Heliotropism in some Arctic Flowers[1]

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Abstract. Heliotropism is described for the flowers of four species of arctic plants. Only one, *Papaver radicatum* is heliotropic throughout the 24 hours of sun. The others, *Dryas integrifolia, Matricaria ambigua,* and *Senecio congestus* are heliotropic for several hours centered about solar noon. Heliotropism is abolished in cloudy weather. The significance of heliotropism is discussed in relation to intra-floral temperatures and reproduction.

Introduction

Heliotropism is defined here as the diel bending response, or turning, of plants directly to and with the sun. Thus heliotropism is a form of positive phototropism. Loeb (1890) used the term heliotropism to describe what is now known as phototaxis (Fraenkel and Gunn 1961) and until recently botanists have used the term interchangeably with, and to mean phototropism. Taxes are exhibited through locomotion, while tropisms are exhibited through curvatures of sedentary plants.

Although blooms such as *Helianthus* and others have long been known to turn to the sun throughout the day (Hooker 1881, Wiesner 1879, 1882) I can find no modern comprehensive account of this phenomenon except for two small works (Polikarnov 1954, Morozov 1963) demonstrating heliotropism in sunflowers under field conditions. Review articles such as by Schrank (1950), Brauner (1954), Reinert (1959), Briggs (1963, 1964) and others discuss the general mechanisms of phototropism and the physiology of auxins, but do not mention heliotropism *per se*. Schrank (1950) and Leopold (1964) briefly mention the responses of leaves to the sun.

Methods

Most of the following work was carried out at Hazen Camp (81° 49' N., 71° 18' W.) on northern Ellesmere Island, N.W.T. At various times during several days of sunny weather in 1967 and 1968 about 1,300 flowers of *Dryas integrifolia* M. Vahl (Rosaceae) and 137 flowers of *Papaver radicatum* Rottb. (Papaveraceae) were counted. The angle their radial axes made with respect to the horizontal component of the direction of insolation was noted according to the 45° sectors centered about the angles given as shown in Figure 1. The vertical component, i.e. the angle of solar altitude, is comparatively low and steady in the arctic, so the angles flowers made with respect to it were not measured.

While on the Tuktoyaktuk Peninsula, District of Mackenzie, N.W.T., in 1970 I noted

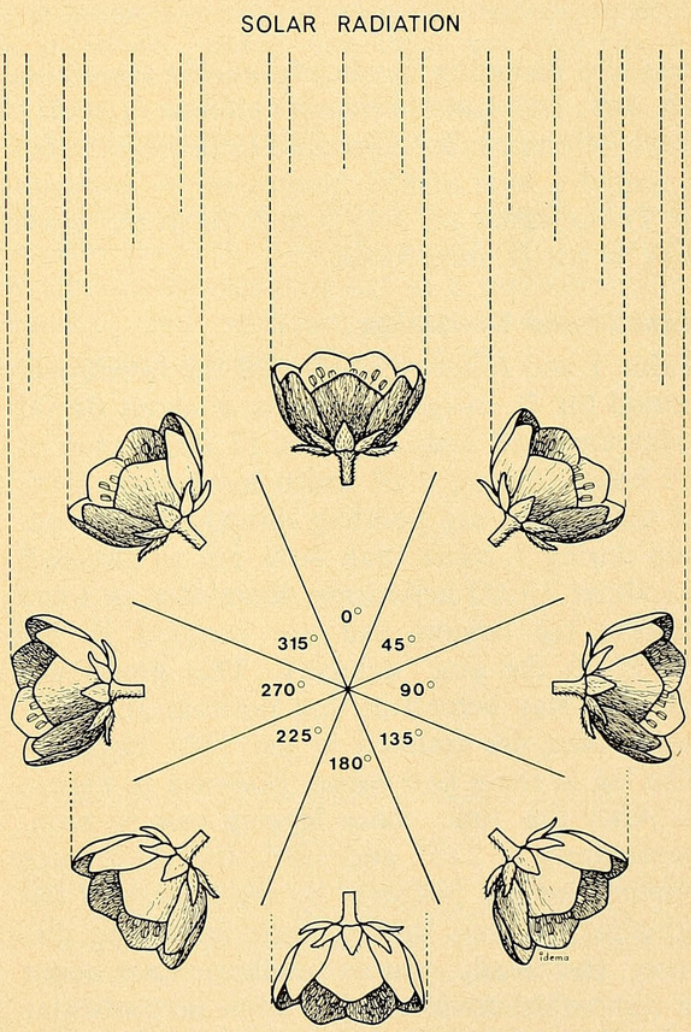

FIGURE 1. Orientation of flowers according to the 45° sectors of the direction of solar radiation used to determine heliotropic period (see text).

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TABLE 1. — Dryas integrifolia, per cent in each sector with respect to the horizontal component of the angle of solar incidence (0° facing directly into the sun.)

Time	Date	% at each angle								Number of Flowers
		Angles								
		0	45	90	135	180	225	270	315	
0001	2.VII.1968	12	3	3	8	21	22	24	13	174
0200		10	3	5	12	26	12	21	13	154
0400		14	6	18	12	21	12	10	7	174
0700	5.VII.1967	73	5	11	1	2	2	6	1	274
0800	26.VI.1967	57	6	25	3	5	0	1	1	186
1100	27.VI.1967	92	2	0	0	0	0	4	2	50
1400		62	3	5	0	0	0	6	20	81
1700	8.VII.1968	20	5	4	4	5	10	20	31	166
2200	25.VI.1967	11	0	4	0	7	11	36	32	28
2300		5	0	0	10	15	15	45	10	20
										1307

that the flowering heads of *Senecio congestus* (R. Br.) DC, and *Matricaria ambigua* (Ledeb.) Kryl. (Compositae) appeared to be heliotropic. I scored a total of 857 blooms of *M. ambigua* at Tuktoyaktuk on July 9 and 10 in the same way as for *D. integrifolia.*

Results and Discussion

Table 1 and Figure 2 show that the heliotropic period for *D. integrifolia* starts at about 04:00 solar time and ends at about 17:00, a span of 13 hours, during 9 of which more than 50% of the flowers are pointing directly at the sun, and during 7, more than 70% are so directed. At about 13:00 heliotropy diminishes as some flowers lag behind and are counted in the "315° to the sun" category. This group apparently stay behind in that position and so 3 hours later are counted in the 270° category. The lag in these two curves is shown in Figure 2. After this time, more lagging can be seen, particularly at 225° and 180°, but these later orientations are obscured by the lagging of the remaining flowers and by their increasing disarray. Eventually, just as the flowers are about to resume heliotropism, they show no particular orientation.

Hocking and Sharplin (1965) state that *D. integrifolia* at Hazen Camp is heliotropic throughout the day, but my results disagree. *Papaver radicatum,* however, does remain heliotropic throughout the 24 hours of sun. During 13 different times throughout the 24 hours all the flowers of this plant were found directly facing the sun (see Figure 2). At Hazen Camp other blooms which may be somewhat heliotropic are *Potentilla nivea L.* ssp. *Chamissonis* (Hult.) Hiit. (Rosaceae) and *Taraxacum arctogenum* Dahlst. (Compositae). *Arnica alpina* (L.) Olin ssp. *angustifolia* (M. Vahl) Maguire (Compositae) is not.

The same effect as found in *D. integrifolia* is evident for *M. ambigua.* Between 18:00 and 20:00 hours solar time heliotropism ceases and blooms lag, appearing at 315° to the sun. As the light wanes and temperature drops many blooms become oriented horizontally, open to the sky. (*D. integrifolia* flowers do not become noticeably oriented to the sky when they are not showing heliotropism.) Between 04:00 and 08:00 heliotropism resumes as the blooms re-orientate to the sun. A cycle showing the heliotropic and non-heliotropic periods for *M. ambigua* is given in Figure 3.

All the blooms studied appear heliotropic during relatively clear and calm weather. During cloudy conditions no particular orienta-

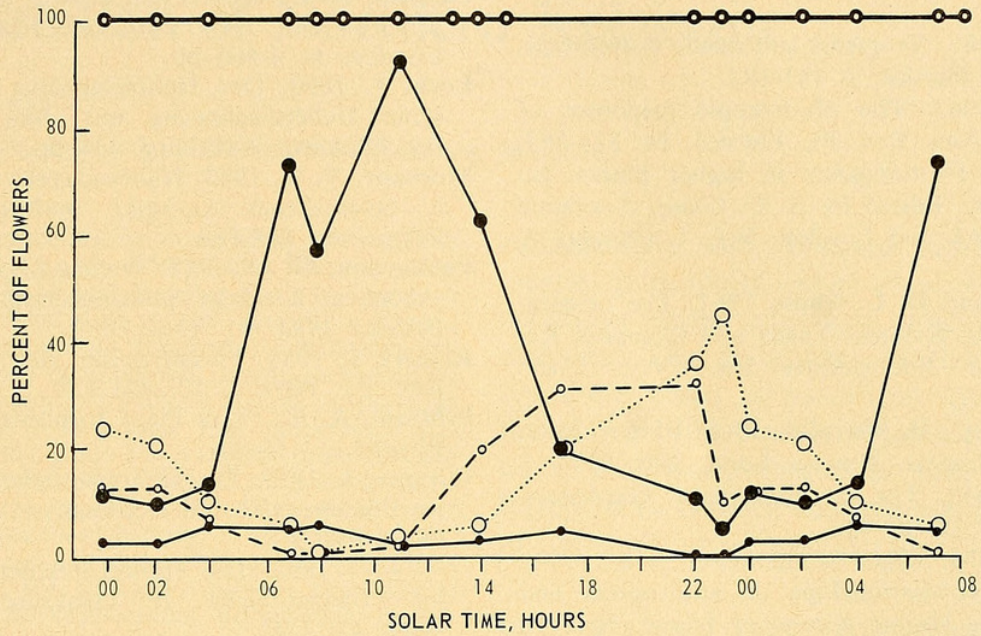

FIGURE 2. Per cent of flowers of *Dryas integrifolia* and *Papaver radicatum* showing various orientations to the sun throughout a day (composite of counts of several days observations). For clarity only four of the eight categories scored in *D. integrifolia* are shown. Heavy open circles and solid line, *P. radicatum*. Large solid circles and solid line, *D. integrifolia* facing directly to sun (0°). Small solid circles and solid line, *D. integrifolia* at 45° to sun. Small open circles and broken line, *D. integrifolia* at 315° to sun. Large open circles and dotted lines, *D. integrifolia* at 270° to sun.

tions to the sun are noticeable, and in wind the blooms are blown about.

I (Kevan 1970) made a detailed study of the temperature in flowers in the high arctic and related it to pollination biology. I found the mean temperatures in heliotropic flowers of *Dryas integrifolia* were about 3°C above the mean ambient air temperature (9°C) while those pointing away from the sun only about 1°C above ambient. On other occasions I found heliotropic flowers had mean temperature elevations above ambient of about 6°C and 7°C. Similar results were obtained for *Papaver radicatum*. Results on intral-floral temperatures of the Composites *Taraxacum* and *Erigeron* (Kevan 1970) suggest that *M. ambigua* and *S. congestus* also develop temperature excesses in direct sunlight.

The signifance of heliotropism to plants can be understood in the arctic environment with its low heat budget. The rates of metabolism of heliotropic flowers and inflorescences must be increased by solar warming for prolonged periods relative to non-heliotropic ones. Probably pollen tube growth and ovule development are hastened and increase the chance of successful seed-set. Also the ameliorated thermal regime in flowers may act as a mechanism for holding and attracting pollinators (Hocking and Sharplin 1965, Kevan 1970).

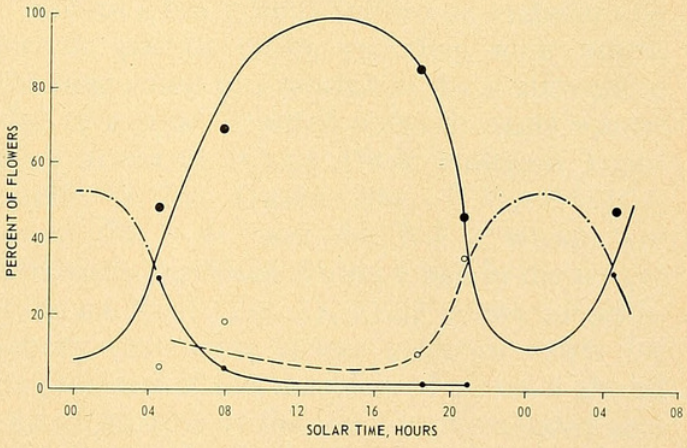

FIGURE 3. Percent of inflorescences of *Matricaria ambigua* showing various orientations to the sun throughout a day (composite of observations of several days and counts from 9 and 10 July, 1970, Tuktoyaktuk, N.W.T.). For clarity only three of the nine categories scored are shown. Large solid circles, facing directly into the sun. Small open circles, at 315° to sun. Small solid circles, facing the zenith.

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