

# Neither Wild nor Cultivated: American Ginseng (*Panax quinquefolius* L.) Seller Surveys Provide Insights into in situ Planting and Husbandry<sup>1</sup>

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**Neither Wild nor Cultivated: American Ginseng (*Panax quinquefolius* L.) Seller Surveys Provide Insights into in situ Planting and Husbandry.** American ginseng has been gathered commercially in eastern North America for nearly 300 years. A possible contemporary influence on wild supplies is the augmentation of wild ginseng populations by harvesters using commercially available stock from cultivation. We utilized a confidential, annual survey over eight years (2012–2019) in Pennsylvania, United States, to examine the extent to which forest planting of commercial germplasm may account for wild ginseng harvest amounts. Three in ten (28%) root sellers reported that some of the ginseng they sold as “wild” was produced using in situ production methods involving scattering seeds in the forest. One in four (26%) of planters reported using commercially available planting stock in these efforts. Moreover, there was geographic overlap between study participants and the top wild ginseng harvest counties, suggesting planting activities might contribute partially to higher harvest amounts. Respondents confided a hesitancy towards reporting ginseng planting activities on buyer paperwork, as is increasingly being requested, fearing price devaluation, theft, taxation, and disagreement over what constitutes “wild.” Our results suggest that an improved understanding of U.S. wild ginseng origins and trends, especially as influenced by in situ planting and forest farming, will require confidential reporting mechanisms to accommodate seller concerns surrounding disclosure.

**Key Words:** American ginseng, Forest farming, In situ cultivation, Middle ground, Non-timber forest products.

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## Introduction

The genus *Panax* has been valued in eastern Asia for its purported tonifying properties for more than one thousand years (Hu 1976, 1977; Upton 2012).

American ginseng (*Panax quinquefolius* L., Araliaceae), hereafter referred to as ginseng, is indigenous to eastern North American forestlands, where it has been harvested over the past three centuries for trade primarily in east Asia (Carlson 1986; Evans 1985; Liu et al. 2021; Schorger 1969). The roots and attached rhizomes are sold to consumers willing to pay a premium for wild-appearing products. Consistent market preferences by Asian consumers for ginseng roots that exhibit “wild” traits, determined by taste, shape, color, and texture (Guo et al. 1995; Roy et al. 2003), coupled with the limited geographic native range, have resulted in ginseng

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becoming an important non-timber forest product export. For the past century, the price paid by Asian consumers for wild-appearing ginseng roots has generally been much greater than prices paid for cultivated roots, resulting in up to 98% of the annual wild ginseng harvest in the United States being shipped to east Asian countries (Robbins 1998; USFWS 2013). In recent decades, prices paid in Asian markets may be as much as 100 times greater for wild-appearing roots (Burkhart and Jacobson 2009; Davis and Persons 2014), with wide variation in prices due to buyer preferences for root traits such as shape, age, and cleanliness (Electronic Supplementary Material [ESM] Fig. 1).

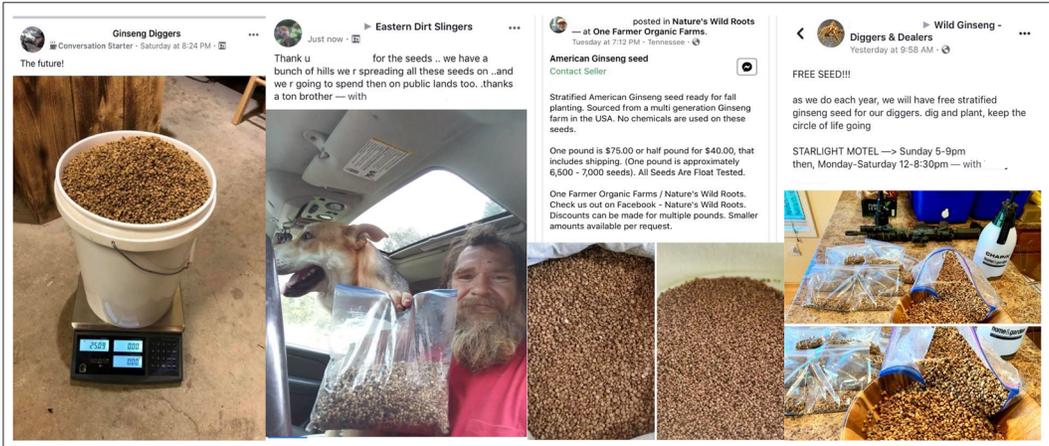
Ginseng is a shade-obligate perennial herb, requiring at least three growing seasons before harvest in cultivation systems (OMAFRA 2005). However, when forest grown, 10 or more years may be required to reach an equivalent harvestable size (McGraw 2020; McGraw et al. 2013). When harvested for trade, the root and attached rhizome, known as the “neck,” are generally taken, resulting in plant mortality. Ginseng reproduces sexually, although seed output is often limited in the wild (Charron and Gagnon 1991; McGraw et al. 2013). Harvester attention to population numbers, stages, and growth rate are necessary for sustained harvests and even then, recovery rates are slow (McGraw 2020; McGraw et al. 2013). In the United States, the ginseng trade is regulated by both the state and federal governments. Since 1975, ginseng has been included on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2020). To meet its treaty obligations, the United States Fish and Wildlife Service (USFWS), requires that states track ginseng harvest amounts to provide data on long-term trends. In response, states have developed permitting programs for ginseng buyers, commonly referred to as “dealers,” to compile harvest quantities through point-of-sale paperwork. Dealer honesty and seller willingness to disclose information about the product being sold are critical for accurate data collection. (Burkhart 2011; Robbins 1998).

Between 1978 and 2018, 20,000 to 160,000 pounds of wild roots were certified for export annually from the United States, originating from 19 eastern U.S. states and one Tribe (USFWS 2019a, b). This is equivalent to 8 million to 32 million plants per year, if extrapolated using state (e.g., PA DCNR 2019) data that estimate on average 200 dry roots/plants required per pound (range 127–256). Recent reported trade volumes are generally lower

than records dating from the 1800s, when exports ranged from 2 million to 7 million pounds per decade (Carlson 1986; Liu et al. 2021). States are reporting record low harvest amounts, with the USFWS reporting that 2016–2018 harvests were the lowest since tracking began in 1978 at the federal level (USFWS 2019b). Trade data provide commerce trends but do not necessarily indicate species abundance. Harvest amounts from many eastern U.S. states are erratic due to socio-economic circumstances (e.g., unemployment) and fluctuating annual ginseng prices paid to harvesters (Frey et al. 2019; Kruger et al. 2020; Schmidt et al. 2019). Determining the conservation status of ginseng is also complicated by limited agency funding and complex law enforcement jurisdictional boundaries (Burkhart et al. 2012; Robbins 2000).

The use of wild trade data to infer population status is further obscured by in situ planting across the harvest range, particularly on privately owned forestlands. The sharing and planting of ginseng germplasm within the indigenous range of the species can be seen on social media platforms with many individuals selling and distributing seed sourced from artificial-shade cultivation systems to be used for planting on forestlands (Fig. 1). Ginseng cultivation under artificial shade can be traced back for more than a century in eastern North America (Butz 1897; Harding 1912) and is currently the primary method for large-scale production in regions of North America such as the U.S. state of Wisconsin (WI) and Ontario, Canada. Ginseng cultivation allows for better disease control and mechanization of production. Additionally, cultivation shortens the time until harvest, and increases yields (OMAFRA 2005). Ginseng seed is collected and sold as a by-product of cultivated root production, and the value of seed can add considerable profit to ginseng crops. More seed is produced from plants grown under artificial shade than wild or forest-grown plants (McGraw 2020; Schluter and Punja 2000), which makes the former more widely available and inexpensive. Moreover, most export states have regulations in place that prohibit removing seeds from areas where wild plants are harvested. Therefore, the availability of legal seed stock is almost entirely limited to artificial shade produced seed.

Many forest landowners and wild ginseng harvesters purchase commercially available stock for forest farming or cultivation purposes. Purchased seed is the sole option when there are no existing wild plants to gather seed from or for “stocking”



**Fig. 1.** Examples of recent (2018–2020) social media posts advertising commercially sourced, artificial shade produced American ginseng from Wisconsin, U.S.A. and Ontario, Canada for planting on forestlands.

purposes in areas that are actively and/or intensively harvested (Burkhart 2011; Davis and Persons 2014). There has been consistent demand for ginseng seed in the United States from landowners interested in “forest farming” ginseng, which has two recognized approaches: woods-cultivated and wild-simulated (NAC 2020). Woods-cultivated is a more intensive approach and may include raised beds, soil tillage and amendments, and vegetation management. Wild-simulated utilizes in situ growing conditions and exposure to environmental stress to produce a wild-appearing product. Wild-simulated production may only involve the planting of seeds or transplants in favorable habitats (Davis and Persons 2014; Persons 1986). Planting sites are typically selected using floristic indicator species (Burkhart 2013) and the approach often results in roots indistinguishable from wild, and may result in naturalized, reproducing feral, or “wild” plants (Farrington 2006).

While the recognition of two forest farming approaches provides a convenient framework for landowner education, a continuum of husbandry practices featuring an increasingly complex lexicon has been developed and distributed through magazine articles (e.g., Brewer 1990), popular books (e.g., Davis and Persons 2014; Persons 1986; Pritts 1995), University extension bulletins (e.g., Beyfuss 1998; Hankins 2000; OMAFRA 2005), and most recently social media platforms (Table 1). This lexicon, developed largely by planters and growers,

is increasingly used by U.S. state ginseng management programs on dealer paperwork to better track the origins of ginseng sold as wild. The development of accurate forest farming tracking mechanisms at the state level continues to be urged by the federal government for improving our understanding of wild ginseng status and supply chains, and a desire to “explore with the states strategies to track and report wild-simulated roots separately from wild roots” has been identified as a future action (USFWS 2019b).

To gain a better understanding of how ginseng planting in the U.S. state of Pennsylvania may contribute to the ginseng supply and status, we conducted a multi-year survey of ginseng root sellers. Pennsylvania does not track ginseng planting on forestlands; rather, the state utilizes CITES-driven reporting categories such as “wild” or “artificially propagated” on buyer (referred to as “dealers” colloquially) paperwork. During the years 2012 through 2019, we annually mailed out a survey instrument to request information from sellers, post-sale, about the in situ husbandry practices used to produce the ginseng roots that were sold to buyers as wild. In undertaking these efforts, we were interested in understanding the answers to the following questions.

1. Can ginseng seller information gathered by buyers be used to document in situ ginseng planting?

TABLE 1. AMERICAN GINSENG HUSBANDRY APPROACHES IN THE EASTERN UNITED STATES: LEXICON AND PRACTICES.

Descriptive term	Sold as	Husbandry practices associated with production					
		Wild seed sown	Commercial seed sown	Tillage and/or manipulation of soil conditions	Pesticides used	Forest structure and composition managed	Shading structures used
Wild-simulated, Virtually-wild, Enrichment plantings	Wild	+	+	–	±	±	–
Woods-grown, Wood's--cultivated, Forest-grown, Wild-cultivated	Wild,						
Wild-cultivated or Cultivated	+	+	+	+	+	±	
Wild-stewarded, Wild-crafted, Managed	Wild	+	±	–	–	–	–
Wild	Wild	±	–	–	–	–	–
Cultivated, Field-grown, Artificially propagated, Tame	Cultivated	–	+	+	+	–	+

+ Used with this approach – Not used with this approach

2. What types of in situ planting and forest farming activities occur in Pennsylvania?
3. What is the source of the planting stock used in Pennsylvania in situ husbandry and farming activities?

Additionally, we were interested in understanding how different U.S. states tracked ginseng planting. We therefore conducted an email-based survey of state ginseng programs within the 19 U.S. harvest states.

## Materials and Methods

### STUDY LOCATION AND SURVEY SAMPLE FRAME IDENTIFICATION

Our ginseng seller survey was conducted within Pennsylvania (PA), which ranks eighth to fourteenth in total harvest amounts among the 19 ginseng producing states (2012–2018). Since the late 1980s, the Department of Conservation and Natural Resources (DCNR) has been responsible for tracking the wild ginseng trade in PA. Between

1990 and 2018, the annual harvest and certification amounts from PA were between 664 and 4236 dry pounds, with a general downward trend observed in reported annual harvest amounts (ESM Fig. 2).

The sample frame used in this study was developed in collaboration with PA DCNR, which gathers information on ginseng root sellers as part of their “Vulnerable Plant” ginseng licensing program. In this program, purchase logbooks are maintained by licensed dealers and submitted to PA DCNR on an annual basis. These logbooks contain the names and addresses of individuals selling ginseng within PA during the previous state-regulated “digging season” or commerce year (i.e., September–December).

Beginning in 2012, dealer transaction reports submitted to PA DCNR from the prior commerce year were examined to identify redundancies, remove incomplete names and addresses, and exclude obvious fake names. Because there is no requirement that a seller must provide identification to the buyer, there could be no assurance that names and addresses gathered were authentic.

A single stage survey delivery and participant solicitation was used in each year. At each survey

mailing date, a survey packet containing a cover letter, a survey form, and a return addressed, postage-paid, envelope was mailed to recipients. Following guidance provided by Dillman et al. (2014), a unique identifier code was included on each return envelope and was used to link survey respondents to a name and address from the master survey mailing list. These individual identifier codes were removed prior to analysis but can be used for respondent and study validation.

Surveys were mailed to names and addresses annually in August or September of each year over the eight-year period of 2012–2019 using names compiled from 2011 to 2018 dealer transaction logs. This annual survey effort utilized a cross-sectional sampling approach, but some longitudinal findings were also obtained (e.g., number of unique versus repeat sellers) and are discussed.

### *Annual Root-Seller Survey*

Survey design followed guidance provided by Dillman et al. (2014). Discussions with ginseng collectors, forest farmers, PA DCNR ginseng program personnel, along with our prior experience with ginseng stakeholder surveying, were all used to guide survey topics, questions, and language. The final instrument contained seven questions, with three sub-sections containing follow-up questions (a copy of the survey is provided as ESM 3). The questions were organized around understanding the origins of the ginseng sold (e.g., found versus grown), but also included questions pertinent to interpretation of annual harvest data (e.g., reason for selling, amount held over).

Question formats were primarily box selection, binary response, and requests for short explanations. Language such as “grower,” “cultivate,” or “farm” were avoided; instead, terms such as “planter,” “planting,” and “found” were used to specify behaviors and activities. Similarly, terminology such as “wild-simulated” and “woods-grown,” while used in popular books, magazines, and cooperative extension bulletins to refer to methods of forest-based ginseng cultivation, were not used in this survey so as not to limit or confuse respondents.

The survey instrument was pre-tested in 2011 with five key informants to identify and correct ambiguities within the instrument. In 2017, the survey instrument was slightly modified based on five years of initial use. The response format for the question, “Which of the following best describes the

scale of your ginseng planting or farming activities?” was altered from written numeric answer to check box options. To analyze the question responses across all years, the survey written numeric responses from years prior to 2017 were coded to be consistent with one of the box categories (10,000 or more plants, 1000–9999 plants, 100–999 plants, or just a hobby/fewer than 100 plants).

### STATE GINSENG PROGRAM COORDINATOR SURVEY

In February 2019, an email query was sent to the 19 U.S. state ginseng harvest program coordinators to ask how ginseng planting and cultivation is tracked in their state and, if so, what categories are used on ginseng transaction paperwork. This was posed as an open-ended question.

### DATA ANALYSIS

Survey responses were coded by year (2012–2019) and county and then pooled to examine question responses both within and across years and by county. State and county level ginseng harvest amounts data from 2012 to 2018 were acquired from PA DCNR. The Statistical Package for the Social Sciences (v. 26, SPSS Inc. 2019) was used to calculate descriptive statistics including response frequencies and counts, question sample sizes, and Pearson’s  $r$  values for correlation analyses. In the cover letter included with each survey, it was explained that respondents could refuse to answer any questions they were uncomfortable answering. This, and the fact that not all survey sections and questions were applicable to each respondent, altered the sample size for each question.

## Results and Discussion

### SURVEY RESPONSES AND COVERAGE

Of the 6993 surveys mailed between 2012 and 2019, 1102 were completed, returned, and linked to a valid name and address using the unique recipient identifier code included on return envelopes (ESM Table 1). Adjusted survey return rates, which were calculated after removing surveys returned as “non-deliverable” due to non-existent addresses, ranged from 13% to 23% with an overall response rate of 17% calculated for all survey years. The

number of repeat survey respondents ranged between 40 and 112, with a total of 513 repeat respondents (some of whom may have participated in more than two years).

Usable surveys were received from residents of 55 counties (82%) within PA, representing all geographic regions of the state. County level trade data indicate the majority of ginseng originates from the western half of the state, with 15 counties in this region each having cumulative 1991–2018 harvests totaling more than 1000 pounds. Collectively, these 15 counties account for more than half the recorded historic harvest of 49,691 pounds (PA DCNR 2019), which is equivalent to around 10 million plants. Fayette County, in southwest PA, has been the greatest source of wild ginseng exports with a total of 4954 pounds recorded between 1989 and 2018. We observed overlap between the top 15 ginseng harvest counties in PA and survey participant mailing addresses, with most respondents originating from counties in southcentral, southwest, and northcentral PA (Fig. 2a). Furthermore, a strong positive relationship ( $r = 0.88$ ,  $p < 0.001$ ) was observed between total amount of ginseng harvest by county (2012–2018) and total number of survey respondents by county (Fig. 2n), indicating the surveys were completed and returned more in areas of the state with the highest ginseng harvest amounts.

Despite careful screening of dealer transaction names and addresses to remove duplicate, incomplete, or obviously falsified names and addresses, 621 surveys (9%) were returned because they were undeliverable. Seller transactions are recorded on paper forms by the dealer and must be transcribed by PA DCNR program staff. This process results in incomplete or incorrect address information, something that both sellers and dealers recognize and may take advantage of. A total of 165 individual names, for example, were associated with two or more different addresses in 2015 alone. To improve accuracy of dealer-generated sampling frames, and thus cost effectiveness of surveys as a data gathering tool, a requirement for proof of identity and/or licensing could be used in PA, as is done in some U.S. states. A challenge inherent in surveying is the need to adequately capture the survey population of interest and minimize coverage error (Dillman et al. 2014; Weisberg 2005). Since there are no lists of those involved in ginseng planting or forest farming activities in PA, sampling frames were comprised of availability samples, drawn from ginseng seller transaction logbooks. A limitation of this sample is

that it excludes individuals involved with ginseng planting but who did not sell during the survey period. Additionally, individuals planting ginseng but not selling ginseng, selling ginseng out of state, or selling ginseng directly to a consumer are not captured by our sampling frame.

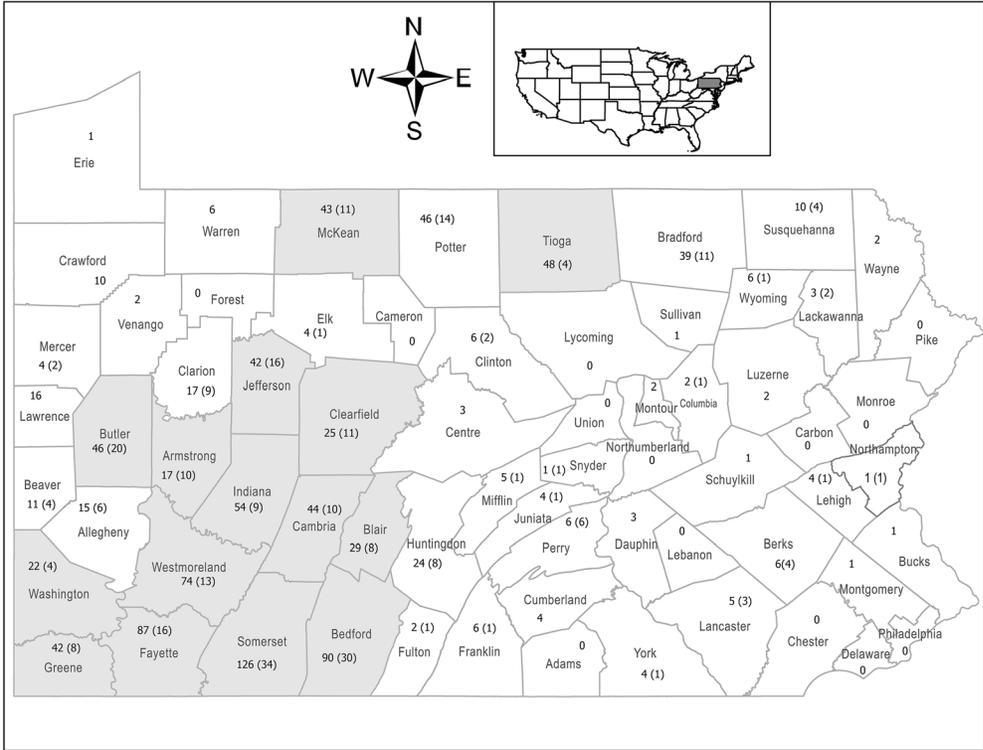
#### AGROFORESTRY AND IN SITU PLANTING: GINSENG AS THE “MIDDLE GROUND”

We found that ginseng husbandry in PA involves seed and root planting in situ, using a continuum of husbandry approaches, sometimes supplemented with purchased germplasm from artificial shade farms in WI or Ontario, Canada. On average, 3 in 10 respondents (28%) indicated that the ginseng sold as wild had been grown from seeds or transplants (Fig. 3). Additionally, many respondents indicated that the ginseng that they sold as wild originated both from planted stock as well as wild collected plants. A strong positive relationship was observed between total ginseng harvest amounts by county and total number of reported ginseng growers by county (Pearson's  $r = 0.804$ ,  $p < 0.001$ ). Counties with the highest total ginseng harvest amounts also had the highest number of respondents who reported planting ginseng (Fig. 4), which suggests that planting contributes in part to these harvest amounts.

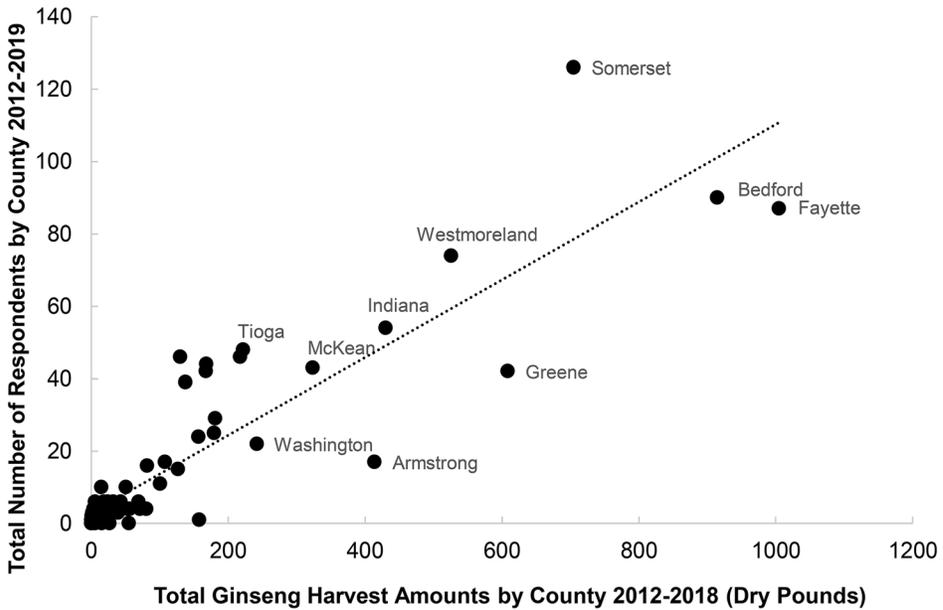
Of those respondents who specified a forest farming method, the most popular (81%) was the “wild-simulated” method, which entails scattering seeds in natural forest conditions. Of all the respondents, 12% reported growing “woods-cultivated” ginseng in prepared beds and 2% reported field growing their ginseng under artificial shade (Fig. 5a). Survey respondents were also asked to report the scale of their planting. Across all years, 106 respondents (14%) reported growing fewer than 100 plants or that ginseng growing was just a hobby. The number of respondents who reported small-scale planting increased during the survey, which may indicate growing popularity in ginseng forest farming (Fig. 5b). Large-scale ginseng forest farming (over 10,000 plants) was reported by 45 respondents (33%) over all survey years.

Despite few respondents reporting large-scale forest farming, a single individual can significantly increase dealer reported wild harvest amounts. For example, one farmer participating in our survey contributed as much as 100 pounds (dry weight) annually to the total PA wild harvest during the past 15 years (D. Colwell, pers. comm. 2012–2018,

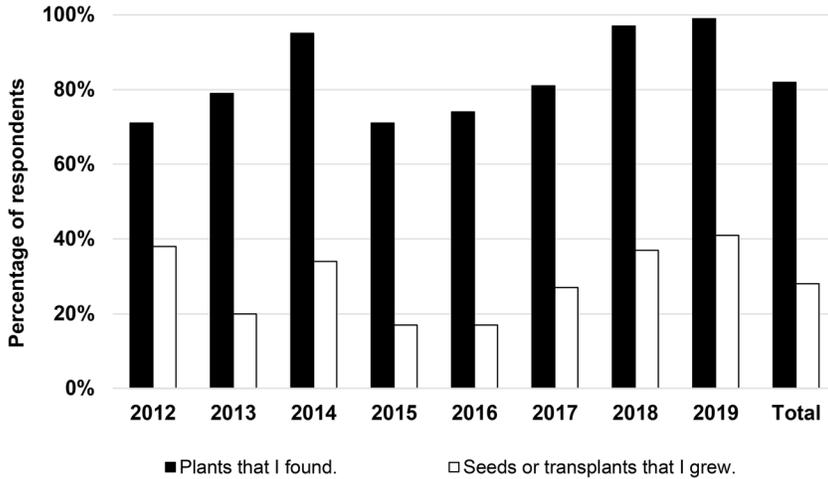
**A**



**B**



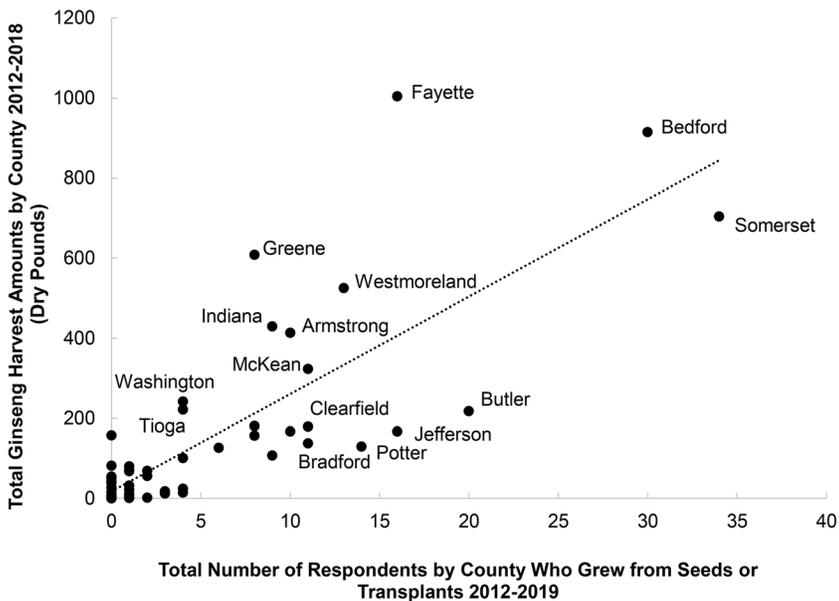
**Fig. 2.** **a** Top 15 ginseng harvest counties (shaded) in Pennsylvania 1991–2018 and number of survey respondents and (growers) from each county 2012–2019. **b** Correlation between total ginseng harvest amounts by county (2012–2018) and total number of survey respondents by county. A strong positive relationship was observed (Pearson’s  $r = 0.88$ ,  $p < 0.001$ ,  $n = 67$ ) indicating that the survey instrument was completed more in counties with the largest ginseng harvest amounts. The top 10 ginseng harvest amount counties are labeled.



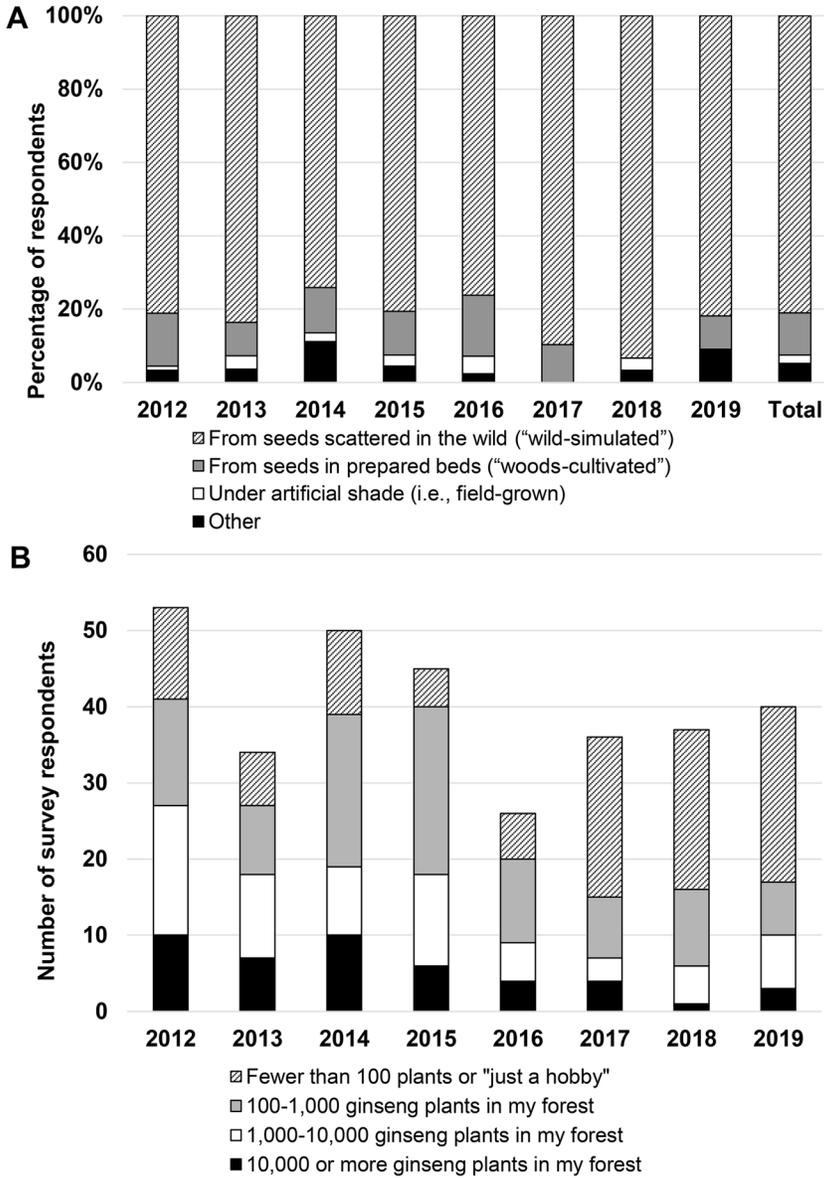
**Fig. 3.** Origins of wild American ginseng sold in Pennsylvania during survey years 2012–2019. Survey respondents were asked: “What is the source of the ginseng that you sold (in the year prior to the survey being completed)?”, yearly  $n = 79\text{--}187$ , total  $n = 1059$ .

confirmed using data provided by PA DCNR). Because of limitations regarding how ginseng seller information was provided to us by PA DCNR, we were unable to relate survey respondent planting and forest farming question responses to their

quantities sold submitted by dealers. This would have allowed us to determine individual seller contributions to annual reported ginseng harvest amounts over the survey period. The coupling of dealer records with survey results in this manner



**Fig. 4.** Correlation between total number of survey respondents by county who indicated that the source of the ginseng that they sold that year was grown from seeds or transplants versus total dry pounds of ginseng harvested by county from 2012 to 2018. A strong positive relationship was observed (Pearson’s  $r = 0.804$ ,  $p < 0.001$ ,  $n = 67$ ) suggesting that ginseng cultivation could be contributing to PA ginseng harvest amounts in high harvest amount counties. The top ten counties for ginseng harvest and growers are labeled.



**Fig. 5.** Source and scale of ginseng planting. Survey respondents were asked in **a** “How was this ginseng grown?”; percentages based on yearly  $n = 29-90$ , total  $n = 427$  and **b** “Which of the following best describes the scale of your ginseng planting or farming activities?”

would strengthen the utility of both data sets by allowing the linking of individuals who report in situ farming with their overall contribution to state reported harvest amounts.

A challenge facing PA and other harvest states is how to increase transparency regarding wild ginseng origins and document public involvement in planting activities. A clear lexicon around ginseng

planting, husbandry, and forest farming would help facilitate a more accurate understanding of wild ginseng status and improve conservation and enforcement efforts. USFWS has continued to urge states to implement measures for differentiating “wild-simulated” ginseng from “wild” (USFWS 2019b). Reporting categories historically have been derived from CITES and many states consequently

only recognize “wild” or “artificially propagated” ginseng—the latter of which is CITES terminology for cultivated or farmed materials. Recently, a new production category has been approved by CITES signatories referred to as “human assisted” (CITES 2019). This production category is intended to better acknowledge the status surrounding many wild plant species that do not fall “within the definition of ‘artificially propagated’ and are considered not to be ‘wild’ because they are propagated or planted in an environment with some level of human intervention for the purpose of plant production” (CITES 2019).

Our survey results indicate that wild ginseng may occupy what has been dubbed in reference to plant domestication processes, a “middle ground,” in which husbandry may play a significant role in the occurrence, abundance, and genetic composition of a plant species, but without any clear morphological indicators of domestication (Smith 2005). This middle ground may represent a transition in the ginseng industry as husbandry and planting with purchased stock becomes increasingly necessary because of increasing scarcity of available wild supplies.

Our 2019 email survey of state ginseng program coordinators revealed that many U.S. states (e.g., Kentucky, Tennessee) are asking sellers and dealers involved in supply chains to more accurately identify the source of the product being reported in transaction logbooks through the addition of categories such as “wild-simulated” and “woods-cultivated” (ESM Table 2). Alternatively, some states (e.g., West Virginia, Maryland) have developed voluntary ginseng “grower” enrollment and reporting programs to document *in situ* husbandry. Several state ginseng program coordinators in our email query noted that there is likely widespread planting occurring in their state, but they have no mechanism or resources to account for these activities.

During our eight-year survey period, we received numerous letters and phone calls from survey recipients who had concerns regarding the purposes of the survey, and these concerns provide caution and guidance regarding how to successfully track ginseng planting activities and forest farming. Overall, individuals who contacted us were hesitant to disclose information about husbandry practices and stock used to produce roots for sale. This hesitancy occurred because even though roots may appear wild, they feared their product would be devalued by the dealer if they admitted to any type of husbandry (such roots are often referred to as “tame” by

dealers). Because wild ginseng is bought in the United States, but primarily sold in east Asian countries (Robbins 1998; USFWS 2013), producers do not fully understand consumer preferences, which are based on longstanding cultural predilections and traditions (Guo et al. 1995; Liu et al. 2021; Roy et al. 2003). Producers do not generally know how roots are graded and valued; therefore, they are suspicious of dealer assessments and prices. Such reservations arise through experience with dealers who do not pay wild prices for “wild-simulated” ginseng roots, despite the inability to differentiate between such roots based on appearances. Respondents who contacted us felt that the government would be hurting them, and forest farmers more generally, by forcing disclosure of sensitive production information on dealer paperwork. It was feared, this information could be used by dealers to justify paying a lower price, despite the root otherwise passing for wild (R. Yenzi, pers. comm. 2012–2020).

Survey respondents also conveyed concerns about attracting thieves to their property by indicating that they are cultivating or forest farming on dealer paperwork. This paperwork is compiled by dealers with a financial incentive to obtain roots for re-sale, and dealers interact with many harvesters—some potentially unethical and prone to theft. Because sellers must provide a name and address on paperwork, along with how it was produced, the dealers would then know that they are planting on their property and this information could be shared with local diggers who could rob their ginseng patches. Theft is a particularly well-documented issue with ginseng growers because it is expected that they will have larger numbers of plants, in more visible arrangements in their woods, than what would normally be encountered when collected from the wild (Burkhart 2011; L. Harding, pers. comm. 2012–2020; Podladnik 2008).

Another respondent concern regarding efforts to develop forest farming transparency, is the issue of taxes. Many respondents contacted us because they believed our survey might be a state-funded mechanism to assess taxes on their ginseng. In many U.S. states, ginseng is not recognized formally as a “crop” and does not attract the attention of agricultural agencies and taxation. Despite well-developed dealer licensing programs in states such as PA, ginseng supply chains remain largely informal with voluntary reporting of derived income to tax authorities. Many involved with ginseng collection, planting, and forest farming harbor deep suspicions towards

government and feel that any effort to document forest farming is only a ploy to assess crop values and taxes owed (Burkhart 2011; D. Colwell, pers. comm. 2012–2020).

Finally, survey respondents who contacted us were largely unfamiliar with any type of ginseng forest farming lexicon (including the term “wild-simulated”). Many terms are beginning to be used by some states on dealer paperwork and additional categories beyond “wild” or “cultivated” are not clearly understood or appreciated for both practical and philosophical reasons. Many believe that “wild” versus “wild-simulated,” for example, is simply a matter of knowledge and perspective. A commonly held reason against making any such distinction is found in the following respondent sentiment: “If I dig wild ginseng and plant its seed back in the same spot, as is required by regulation, is the new plant then ‘wild-simulated?’” Another respondent shared a similar sentiment this way: “If I plant a wild-simulated seed and it begins to produce seeds and seedlings on its own, are the young plants then ‘wild’ if I did not plant them?” (S. Trout, pers. comm. 2018–2020).

These findings collectively suggest that for transparency to be achieved, there needs to be a way to hide in situ production methods from dealers on required paperwork. It is clear many who sell wild ginseng are suspicious of efforts to track origins. Attempts to clarify the source of “wild” ginseng using specialized terminology on point-of-sale paperwork will be resisted or falsified on account of such suspicions. As a possible illustration, Kentucky (KY) is consistently one of the top five wild ginseng harvest states in the United States (USFWS 2019a) and sellers have been required since 2011 to disclose the origin or production method using the categories “wild,” “cultivated,” “wild-simulated,” and “woods grown.” Sellers have used these last two forest farming-related categories on less than 1% of transactions when reporting product origins, despite dealers reporting as many as 16,000 seller transactions per year (A. Lucio, pers. comm. 2020).

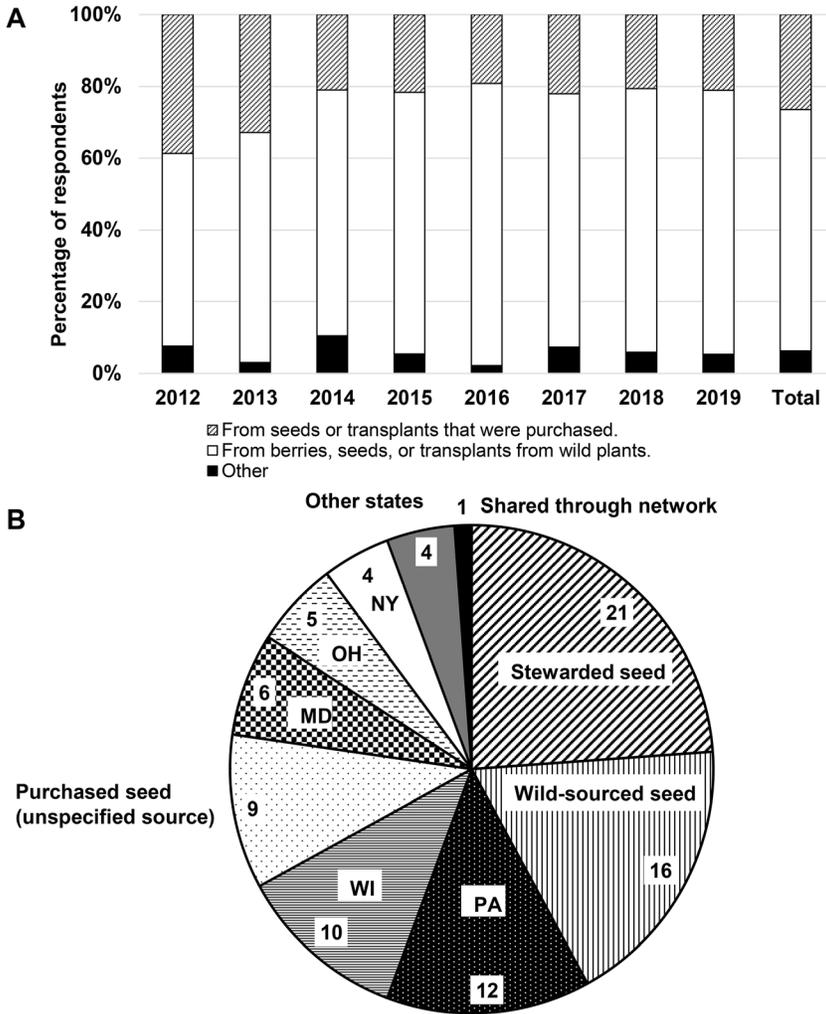
Throughout the survey period we observed that the most common channels for obtaining ginseng planting stock, especially seed, are licensed dealers. Seed is regularly offered for sale on social media and those in PA with whom we have communicated may distribute hundreds, even thousands, of pounds of seed each year (Burkhart, unpublished PA dealer seed distribution survey data 2014–2018). Many dealers give seed away free-of-charge to sellers for “re-stocking” purposes. In 2017, for

example, we surveyed dealers to ask about their involvement in seed distribution and one respondent reported giving away more than 100 pounds of seed in that year alone. It would be insightful if states began to ask or require licensed dealers to report the amount and origins of any seed they distribute as part of licensing requirements each year. This would provide a sense of scale of public planting activities and highlight possible geographic areas for targeted regional native germplasm conservation and maintenance.

#### SOURCES OF GINSENG PLANTING STOCK, WILD GERMPASM CONSERVATION, AND UNCONSCIOUS SELECTION

Of those respondents who reported planting ginseng, 67% reported planting seeds, berries, or transplants that were wild collected while 26% report purchasing seeds, berries, or transplants (Fig. 6a). When asked to provide the geographic origins of their planting stock in an open response question, sellers indicated that ginseng planting stock was obtained from a variety of sources (Fig. 6b). The largest group (24%) reported sowing seed or berries collected from their own plants that we referred to as “stewarded seed.” While approximately 18% of respondents wrote that they collected the seed or berries that they planted from wild plants. Not all sellers responded to this question and others listed multiple stock sources. For those respondents who specified a geographical origin, the top three states were PA (14%), WI (11%), and Maryland (7%). Of the respondents, 10% reported planting purchased seed of unspecified geographical origin. It should be noted that many dealers and commercial vendors distribute WI stock, but seed buyers may only know the state where the seed were sold from and not the ultimate origins (Burkhart 2011; Burkhart, unpublished PA dealer seed distribution survey data 2014–2018). Thus, these states are more indicative of seed seller locations and not necessarily of where the stock was grown.

The widespread importation of ginseng stock for planting purposes in PA is not a new phenomenon, but has a history dating back to the early 1900s. Ginseng was initially collected within PA for the export trade market with China, but during the late 1800s it was also gathered for sale within a rapidly expanding cultivation industry. Between 1900 and 1935, ginseng plantations or “gardens” existed in many counties within the state as evidenced by



**Fig. 6.** **a** When asked “Were they grown using seeds or transplants?”, respondents were prompted to check either seeds or transplants that were purchased, wild collected, or specify another. Percentages based off yearly  $n = 34\text{--}106$ ; total  $n = 493$ . **b** Origins of planting stock totaled over all survey years (2012–2019). For those who purchased seeds or transplants, they were asked to write in the state that the seeds or transplants were shipped from (numbers indicate  $n$  per category, total  $n = 88$ ).

grower advertisements. Commercial cultivation was taking place throughout the state as part of a broader ginseng cultivation “boom” that swept through the mid-Atlantic region during the early 1900s (Hardacre 1974; Harding 1912). During this era, cultivation occurred both on forestlands and under artificial shade constructed of wooden lath, or “arbors” (Butz 1897). In the past, it appears that any attention to planting stock was directed towards conscious selection for improved or uniform root shapes, higher fecundity, and/or earlier harvest (Nash 1898; Paseador 1903).

There is genetic evidence supporting the anthropogenic distribution of cultivated (i.e., artificial shade-grown) ginseng seed within PA and other states (Boehm et al. 1999; Schlag and McIntosh 2012; Young et al. 2012). A microsatellite-based genetic diversity study of ginseng accessions field-collected from 17 states along with 50 known cultivated accessions from WI and North Carolina found the ginseng population to be highly structured, forming three genetically distinct groups of wild collected plants when clustered geographically: Tennessee/Ohio Valley, Appalachian/Blue Ridge,

and WI. The presumed wild collected WI group overlapped with the known cultivated ginseng from both WI and North Carolina. Additionally, some ginseng accessions presumed to be wild collected in Pennsylvania, Ohio, Virginia, Kentucky, New York, and Arkansas clustered with the WI group possibly indicating wide distribution of WI germplasm to other states (Young et al. 2012). Another study, which used Randomly Amplified Polymorphic DNA (RAPD) markers, found that ginseng accessions from PA wild populations were genetically like accessions collected from cultivated populations in seven U.S. state and three Canadian provinces (Boehm et al. 1999). This suggests that some PA wild accessions originated from cultivated germplasm or that PA wild populations were an initial source of cultivated ginseng germplasm. Another RAPD study found one wild-collected population from MD was more similar genetically to a cultivated population grown from purchased mixed seed of WI/TN origins (Schlag and McIntosh 2012).

Genetic studies of ginseng using different types of molecular markers have shown that overall ginseng species genetic diversity is high, as is diversity across wild and cultivated populations, but that diversity is distributed differently in wild and cultivated populations (Cruse-Sanders and Hamrick 2004; Grubbs and Case 2004; Schlag and McIntosh 2012; Schluter and Punja 2002). These studies show consistently that wild ginseng populations have a higher proportion of variation among populations than cultivated populations and that the latter have a higher proportion of within-population diversity than wild populations. The higher levels of within-population variation reported for cultivated ginseng could likely be the result of the planting of mixed lots of ex-situ seed stock, which our survey indicates is practiced by some PA forest farmers (Fig. 6b).

The long-term consequences of the introduction of non-native seed/ecotypes into wild ginseng populations is still to be determined. Such introductions can increase a population's genetic diversity, thereby enhancing its evolutionary potential (Broadhurst et al. 2008). This can benefit populations undergoing inbreeding depression (Edmands 2007; Tallmon et al. 2004) or experiencing changing environmental conditions (Broadhurst et al. 2008; Sgro et al. 2011). A study by Mooney and McGraw (2007) suggests that inbreeding depression may be an important threat to the long-term maintenance of wild ginseng populations. It has been argued that to maximize the potential for adaptation, future climate scenarios should be

considered when moving seeds in an intentional "assisted migration," and that seeds should be sourced to some degree from regions that are growing in climates like the predicted future climate of a region (Sgro et al. 2011). However, with ginseng, seed stock potentially well-adapted to a cooler region (WI) is being planted in warmer regions (in PA and across southern Appalachia). Given that the climate trend in the Northeast region of the United States is warming temperatures and longer frost-free periods (Dupigny-Giroux et al. 2018), the widespread planting of these seed stocks may not benefit native populations or the ginseng industry in PA.

Another concern is that the introduction of non-native seed may result in "genetic swamping," or the rapid increase in number of the introduced ecotypes or alleles in a population (Kramer and Havens 2009). If introduced ecotypes or alleles have a fitness advantage over the local ecotype, replacement of the local ecotype may occur (Hufford and Mazer 2003). Furthermore, if hybridization occurs between ecotypes, which is possible given ginseng mixed-mating system (Mooney and McGraw 2007), outbreeding depression can occur and reduce the fitness of the population by diluting locally adapted alleles or by disrupting advantageous epistatic associations among loci (Edmands 2007; Hufford and Mazer 2003). Genetic swamping and fitness depressions resulting from seed movement can result in loss of valuable genetic resources, like locally adapted ecotypes that could benefit ginseng conservation efforts. Additionally, Schlag and McIntosh (2013) found a strong relationship between ginsenoside chemotypes and RAPD markers, showing that ginsenoside composition has a partial genetic basis. Therefore, losses in genetic variation could hamper potential breeding efforts that could benefit ginseng husbandry such as producing cultivars with unique ginsenoside compositions or useful traits such as drought or temperature tolerance.

Many ginseng planters and forest farmers view any genetic concerns associated with planting stock origins as hypothetical, academic, and/or hyped (Burkhart 2011). Nevertheless, the success of those attempting to plant ginseng on forestlands using commercial, artificial shade-grown stock remains an important research topic in need of greater attention. As forest planting activities are promoted as a mechanism to achieve both economic and conservation aims, the predominant reliance on genotypes that are rapidly undergoing unconscious selection (especially when compared with wild plants) (Zohary 2004) through artificial shade culture

may prove to be an increasingly important, and possibly limiting, factor in ginseng forest farming success. This will be especially true with each subsequent ginseng generation as selection favors genotypes better suited for artificial-shade production systems and that, unlike their slow growing forest counterparts, will achieve reproduction after only two years. A dependency on artificial shade-grown planting stock is also subject to political, societal, and agricultural disruptions, as stock must be obtained annually from limited geographic areas in the United States and Canada where such cultivation occurs. In recent years, for example, WI ginseng farmers have been severely hurt by tariffs imposed because of trade disputes (Mok 2020), resulting in seed supply uncertainties, shortages, and price volatility (Burkhart, pers. obs.). All these factors point to a growing need for the concerted and coordinated development of a U.S. ginseng germplasm conservation and propagation network focused on in situ maintenance and selection. Further, this network should pursue an “ecosystem domestication” approach (Michon and de Foresta 1996) in which breeding and lineage maintenance is conducted in situ using forest farming practices as a desirable alternative to the intensive artificial shade culture approach that currently supplies ginseng seed markets.

## Conclusions

Wild plant trade monitoring and conservation efforts are more likely to have their intended beneficial outcome when informed by an understanding of how species markets are structured and supplied. Lacking such understanding, even the most well-intentioned conservation and trade monitoring efforts may be of little practical value (Larsen and Olsen 2007; Strandby and Olsen 2008). This study is the first longitudinal attempt to understand the degree to which planting, and the agroforestry practice forest farming, may underlie the supply of ginseng in PA, and to understand the behaviors and attitudes that may influence reported harvest amounts. Findings reveal a complex management scenario in which sellers reporting “wild” ginseng on state tracking paperwork are planting, forest farming, and husbanding the product sold. Findings further suggest that a complex suite of husbandry practices, including the importation and planting of purchased stock, are involved in modern “wild” ginseng occurrence and many populations may

increasingly therefore occupy a “middle ground” between wild and cultivated. Moreover, the supply chain lexicon surrounding ginseng reporting is confusing, highly contentious, and without common agreement among sellers, dealers, and state program coordinators.

The insights gained from the use of a confidential survey instrument, as was done in this study, suggests that U.S. state-level surveys, using seller information provided by licensed dealers on currently required paperwork, could be an important tool to help inform state and federal ginseng conservation and management. This survey could be used to gather information about the source of the ginseng being sold as wild in the marketplace, while alleviating some of the concerns (e.g., price devaluation) sellers have about sharing information at the point-of-sale on dealer paperwork. Moreover, if targeted towards larger volume sellers, annual surveys could provide “leads” to individuals planting and growing ginseng as a forest crop, since these sellers are likely to increasingly reflect forest farmers given overall general decline of ginseng supplies from eastern U.S. states. In developing this annual survey, the inclination to introduce husbandry terminology via an increasingly complicated lexicon (e.g., “wild-simulated, woods-cultivated, virtually wild, wild-stewarded, artificially propagated, wild”) should be avoided. Findings from this study suggest that attempts at clarifying the origins of “wild” ginseng through this type of specialized terminology in dealer paperwork as well, will be resisted or falsified while seller concerns regarding price devaluation, taxes, and crop security persist. Many sellers and dealers also do not distinguish between “wild” and “wild-simulated” categories, on either practical or philosophical grounds, further complicating or hindering any attempts to document forest farming along these lines.

## Supplementary Information

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Since 2012, we have behaved ethically and with integrity towards each other and with all participants and collaborators associated with this study. We reviewed and used the International Society of Ethnobiology (ISE) Code of Ethics as our baseline since 2013 and have sought and gained IRB approval in each survey year. All instruments, consent forms, letters, and research methods were approved by the Pennsylvania State University Office for Research Protections (IRB study 00007062) and clearly outline the objectives and any associated risks of participating in this research to participants. We have made every effort be available to survey respondents for voicing of questions and concerns, many of which are shared in the manuscript discussion.

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