Journal of the Minnesota Academy of Science

Volume 47 | Number 1 Article 6

1981

Composition of Goldenrod (Solidago: Compositae) Populations by Species in the Upper Midwest

William E. Miller
United States Department of Agriculture

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WILLIAM E. MILLER*

ABSTRACT — In each of 100 abandoned agricultural fields grown over with goldenrod, stems were diagnosed and counted in 20 occupied 0.4 M plots selected by hoop tossing. Preliminary results differed little between hoop tossing and random plot selection, and between 0.9 and 0.4 m plot sizes. In rank order of stem abundance the taxa were *Solidago altissima* L. *S. canadensis* L. complex *S. gigantea* Ait. *S. graminifolia* (L.) Saliab. *S. nemoralis* Ait. *S. ulmifolia* muhl. others. An average of 2.2 taxa were recorded per field, and three or more taxa in at least one plot in 34 percent of fields. Where *S. altissima-S. canadensis* complex stems were resolved to species, *S altissima* was approximately three times more abundant than *S. canadensis*.

Goldenrods comprise a diverse assemblage of *Solidago* species which reproduce by seed and rootstocks. They occur in various upper midwest plant communities (Curtis 1959) but are most abundant in intermediate stages of secondary successions. Some species can attain dominance 5 to 15 years following abandonment of agricultural land and retain it for 15 to more than 25 years (Bazzaz 1968, Drew 1942, Quarterman 1957), depending on factors such as soil porosity and last crop (Beckwith 1954).

Despite advancing knowledge of goldenrod growth requirements (Werner and Platt 1976) and numerous studies of secondary succession, there is no clear picture of the relative abundance of different taxa in upper midwest goldenrod populations, nor how frequently their stands are mixed. The present study examines these questions by extensive sampling in abandoned agricultural fields, one of the commonest goldenrod habitats. The study developed from an interest in goldenrods as hosts of monophagous insects (Miller 1959, 1963, 1976) and as positive and negative influences on various human activities. Some goldenrods are valued in apiculture as late-season sources of pollen and nectar (Oertel 1939) and some are potential sources of rubber (Polhamus 1933). However, some are allegedly allelopathic (Brown and Roti 1973) and several upper midwest species introduced into Europe reduce moisture and other resources available to tree seedlings, prompting forestry interest in their control (capek 1971).

Hoop-tossing method preferred

One hundred study fields were chosen using the following criteria: (a) sub-continuous vegetation cover occupying a potential sample area between 0.2 and 0.5 ha, (b) half or more of vascular stems consisting of goldenrod, and (c) no woody vegetation taller than goldenrod in the sample area. Study fields were taken as encountered during motoring and none were contiguous. Goldenrod was at or near its population peak in such fields.

All goldenrod stems taller than 6 cm were counted in each of 20 occupied plots per sample area. In one-fourth of the sample areas, stems of other vascular plants also were counted to monitor subjective determination of relative goldenrod abundance.

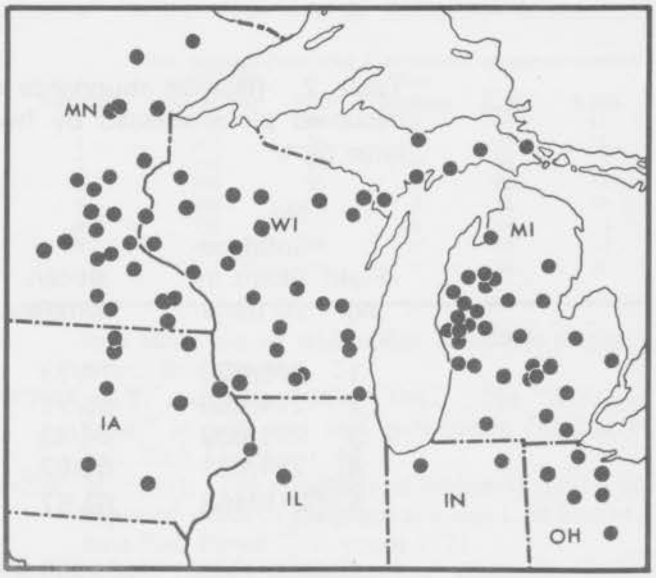

Fig. 1 — Location of the fields in study of goldenrod

Tossing a circular light-weight tubular hoop was the preferred method for selecting plots in sample areas because it facilitates rapid sampling of many fields in a wide area. The hoop was tossed again if it did not land around at least one goldenrod stem; no more than two additional tosses were necessary in any field.

Before placing reliance on hoop tossing, however, results were compared with strictly random selection of occupied plots. Square sample areas 0.2 to 0.4 ha were established in continuous stands with sides parallel to cardinal directions each providing more than 3,000 potential non-over lapping 0.4 m^2 plots. After a cardinal orientation was chosen randomly, 20 plots were selected by drawing location coordinates from a random number table, and 20 were selected by hoop tossing.

Two plot sizes, 0.4 and 0.9 m^2, both within the range commonly used in such sampling, were likewise compared

*WILLIAM E. MILLER is chief insect ecologist at the North Central Forest Experiment Station of the United States Department of Agriculture at St. Paul, Minnesota. He has attributed his interest in botany and goldenrod biology to working with insects that he characterizes as "pretty fair botanists."

Table 1. Relative abundance of Solidago taxa in 0.4 m² occupied plots selected by hoop tossing (a) and random process (r) in 0.2 to 0.4 ha sample areas. Data presented as a/r.

Field no.	No. Solidago stems in 20 plots	Percentage Solidago: [1] alt-can complex	gig	nem	gram	spec
1	267/290	48/47	51/47	1/5	< 1/1	0/0	0/0
2	311/327	89/94	4/4	2/0	0/0	2/2	3/< 1
3	531/532	85/90	14/10	0/0	0/0	< 1/0	0/0

1 Species abbreviated: alt-altissima, can-canadensis, gig-gigantea, nem-nemoralis, gram-graminifolia, rig-rigida, spec-speciosa

Table 2. Relative abundance of Solidago taxa in nested 0.4 and 0.9 m² occupied plots selected by hoop tossing. Data presented as small plot/large plot.

Field no.	No. Solidago Stems in 20 plots	Percentage Solidago: [1] alt-can complex	gig	nem	rig	gram	spec
1	276/620	74/73	2/3	2/2	18/17	0/0	4/5
2	214/456	66/71	32/27	2/2	0/0	0/0	0/0
3	291/639	84/83	15/16	1/< 1	0/0	<1/<1	0/0
4	284/641	61/62	37/36	1/2	0/0	<1/<1	0/0
5	215/463	69/67	0/0	8/8	11/14	0/0	12/11

1 Species abbreviated as in Table 1.

before one size was adopted. This comparison was done by using a hoop of 0.4 m² area centered inside a 0.9m² hoop.

Fields were sampled between August 14 and October 19--the goldenrod flowering period--to aid species identification. Rapid diagnosis was possible except for two pairs whose members are very similar: *Solidago altissima* L.-*S. canadensis* L. and *S. juncea* Ait.-*S. missouriensis* Nutt. Each was recorded as a complex. In certain fields where multiple visits and intensive study were feasible, *S. altissima* and *S. canadensis* were separated for counting based on differences in flowering period, involucre length, and leaf and stem characters. Available involucre length criteria (Fernald 1950) did not seem to accurately separate these species; the criteria were therefore adjusted to local frequency distributions which ranged from 2.1 to 4.5 mm, and to fresh material as well which was found to be 9 percent longer before herbarium shrinkage (30 n). Karyotype examination following Beaudry and Chabot (1957) of one typical specimen of each species supported diagnoses. Voucher specimens from this study are in the Michigan State University Herbarium, East Lansing.

Comparison of results

The sampled fields were located in parts of Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana, and Ohio (Fig. 1).

Results obtained by hoop tossing and random plot selection in three Minnesota fields are compared in Table 1. In two of these fields more species were recorded by hoop tossing, but this is probably fortuitous because the additional species were uncommon. The greatest difference in the comparison was five points; from this it was concluded that hoop-tossing results approximated random-plot results.

Results obtained with the two hoop sizes in five Minnesota fields are compared in Table 2. The same species appeared in both plot sizes. The greatest difference in the comparison was five points; from this it was concluded that

Table 3. Relative abundance of Solidago taxa in sample areas of 100 upper midwest fields.

Solidago:	Percentage fields where recorded	Percentage in fields where recorded	stems in all fields
altissima L.-canadensis L. complex	98	75	74
gigantea Ait.	56	28	16
graminifolia (L.) Salisb.	39	12	4.7
nemoralis Ait.	22	15	3.2
ulmifolia Muhl.	11	13	1.4
rigida L.	7	2	0.1
juncea Ait. missouriensis Nutt. complex	4	3	0.1
speciosa Nutt.	2	35	0.5
			100.0

hardly more information was gained in the 0.9 m² plot size than in the 0.4 m², and the latter was adopted for the study.

Eight *Solidago* taxa were recorded in the 100 study fields (Table 3). In relative stem abundance, rank order was *S. altissima-S. canadensis* complex > *S. gigantea* > *S. graminifolia* > *S. nemoralis* > *S. ulmifolia* > others. Relative abundance of *S. altissima-S. canadensis* complex and *S. gigantea,* the two most common taxa, remained constant through much of the five-fold range in goldenrod density index (Table 4). In the 25 fields where all vascular stems were counted, goldenrod comprised from 53 to 99 percent of stems, averaging 82 percent.

In seven Michigan fields where *S. altissima* and *S. canadensis* were largely separated, the first species was approximately three times more abundant than the second (Table 5). If these results are extended to the whole study, *S. canadensis* approaches *S. gigantea* in relative stem abundance. In Wisconsin fields, resolution of *S. altissima-S. canadensis* complex into species was more difficult and the attempt was abandoned.

More than one taxon was recorded in 80 percent of study fields. This number depends on true proportion of stems of each taxon in the sample area, and on intensity of sampling. Twenty tosses of the 0.4 m hoop produced an average of 2.2 taxa per sample area. At least one plot containing three or more taxa appeared in 34 percent of sample areas, and the maximum in one plot, four areas appeared in eight percent of the sampled plots.

In conclusion, eight constituent taxa were recorded in upper midwest old field *Soldiago* populations. *Solidago altissima-S. canadensis* complex is the most abundant taxon, and *S. altissima* probably the most prevalent species. Relative abundance of the two most common taxa was not influenced by overall goldenrod stem density. Mixed stands are common as judged by maximum numbers of taxa per 0.4 m² plot. Finally, results apply to stem density, not to individual plant or clone density; cloning propensity could differ among species.

ACKNOWLEDGEMENTS

J.H. Beaman, G.B. Ownbey, T. Morley, L.K. Miller, and M.P. Martin are thanked for their help with goldenrod identification, field work, and analysis of the data.

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Table 4. Relative abundance of Solidago altissima-S. canadensis complex and S. gigantea with respect to overall Solidago density.

Index No. Solidago stems/m² [1]	No. Fields	Mean percentage Solidago: [2] altissima-canadensis complex	gigantea
10	7	-	-
11 - 20	26	71	30
21 - 30	28	76	26
31 - 40	27	72	28
41 - 50	8	-	-
50	4	-	-
Total	100		

1 Not absolute density because occupied plots were used.
2 Differences within columns not significant based on analysis of variance (P_F .05). Means from eight or fewer fields not considered because of small sample size.

Table 5. Relative abundance of S. altissima and S. canadensis.

Field No.	No. Solidago stems in 20 occupied plots	Percentage S. altissima-S. canadensis complex: Total	Not Resolved	S. alt	S. can
1	196	85	3	41	41
2	254	71	3	21	47
3	166	97	25	65	7
4	246	91	2	88	1
5	236	64	2	48	14
6	136	73	16	54	3
7	202	66	0	62	4
	Mean	78	7	54	17

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