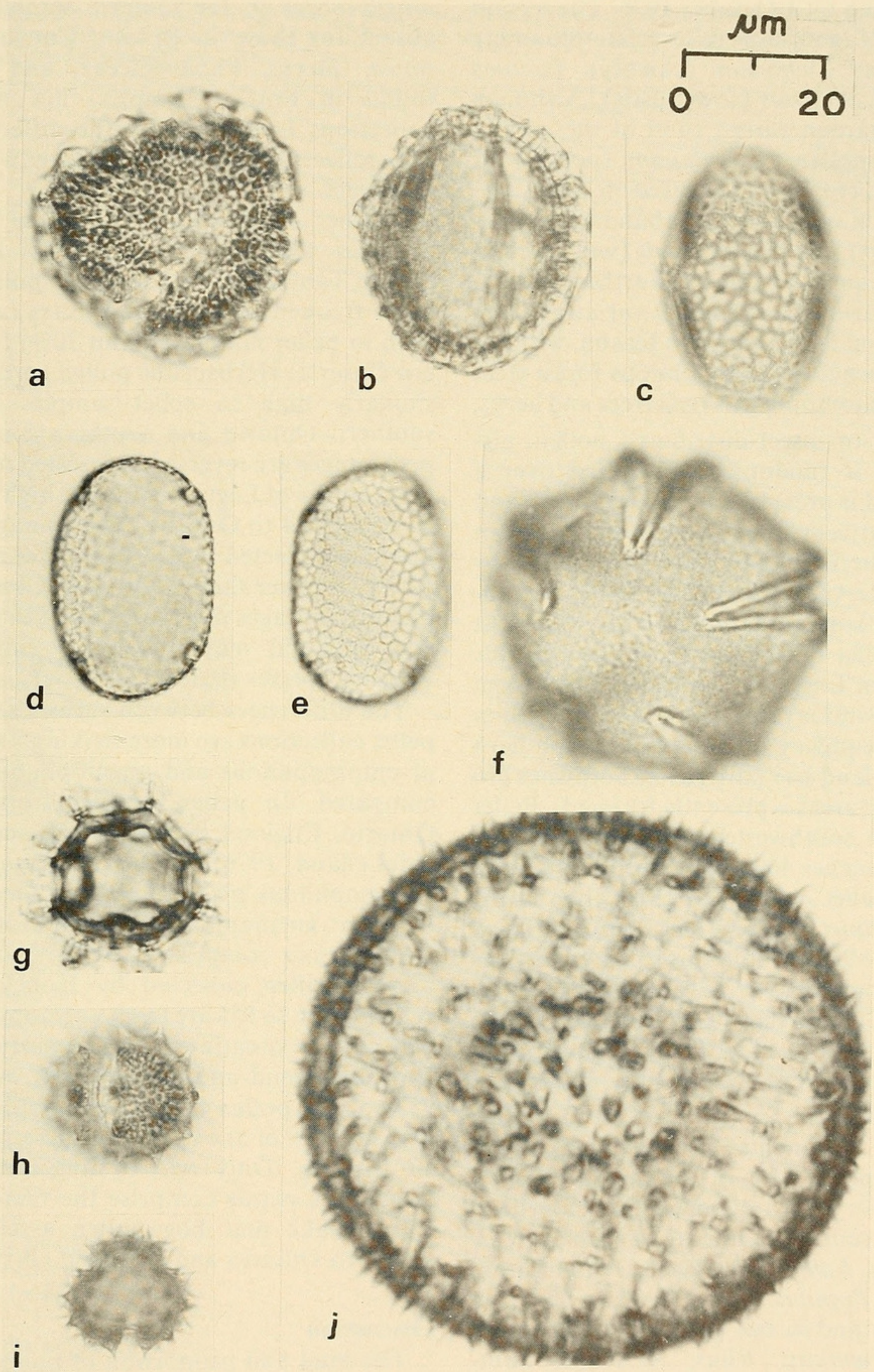

FIGURE 4. Pollen from summer and fall pellet collections: a, *Arctium* (burdock) ov; b, *Articum* ev; c, *Trifolium pratense* (Red Clover) ev; d, e, *Impatiens* (jewel-weed) pv; f, *Echinocystis* (wild cucumber) ov; g, Liguliflorae, c.f., *Cichorium* (Chicory) ov; h, Tubuliflorae, c.f., *Chrysanthemum* (ox-eye daisy) ev; i, Tubuliflorae, c.f., *Solidago* (golden-rod) pv; j, *Althaea* (hollyhock) ov.

end of sampling on 1 October 1976. The second occurrence of Liguliflorae reflects late-blooming weeds such as *Cichorium* (chicory), *Lactuca* (lettuce), and *Sonchus* (sow thistle). Although there was a garden within 10 m of the apiary, virtually no pollen of *Solanum* (potato) or *Lycopersicum* (tomato) appeared in pellet collections. Pollen of the locally abundant *Saponaria* (soapwort) and *Echinocystis* (wild cucumber) was infrequent (Table 1). Further study in southern Ontario will document variation from hive to hive and from season to season, with the expected sequence of anemophilous forest trees followed by entomophilous fruit trees and herbs.

In contrast to insect-distributed pollen, airborne pollen is randomly distributed over a wider area and is preserved in lake sediment and bog peat. Relative frequencies of airborne pollen found in southern Ontario were documented by Webb and McAndrews (1976). Table 2 compares a mud-surface sample from Pinehurst Lake with pellet data from the Campbell Bee Yard and from England. The pellet study from southern England is remarkably similar both in the relative frequency of woody-plant and herb pollen and in land-use patterns at both sites (10 to 15% of both areas is presently forested). Pellet studies from southwestern Scotland, where forest cover reaches 40%, have different taxa in Honey Bee pellet collections (McLellan 1976) and include *Pinus, Picea, Abies, Alnus, Ostrya,* and *Fagus* — all anemophilous forest taxa. Pollen of anemophilous herbs (*Ambrosia, Artemisia,* the Cyperaceae, and *Rumex*) rarely occurs in bee pellets, even if the proportion of open or arable land where the plants are abundant is large.

In surface sediments of Pinehurst Lake, *Quercus* comprises 22% of the pollen counted and *Betula* 7%; both taxa occur in bee pellets, but in low percentages. Other taxa such as *Acer, Juglans, Tilia, Salix,* Gramineae, Tubuliflorae, Liguliflorae, *Populus,* and *Plantago* occur in lake sediment and in bee pellets in comparable amounts. *Rhamnus, Rhus, Aesculus, Sambucus, Cornus, Lythrum,* Leguminosae, Rosaceae, Liliaceae, *Impatiens,* Ranunculaceae, Cruciferae, Umbelliferae, Cucurbitaceae, Onagraceae, and *Hamamelis* are found only in bee pellets; of these, *Rhamnus, Rhus, Sambucus, Cornus, Impatiens,* Umbelliferae, and *Hamamelis* occur in the Ontario samples, but are absent for those in Britain. Conversely, *Castanea, Buxus,* Papaveraceae, and *Viola* are found in English samples, but not in the collections from Ontario; the difference probably reflects opportunity rather than inclination to collect.

Further comparison of tree and shrub percentages with the percentages of herbaceous taxa in Table 2 shows that woody pollen taxa are more frequent in airborne spectra (about 70%) than in pellet samples (about 30%) from southern Ontario. Herbaceous pollen percentages are similarly high in pellet samples both from southern Ontario and southern England. The percentages are reversed in forested regions. The percentages of Leguminosae are high in England as compared to Ontario. The average of Leguminosae collected in Scotland (McLellan 1976), 14.9%, is lower than in Ontario. Comparatively high percentages of Cruciferae both in England and Scotland may reflect the cultivation of *Brassica* species (kales).

The differences between surface samples and pellet collections are more striking if the number of entomophilous and anemophilous taxa are compared. In pellet samples from southern Ontario, England (Synge 1947), and Scotland (McLelland 1976), 20 to 40 taxa are from entomophilous plants and from three to seven taxa are anemophilous. Pollen from entomophilous taxa comprise 91 to 95% of the total annual pollen collected by Honey Bees; the remaining 5 to 9% are from anemophilous taxa. The reverse situation occurs in surface samples from lake mud and bog surfaces, where 94 to 95% of the pollen is from anemophilous taxa. The number of anemophilous taxa ranges from 17 to 21%. Only two to five taxa of entomophilous plants comprise the remaining 5 to 6% of lake and bog pollen assemblages in southern Ontario and Scotland (Birks 1972).

Discussion

The kind and proportion of pollen in Honey Bee pellets vary from place to place depending upon the flora available as determined by land use within a foraging area. The variation expected from hive to hive and from year to year in any one location depends upon the collective foraging of any one hive and on pollen avail-

TABLE 2—Comparison of percentage frequencies of pollen from lake sediments and from annual collections of bee pellets. E4 and K5 are separate but adjacent hives studied during the same year. A plus sign (+) indicates less than 1%; an asterisk (*) indicates entomophilous taxa

	Southern Ontario		England (from Synge 1947)	
	Pinehurst Lake	Campbell Bee Yard	E4	K5
Quercus (oak)	22	2	1	
Pinus (pine)	13			
Betula (birch)	7			1
Ulmus (elm)	6		1	1
Acer (maple)	4	5	2	2
Fagus (beech)	4			
Fraxinus (ash)	3		2	2
Ostrya (ironwood)	3			
**Salix* (willow)	2	3	+	2
Cupressineae (cedar, juniper)	2			+
Picea (spruce)	1			
Tsuga (hemlock)	1			
Alnus (alder)	1			
Abies (fir)	+			
Juglans (walnut)	+	+		
**Tilia* (basswood, linden)	+	+		
*Rosaceae (fruit trees, roses)	+	5	17	17
**Rhus* (sumac)		13		1
**Rhamnus* (buckthorn)		1		
**Sambucus* (elderberry)		1		
**Aesculus* (horse chestnut)		1	1	+
**Cornus* (dogwood)		+		
Populus (aspen, poplar)		+	2	3
**Buxus* (boxwood)			+	1
Castanea (chestnut)			+	+
Woody pollen total	72	33	27	30
Ambrosia (ragweed)	12			
Gramineae (grasses)	7	+		1
Cyperaceae (sedges)	2			
Rumex (sorrel, dock)	2			+
*Leguminosae (legumes)		25	59	49
**Lythrum* (loosestrife)		10		
*Liguliflorae (dandelion, etc.)	+	10	2	4
**Impatiens* (jewel weed)		9		
*Tubuliflorae (goldenrod, etc.)	+	8	+	2
Artemisia (sage)	+			
Chenopodiineae (goosefoot)	+			
*Cruciferae (mustards, kales)		1	6	7
*Onagraceae (fireweed)		+	1	2
Plantago (plantain)	+	+		1
*Liliaceae (lilies)		1	+	1
*Ranunculaceae (buttercups)		1	+	1
*Cucurbitaceae (cucumbers)		+	1	1
*Papaveraceae (poppies)			1	+
**Viola* (violet)			+	1
*Umbelliferae (parsley, etc.)		+		
**Lonicera* (honeysuckle)		+		
**Symplocarpus* (skunk cabbage)		+		
*Saxifragaceae		+		
*Scrophulariaceae			+	+
Herbaceous pollen total	27	66	72	70

ability. Pollen availability is determined by the phenology of any plant taxon and plant response to weather conditions. Anthropogenic factors such as harvesting or weed eradication also affect pollen availability.

Bees forage on available pollen sources regardless of the floral adaptations that distinguish certain flowers as "bee flowers." We have observed bees collecting from such anemophilous taxa as *Populus tremuloides* (aspen), *Ambrosia* (ragweed), and *Quercus* (oak) in other parts of North America. Taxa considered as anemophilous (Faegri and van der Pijl 1971) on the basis of floral morphology are collected by bees. Anemophilous forest taxa are more numerous in bee pellets where forest cover is greater although their percentages are low (about 9%). In southern Ontario and southern England, where entomophilous crops and weeds of Eurasian origin dominate the rural landscape, bees collect pollen from anemophilous taxa in early spring before the entomophilous taxa flower.

The combined study of wind-dispersed pollen and pollen collected by Honey Bees offers a new dimension to both types of investigation. The pollen rain reflects only regional wind-dispersed pollen. Pollen from bee pellets reflects both native and introduced vegetation as well as flowering times. Combining such studies may eventually provide a more complete picture of pollination and pollination ecology in relation to both the native and the introduced (or exotic) flora.

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