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MORPHOLOGICAL CAUSES FOR THE RETENTION OF PRECIPITATION IN THE CROWNS OF ALPINE PLANTS

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Monson R. K., Grant M. C., Jaeger C. H. and Schoettle A. W. *Morphological causes for the retention of precipitation in the crowns of alpine plants*. Environmental and Experimental Botany **32**, 319–327, 1992. Studies were conducted on 27 species of alpine plants to test the hypothesis that structural characteristics of leaves have a predictable influence on the amount of moisture retained by a plant crown following a simulated rain event. The retention of precipitation in crowns has been previously demonstrated as one factor potentially contributing to the direct effects of acid rain on alpine plants. The results of this study demonstrate that a significant share of the amount of water retained could be explained by general structural features of leaves and flowers common to all the diverse taxa studied. Water retained per unit leaf area was best explained by pubescence rank, number of leaves, petiole base width, flower mass, flower wettability and petiole base angle. Water retained per unit mass was best explained by pubescence ranking, number of leaves, petiole base width, leaf area, flower wettability, flower mass and number of flowers.

INTRODUCTION

The interception of acidic rain by plants has been implicated as a major cause of productivity losses in both agronomic and natural ecosystems.[7,13] Contact with acid rain is known to cause lesions on vegetative tissues[5,6] and reductions in reproductive success.[2,3] Plant morphological features can influence the distribution of acid rain as it accumulates on aerial surfaces, in some cases exacerbating the potential for damage. Funk and Bonde[8] observed damage to axillary floral meristems in an alpine plant species when acidic solutions became pooled in the basal region of the leaves. Pooled acidic solutions have been shown to cause epidermal damage to tissues in other species as well.[5,6] Despite a general recognition of the damage that can be caused by contact with acid rain, very little is known about the morphological features of plants that influence acid rain interception or subsequent distribution across aerial surfaces.

In the current study we tested the hypothesis that structural characteristics of shoots have a predictable influence on the amount of moisture retained by a plant crown following a simulated rain event. We reasoned that if a given mass of shoot tissues were structured such that it had

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numerous small leaves with broad leaf or petiole bases, it would retain more water compared to tissue with fewer, large leaves with narrow bases or petioles. Small leaves with broad bases would retain water in the frequent, close spaces between leaves and in the broad intersections between leaf and stem. Additionally, we tested the hypothesis that because of the more highly divided structure of floral tissues, they too might retain significant amounts of moisture due to their structural features. In this study we were not interested in assessing damage by acid rain *per se*. Rather, we wished to address the potential for predictable patterns in rain retention, one possible factor contributing to acid rain-induced damage (or indeed, damage from any water-soluble component of rain) in plants. It is hoped that such information will prove useful to future efforts aimed at understanding species-specific differences in the susceptibility to acidic damage.

MATERIALS AND METHODS

Study area

The studies were conducted in the Glacier Lakes area of the Snowy Range near Laramie, Wyoming (106°W, 41°N). The hydrology, geology and ecology of the Glacier Lakes Ecosystem Experiment Site have been described in a recent report.[11] Twenty-seven plant species were examined in their natural habitats. The habitats included a rocky fellfield and a dry meadow site which were established along the easterly topographic rise from east Glacier Lake at distances approximately 200 and 100 m from the eastern edge of the lake, respectively. The fellfield site was located on a broad, flat shelf with frequent large boulders. The dry meadow site was located on gently sloping ground with fewer rocks than the fellfield site. A wet meadow site was established at the lake margin. The soil at this latter site was saturated with water during June, but became drier during the middle of the summer. Finally, one species, *Erythronium grandiflorum* (glacier lily), growing in a snowbed site was examined. The snowbed lasted until mid-July. After snowmelt, the site was characterized by coarse soil surface, with sparse vegetation, dominated by *E. grandiflorum*. Most precipitation that occurs during the summer is in the form of heavy thundershowers. Thus, our studies were concentrated on the effects of wet, heavy precipitation (as opposed to snow, mist and fog), using simulated rain events of a magnitude that would induce the maximum water-holding capacity of a plant crown.

Simulated rain treatments

Simulated rain events were conducted during 7–12 July and 15–17 August 1988. We measured how much loose water was held by a crown following a simulated rain event, as a function of 19 different morphological characteristics. After spraying water on a crown (or part of a crown) the quantity of loosely bound water was obtained by inverting the excavated crown (or part of the crown) and gently tapping it while inserted into a polyethylene bag. The tapping was continued until all pooled water was freed, even that held as tightly adhered droplets.

Details of the spraying protocol were as follows. Prior to spraying, the experimental plant was measured for crown height and diameter. After making these measurements, if the crown (or part of the crown) being sprayed was rooted in the ground, it was excavated with a hand trowel. After excavation, the plant was placed in its natural orientation back into the excavated region of the soil and sprayed. Crowns were sprayed within 15 sec of excavation to avoid problems with crown wilting. The excavated crown was then gently lifted from the soil, inverted into the plastic bag and gently tapped. The bag containing the water was sealed and returned to the laboratory for weighing. In the case of coniferous trees the sprayed branch was severed from the tree and the water tapped into the bag. After weighing, the bags were cut at three sides, opened to the air, and left to dry to constant mass on the lab bench. After 48–60 hr of drying, the bags were reweighed. This procedure allowed us to quantify the trapped water and account for the mass of any soil or loose plant debris that might have been knocked into the bag during tapping of the crown.

Rain was simulated by spraying plants from a height of 1 m from the top of the canopy using a pressurized herbicide sprayer. The sprayer was calibrated at the study site to determine the pressurization required to deliver between 350 and 450 cm^3 of water in a 30 sec burst. At a height of 1 m the water was delivered in a roughly circular

pattern with a diameter of approximately 24 cm. The amount of water used for the spray treatment (350–450 cm^3) was chosen because it represents twice the approximate volume of a cylindrically shaped crown of 5 cm diameter and 7 cm height. These dimensions represented the average size of the plants (or portions of plants) that were studied. Spraying with twice the approximate crown volume ensured that enough simulated rain was applied to saturate the crowns, such that excess water dripped freely at the end of the spray treatment.

The total number of plants analyzed in this study was 183. These plants were from 27 different species distributed across four different alpine habitats. Typically, four plants from each species in each habitat type were measured, although in some cases five to eight replicate plants were used. This was true for *Acomastylis rossii* in the fellfield site (eight replicates) and *Bistorta bistortoides* in the dry meadow site (five replicates). Six species were sampled that occurred in both the fellfield and dry meadow habitat types. Two species were sampled that occurred in both the wet meadow and dry meadow habitat types. Nine of the species were sampled during July and August with the remaining species sampled in only one of the months. For the multiple regression analyses described below, sample sizes were restricted to four for each species and to one sampling period only. As described above, for the largest plants only portions of the plant were sampled. Those species for which only a portion of the plant was studied are: *Silene acaulis*, *Arctostaphylos uva-ursi*, *Phlox pulvinata*, *Trifolium dasyphyllum*, *Eritrichium aretoides*, *Picea engelmannii* and *Pinus flexilis*. The first five species form extensive mats (so only a portion of the mat was sampled), while the last two species form trees (so only the terminal 40 cm of the branch tips was sampled).

Morphological measurements

After tapping the loose water from the crowns, the excavated plants were placed into plastic bags, stored on ice, and returned to the laboratory for analysis of morphological traits. The traits that were chosen represent those that appeared most likely to influence the retention of water on leaf surfaces, in the space between the leaf/petiole base and the stem, or by capillarity in the spaces between finely divided leaves or leaflets. To test the hypothesis concerning flower water retention, flower wettability was measured and compared to leaf wettability. Measurement techniques were as follows:

1. *Pubescence.* It was hypothesized that increased pubescence would result in increased water retention due to the capillarity of holding water droplets between the leaf hairs. The degree of leaf pubescence was estimated using a relative ranking between 0 and 3, with 0 being the least pubescent and 3 being the most pubescent. Examinations of leaf surfaces were made with a hand lens. In order to provide some perspective of the relative ranking, the least two pubescent species were *Psychrophila leptoselpa* and *Erythronium grandiflorum* (pubescence ranking 0). The two most pubescent species were *Antennaria umbinella* and *Hymenoxys grandiflora* (pubescence ranking 3).

2. *Leaf/petiole base angle in cross-section.* It was hypothesized that the greater the cross-sectional angle of the leaf or petiole base, the greater the volume of the leaf/stem junction, and the greater the capacity to hold pools of water that might collect there. The cross-sectional angle of the petiole or leaf base at the point of insertion was measured with a modified protractor. The device had two pieces of thread originating from the central point of the protractor and extending to the angle scale at the perimeter. A leaf base or petiole was stood on cross-sectional end at the central point of the protractor and the threads were used to delineate the cross-sectional angle and extend that angle to the scale at the protractor's perimeter.

3. *Leaf/petiole base width.* It was hypothesized that the wider the leaf or petiole base, the greater the volume available at the leaf/stem junction for water pooling. The width of the petiole or leaf base at the point of insertion was measured to the nearest 0.5 mm using precision calipers.

4. *Leaf angle.* It was hypothesized that a leaf angle of 45° with respect to the vertical stem would produce a larger volume capable of supporting water pooling at the leaf/stem junction. Leaf angle from the horizontal was measured *in situ* for the third through to the sixth nodes from the apex. The protractor was used for these measurements. The leaf angles were averaged to provide one value for each plant.

5. *Leaf number and leaf area.* It was hypothesized that the greater the leaf number and the smaller the leaf area, the more highly divided the structure of the shoot, and the greater the potential for water to be held by capillary force in the spaces between the leaves. In the laboratory, all leaves were counted on each plant (or portion of plant) and the total projected leaf area was measured with a leaf area meter (model AMS, Delta-T, Cambridge, U.K.).

6. *Area of functional leaf unit.* This index was developed to account for the fact that some species had a large, non-dissected leaf lamina, whereas others had a small, highly dissected lamina. We hypothesized that these different types of laminae would capture precipitation differently. The functional unit was defined as the entire lamina in the case of non-dissected leaves, and the leaflet or lobe in the case of dissected leaves.

7. *Leaf wettability and flower wettability.* Leaf and flower wettabilities were measured in the laboratory. Individual leaves or flowers were weighed, then immersed in water to ensure complete exposure of the organ to the water. The leaf or flower was then removed from the water, allowed to drip for 15–20 sec (until all dripping had stopped), then reweighed. Finally, the leaf or flower was dried and the dry mass determined. Wettabilities were expressed as amount of water retained following immersion per unit of leaf or flower area.

8. *Leaf dry mass, flower dry mass, and total aboveground dry mass.* The masses of leaves, flowers, and total aboveground portions of the plant were measured after oven drying for 48 hr at 70°C.

Data analysis

In order to explore the relationships among the various morphological features, the following questions were asked: Which structural features of the crown most influence precipitation retention and what are the quantitative relationships of these features with respect to precipitation retention? To address these questions, we conducted a multiple-regression analysis of the morphological traits in relation to the amount of water retained and to the amount of water retained per unit of crown biomass as well as per unit of crown leaf area.

Standard stepwise multiple regression analyses were used in a heuristic fashion to examine the ability of various combinations of morphological traits to predict water retention per unit of leaf area or aboveground biomass. The results reported below were essentially stable independent of the stepwise method (forward or backward) and essentially independent of the inclusion or exclusion of the structural traits not listed in the final set of predictor variables. Strong statistical association or statistical predictive power does not, in and of itself, demonstrate a direct causal relationship. In multiple regression analysis, unmeasured or so-called latent variables highly correlated with one or more measured variables can cause misidentification of the true source of causal variation.

RESULTS

Stepwise multiple regression analysis, all species combined, of water retention vs morphological variables revealed that leaf dry mass was the single most important predictive character; it explained 47% of the variability in the volume of loosely bound water retained by entire plant crowns (data not shown). Thus, the larger a crown, the more water it will hold. Flower mass contributed an additional 11% of the variability. Most of the water retained by a crown, therefore, is retained because of structural features (including size) associated with the leaves. The amount of water retained per unit leaf area by entire canopies ranged over four orders of magnitude for the 27 species that were examined (Table 1). Approximately 22–32% of the variability in the amount of water retained per unit leaf area could be explained by structural differences among crowns (Table 2). Pubescence rank and flower mass accounted for the largest share of water retention per unit leaf area while leaf number and the width of the petiole base accounted for the most variation in water retention per unit of functional leaf area. Pubescence rank and leaf number were also the most important factors explaining variability in the amount of water retained per unit of biomass (Table 2). Other important factors included flower wettability, leaf angle, flower mass and flower number.

When individual leaves were removed from the plant crown and examined to determine the

Table 1. Species ranked according to average total water retained per unit of leaf area

Species	g water retained/ m^2 leaf area
Potentilla nivea	49.89
Sedum lanceolatum	23.44
Achillea lanulosa	4.63
Potentilla diversifolia	3.79
Clementsia rhodantha	3.72
Pedicularis groenlandica	1.73
Phlox pulvinata	1.71
Tonestus pygmaeus	1.55
Erigeron melanocephalus	1.33
Pinus flexilis	1.22
Trifolium dasyphyllum	1.04
Eritrichium aretioides	0.78
Acomastylis rossii	0.74
Polemonium viscosum	0.71
Antennaria umbinella	0.62
Erigeron pinnatisectus	0.56
Hymenoxys grandiflora	0.51
Arctostaphylos uva-ursi	0.40
Picea engelmanii	0.38
Carex nigricans	0.35
Pedicularis parryi	0.33
Psychrophila leptosepala	0.15
Bistorta bistortoides	0.09
Agropyron scribneri	0.09
Silene acaulis	0.05
Erythronium grandiflorum	0.02
Carex nardina	0.00

Plants of the same species that occur in more than one habitat type were combined.

amount of water retention on the external surfaces after immersion (wettability), values were obtained that were generally one to three orders of magnitude lower than the water retention of whole crowns (compare values in Tables 1 and 3). These results indicate that most of the water-holding capacity of crowns is due to emergent properties at the crown level of organization, i.e. properties that cannot be predicted on the basis of isolated leaf properties alone. Although the amount of flower biomass had only a small influence on water retention by the entire crown, each flower of most species had a fairly high capacity to retain water. In determining the capacity for a cm^2 of leaf area to capture water vs a cm^2 of flower area, in nearly every species flowers can capture more (Table 3).

The degree of linear association among all pairs of morphological traits is shown in Table 4. The strongest correlations showed up among the various measures of size such as shoot weight, leaf number, leaf area, etc. The vast majority of character pairs, however, show no significant correlation indicating a high level of independent variation in those characters.

DISCUSSION

The results of this study support the hypothesis that the structural features of leaves and flowers have a predictable influence on the amount of moisture retained by a plant crown following a simulated rain event. The results presented in

Table 2. Multiple regression analysis of the statistically most important leaf and flower morphological traits listed in order of their ability to predict the amount of loosely bound water retained by all plants across all taxa following a simulated precipitation event

Dependent variable	Independent variables	P value	r^2
Water retained/unit leaf area	Pubescence rank, flower mass, flower wettability, leaf angle, petiole base width	$\leqslant 0.0001$	22%
Water retained/unit functional leaf area	Leaf number, petiole base width, flower mass, petiole base angle, flower wettability	$\leqslant 0.0001$	28%
Water retained/unit leaf mass	Pubescence rank, petiole base width, flower wettability, flower mass	$\leqslant 0.0005$	21%
Water retained/unit plant mass	Leaf number, leaf area, pubescence rank, flower number	$\leqslant 0.0001$	25%

Each dependent variable ratio was transformed to natural logs to improve linearity.

Table 3. Individual leaf and flower external water-holding capacities (wettabilities) of several alpine species

Species	Leaf wettability (g H_2O/m^2 leaf area)	Flower wettability (g H_2O/m^2 flower area)
Polemonium viscosum	0.071 ± 0.047	0.049 ($n = 1$)
Eritrichium aretioides	0.059 ± 0.015	
Erigeron pinnatisectus	0.053 ± 0.015	0.043 ± 0.015
Achillea lanulosa	0.046 ± 0.008	0.063 ± 0.008
Phlox pulvinata	0.042 ± 0.008	0.065 ± 0.008
Silene acaulis	0.040 ± 0.001	0.064 ± 0.028
Tonestus pygmaeus	0.033 ± 0.004	0.055 ± 0.004
Potentilla nivea	0.032 ± 0.007	0.055 ± 0.008
Acomostylis rossii	0.025 ± 0.005	0.067 ± 0.008
Hymenoxys gradiflora	0.024 ± 0.004	0.032 ± 0.004
Arctostaphylos uva-ursi	0.018 ± 0.001	
Pedicularis paryii	0.018 ± 0.002	0.032 ± 0.003
Clementsia rhodantha	0.016 ± 0.003	0.053 ± 0.004
Antennaria umbinella	0.015 ± 0.003	0.026 ± 0.004
Pedicularis groenlandica	0.012 ± 0.003	0.025 ± 0.001
Psychrophila leptosepla	0.012 ± 0.001	0.094 ± 0.037
Sedum lanceolatum	0.010 ± 0.002	0.056 ± 0.018
Carex nardina	0.009 ± 0.001	0.051 ± 0.013
Potentilla diversifolia	0.009 ± 0.001	0.057 ± 0.004
Erigeron melanocephalus	0.008 ± 0.001	0.022 ± 0.003
Bistorta bistortoides	0.005 ± 0.001	0.004 ± 0.001
Agropyron scribneri	0.005 ± 0.001	0.017 ± 0.003
Pinus flexilis	0.004 ± 0.001	
Trifolium dasyphyllum	0.004 ± 0.002	0.043 ± 0.006
Carex nigricans	0.004 ± 0.001	0.043 ± 0.001
Picea engelmanii	0.003 ± 0.001	
Erythronium grandiflorum	0.001 ± 0.001	0.075 ± 0.007

Flower wettability is expressed per unit of total, exposed floral area, measured on flowers at full anthesis by summing the areas of all dissected parts. Values are mean ± S.E. ($n = 2$–4, unless otherwise indicated). Missing values are for plants which lacked flowers during our measurements.

Table 2 indicate that the most important determinants measured of how effective a gram of shoot tissue will be in capturing wet precipitation are its surface area and the degree to which that surface area is divided into small leaves, leaflets or flowers. The large importance of factors such as leaf number and leaf area as well as flower number reflect these influences of area division on a plant's capacity to capture water. In contrast, the ability of a gram of leaf tissue to capture water is best explained by a somewhat different set of characters. Leaf pubescence proved to be the most important property of water retention per gram of leaf tissue highlighting the functional significance of water trapping capabilities of these surface hairs. Similarly, flower wettability played a major role along this scale of measurement although it was slightly less important than the dimension of the petiole base. Leaf pubescence presumably contributes to water capture by increasing the roughness of the surface and thus the number of interstitial spaces in which adhering water droplets can be trapped. Larger petiole base widths presumably contribute to water capture by providing troughs at the junction of the leaves and stems. Flower mass typically indicates a rather highly dissected type of biomass contribution which presumably functions much in

Table 4. Pearson correlation coefficients for all pairwise combinations of all structural traits

	2	3	4	5	6	7	8	9	10
2. Shoot wt	1	−0.21	−0.26	−0.19	0.05	0.84	0.74	−0.15	0.83
3. Pubescence rank		1	0.04	−0.13	0.00	−0.12	−0.33	−0.28	−0.30
4. Petiole base angle			1	0.43	−0.14	−0.29	−0.16	0.03	−0.24
5. Petiole base width				1	−0.08	−0.20	−0.00	0.14	−0.08
6. Leaf angle					1	0.13	−0.10	−0.24	0.10
7. Leaf number						1	0.66	−0.20	0.71
8. Leaf area							1	0.21	0.84
9. Functional leaf area								1	−0.07
10. Leaf mass									1
	11	12	13	14	15	16	17	20	21
2. Shoot wt	0.01	0.29	0.20	0.17	0.12	−0.10	0.72	0.16	0.39
3. Pubescence rank	0.01	−0.26	0.11	0.14	0.11	0.01	−0.03	−0.15	−0.10
4. Petiole base angle	0.02	−0.24	0.04	0.07	0.12	0.32	−0.14	0.01	−0.11
5. Petiole base width	0.03	0.08	−0.23	0.10	0.16	0.07	−0.18	0.01	−0.12
6. Leaf angle	0.03	0.40	0.01	−0.09	−0.08	−0.22	−0.01	0.01	−0.18
7. Leaf number	−0.02	0.19	0.22	−0.06	−0.10	−0.13	0.56	−0.01	0.30
8. Leaf area	−0.06	0.12	−0.10	0.03	−0.00	−0.09	0.73	0.40	0.59
9. Functional leaf area	−0.11	−0.21	−0.11	0.00	−0.04	−0.06	−0.08	0.40	0.39
10. Leaf mass	−0.07	0.47	−0.10	−0.02	−0.05	−0.18	0.76	0.23	0.36
11. Leaf wettability	1	−0.04	0.06	0.04	0.06	0.06	−0.08	0.09	0.04
	2	3	4	5	6	7	8	9	10
12. Specific leaf wt	0.29	−0.26	−0.24	0.08	0.40	0.19	0.12	−0.21	0.47
13. Flower number	0.20	0.11	0.04	−0.23	0.01	0.23	−0.10	−0.11	−0.10
14. Flower area	0.17	0.14	0.07	0.10	−0.09	−0.06	0.03	0.00	−0.02
15. Flower mass	0.12	0.11	0.12	0.16	−0.08	−0.10	−0.01	−0.04	−0.05
16. Flower wettability	−0.10	0.01	0.32	0.07	−0.22	−0.13	−0.09	−0.06	−0.18
17. Total water retained	0.72	−0.03	−0.14	−0.17	−0.01	0.56	0.73	−0.08	0.76
20. Height	0.16	−0.15	0.02	0.01	0.01	−0.01	0.40	0.40	0.23
21. Diameter	0.39	−0.10	−0.11	−0.12	−0.18	0.30	0.59	0.38	0.36
	11	12	13	14	15	16	17	20	21
12. Specific leaf wt	−0.04	1	−0.11	−0.07	−0.08	−0.21	0.22	−0.12	−0.13
13. Flower number	0.06		1	0.20	0.15	0.41	0.07	−0.05	0.09
14. Flower area	0.04			1	0.89	0.14	0.25	0.14	0.08
15. Flower mass	0.06				1	0.18	0.23	0.17	0.03
16. Flower wettability	0.06					1	0.00	0.02	−0.03
17. Total water retained	−0.08						1	0.38	0.45
20. Height	0.09							1	0.59
21. Diameter	0.04								1

Sample size is $n = 123$ for all pairs and all correlations reflect the original scale of measurement for all variables. The character numbers, shown with their names along the left hand column, signify the same traits when used as column headings. Correlations with absolute values larger than 0.18 are significant at $P \leqslant 0.05$.

the same manner as do highly divided leaf surface areas. When taken together, the results of these studies reveal that the crown architectures of different species are structured in ways that result in significantly different amounts of water capture. At the same time, these results show that some very general structural attributes, applicable to a broad range of taxa, prove to be highly useful in predicting water retention characteristics.

The influence of morphological traits on water retention and "pooling" patterns on the shoot could have important implications for species-specific differences in damage by acid rain. FUNK and BONDE[8] found that floral buds of the alpine rosette plant *Acomastylis rossii* were aborted following exposure to pooled solutions of sulfuric acid (pH = 2.5–3.5) in the leaf axils. In plants from other ecosystems pooled acidic solutions have also been shown to cause a variety of injuries to plants.[5,6] The results of this study indicate that the influence of leaf/petiole base structure on the pooling of water in alpine plants is widespread. Visual observations made during the spraying indicated that large droplet pools were common in the leaf axils of alpine plants. Given the common expression of the rosette growth-form in alpine plants,[1] with floral buds positioned at the base of leaves and petioles, the potential exists for the type of damage proposed by FUNK and BONDE to be widespread in alpine plants.

An additional morphological trait that could also have a large influence on plant susceptibility to acidic precipitation is flower wettability (Tables 2, 3). Due to the delicate, feathery nature of many floral parts, flowers tend to retain large quantities of water. High flower wettabilities could have profound implications for reduction of fitness of alpine plants if alpine acid deposition were to reach excessive levels. Acid deposition falling on flowers would bring acidic solutions into direct contact with the organs that are actively involved in the production of pollen and eggs, as well as those that foster seed maturation. Several past studies have demonstrated the high sensitivity of plant reproductive processes to acidic solutions. Simulated acid rain applied to stigmatic surfaces at the time of pollination has been shown to inhibit pollen grain germination.[2,3,12,11] Acid rain applied to corn stigmas after pollination has been shown to inhibit seed production, presumably through inhibition of pollen tube growth.[4] Even if applied to stigmatic surfaces prior to pollination, acid rain can exert a residual inhibition of pollen germination.[15]

Recent studies have demonstrated that precipitation in Rocky Mountain alpine environments is clearly acidic.[9,10] Several research efforts are currently underway to assess the potential impact of such acidic deposition on alpine plant growth and vigor. In the current study we have demonstrated that morphological features of alpine plants can influence the retention of precipitation in predictable ways. Further studies involving the application of simulated acid rain to plants *in situ* are required to determine if structural features foreshadow differential susceptibilities of alpine plants to acid rain. Such studies could contribute to a more comprehensive understanding of the relationship between acidic damage and plant structure.

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