

Berry Ripening and Harvest Season in Wild American Ginseng

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Abstract - American ginseng (*Panax quinquefolius* L.) is a rare to uncommon CITES Appendix II-listed perennial plant species that is harvested from the wild to supply the herbal trade. Harvest seasons for American ginseng are intended to coincide with berry ripening in the species. However, geographic patterns of harvest seasons among states suggest they may not be tied to ripening phenology. In this study, we experimentally established the relationship between berry color and subsequent seed germination 1.5 years later in a natural population. We then monitored berry ripening August 15, September 1, and September 15 in 31 populations across much of ginseng's natural range. We found no biological basis for state-to-state differences in harvest seasons, and clear evidence that in some states the harvest season is set too early to ensure full berry ripening. Variation among years was examined in a subset of populations: Results from that analysis do not alter the conclusion that improvement in ginseng management could be achieved by establishing biologically based harvest seasons.

Introduction

American ginseng (*Panax quinquefolius* L.) is harvested from the wild to supply the Asian ginseng market (Robbins 1998, 2000). Economically, ginseng is the most prominent wild-harvested herbaceous medicinal plant in North America. Concern about the sustainability of harvest led to its listing in Appendix II of the Convention on International Trade in endangered Species of Wild Fauna and Flora (CITES) in 1975. Since that time, the US Fish and Wildlife Service's Office of Scientific Authority has

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required states wishing to allow harvesting to provide evidence that the harvest is not detrimental to the long-term viability of natural populations.

After the species was CITES listed, many states implemented harvest seasons to enhance harvest sustainability. The purpose of the harvest season was to allow mature ginseng plants to fully ripen fruits so that harvesters could plant the seeds, thus ensuring replacement of the harvested individuals. The theory underlying this policy is that if harvesters, on average, plant enough seeds to eventually replace the plants removed by harvest, then harvest would be sustainable. Thus, a second component of harvest regulations in most states (except Virginia and North Carolina, where replanting is “recommended”) is a requirement that harvesters plant seeds of the plants they remove from the population.

While harvest seasons were devised to ensure berry ripening, what is less clear is why harvest season onset varies considerably across the range of ginseng (Fig. 1). One state (PA) has set Aug. 1, five states (GA, KY, TN, WV, VA) have set Aug. 15, two Aug. 20 (MD, VT), nine have set Sept. 1 (AL, AR, IN, MN, MI, NY, NC, OH, WI), one has set the first Saturday in September (IL), and one (IA) has set Sept. 15 as the start of the harvest season. As is quite apparent from the map of harvest onset dates (Fig. 1), there is no clear geographic pattern to these dates, suggesting that they may not have corresponded with berry phenology differences across the range. Published data on berry ripening in ginseng is scant (but see Anderson et al.

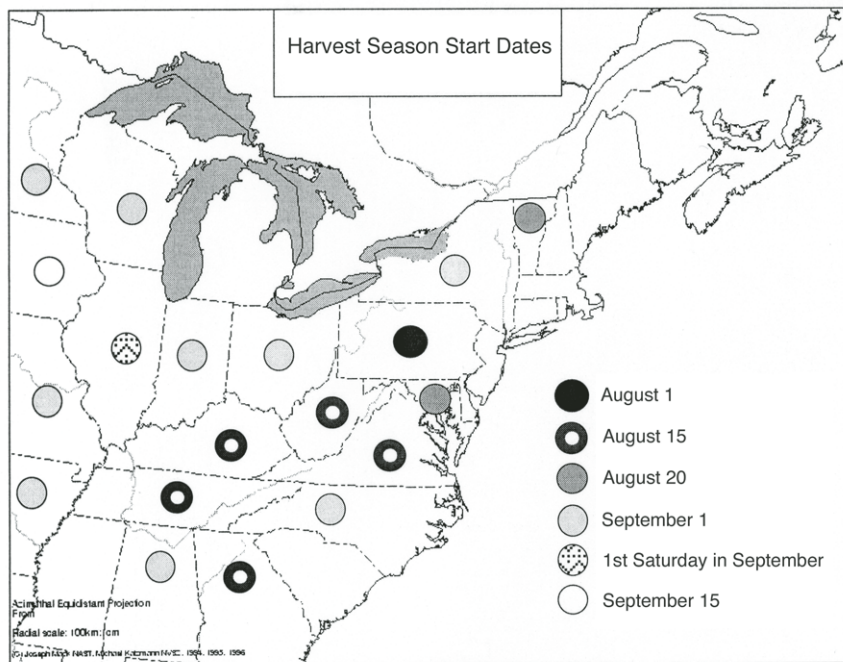


Figure 1. Harvest season start dates for states permitting harvesting of wild ginseng.

1993, Carpenter and Cottam 1982, Lewis and Zenger 1982). Therefore, it seems likely that harvest seasons were set without a strong scientific basis.

In this study, we asked three questions to address the need for a scientific basis for ginseng harvest seasons. (1) Does fruit (berry) color correspond with seed maturity and subsequent germinability? We answered this question using a multi-year study of a single population of ginseng near the center of its range. (2) Does ginseng berry ripening show distinctive geographic variation in seed ripening that could lead to logical state-to-state differences in harvest season? To answer this question, we formed a ginseng berry monitoring network spanning broad latitudinal/longitudinal, elevational, site history, and forest community settings, and examined berry ripening across that range in summer and fall of 2003. (3) To what degree does berry ripening vary in contrasting years within a site? This question was addressed by examining berry ripening patterns over multiple years in several populations near the center of ginseng's range.

Methods

Berry color and subsequent seed germinability

In May, 1998, a natural population of American ginseng was located on Chestnut Ridge ca. 15 km east of Morgantown, WV (precise coordinates withheld for conservation reasons). On August 1, August 26, and September 22, 1998, ginseng berries, randomly selected from those available at each date, were collected from the 20 reproductive adult plants in the population. Because they were randomly chosen, the frequency of green and red fruits at each date reflected the natural frequency occurring at that time. On August 1, all berries were green, on August 26 there was a mixture of red and green fruits, and by Sept. 22, all fruits were red. Seeds were planted 1 cm deep within paper "nut cups" (to prevent seed migration) in native soil. Seeds collected at different dates were placed in randomly selected positions (20 cm spacing) within a 1-m x 2.4-m gridded block located 3 m uphill from a cluster of natural ginseng plants. Control locations within the grid were not planted and showed no germination. Fruits were planted whole to simulate what harvesters are encouraged to do. Although fruits were planted intact, individual seed number planted was determined by examining the bulges in the fruit. A total of 25, 18, and 15 seeds were planted on the 3 respective dates.

Ginseng seeds exhibit morphophysiological dormancy (Baskin and Baskin 1998), resulting in an 18-month dormancy period. On May 7 and May 12, 2000, seed germination was scored at each position within the grid. Germination was compared among dates and by seed color using a log-likelihood test (G-test; Sokal and Rohlf 1995).

Geographic variation in berry ripening

Since ginseng is relatively rare, it was not possible to obtain a purely random sample of populations to monitor. Rather, we examined berry ripening in populations that were known to us from many different contexts.

Some of these were discovered through random sampling of communities in previous fieldwork, while others were known to us from a variety of contacts with other professional or amateur botanists or naturalists. We monitored 31 natural populations found in nine states or provinces (IL, KY, ME, MO, NC, OH, Quebec, VA, WV) covering a broad range of environments. While the populations were not selected at random from all possible populations, we treated them as a random unbiased set of populations for statistical purposes. In total, 402 mature, fruit-producing ginseng plants were monitored from mid-August until mid-September, with 2035 berries being censused overall.

Ginseng berry monitoring was performed three times in each population; August 15 (± 3 days), September 1 (± 3 days), and September 15 (± 3 days); the only exception being the single Maine population, which was not monitored on the first date. These dates were chosen as they correspond to the most frequent harvest onset dates adopted by states with a harvest season. For practical purposes, they are probably also dates that would represent reasonable management options.

A standard monitoring protocol was adopted for all sites. We targeted a sample size of 5–15 fruit-bearing plants per population for monitoring, with the goal being to sample “representative” plants. The difficulty of finding and sampling all plants in the population, then randomly sampling from these, precluded a truly random sample. However, we assert that the plants monitored were not selected in any way, other than the criteria that they were producing berries, and therefore they could be treated as random for statistical purposes. More plants were monitored in several populations that were being monitored for other purposes. For 3 populations, only 3 or 4 plants were available for study by the initial census, but these data were included anyway.

Plants were cryptically marked for identification to minimize alteration of harvest or browse frequencies which could bias the ripening pattern. An initial berry count was made at the first census, and this census included berries found underneath a parent plant, but only if the berries could be unambiguously associated with a particular parent. At each census, each berry was categorized as green, pink, or red, with pink generally referring to a short transitional phase. In analyzing the data, we considered proportion remaining green (of the initial berry count) the reliable and relevant statistic for analysis. Between censuses, some berries ripened and dropped to the ground, so assessing the progress of development was most readily done by quantifying green berries remaining on the plant. Some plants and berries were lost to herbivory during the census, and these plants were excluded from the analysis after they disappeared because their ripening status was unknown. To simplify the presentation, for the purposes of our study, we considered “pink” to be “red,” or ripe, since the frequency of the pink stage was low at every census and pink berries were clearly ripening.

On each monitored plant, the proportion of initial berries remaining green was calculated. Since the dependent variable was a proportion, the data were arcsine-square-root-transformed to improve normality prior to

analysis (Sokal and Rohlf 1995). Since harvest dates are set according to political boundaries, we analyzed patterns of berry ripening in this way. The data were subjected to a nested ANOVA, with state as a fixed main effect, and population as a random effect nested within state. Beyond this basic structure, we decided to analyze the data two ways: one in which initial berry number was used to weight observations, and one without weighting observations by berry number. The former analysis amounts to considering berry ripening progress on a per fruit basis (by counting each plant proportionally more heavily if it had more fruits), while the latter unweighted analysis examines fruit ripening as an adult plant trait and gives no more weight to large, heavily fruited plants than smaller plants having fewer fruits. Both perspectives contribute to our understanding of fruit ripening properties.

Annual variation in berry ripening

The logistical challenges and expense of re-sampling all 31 populations in multiple years makes it unlikely that the berry ripening study will be repeated in future years. Yet clearly the question of whether 2003 was somehow unique is important, and the issue of consistency of ripening patterns within and among populations needs to be addressed. Fortunately, in the course of other studies of ginseng ecology, we performed repeated berry censuses of several West Virginia populations included in this study over other years. Of those, we found one pair of populations that were censused within 3 days of August 15 in all three years. These two populations were in close proximity to each other in northern West Virginia; however they had contrasting rates of berry ripening in 2003. In addition, three populations were censused within 3 days of September 10 in two years (2002, 2003). These three populations varied in elevation (536 m, 722 m, and 806 m) and aspect (15°, 146°, and 336°), and were separated by up to ca. 75 km. Both datasets provided an opportunity to test for annual variation in berry ripening (2-way ANOVA; main effect of year), and to test whether differences between populations in ripening stage at a particular date depended on the observation year (2-way ANOVA; year x population interaction). All data were arcsine-square-root-transformed prior to analysis. The ANOVA model was structured such that observations of proportion remaining green were weighted by fruit number in the inflorescence; as described above, this approach takes a "berry population" point of view, which is appropriate for comparing ripening patterns among years.

Results

Overall, 31% of the ginseng seeds planted in 1998 germinated 18 months after planting. Germination varied significantly as a function of seed planting date, however ($G = 19.203$, $p < 0.0001$), with very low rates of germination of all-green seeds planted on August 1 (Fig. 2A). Germination rate increased at the end of August and September dates as the proportion of seeds from red berries increased. Breaking down germination rate by berry

color, we observed that seeds from red berries germinated at nearly 3 times the rate of seeds from green berries (Fig. 2B). This significantly greater germination rate of seeds from red berries ($G = 6.890, p = 0.0087$) reflects the greater degree of maturation of these seeds: normally the outermost berries on a cluster reddened first, corresponding to the flowers that reached anthesis earlier in the growing season.

Rangewide, the grand mean (mean of population means) percent of berries remaining green on the plants was 80%, 44%, and 13% on August 15, September 1, and September 15, respectively. The statistical analysis of berry ripening revealed large population to population variations within states at each census date (Table 1, Fig. 3). This is most evident in Ohio data for August 15, where half of the populations had substantial ripening by that date, but the others were unripe (Fig. 3). On September 1, several

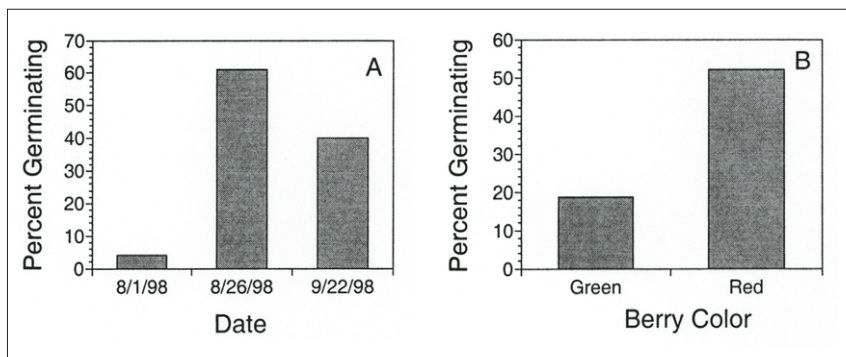


Figure 2. Germination of ginseng berries 18 months after planting as a function of (A) date of berry collection, and (B) color of berries.

Table 1. Results of nested ANOVAs (F values with prob > F in parentheses) on the arcsine-square-root-transformed proportion of seeds remaining green in monitored natural ginseng populations. Maine was excluded because it contained only one replicate population. The second set of ANOVAs subtracted Missouri (as well as Maine) from the analysis to test whether that one state skewed the overall results. Results are included where proportions were weighted or not weighted by berry number.

Source of Variation	Weighted:	August 15		September 1		September 15	
		No	Yes	No	Yes	No	Yes
All states (-ME):							
State/province		5.164 (0.0011)	1.680 (0.1664)	2.421 (0.0522)†	1.822 (0.1338)	3.179 (0.0169)	3.591 (0.0102)
Population (state)		2.784 (< 0.0001)	6.615 (< 0.0001)	6.753 (< 0.0001)	10.356 (< 0.0001)	5.599 (< 0.0001)	7.799 (< 0.0001)
All states (-ME, -MO)							
State/province		1.771 (0.1524)	1.274 (0.3128)	2.274 (0.0753)†	1.801 (0.1488)	3.315 (0.0185)	3.651 (0.0128)
Population (state)		2.869 (< 0.0001)	6.353 (< 0.0001)	6.956 (< 0.0001)	10.667 (< 0.0001)	5.766 (< 0.0001)	8.032 (< 0.0001)

† trend ($0.05 < p < 0.10$)

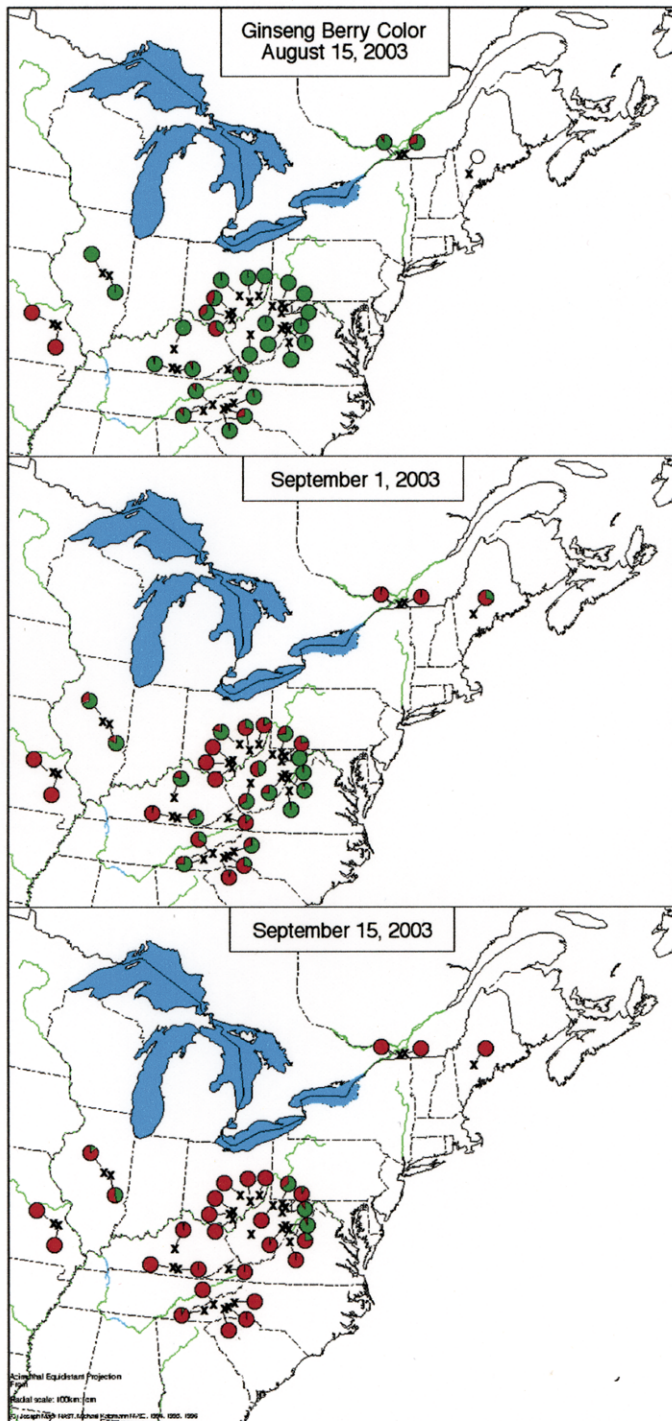


Figure 3. Berry ripening patterns across the range of ginseng in 31 populations sampled ca. August 15, September 1, and September 15, 2003. Maine population not sampled August 15.

locations showed significant population variation (Fig. 3). On September 15, population-level variation was evident particularly in West Virginia, where populations within 5 km of each other showed sharply differing levels of ripening (Fig. 3).

Berry ripening differed among states in the first and last census for the unweighted analysis, but only at the last census when observations were weighted (Table 1). At the first census, the difference for unweighted data was primarily due to the unusually early ripening of berries in Missouri, where the two monitored populations had already begun dropping berries by August 15. Excluding Missouri (and Maine, due to lack of replication), there were no consistent differences among states in berry ripening on August 15 or September 1 for either analysis. By September 15, state differences were apparent again due to the persistent unripe plants found in one Illinois and three West Virginia populations, while most other states had completely ripe berries by that point (Fig. 3).

The multi-year berry ripening censuses suggest relatively consistent patterns among years. On August 15, there was no difference in berry ripening among the three years in the two populations that were censused near that date (no "year effect," $p = 0.2444$). Most berries were green on August 15 in all three years (97.6%, 100%, and 100%, in 2001, 2002, and 2003, respectively). In addition, there was no difference between populations in the response of berry ripening to inter-annual differences in climate (no 2-way interaction; $p = 0.6845$). On September 10, the same pattern was found, with no variation among years ($p = 0.6146$), no variation among populations ($p = 0.3701$), and no difference in population responses to years ($p = 0.2874$). In these populations, a mean of 35% and 42% of berries remained green in 2002 and 2003, respectively, on September 10.

Discussion

The germination trial with ginseng seeds collected at varying stages of ripeness clearly demonstrates that fruit color is a good, though not absolute, indicator of seed germinability. Previous work had suggested that berry color should be used to guide harvest seasons (Carpenter and Cottam 1982) without substantiating data. Now the association between fruit color and future germination is established, although seeds from green berries in the latter stages of development do sometimes germinate.

No environmental factors were explicitly measured at the 31 populations censused in this study that would help explain geographic variation in ripening. Indeed, a priori it would be difficult to predict what climatic and local environmental factors might explain this variation over such a broad geographic range. Temperature and growing season precipitation seem likely to play a role; however, the time frame over which their effects would be manifested on fruit ripening phenology is not clear. For example, early spring warm or cold temperature could either accelerate or delay plant development after winter dormancy and result in changes in fruit ripening.

What is clear, despite our lack of environmental measures, is that longitudinal and latitudinal gradients (which are broadly correlated with temperature and precipitation patterns) do not readily explain variation in berry phenology. Also abundantly clear is that state boundaries are uncorrelated with phenology patterns. The two Missouri populations that ripened early are likely not typical of that state, as an earlier study, also in east-central Missouri, demonstrated that 40% of the fruits were still green on September 11 (Lewis and Zenger 1982). Indeed, the ANOVA results showed strong among-population variation in ripening within states at all dates, particularly in states that were more extensively sampled (NC, OH, WV). Omitting the unrepresentative Missouri and Maine populations, statistically significant state-to-state variation was evident only on September 15 (although a trend was observed for September 1, when the data were unweighted). The September 15 variation among states was also likely due to the greater intensity of sampling performed in West Virginia, such that some late-ripening populations were encountered. Some prior work on fruit ripening had suggested that within-state variation in fruit ripening followed a geographic pattern: Specifically, populations on south-facing slopes consistently ripen fruits more quickly than those on other aspects within the province of Quebec (A. Nault, pers. observ., 2003). Also, southern populations within Illinois (Anderson et al. 1993) and Wisconsin (Carpenter and Cottam 1982) were shown to ripen fruits more quickly than northern populations within those states. For the larger north-south gradient examined in our study, no such pattern was observed; fruits in populations at the distribution margin in Maine and Quebec ripened faster than some (but not all) in the central portion of the range.

We recognize that lack of a difference in one year (2003) does not “prove” uniformity; rather, we were simply unable to garner statistical support for state-to-state differences. More extensive sampling in 2003, or sampling in different years, might yield further evidence of state-to-state differences. However, what is clear from our data is that among-population variation is far larger than among-state variation. One policy option would therefore be to establish a single harvest season over the entire range. Having one harvest onset date common to all states would in fact discourage one of the tactics that can be used by harvesters to evade regulations, namely harvesting early in one state and selling the product in a nearby state with an earlier harvest season. This behavior makes harvest seasons less effective than they might otherwise be, and it also confounds the tracking of harvest data by state, since not all roots sold in a state may be from the state when harvesters cross state lines to sell.

If one harvest season onset is adopted for all states, what *should* the optimal date be, given the mandate of CITES that harvest must be determined annually to be non-detrimental? This is a policy question to be answered, in the end, by policymakers. However, conservation biologists may play a role by considering the consequences of possible alternatives.

Given the precedent set by current policies, and the ease of implementing various alternatives, it seems likely that the possible dates for harvest onset would be August 15, September 1, and September 15.

An August 15 harvest onset date has one advantage; the states that frequently rank 1–4 in harvest quantity (KY, WV, TN, and VA; $\approx 60\%$ of the national total) currently have this date as the beginning of the harvest season. The majority of harvesters would not have to conform to a new date, making an August 15 uniform date the easiest to implement. The disadvantage of allowing harvest to begin August 15 is that clearly a large portion of the plants may be harvested prior to seed ripening. Since planting seeds is the only option open to harvesters to ensure recovery, an August 15 date may well result in a ratcheting down of population sizes over decades of repeated harvest events, until extinction is all but inevitable (Van der Voort et al. 2003).

By September 15, the majority of berries are ripe across the range of ginseng. In fact, in many populations, the fruits had completely dispersed by September 15 since they tend to remain on the plant for approximately one week after turning red. The positive aspect of a uniform date of September 15 is therefore the high proportion of ripe fruits at that time. In addition, adult plants that have already dispersed seeds could be more difficult to find because the bright red fruits help harvesters notice the plant as they search in the woods. Some portion of adult plants senesce or get browsed prior to September 15. Thus, some adult plants would escape harvest that might otherwise be found if the season began on that date. There are at least three negative aspects of a September 15 date for harvest onset: (1) If many fruits have dispersed, harvesters will not be able to plant the seeds (as most states recommend or require), preventing them from counteracting their negative effect on population dynamics with enhanced recruitment. When seeds are scattered on the soil surface, they are subject to herbivory by rodents or excessive drying, either of which can cause mortality. An experimental study showed that seeds planted 2 cm deep germinated at a rate 8-fold higher than those scattered on the surface (J.B. McGraw, unpubl. data, 2002). This problem would be exacerbated as the season progressed into late September and early October. (2) A September 15 deadline would entail regulation changes in 18 of 19 states that allow ginseng harvest and would likely affect $> 95\%$ of the harvesters involved. (3) Although the large majority of adult plants had not senesced by September 15, harvesters might be suspicious that many harvestable plants would be missing by that date, and therefore be more tempted to harvest out-of-season.

September 1 may represent a compromise between the advantages and disadvantages of the earlier and later dates. September 1 would entail the fewest changes in state regulations since 9 of 19 states have already designated that date as the beginning of the harvest season (although it would affect more harvesters). While almost half the fruits remained green at that point rangewide, our study showed that 50% of the seeds from green berries planted near that stage of development (August 26) germinated, while only

4% of seeds from green berries planted in early August germinated ($G = 10.86$, $p = 0.001$). An added advantage of September 1 is that in most populations, the fruits are still on the plant at that date, making it possible for harvesters to plant the seeds, and thus ensuring recruits to the harvested population. The disadvantage of September 1 (many berries are still unripe) could be more than counteracted by the 8-fold advantage of seed protection provided by conscientious harvesters.

Setting the harvest season is only one important management tool for improving the long-term prospect for sustainable ginseng harvest. For example, the state of Kentucky has set a ginseng buying season for dealers that begins 15 days after harvest season begins: Given that it takes time to clean and dry ginseng roots after harvest, this differentiation of harvest and buying seasons discourages harvest prior to season onset. New harvest season regulations will not work without unambiguously informing harvesters and dealers of the changes and the scientific basis for it.

Encouraging and, where possible, enforcing, best harvest practices will also contribute to harvest sustainability. The requirement (or strong recommendation) of most states that harvesters take only reproductive plants with ripe seeds, and plant those seeds 2 cm (or 1 inch) deep at the site should become standard practice. Leaving smaller reproductive individuals unharvested so they may grow to larger (and more valuable) reproductive sizes would likely enhance population viability, much as size limits aim to do with fisheries. Charron and Gagnon's (1991) elasticity analysis suggested that the fate of these smaller individuals indeed influence population growth rate to a larger degree than for many other perennial plants. Populations will likely benefit from other self-restraining actions by harvesters, including not harvesting from the same population every year and leaving some portion of the largest and most fecund individuals (akin to "catch-and-release" by fishermen). Late-season stem clipping of plants being deliberately left by harvesters can save the plant for harvest in a later year and simultaneously prevent other harvesters from finding and digging the plant. With an appropriate combination of regulatory change and improved harvest practices, the culturally important ritual of ginseng harvest may be sustained indefinitely.

Acknowledgments

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