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Agave palmeri Inflorescence Production on Fort Huachuca, Arizona

Jeffrey S. Fehmi, Shelley Danzer, and Joanne Roberts

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Jeffrey S. Fehmi

Construction Engineering Research Laboratory
PO Box 9005
Champaign, IL 61826-9005

Shelley Danzer

ITAM Coordinator
Fort Huachuca Military Reservation
Range Control
Fort Huachuca, AZ 85613

Joanne Roberts

(former) LCTA Coordinator
Fort Huachuca Military Reservation
Range Control
Fort Huachuca, AZ 85613

Final Report

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ABSTRACT: Agave (*Agave palmeri*) is important to Fort Huachuca because of its status as a critical resource for the lesser long-nosed bat (*Leptonycteris curasoae*). The bat depends on agave flower nectar as a primary food source in late summer and early fall. Fort Huachuca contains some of the few remaining roosting sites for this bat in the southwestern United States, and also has abundant agave stands, which are distributed throughout the grasslands. Plant density data were obtained from 29 randomly chosen flowering plants. Density ranged from 700 to 2200 plants per hectare with approximately 10 percent flowering stalks. Analysis of the density data indicated that agave plants were significantly and substantially clustered around flowering plants. Individual plants seem to flower based on several criteria including basal diameter and presence of neighbors. The closer and larger the neighboring agave were, the more likely a particular plant was to flower. Ungulate herbivory affected 50 percent of the agave inflorescences. Given the lack of predators and minimal hunting, herbivore numbers seem likely to increase, putting greater pressure on inflorescence numbers especially in years when fewer plants flower. Other than the loss of inflorescences, the agave population at Fort Huachuca appears robust and self-sustaining.

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Preface

This study was conducted for the U.S. Army Environmental Center (AEC) under the Conservation Assistance Program ECS-RE/COMP (B03-0065), "Assistance to Fort Huachuca (request 1102-01)." The AEC technical monitor was John Barczak. The ERDC Program Manager was H. Roger Hamilton, CEERD-EE.

The work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN) Construction Engineering Research Laboratory (CERL). Part of the work was conducted by Shelley Danzer, Integrated Training Area Management (ITAM) Coordinator, and Joanne Roberts, former Land Condition Trend Analysis (LCTA) Coordinator at Fort Huachuca, AZ. Insect identifications were provided by Dr. Carl A. Olson, Associate Curator, Department of Entomology, University of Arizona, Tucson, AZ. The CERL Principal Investigator was Jeffrey S. Fehmi. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Stephen E. Hodapp is Chief, CEERD-CN-N, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Agave (*Agave palmeri*) is important to Fort Huachuca, located in southeastern Arizona, because of its status as a critical resource for the lesser long-nosed bat (*Leptonycteris curasoae*), which was federally listed as endangered in 1988. The bat is dependent upon the nectar from agave flowers in late summer and early fall as a primary food source. As one of the few remaining roosting areas in the United States for the lesser long-nosed bat, Fort Huachuca must ensure that the agave resource is managed to help conserve the bat population. In 1989 Fort Huachuca established Agave Management Areas (AMAs), based on density of highly visible reproductive adult agave plants.[1] Military training restrictions are applied to the AMAs.

Individual plants can live for 25 or more years but flower only once before dying. The basal rosette sends up an inflorescence (a flowering stalk) from 4.5 to 9 m in height and from 7.6 to 15.25 cm in diameter. The inflorescence will comprise more than half the plant's total biomass when fully formed.[2] The plant is already dying by the time seeds are produced. It is not known what causes some agave plants in an age or size class to initiate flowering while others may continue to grow for many more years before flowering.

Objectives

Because the agave flowers are a critical resource for the endangered lesser long-nosed bat, it would be useful for natural resource managers at Fort Huachuca to

[1] Derdeyn, D. 1989. "Information Paper: Initial survey of fire effects on Agave spp. on Fort Huachuca, Arizona and recommendations to protect the feeding habitat of Sanborn long-nosed bat." Game Management Branch, DEH, U.S. Army Garrison Fort Huachuca, AZ, 18 pp.

[2] Howell, D.J. and B. Roth. 1981. "Sexual reproduction in agaves: the benefits of bats; the cost of semelparous advertising," *Ecology* 62:1-7.

be able to make broad predictions of the number of plants that will flower in any given year. This project was initiated to assess correlates of agave flower production to potentially predict which plants, of appropriate age and size, may flower and which will not. A secondary objective of the project was to determine if there are any other obvious impediments to inflorescence availability or production. This evaluation will augment the on-going annual monitoring of agave populations underway at Fort Huachuca.

Approach

Flowering agave were surveyed in late September 2003, concurrent with the annual monitoring of agave populations. For this survey, areas with agave plants were selected from previously established stakes marking locations of agave monitoring transects (Figures 1 and 2). A random direction was chosen from the beginning transect stake and the first flowering agave plant along that azimuth was chosen as the focal plant. If no flowering agave was found along the azimuth, then the reverse azimuth (± 180 degrees) was used.

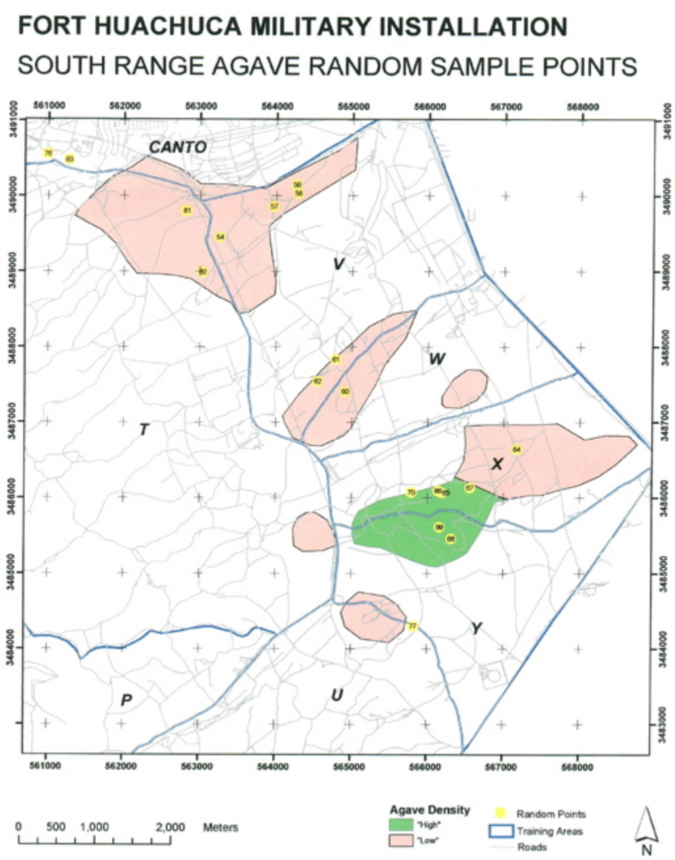


Figure 1. South range agave random sample points.

The sampling protocol evolved throughout the survey. Initially, the survey was based on 47 randomly chosen flowering plants. For each of the 47 flowering plants, global positioning system (GPS) coordinates, number of leaf whorls, plant basal diameter, nearest neighbor (NN) distance, NN leaf whorls, NN basal diameter, distance to the nearest flowering plant, and the number of plants within a 2-m radius was recorded. For 42 plants, the distance to a plant that flowered in a past year was added; for 34 plants, the number of agave plants within a 10-m radius was added; and for 29 plants, the number of flowering agave plants within a 10-m radius and the number with inflorescence herbivory was added.

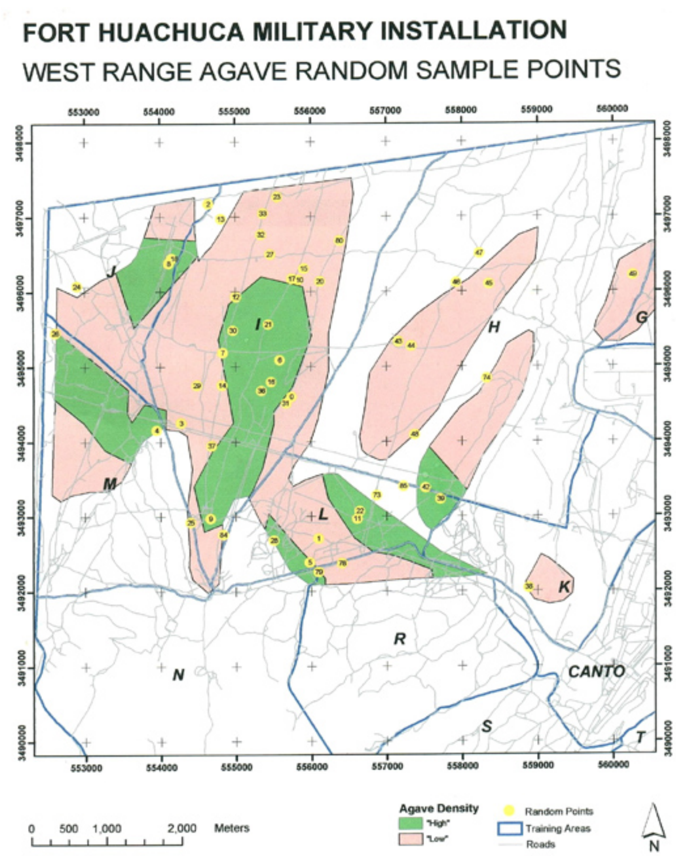


Figure 2. West range agave random sample points.

Average plant diameter, number of leaf whorls, basal diameter, flowering status, and distance to the nearest neighbor were used to build a correlative picture of the typical flowering agave plant. Distance from the randomly selected flowering plant to the nearest neighbor, the nearest flowering plant, and the nearest previous year's flowering plant allowed for indirect estimation of agave density by size class. Agave density (plants per unit area) was calculated by first determining the area, using the distance between the focal plant and the nearest neighbor as the radius of a circle, then counting the number of plants within the full circle. Density of plants that flowered in a previous year was also calculated using the above method. This estimate may be less accurate due to some ambiguity in determining which plants flowered last year and which were from previous years. Plants that flowered last year typically had a brown inflorescence, an upright stalk, some faintly green leaves, and the inflorescence stem was relatively free of rot and insect damage. Despite these criteria, some of the plants identified as last year's flowering plants had one or more sign that it may have actually flowered in a prior year. As a result, these data likely overestimate last year's reproduction.

Mode of Technology Transfer

This report will be provided to the staff at Fort Huachuca and will be forwarded to the groups within the Army that have potential benefit from the research. The report will also be forwarded to groups within the region that have, manage, or research agave.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Results and Discussion

Flowering Stem Density

Density of flowering agave plants was estimated in two different ways: (1) distance between neighbors and (2) counts within a 10-m radius circle (Figure 3 and Appendix A). Based on the average distance from the focal plant to its nearest neighbor (1.5 m), the density estimate was 280 plants per hectare. The estimate based on the average of 21.2 plants per 10-m radius plot was 80 plants per hectare. A T-test of the two estimates shows that they are on the edge of being significantly different (P = 0.05). This implies some clumping in the spatial arrangement of the flowering agave plants with flowering plants being closer together than otherwise might be expected given the overall population density.

Figure 3. Agave population densities on Fort Huachuca can be substantial.

The average distance to a prior year's flowering plant (11.1 m) resulted in an estimate of 250 flowering plants per hectare, using the same basic method as the distance between neighbors above (Figure 4). This is statistically indistinguishable from the estimate of the current year's plants (n = 280). As mentioned above, this method seems quite likely to overestimate the previous year's production due to difficulties in identifying only the plants from the previous year. However, it is a good indicator that the agave population is producing a similar order of magnitude of flowering plants every year.

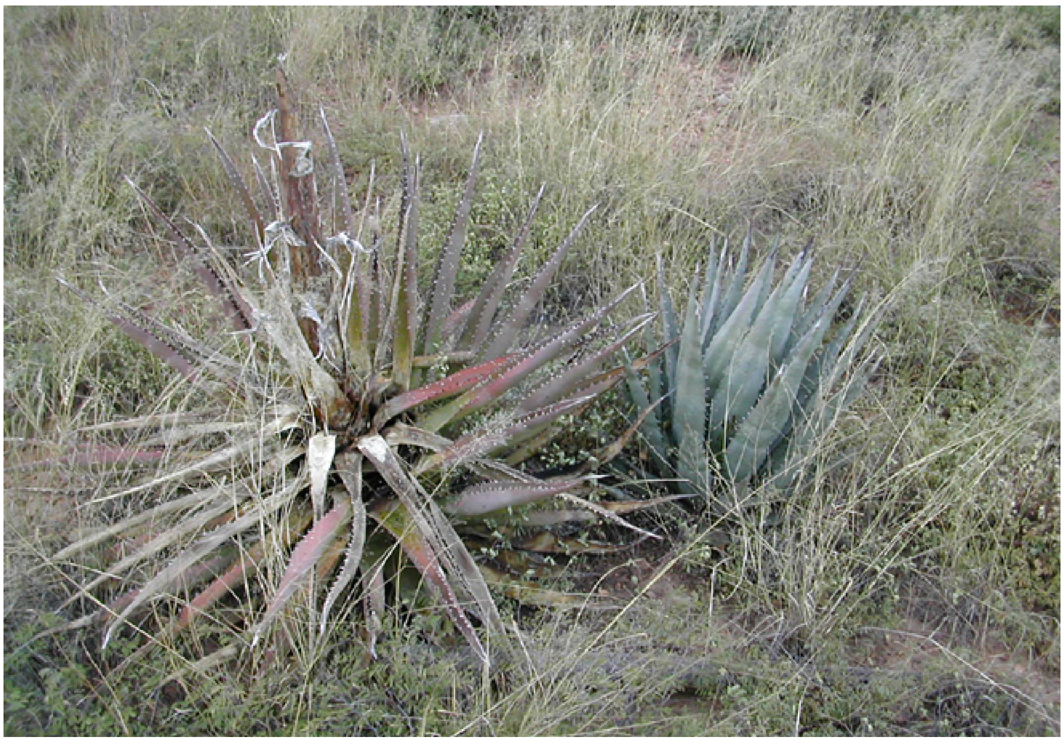


Figure 4. A plant that flowered last year.

Agave Population Stand Density

Population stand density of agave plants was estimated in three different ways: (1) the distance to the nearest neighbor, (2) number of plants within a 2-m radius circle, and (3) number of plants within a 10-m radius circle. Agave plants have some ability to reproduce clonally and this makes plants likely to be clumped.[3] The different methods show the intensity of the clumping, with estimates of

[3] Gentry, H.S. 1982. A*gaves of Continental North America.* University of Arizona Press, Tucson, AZ. 670 pp.

much higher densities closer to the plant compared with density estimates from further away. The nearest neighbor averaged of 1.5 m from the flowering plant resulted in an average density of 3.7 plants per square meter (37,000 plants per hectare). An average of 2.7 plants per 2-m radius plot gave an estimate of 0.2 plants per square meter (2,170 per hectare). An average of 21.2 plants in the 10-m radius plots gave an estimate of less than 0.1 plant per square meter (700 per hectare). This analysis indicates that agave plants are significantly and substantially clustered around the flowering plants, and suggests that the density estimates are biased by the clustering and may not be reliable. Clustering may have an effect on the way that agave population surveys are done. As a result, Population and density estimates should be gathered from randomly allocated areas larger than 4 m^2, rather than centered on flowering plants.

Correlates of Flowering

Flowering agave plants had an average of 26 leaf whorls and a basal diameter of 31.6 cm. The smallest plant had 14 whorls and a diameter of 12 cm. Of the largest flowering plants, one had 52 whorls and a 42-cm diameter; the other had 38 whorls and a 50-cm diameter. The nearest neighbor averaged nearly 11 whorls and 15.1 cm in diameter. More than half of the flowering plants (57%) had a neighbor within 1 m (Figure 5). Regression analysis showed that the distance to the nearest neighbor weighted by the basal diameter of the neighbor was a significant predictor ($P = 0.06$) of the flowering plant's basal diameter. This suggests that plants with closer and larger neighbors flower at a smaller basal diameter than plants with farther/smaller neighbors. This makes biological sense in that the plants closest to one another are likely to be clones. As the larger parent plant begins to compete for resources with its smaller clone (or "kid" as they are known) flowering seems the best bet-hedging strategy. This allows the plant the benefits of an unimpeded clone perhaps partially protected by the carcass of the parent as well as the benefits of sexual reproduction.

A convincing argument could not be made for any other variables having predictive power on flowering plant size. This has as much to do with the complexity of the problem as with the relatively small size of the data set. Additional data might resolve the issue more satisfactorily.

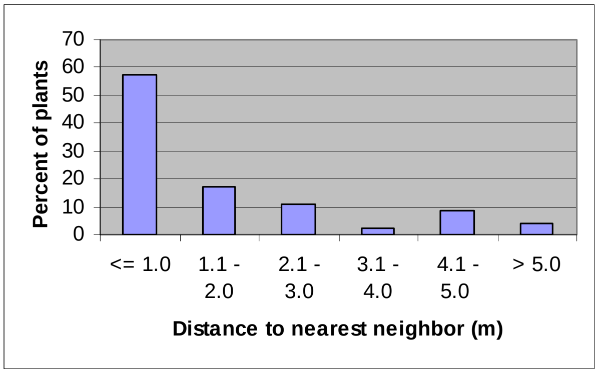


Figure 5. A histogram of NN distance.

Herbivory of the Inflorescences

Herbivory was identified when the inflorescence was missing and appeared to have been bitten off. These indicators seemed unlikely to be due to causes other than herbivory because broken inflorescences, another possibility, typically remained attached to the plant and tipped off to the side (Figure 6). To be identified as herbivory, the inflorescences were not found anywhere near the plant. In this dry climate, the inflorescences can persist for many years. Figure 7 shows inflorescence herbivory (inflorivory). Appendix B contains additional photographs showing inflorivary.

Figure 6. An agave plant with the inflorescence broken off by the wind.

Figure 7. An example of herbivory of the agave inflorescence.

The average observed herbivory of the current year's inflorescences was 50%. The herbivory was variable with eight of the 10-m plots showing no signs of inflorescence herbivory, nine 10-m plots having 100% herbivory, and the rest of the plots being in between. Given the strong interest in maintaining agave as a food source for the endangered lesser long-nosed bat, this loss of inflorescences seems high. Inflorivory also seems important because the herbivores consuming the agave inflorescences are common and not a target for conservation. Most herbivory is a result of large ungulates (pronghorn antelope [*Antilocapra Americana*] or deer [*Odocoileus* spp.]). More research may be needed to determine the conditions under which the inflorescences are consumed, perhaps in the context of an herbivore control strategy to protect the agave in the interim.

Pocket Gopher Herbivory

There was some evidence of mortality due to herbivory by pocket gophers (*Thomomys* sp.) (Figure 8 and Appendix C). This effect did not seem common enough for a survey at the onset of this study. However, based on informal observations, mortality seemed concentrated in the 3- to 10-whorl size class. Even small losses of the smaller size classes can have a major effect in the life cycle of the agave. Yet, given that the gopher is endemic, its effect on the agave population would be continuous, and is probably minimal. In this area, agave plants do reach flowering age and seem relatively common in all size classes, so the gophers are probably not a major concern. Further review of the available literature would aid in making a more informed determination of the effect of pocket gophers. The size of this effect on agave could be easily surveyed in a future study.

Figure 8. An example of an agave plant presumably killed by gophers.

Insect Herbivory

There was ample evidence of insect herbivory on the agave plant leaves. It is unclear if this kind of herbivory is a contributor to mortality, but it certainly may contribute to plant stress. Based on the insects observed during this study and the kind of damage observed, grasshoppers (*Dissosteira* sp.) are believed to be the likely insects responsible (Figure 9 and Appendix D). However, given that the grasshoppers in question likely endemic, their effect on the agave population will have been continuous and probably not a major concern. The size of this effect could be easily surveyed in a future study. A review of the available literature would also contribute to understanding the importance of this kind of herbivory.

Figure 9. A katydid (*Dichopetala brevihastata*) grazing on agave.

3 Conclusions and Recommendations

Conclusions

The agave resource at Fort Huachuca is thriving and there are many flowering plants. This survey found that there were between 700 and 2,200 plants per hectare with about 10% of them were flowering. Analysis of the density data indicate that agave plants were significantly and substantially clustered around the flowering plants. Given the strong clustering noted, the survey techniques may not have covered a large enough area to be reliable. Agave plants seem to flower based on a two-stage determination. First is the basal area of the plant, which was typically around 30 cm (± 9 cm) basal diameter, indicating that the plant is large enough/old enough. Second was the presence of neighbors. The closer and larger the neighboring agave were, the more likely the affected plant was to flower.

The average herbivory of the agave inflorescences (50%) is of special concern because the endangered lesser long-nosed bat is dependent upon the flower's nectar as their primary food source during the late summer and early fall. The herbivore numbers seem likely to increase, putting greater pressure on inflorescence numbers in years when fewer plants flower. The pressure by herbivores may take a high percentage of the available inflorescences in these less productive years. Additional research may be needed on the herbivores and the situation in which the inflorescences are consumed. Despite the herbivory, the agave population at Fort Huachuca appears robust and self sustaining.

Recommendations

Stability of the agave population as a major forage resource for the lesser long-nosed bat is important to all of the land management agencies in this region, including Fort Huachuca. Although there has been significant research on the lesser long-nosed bat, there has been little research on agave biology, population distribution, and factors defining agave habitat. Only a relatively small sample was used to determine variables that may have predictive power on flowering plant size. This project could be expanded by increasing sample size for more robust analyses. It was clear from this study that herbivory of current year agave inflorescences was significant. Although herbivory was from endemic species, there is little known about the impact of herbivory on the agave population. It is recommended that this research be expanded to better understand the effect of herbivory on agave inflorescences. An herbivore control strategy may be initiated to protect the agave while more research is conducted on the species and the conditions under which inflorescences are consumed. A review of the available literature would also contribute to understanding the importance of herbivory on agave species.

Appendix A: Data Tables

Basic Plant Information

Sampling Date	Agave monitoring plot number	Plant number	UTM East (prefixed by 125)	UTM North (prefixed by 34)	Number of leaf whorls	Basal diameter (cm)	Distance to NN (m)	NN flowering (F)/ not flowering (NF)	Number of NN leaf whorls	NN basal Diam (cm)
22-Sep-03	16	1	55351	94666	15	20	0.4	NF	11	12
22-Sep-03	36	2	55430	94798	18	22	0.6	F	20	30
22-Sep-03	36	3	55450	94841	23	37	0.6	NF	9	8
22-Sep-03	6	4	55451	95124	24	25	4.8	NF	12	15
22-Sep-03	6	5	55690	95149	24	38	2.6	NF	10	8
22-Sep-03	7	6	55386	95592	24	19	1.8	NF	6	6
22-Sep-03	7	7	55444	95590	26	24	4.2	NF	9	8
22-Sep-03	30	8	54837	95194	14	12	2.7	NF	16	23
22-Sep-03	30	9	54858	95213	33	29	1.8	NF	25	41
22-Sep-03	30	10	54829	95209	39	48	0.5	NF	13	13
22-Sep-03	14	11	54962	95463	27	23	0.4	NF	6	8
22-Sep-03	14	12	54974	95451	21	20	5.5	F	22	34
22-Sep-03	14	13	54972	95478	19	36	0.9	NF	4	5
23-Sep-03	22	14	56646	93081	18	24	1.0	NF	4	4
23-Sep-03	22	15	56670	93070	15	27	0.7	NF	7	13
23-Sep-03	70	16	65777	86072	15	22	4.1	NF	3	2
23-Sep-03	70	17	65779	86096	19	33	5.2	NF	17	36
23-Sep-03	70	18	65760	86086	19	32	4.3	F	18	31
24-Sep-03	66	19	66112	86114	21	30	0.9	NF	11	23
24-Sep-03	66	20	66097	86105	26	45	0.5	NF	11	18
24-Sep-03	66	21	66083	86100	21	38	0.4	NF	9	20
24-Sep-03	67	22	66536	86130	20	39	0.7	NF	7	14
24-Sep-03	67	23	66565	86129	21	33	0.6	NF	10	26
24-Sep-03	67	24	66553	86109	40	50	0.7	NF	12	16
24-Sep-03	64	25	67200	86631	27	39	0.6	NF	10	12
24-Sep-03	64	26	67175	86671	28	22	0.4	NF	11	17
24-Sep-03	64	27	67192	86665	52	42	2.6	NF	17	15
25-Sep-03	11	28	56597	92968	22	36	1.8	NF	16	20
25-Sep-03	11	29	56583	93003	40	39	1.7	NF	5	8
25-Sep-03	11	30	56570	92991	24	31	1.0	NF	12	15
25-Sep-03	79	31	56061	92270	25	24	0.8	NF	6	7
25-Sep-03	79	32	56089	92229	22	27	1.4	NF	14	16
25-Sep-03	79	33	56112	92245	26	25	2.4	NF	9	9
25-Sep-03	78	34	56397	92376	29	28	1.2	NF	6	6
25-Sep-03	78	35	56393	92350	38	50	2.8	NF	7	8
25-Sep-03	78	36	56419	92363	25	24	0.3	NF	6	5
25-Sep-03	5	37	55973	92386	36	41	0.2	NF	8	9
25-Sep-03	5	38	55992	92401	22	25	0.1	NF	6	7
25-Sep-03	5	39	56022	92415	27	33	0.3	NF	5	6
25-Sep-03	28	40	55554	92708	14	16	0.3	NF	6	8
25-Sep-03	28	41	55573	92705	30	32	3.3	NF	7	13
25-Sep-03	28	42	55569	92723	29	39	1.7	NF	28	35
25-Sep-03	84	43	54830	92786	40	45	0.5	NF	22	40
25-Sep-03	84	44	54795	92772	34	42	0.5	NF	5	4
25-Sep-03	84	45	54782	92762	29	31	0.2	NF	10	14
25-Sep-03	25	46	54397	92946	36	40	0.2	NF	8	7
25-Sep-03	25	47	54373	92959	27	29	1.5	NF	14	14
				Ave.	26.04	31.62	1.53	3 of 47	10.85	15.09
				SD	8.18	9.20	1.47		5.80	10.21
				min	14	12	0.1		3	2
				max	52	50	5.5		28	41

Flowering Plant Density

plant	Distance to nearest flowering plant (m)	number of flowering plants w/in 10 meters*	distance to nearest plant that appears to have flowered last year (m)	NN Density flowering plants (m^2)	10 meter Density flowering plants (m^2)	Last years flowering density plants (m^2)
1	5.7	–	--	0.020	--	–
2	10.6	–	--	0.006	--	–
3	20.3	–	--	0.002	--	–
4	22.8	–	0.7	0.001	--	0.650
5	22.8	–	17	0.001	--	0.001
6	21	–	28.9	0.001	--	0.000
7	23.2	–	18.1	0.001	--	0.001
8	10.5	–	9.8	0.006	--	0.003
9	8.5	–	22.8	0.009	--	0.001
10	9.3	–	5.4	0.007	--	0.011
11	15.7	–	17.3	0.003	--	0.001
12	5.5	–	6.8	0.021	--	0.007
13	1.3	–	3.4	0.377	--	0.028
14	5.7	–	9.1	0.020	--	0.004
15	6.9	–	17.3	0.013	--	0.001
16	14	–	14.1	0.003	--	0.002
17	8.1	–	11.6	0.010	--	0.002
18	4.3	–	8.3	0.034	--	0.005
19	9.8	2	5.3	0.007	0.010	0.011
20	5.8	2	8.4	0.019	0.010	0.005
21	3.5	3	10.1	0.052	0.013	0.003
22	20.1	0	15.6	0.002	0.003	0.001
23	8.1	1	5.5	0.010	0.006	0.011
24	7	4	4.7	0.013	0.016	0.014
25	28.6	0	23.6	0.001	0.003	0.001
26	8.5	1	9.1	0.009	0.006	0.004
27	21.5	0	24.1	0.001	0.003	0.001
28	17.8	0	25.9	0.002	0.003	0.000
29	12	0	18.4	0.004	0.003	0.001
30	1.4	3	9.7	0.325	0.013	0.003
31	20.4	0	2.5	0.002	0.003	0.051
32	5.9	4	13.4	0.018	0.016	0.002
33	7.1	3	20.4	0.013	0.013	0.001
34	2.6	1	4.8	0.094	0.006	0.014
35	3	3	10.6	0.071	0.013	0.003
36	5.3	1	1.6	0.023	0.006	0.124
37	17.2	0	27.6	0.002	0.003	0.000
38	5.3	1	13.9	0.023	0.006	0.002
39	26.5	0	29.9	0.001	0.003	0.000
40	8.5	2	2.5	0.009	0.010	0.051
41	10.6	0	5.7	0.006	0.003	0.010
42	6.1	3	5.3	0.017	0.013	0.011
43	12.9	1	16.8	0.004	0.006	0.001
44	9.6	1	5.8	0.007	0.006	0.009
45	4.4	3	5.6	0.033	0.013	0.010
46	6	1	24.3	0.018	0.006	0.001
47	8.4	1	--	0.009	0.006	–
Ave.	11.07	1.41	12.60	0.028	0.008	0.025
SD	7.20	1.32	8.21	0.071	0.004	0.100
min	1.3	0	0.7	0.001	0.003	0.000
max	28.6	4	29.9	0.377	0.016	0.650

* Did not include the focal plant, so density calculation is based on this number +1

Population Density

plant	Dist NN (m)	number of plants within 2 meters*	number of plants within 10 meters*	NN Density of plants (m^2)	2 meter Density of plants (m^2)	10 meter Density of plants (m^2)
1	0.4	3	--	3.979	0.318	--
2	0.6	1	--	1.768	0.159	--
3	0.6	1	--	1.768	0.159	--
4	4.8	0	--	0.028	0.080	--
5	2.6	0	--	0.094	0.080	--
6	1.8	1	--	0.196	0.159	--
7	4.2	0	--	0.036	0.080	--
8	2.7	0	--	0.087	0.080	--
9	1.8	1	--	0.196	0.159	--
10	0.5	1	--	2.547	0.159	--
11	0.4	3	--	3.979	0.318	--
12	5.5	0	--	0.021	0.080	--
13	0.9	3	--	0.786	0.318	--
14	1.0	2	33	0.637	0.239	0.108
15	0.7	4	34	1.299	0.398	0.111
16	4.1	0	4	0.038	0.080	0.016
17	5.2	0	8	0.024	0.080	0.029
18	4.3	0	6	0.034	0.080	0.022
19	0.9	2	21	0.786	0.239	0.070
20	0.5	3	25	2.547	0.318	0.083
21	0.4	3	19	3.979	0.318	0.064
22	0.7	3	9	1.299	0.318	0.032
23	0.6	3	15	1.768	0.318	0.051
24	0.7	3	31	1.299	0.318	0.102
25	0.6	3	12	1.768	0.318	0.041
26	0.4	1	25	3.979	0.159	0.083
27	2.6	0	17	0.094	0.080	0.057
28	1.8	1	7	0.196	0.159	0.025
29	1.7	1	24	0.220	0.159	0.080
30	1.0	3	35	0.637	0.318	0.115
31	0.8	2	18	0.995	0.239	0.060
32	1.4	2	26	0.325	0.239	0.086
33	2.4	0	17	0.111	0.080	0.057
34	1.2	1	27	0.442	0.159	0.089
35	2.8	0	22	0.081	0.080	0.073
36	0.3	8	37	7.074	0.716	0.121
37	0.2	1	7	15.916	0.159	0.025
38	0.1	1	10	63.664	0.159	0.035
39	0.3	1	3	7.074	0.159	0.013
40	0.3	3	23	7.074	0.318	0.076
41	3.3	0	28	0.058	0.080	0.092
42	1.7	1	22	0.220	0.159	0.073
43	0.5	2	21	2.547	0.239	0.070
44	0.5	3	32	2.547	0.318	0.105
45	0.2	2	46	15.916	0.239	0.150
46	0.2	5	30	15.916	0.477	0.099
47	1.5	3	25	0.283	0.318	0.083
Ave.	1.53	1.72	21.15	3.752	0.217	0.070
SD	1.47	1.61	10.57	9.794	0.128	0.034
min	0.1	0.0	3.0	0.0	0.1	0.0
max	5.5	8.0	46.0	63.7	0.7	0.1

* Did not include the focal plant, so density calculation is based on this number +1

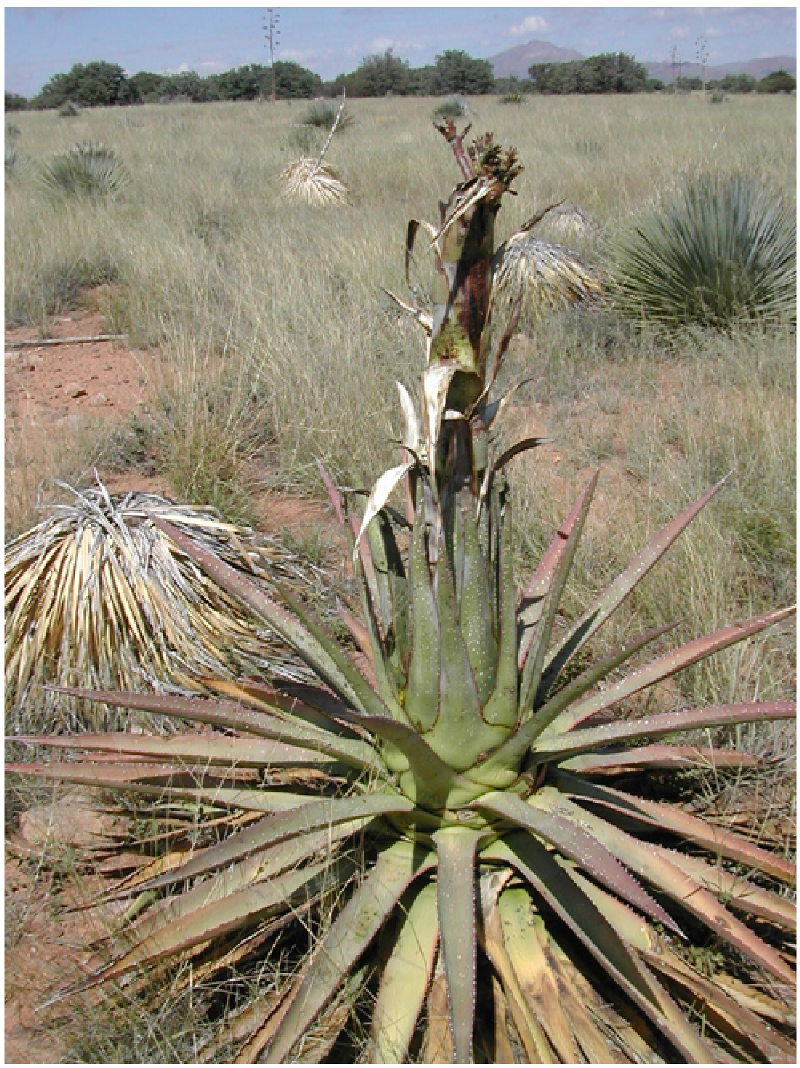
Inflorescence Herbivory

Data collected only from the last 29 sample plants

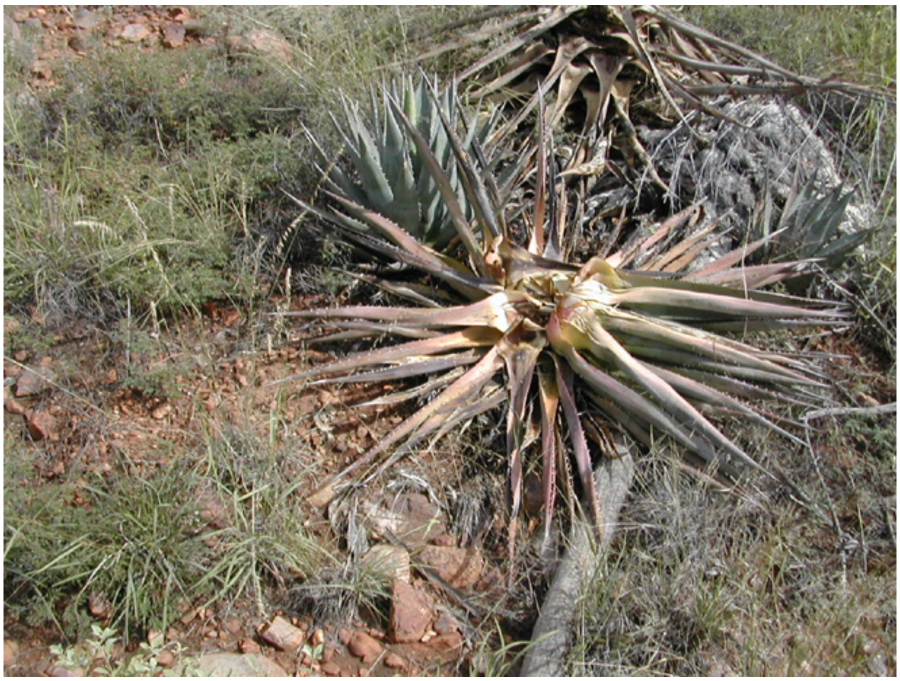
plant	number of flowering plants w/in 10 meters*	number of flowering plants that had inflorescences completely removed	10 meter Density flowering plants m2	percent herbivory
19	2	1	0.010	33.33
20	2	1	0.010	33.33
21	3	2	0.013	50.00
22	0	0	0.003	0.00
23	1	0	0.006	0.00
24	4	3	0.016	60.00
25	0	0	0.003	0.00
26	1	0	0.006	0.00
27	0	0	0.003	0.00
28	0	1	0.003	100.00
29	0	1	0.003	100.00
30	3	4	0.013	100.00
31	0	1	0.003	100.00
32	4	2	0.016	40.00
33	3	2	0.013	50.00
34	1	1	0.006	50.00
35	3	2	0.013	50.00
36	1	1	0.006	50.00
37	0	1	0.003	100.00
38	1	2	0.006	100.00
39	0	0	0.003	0.00
40	2	3	0.010	100.00
41	0	0	0.003	0.00
42	3	4	0.013	100.00
43	1	1	0.006	50.00
44	1	1	0.006	50.00
45	3	4	0.013	100.00
46	1	0	0.006	0.00
47	1	1	0.006	50.00
Ave.	1.41	1.34	0.008	50.57
SD	1.32	1.26	0.004	39.30
min	0	0	0.003	0
max	4	4	0.016	100

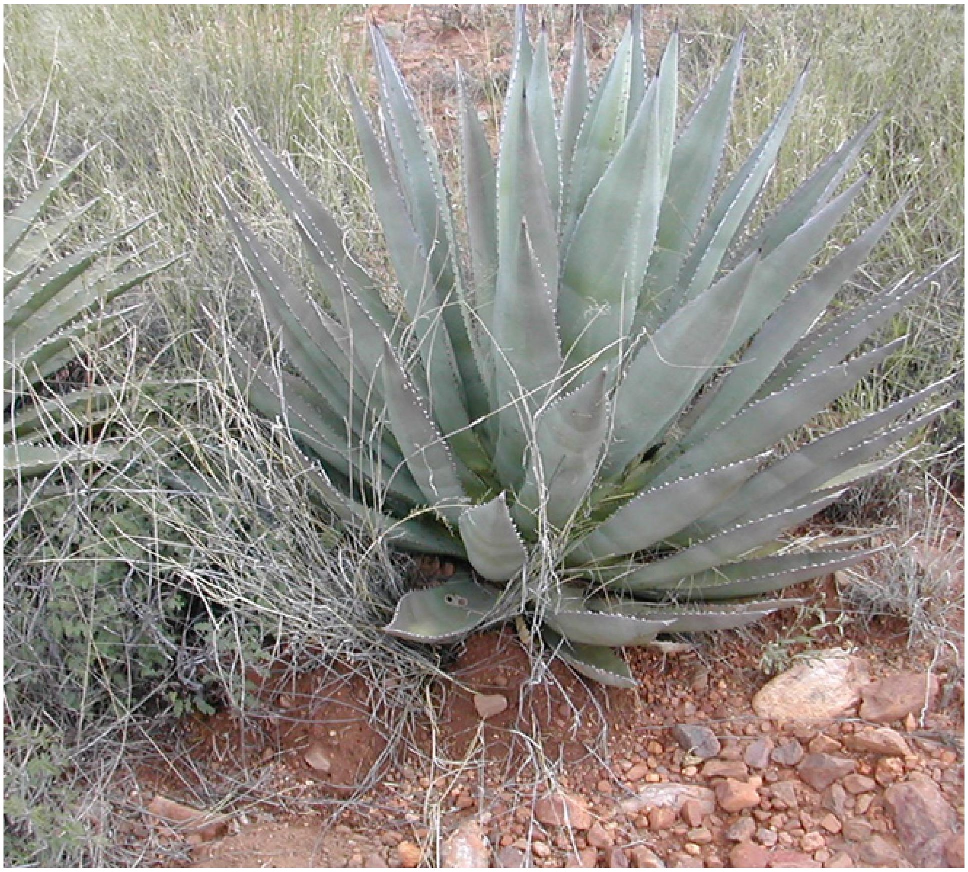
* Did not include the focal plant, so density calculation is based on this number +1

Appendix B: Agave Inflorescences Removed by Herbivores



Appendix C: Examples of Gopher Related Effects on Agave





Appendix D: Potential Insect Herbivores

Short-horned grasshopper nymph

Rainbow grasshopper (*Dactylotum bicolor*)

Pallid-winged grasshopper (*Trimerotropis pallidipennis*)

Boopee (*Boopedon nubilum*) short-winged male

Plains lubber grasshopper (*Brachystola magna*)

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14. ABSTRACT

Agave (*Agave palmeri*) is important to Fort Huachuca because of its status as a critical resource for the lesser long-nosed bat (*Leptonycteris curasoae*). The bat depends on agave flower nectar as a primary food source in late summer and early fall. Fort Huachuca contains some of the few remaining roosting sites for this bat in the southwestern United States, and also has abundant agave stands, which are distributed throughout the grasslands. Plant density data were obtained from 29 randomly chosen flowering plants. Density ranged from 700 to 2200 plants per hectare with approximately 10 percent flowering stalks. Analysis of the density data indicated that agave plants were significantly and substantially clustered around flowering plants. Individual plants seem to flower based on several criteria including basal diameter and presence of neighbors. The closer and larger the neighboring agave were, the more likely a particular plant was to flower. Ungulate herbivory affected 50 percent of the agave inflorescences. Given the lack of predators and minimal hunting, herbivore numbers seem likely to increase, putting greater pressure on inflorescence numbers especially in years when fewer plants flower. Other than the loss of inflorescences, the agave population at Fort Huachuca appears robust and self-sustaining.

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