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POTENTILLA FRUTICOSA (ROSACEAE) AS A NECTAR PLANT FOR BUTTERFLIES

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ABSTRACT. Despite its wide distribution, little documentation exists to confirm that butterflies use the woody shrub *Potentilla fruticosa* (Linnaeus) (Rosaceae) as a nectar plant. During the summer of 2004, we observed 36 individual butterflies belonging to 10 species nectaring on *P. fruticosa* in the Jemez Mountains, New Mexico. Butterflies spent 56% of total observed nectaring time on *P. fruticosa*, where it composed 26% of total blooming forb availability (out of 17 plant species). We used the anthrone method for carbohydrate analysis of *P. fruticosa* nectar samples and found significantly more ($\chi \pm^{SE}$ µg/2ml) carbohydrates (i.e., nectar) in flowers (n=68) excluded from nectivores (26.83±1.35 µg/2ml) than available (n=63) to nectivores (6.71+1.40 µg/2ml). Carbohydrate levels were also significantly higher in nectar later in the sampling season (Two-way ANOVA with repeated measures, $p<0.05$). Although anecdotal observations suggest that *P. fruticosa* is not a preferred nectar source for butterflies in the northern Rocky Mountains and in others areas of its range, our results indicate that *P. fruticosa* is an important nectar resource for adult butterflies in the Jemez Mountains, New Mexico.

Additional key words: *Pentaphylloides floribunda*, flower visitation, Lepidoptera, nectar, nectaring

The wide distribution and blooming phenology of shrubby cinquefoil *Potentilla fruticosa* (Linneaus) (Rosaceae) [syn: *Pentaphylloides floribunda* (Pursh) A. Löve] make it a potential nectar source for many insect species. The life history and ecological characteristics of this shrub are well documented (Elkington & Woodell 1963, NRCS 2006, USGS 2005). In North America, ornamental and wild cultivars bloom from May to September with two main flowering periods in May and August. The latter is more vigorous and produces larger flowers (Elkington & Woodell 1963). *P. fruticosa* is intolerant of shade, and the wild North American form produces yellow flowers, while some horticultural varieties originating from Asia produce white, pink, orange, or red flowers (Elkington & Woodell 1963, NRCS 2006). Inflorescences are terminal and appear solitary or in small clusters. Flowers have five petals, triangular ovate sepals, and open nectaries (Elkington & Woodell 1963, USGS 2005). In North America, *P. fruticosa* ranges from the Arctic slope of northern Alaska to Newfoundland, south to the Sierra Nevada and Rocky Mountains, and east through the Great Lakes to New England and Labrador (Elkington & Woodell 1963, NRCS 2006, USGS 2005). North American individuals appear to be uniformly diploid, but populations are tetraploid in Europe and diploid or hexaploid in Asia (Elkington & Woodell 1963).

Little documentation exists on the use of *P. fruticosa* as a nectar source by insects, other than a limited number of species belonging to the orders Diptera, Coleoptera, Hymenoptera (Elkington & Woodell 1963) and Lepidoptera (Voss 1954, Emmel 1964, Emmel *et al*. 1992, Opler & Krizek 1984). The Brooklyn Botanic Garden (2007) lists *P. fruticosa* as a bee-pollinated species, and several gardening and horticultural websites recommend *P. fruticosa* for butterfly gardens.

Voss (1954) observed five species of butterflies nectaring on *P. fruticosa* in Michigan. These were *Danaus plexippus* (Linnaeus), *Nymphalis milberti* (Godart), *Satyrium titus*, (Fabricius) (Nymphalidae), *Lycaena dorcas* (Kirby) (Lycaenidae) and *Erynnis lucilius* (Scudder & Burgess) (Hesperiidae). In the central Rocky Mountains of Colorado, Emmel (1964) and Emmel *et al*. (1992) observed five species of butterflies nectaring on *P. fruticosa*; *Euphydryas anicia eurytion* (Mead), *Polygonia zephyrus* (Edwards) (Also known as *Polygonia gracilis* (Grote & Robinson), *Satyrium titus titus*, *Euphydryas anicia capella* (Barnes) (Nymphalidae), and *Lycaena rubidus* (Behr) (Lycaenidae). The Wisconsin Department of Natural Resources (2006) listed *P. fruticosa* as a nectar source for the endangered *Calephelis mutica* (McAlpine)

(Riodinidae) and Opler and Krizek (1984) listed *P. fruticosa* as the larval host plant for *L. dorcas*. Webster & deMaynadier (2005) listed *P. fruticosa* as the host and principle nectar plant for *L. dorcas claytoni* (Brower) in Maine.

We have been studying butterfly abundance and species richness in Bandelier National Monument and the Valles Caldera National Preserve, New Mexico, 1999–2004 (Kleintjes Neff *et al*. 2007, USGS 2005). In an experiment evaluating the impact of ungulate browsing upon butterflies and their host plants, we found butterfly richness and abundance to be greatest in areas containing *P. fruticosa* (unpubl. data). We additionally found butterflies nectaring on *P. fruticosa*, yet in the literature we found little documentation to confirm its use as a nectar source in the wild. Moreover, peer review of our initial qualitative observations was met with skepticism by reviewers. As a result, the objective of our study was to quantify the use (e.g., species visitation rates, nectar carbohydrate content) of *P. fruticosa* flowers by adult butterflies in the Jemez Mountains, New Mexico.

MATERIALS AND METHODS

Study Area. During the summer of 2004 (9 July–9 August), we worked within four study plots in the Jemez Mountains, New Mexico. Two were located in Bandelier National Monument (mixed conifer-MC4, meadow-MD) and one each in the adjacent Santa Fe National Forest (ski basin-SB) and Valles Caldera National Preserve (Valles Caldera-VC). We chose sites that had ~25% total available blooming forb cover of *P. fruticosa* due to little or no elk browsing (inside exclosures and near human traffic). All sites were located within openings surrounded by mixed conifer-aspen forest between 2700m and 2830m in elevation. Sites were approximately 1200 m^2 in size except for SB, which was approximately 576 m^2 in size. Sites were considered independent (>2 km from each other). We collected butterfly foraging observations and estimated nectar plant availability in the MC4, MD, and SB sites. We sampled nectar availability for analysis at all four sites.

Adult butterfly foraging behavior. We compiled butterfly foraging observations (1000–1500hr) from 10 July–4 August. Once an individual was sighted, we noted the species and then waited 5 sec. before initiating a 5 min. observation period. Butterflies were identified to species by sight and if necessary compared with voucher specimens or photographs (Glassberg 2001). For each butterfly, we collected detailed foraging time budgets which included recording the percent total observation time (sec) spent flying, basking, nectaring, mating, and in combat. We also recorded the percent time each individual spent nectaring per plant species and basking per substrate.

Floral abundance and phenology. We estimated flower availability for eleven randomly selected plants in each site. We categorized the availability of open *P. fruticosa* flowers/plant by intervals of 50 flowers (1–50, 51–100, 101–150, 151–200 flowers). In three sites (MD, MC4, SB) we randomly selected five flowers for phenology studies (bud-to-bloom-to-closing) to determine the average time an individual flower was open (i.e., nectar was available). We marked individual flowers with flagging and noted the stage (bud, bloom, closing, closed) of development every day until they senesced.

Nectar Plant Availability. We conducted a rapid assessment of blooming forb availability in each butterfly foraging observation site using Foxx and Hoard (1995) for plant species identification. We walked three (20-m) transect lines through each site. At every four meters along each transect we noted the closest blooming forb in a 2-m radius from the observer. We computed frequency of occurrence for available forb species by dividing the occurrence of each species closest to the observer from the total number of observations. Data were collected on 13 July and 6 August.

Nectar availability and analysis. We measured the greatest height and width of each randomly selected *P. fruticosa* shrub per site (n=11). On each plant, we randomly selected 12 freshly opened flowers for nectar analysis. We bagged [treated] six flowers per plant and left six unbagged [untreated]. Bags excluded nectivores 24 hr prior to sampling. Bag material consisted of soft window screening, which excluded nectivores yet allowed air circulation. We extracted nectar from three flowers per treatment with micro-pipettes (10 µl; 1 µl increments) and paper wicks of ©Whatman's filter paper (2x8 mm paper insect "points") (Kearns & Inouye, 1993). We removed flower stamens with forceps prior to nectar sampling to decrease potential contamination by pollen and to make nectaries more accessible. We used the pipette samples to quantify nectar volume in the field and the wicks to analyze total carbohydrate content and type in the lab. We took samples between 0930–1440 hrs within two sampling periods (16–27 July, 29 July–5 August) to correspond with early- and late-season nectar availability. Samples were stored at room temperature and analyzed in lab at the University of Wisconsin-Eau Claire during September–November. We used a Spectronic 20D+ spectrophotometer to estimate the absorbance of total carbohydrate in solution as done by McKenna and Thomson (1988). We pooled individual nectar samples

per plant and averaged the absorbance to estimate mean nectar production per flower. We used a Two-way ANOVA with repeated measurements to test for significant differences ($p<0.05$) between treatments, periods and the interaction of treatment*period. Proportional data received a squareroot arcsin transformation.

Results

Floral abundance and phenology. We found that 57% of all observed plants (n=44) contained 1–50 flowers, 32% contained 51–100 flowers, 9% contained 101–150 flowers and 2% contained 151–200 flowers in full bloom. Mean blooming period length of individual flowers (n=14) was 4.91 (± 0.61SE) days. Although individual flowers bloomed for a short time, new flowers were continuously produced on each shrub.

Nectar Plant Occurrence. Similar percentages (24%, 23%, 30%) of *P. fruticosa*, compared to the availability of other blooming forbs, were available to butterflies in all three sites. Only *Achillea lanulosa* (Nutt) (Asteraceae) had greater (51%) availability than *P. fruticosa* in one site (MD). Overall, *P. fruticosa* was the most available nectar source, with *A. lanulosa* availability a close second (Table 1).

Adult butterfly foraging behavior. We collected foraging observations from a total of 59 individual butterflies. Butterflies spent significantly more observation time (76%) nectaring than any other activity (8% flying, 16% other (basking/mating/combating)) (Univariate ANOVA, df=2, F=80.4, $p<0.01$). Butterflies that nectared (n=54) spent more (56%) time nectaring on *P. fruticosa* than any other plant species (Table 1). *A. lanulosa* was the second most available species of blooming forb (25%), but butterflies nectared on it for only 3.5% of the total observation time. *Helenium hoopesii* ((Gray) Bierner) (Asteraceae), however, comprised less than 1% of total forb availability, yet was the second most preferred species. It received 15% of the total observed nectaring time (Table 1).

Of the 59 total observations, we observed 36 individuals from ten species of butterflies nectaring on *P. fruticosa* (Fig. 1). These species were *Speyeria hesperis hesperis* (Edwards), *Cercyonis oetus* (Boisduval), *Vanessa cardui* (Linnaeus), *Vanessa annabella* (Field) (Nymphalidae), *P. gracilis*, *Hemiargus isola* (Reakirt), *Lycaena arota* (Boisduval), *Plebejus icarioides* (Boisduval), *Leptotes marina* (Reakirt) (Lycaenidae), and an unknown *Colias* species (Fabricius) (Pieridae).

Nectar availability and analysis. We found that *P. fruticosa* produces nectar, although the quantity of nectar produced per flower was minute (<1 µl). Nectar was occasionally noted to enter the micropipettes, but it was not enough to quantify to µl. Analysis of nectar samples indicated the presence of carbohydrates. There was a significantly higher carbohydrate content for bagged than unbagged flowers and carbohydrate levels

Table 1. (A) Total percentage of blooming shrub and forb availability and (B) percentage of total observed time butterflies spent nectaring on blooming forbs in the Jemez Mountains, New Mexico, July–August 2004.

Blooming Forb Species	(A) Percentage of total blooming shrub and forb availability	(B) Percentage of total observation time butterflies nectared on the shrub or forb
Potentilla fruticosa (Linnaeus) (Rosaceae)	25.80	56.17
Achillea lanulosa (Nutt) (Asteraceae)	24.82	3.50
Potentilla pulcherrima (Lehm) (Rosaceae)	10.25	2.23
Galium spp. (Rubiaceae)	9.75	1.85
Potentilla hippiana (Lehm) (Rosaceae)	6.30	0.09
Erigeron spp. (Asteraceae)	4.44	10.18
Campanula rotundifolia (Linnaeus) (Campanulaceae)	3.95	0.00
Geranium richardsonii (Fisch & Trautv) (Geraniaceae)	3.58	0.00
Pseudocymopterus montanus ((Gray) Coult & Rose) (Apiaceae)	2.59	0.00
No blooming shrub or forb	2.59	-
Cirsium undulatum ((Nutt) Spreng) (Asteraceae)	1.85	1.85
Tragopogon dubius (Scop) (Asteraceae)	1.11	0.00
Helenium hoopesii ((Gray) Bierner) (Asteraceae)	0.74	14.81
Helianthella quinquenervis ((Hook) Gray) (Asteraceae)	0.62	7.38
Monarda menthifolia ((Graham) Fern) (Lamiaceae)	0.62	0.00
Unk. Composite	0.62	0.00
Allium spp. (Liliaceae)	0.37	1.94

were also significantly higher later in the sampling season (Two-way ANOVA with repeated measures, df=1 for each; treatment F=106.6, period F=52.2, treatment*period F=17.3, all p<0.01) (Table 2).

DISCUSSION

Our study documented the use of *P. fruticosa* as a nectar source by ten species of butterflies in the Jemez Mountains, New Mexico. This is a new nectar plant host record for nine species of butterflies, other than for *P. gracilis ssp. zephyrus*.

Our results suggest that butterflies preferred *P. fruticosa* nectar more than that provided by other species of available blooming forbs. Although our observations suggest a higher preference for *H. hoopesii* than *P. fruticosa* due to relative plant abundance and foraging studies, it is not known whether this was due to nectar quality, quantity, or foraging energy expenditure. Since *H. hoopesii* is a composite, this behavior may be a result of spending more time on one plant with multiple flowers in one inflorescence instead of expending energy to forage on the multiple single flowers of *P. fruticosa*.

The filter paper wicking technique proved suitable for the amount of nectar collected from *P. fruticosa*. It worked well, as the flowers have shallow nectaries easily accessible by pointed paper wicks. Using micro-capillary pipettes for quantification in the field proved inadequate for the amount of nectar produced by *P. fruticosa*.

It is well documented that the availability of sugar in the adult diet can significantly increase longevity and fecundity (Hill & Pierce 1989, Hill 1989, Norris 1935, David & Gardiner 1962). Since this was a baseline study, we calculated only total carbohydrate content of *P. fruticosa* nectar samples. However, studies have shown that nectars fed on by Lepidoptera are generally sucrose-rich and contain relatively high concentrations of amino acids (Baker & Baker 1977, 1982, 1983, 1990) and that some butterflies detect and select for amino acids in their diet (Erhardt & Rusterholz 1998, Alm *et al*. 1990, Hill & Pierce 1989). Amino acids present in *P. fruticosa* nectar may have affected butterfly preference as a nectar source, but this was not addressed by our study. We suggest that future research quantify both the relative amounts of sugars (i.e., sucrose, fructose, glucose) as well as amino acids in *P. fruticosa* nectar.

Results from our carbohydrate analysis indicate that greater amounts of nectar were removed from flowers available to large (>2.0mm) nectivores compared to

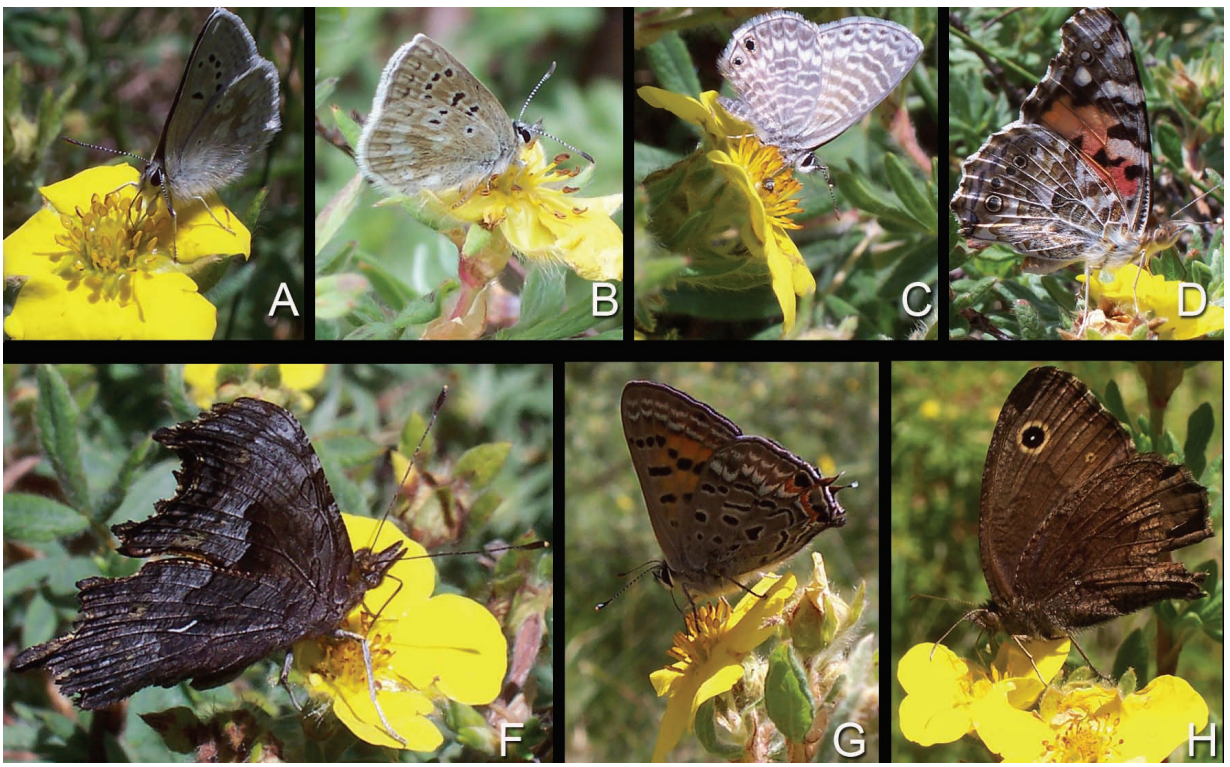

Fig. 1. Butterflies photographed nectaring on *Potentilla fruticosa* in North Central New Mexico. **A.** *Plebejus icarioides*, Jemez Mountains, Los Alamos Co. **B.** *Agriades glandon*, Sangre de Cristo Mountains, Taos Co. **C.** *Leptotes marina*, Jemez Mountains, Los Alamos Co. **D.** *Vanessa cardui*, Jemez Mountains, Los Alamos Co. **E.** *Polygonia gracilis ssp. zephyrus*, Jemez Mountains, Los Alamos Co. **F.** *Lycaena arota*, Jemez Mountains, Los Alamos Co. **G.** *Cercyonis oetus*, Jemez Mountains, Los Alamos Co.

Table 2. Mean (+SE) carbohydrate content for sample treatments and periods in the Jemez Mountains, New Mexico, July–August 2004.

Sample Period	Bagged	Unbagged
1st period	17.42 µg/2ml	4.18 µg/2ml
2nd period	36.24 µg/2ml	9.24 µg/2ml
Mean (+SE)	26.83 ± 1.35 µg/2ml	6.71 ± 1.40 µg/2ml

Two-way ANOVA with repeated measures; treatment (bagged vs. unbagged), sample period, treatment*sample period, all significant at $p<0.01$.

those flowers excluded from foragers. Greater amounts of nectar were also produced later in the sampling season. We do not know whether the seasonality was an artifact of sampling pre and post rainy season or was associated with the phenology of the early and late blooming flush of *P. fruticosa*.

Outside of our study area, we compiled additional observations, both anecdotally and intentionally, on *P. fruticosa* in areas known to experience the impacts of elk browsing. Anecdotally, we noted an *Agriades glandon* (de Prunner) (Lycaenidae) nectaring on *P. fruticosa* near Williams Lake in the Sangre de Christo Mountains. At the National Elk Refuge in Jackson Hole, WY, we quantified butterfly foraging observations and blooming forb availability for 3 days (31 July– 2 August) in 2004. Our intent was to document whether butterflies (and which species) nectared on *P. fruticosa* in the northern Rocky Mountains and whether elk browsing levels were comparable to that in the Jemez Mountains. In two open, mesic meadow plots, blooming *P. fruticosa* accounted for 35% and 15% of flowering plant availability in comparison to *Solidago* spp. (Asteraceae) (25% and 15% respectively) and *Aster* spp. (Asteraceae) (20% and 10% respectively). As a result of 6.5 hours of total observation time (~1000–1200hrs/day) we observed a limited number (<40) of butterflies belonging to 14 species, 5 of which were observed nectaring on flowers and only two of which, *Phyciodes pascoensis* (W. G. Wright) (Nymphalidae), and *L. rubidus*, were nectaring on *P. fruticosa*. We also collected nectar samples, but they were stolen and thus unavailable for analysis. Our limited evidence from the refuge suggested that *P. fruticosa* was not a preferred nectar source for butterflies, but more data are needed to validate this assumption.

Our research confirms that *P. fruticosa* is a preferred nectar source for butterflies in the Jemez Mountains, New Mexico. We speculate that this is due to a limited number of shrub and forb nectar sources later in the summer and during periods of drought. This supports the importance of the availability of this widely distributed and "weedy" shrub for nectaring insects, especially in areas where the species suffers from overbrowsing by cattle and ungulates, which can reduce flower availability.

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