Analysis of the age of *Panax ginseng* based on telomere length and telomerase activity

Jiabei Liang1,2*, Chao Jiang1,3*, Huasheng Peng1, Qinghua Shi4, Xiang Guo4, Yuan Yuan1 & Luqi Huang1

1State Key Laboratory Breeding Base of Dao-di Herbs, National Resource Center for Chinese Materia Medica, China Academy of Chinese Medical Sciences, Beijing 100700, P.R. China, 2College of Pharmacy, Chengdu University of Traditional Chinese Medicine, Chengdu, People’s Republic of China 610072, 3Beijing Area Major Laboratory of Protection and Utilization of Traditional Chinese Medicine, College of Resources, Beijing Normal University, Beijing, People’s Republic of China 100875, 4State Key Laboratory of Plant Cell and Chromosome Engineering, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Beijing 100101, China.

Ginseng, which is the root of *Panax ginseng* (Araliaceae), has been used in Oriental medicine as a stimulant and dietary supplement for more than 7,000 years. Older ginseng plants are substantially more medicinally potent, but ginseng age can be simulated using unscrupulous cultivation practices. Telomeres progressively shorten with each cell division until they reach a critical length, at which point cells enter replicative senescence. However, in some cells, telomerase maintains telomere length. In this study, to determine whether telomere length reflects ginseng age and which tissue is best for such an analysis, we examined telomerase activity in the main roots, leaves, stems, secondary roots and seeds of ginseng plants of known age. Telomere length in the main root (approximately 1 cm below the rhizome) was found to be the best indicator of age. Telomeric terminal restriction fragment (TRF) lengths, which are indicators of telomere length, were determined for the main roots of plants of different ages through Southern hybridization analysis. Telomere length was shown to be positively correlated with plant age, and a simple mathematical model was formulated to describe the relationship between telomere length and age for *P. ginseng*.

Ginseng, which is the root of *Panax ginseng* C.A. Meyer (Araliaceae), has been used in Chinese medicine for thousands of years as a stimulant and dietary supplement1. In European and American countries, ginseng phytomedicines have been used to increase physical and mental performance, provide resistance to stress and disease, and prevent exhaustion for decades2. Ginseng plants begin flowering in their fourth year, and the roots can live for hundreds of years after maturing at 4–6 years of age. The older the root, the higher its medicinal value because of the higher concentration of ginsenosides, which are the active chemical compounds in ginseng3,4. However, chemical analyses often require gram quantities of dried ginseng material, and it is difficult to extract such quantities while leaving the ginseng intact; thus, chemical analysis greatly decreases the ginseng’s value. Therefore, effective methods for identifying the age of ginseng roots are urgently needed to improve quality control and protect the interests of ginseng consumers.

Telomeres, which are specialized structures at the physical ends of eukaryotic chromosomes that consist of highly conserved, repeated DNA sequences5,6, shorten with each round of DNA replication7–10 because DNA polymerases cannot completely replicate linear DNA molecules. In gymnosperms, telomere length can be used to predict the future replicative capacity of cells11,12. Highly significant correlations between telomere length and age have been observed in humans8,13, Australian sea lions14, martins and dunlins15 and different stages of barley16. Therefore, telomere shortening can be used as a marker of cell replication and aging. Telomerase activity has been detected in plants using a polymerase chain reaction (PCR)-based telomerase repeat amplification protocol (TRAP) assay17. Telomerase appears to be developmentally regulated in plants, which is similar to what occurs in humans18. These reports indicate biological correlations between telomere length and age. However, plant telomeres are maintained by telomerase. Telomere lengths remain stable in tomato leaves19, whereas they change cyclically, lengthening and shortening with age, in the needles of *Pinus longaeva*20. After the first plant telomere sequence was cloned from *Arabidopsis*21, nearly all plant telomeres were found to consist of the heptanucleotide

*These authors contributed equally to this work.
repeat (TTTAGGG)n\textsuperscript{22,23}. Arabidopsis-type repeats have also been found in \textit{P. ginseng}\textsuperscript{24}. However, researchers have not yet ascertained whether Arabidopsis-type repeats are located in telomeres or their relationship with age.

In this study, we combined traditional identification methods and measurements of telomere length in ginseng plants of known age. Preliminary investigations indicated that telomere length was slightly positively correlated with the age of the ginseng plant. Analysis of telomerase activity in different parts of the plant further revealed that the main root was the most active meristematic region. Therefore, we used this tissue to evaluate telomere length. Determination of telomere terminal restriction fragment (TRF) lengths in \textit{P. ginseng} specimens of different ages demonstrated that the telomeres in the main roots showed a significant increase in TRF length with plant age that could be used for age estimation for 2–8 years.

**Results**

Fluorescence in situ hybridization to determine telomere sequences. The telomeres of most higher plant species are composed of the repeated sequence (TTTAGGG)n. To investigate \textit{P. ginseng} telomeres comprising the same repeat, we using the complementary end digoxigenin-labeled, telomere-specific oligonucleotide (CCCTAAA)\textsubscript{3} as a probe to perform in situ hybridization. Hybridization signals visualized as green fluorescence demonstrated that Arabidopsis-type telomeric sequence repeats, (TTTAGGG)\textsubscript{n}, were located in the chromosomes of \textit{P. ginseng} (Fig. 1).

Growth rings in the roots of \textit{P. ginseng} from Ji’an. The paraffin sections of \textit{P. ginseng} rhizomes of different ages collected from Ji’an revealed distinct growth rings in the xylem of secondary roots, and the number of growth rings in the main root was consistent with an age of 1–6 years (Fig. 2). However, microscopy analysis showed that the growth rings of the ginseng specimens did not precisely reflect age after 6 years.

Telomeric activity of different ginseng tissues. A representative TRAP analysis image that was used to quantify telomerase activity is shown in Fig. 3. Average telomerase activities in various tissues and different stages of plant development were assayed using TRAP, and the results indicated that the main root showed the highest average telomerase activities of all of the examined tissues. Because telomerase can lengthen telomeres, and the activity of telomerase

---

**Figure 1** | In Situ Localization of TTTAGGG Telomeric Motifs on \textit{P. ginseng} Chromosomes. The the digoxigenin–dUTP nick tag sequence (CCCTAAA)\textsubscript{3} telomeric probe was hybridized with adventitious root of \textit{P. ginseng} metaphase chromosomes and counterstained with propidium iodide.

**Figure 2** | The growth rings in the ginseng root of 1 ~ 6 years. (A), (B), (C): 1 year ginseng root, 2 year ginseng root, 3 year ginseng root, Bar = 1000 μm; (D), (E), (F): 4 year ginseng root, 5 year ginseng root, 6 year ginseng root, Bar = 500 μm.

**Figure 3** | Developmental Regulation of Telomerase Expression in 5 years \textit{P. ginseng}. Telomerase activities in various tissues and different stages of plant development were assayed by TRAP, using 47F as the forward primer and PTelC3 as reverse primers. Lane1: tap root; Lane2: leaves; Lane3: stems; Lane4: root tips; Lane5: seeds.
may be correlated with age, the main roots were used for further analyses.

Tangential cryo-sectioning of 400 μm sections of samples from 5-year-old *P. ginseng* tissues, followed by densitometric quantitation of telomerase activity (in relative units), revealed the highest telomerase activity in the cambium and adjacent zones of differentiating secondary xylem (Fig. 4).

Analysis of TRF lengths in *ginseng* of different ages. DNA fragments were analyzed through DNA gel blot hybridization using the (CCCTAAA)$_3$ oligonucleotide as a probe. A representative Southern blot image that was used to quantify TRFs is shown in Fig. 5a, b, where the hybridization signals represent telomeric regions. The autoradiograph was scanned and imported as a TIFF-format image to measure TRF length. The location of the peak intensity could not be accurately determined by eye. Therefore, an easy-to-use system that was able to determine the distributions of telomeric regions based on copy number and calculate statistics was employed. The unbiased TRF measure software Telotool$^{25}$ was used to measure the TRF lengths of *ginseng* roots. A plot of the relative telomere copy number versus molecular weight was created, which provided the user with a realistic picture of the actual distribution of telomeric lengths. The measurements of TRF length for each sample using Southern hybridization was repeated three times.

We investigated the correlation between TRF length and plant age using *P. ginseng* samples of known age from Ji’an and Fusong. First, DNA fragments were analyzed through Southern hybridization using the (CCCTAAA)$_3$ oligonucleotide as a probe for telomeric DNA (Fig. 5a). Although observations made by eye are not precisely accurate, this easy-to-use method is convenient and allowed rapid analysis of the telomeres of *ginseng* roots by determining copy number$^{26}$. A general model for age-related TRF length in *ginseng* was introduced. Eleven models were simulated using SPSS 20.0 software, and the most suitable linear fitting curve was determined. The obtained results satisfied the 83% confidence limits ($R^2 = 0.832$, $F = 79.029$, Sig. = 0.000), and it was found that TRF length was significantly positively correlated with age after 3 years (Fig. 5b), which indicated that TRF length could be maintained via telomerase activity as tissues developed. Based on these results, we propose a mathematical model through which telomere length can be used to predict *P. ginseng* age:

$$y = 0.827x + 8.231,$$

where, $x$ is age, and $y$ is TRF length.

Discussion

Scientific identification of the potency of traditional Chinese medicines is crucial to ensure their authenticity and effectiveness. Authenticity can be assured based on several factors: the geographic origin or cultivation source of the species; proper harvesting and processing methods; and growth stage$^{27}$. These factors are all important for the quality of Chinese herbal medicines. Because bioactive secondary compounds accumulate as medicinal plants such as *P. ginseng*, *Salvia miltiorrhiza* and *Coptis chinensis* age, older plants
usually serve as better medicinal herbs. However, in the pursuit of economic efficiency, a number of inappropriate strategies, including the use of growth hormones and swelling agents as well as continual transplantation, have been employed to simulate age. Therefore, the quality of Chinese herbal medicines is difficult to determine. This study aimed to establish a reliable and effective method for identifying the age of ginseng that complements traditional methods of age determination.

Gymnosperms and dicotyledonous angiosperms generally undergo primary and secondary growth, whereas monocots usually lack secondary growth. The retention of stem-cell-like meristematic cells plays a critical role in perennial longevity. Stem-cell-like meristematic cells are located in the cambium. Accordingly, when environmental conditions change periodically, associated with different growing seasons, the cambium cell cycle is activated, and the tissue layers form rings (termed growth rings) during each individual period of growth. Arx, Schweingruber and Dietz indicated that growth rings could be an effective biomarker for estimating age in the roots of dicotyledonous perennial herbs. In the present study, growth-ring characteristics were clearly present in 1- to 6-year-old ginseng top roots. However, when the ginseng specimens were older than 6 years, dry, decayed channels emerged within the cambium rings, making the growth rings difficult to distinguish and influence age estimation. Therefore, this method can only be applied over a minimum age range, and a new marker was required for estimation of the age of older ginseng samples.

Telomere length and telomerase activity are useful biomarkers for age prediction in animals and plants due to their close association with cell proliferation. However, it was unclear whether telomerase activity is related to the mechanisms maintaining stem cells in meristems. Our analyses of several P. ginseng tissues showed that telomerase activity was highest in the cambium. Telomerase expression in plants is very similar to that in humans. In plants, telomerase activity is highest in the meristem and reproductive organs, whereas there is little or no activity in the endosperm, leaves and stems. In Ginkgo biloba, tissues with a high percentage of dividing cells also exhibit high levels of telomerase activity, which is consistent with our results. We found that the sampled tissue had a substantial impact on the age estimation in P. ginseng. The main root samples contained most of the organized cambium and annual growth rings. We found that telomere length in the main roots was positively correlated with plant age. However, due to sampling limitations, ginseng plants of older ages were difficult to sample. Therefore, our mathematical model is only suitable for a certain range of ginseng ages.

A study that examined TRF branch length in detail suggested that telomere branch lengths increase with age to some extent in G. biloba, in accord with the results of the present study. Our analyses indicate that ginseng telomere length increases significantly with age; however, in contrast to the progressive shortening of TRFs observed in somatic cells as animals aging, telomere length and telomerase activity change in different patterns during plant development. Telomere lengths have been observed to be stable in tomato leaves in four-week-old to six-month-old plants, and they do not significantly change during plant ontogenesis or leaf senescence in Melandrium album and Arabidopsis thaliana or during cyclical changes of lengthening and shortening in size associated with age in Pinus longaeva. Furthermore, telomeres do not shorten during increased tissue differentiation from embryonic to adult stages in Hordeum vulgare and Pinus sylvestris, whereas they show decreased lengths during Betula pendula tissue culture, while increased lengths are observed with age in G. biloba. These results suggest that the relationship between telomere length and plant development is complex and may be affected by the species and lines involved as well as environmental stress and telomerase and stem cell activities. The present study indicates that telomere length in the top roots of P. ginseng increases with age, as observed in the leaves and calli of G. biloba. Interestingly, many studies show that ginsenoside Rg1, which is one of the main biologically active components of ginseng, can decrease telomere shortening and reinforce telomerase activity in delayed hematopoietic stem cells and reduce senescence in human somatic cells. Similar results were found for a G. biloba extract, which significantly augmented endothelial progenitor cell telomerase activity to prevent the cells from entering senescence. These results imply that the increase in telomere length with age is

![Image](https://www.nature.com/scientificreports/images/fig5.jpg)

Figure 5 | Southern hybridization images used for measurement and quantization of TRF length. Lane M: DNA Molecular Weight Marker III, Digoxigenin-labeled (Roche). Numbers 2, 3, 4, 5, 6, 8 mean different years of P. ginseng samples collected from the city of Ji’an, Jilin province, China. B: Data fitting results and the trend of variation of TRF length with different ages. Overall, average TRF length increased with ages in main root (The following 1 cm of “ginseng lutou”).

### Table 1 | The Ginseng samples collected from two different districts

| Age (year) | 2 | 3 | 4 | 5 | 6 | 8 |
|------------|---|---|---|---|---|---|
| **Fusong** | | | | | | |
| **Ji’an**  | | | | | | |

Ginseng samples of known age were collected from the Ji’an and Fusong districts of Jilin Province, China, in mid-August, 2010 and 2013. The samples were taxonomically identified by Prof. Shiquan Xu, Institute of special animal and plant science, Chinese Academy of Agricultural Sciences. All samples consist of 3 individuals every year.
observed in ginseng and ginkgo may be related to the bioactive components of these plants, which may maintain telomere length by the telomerase mechanism or the ALT mechanism. The correlation between telomere length and telomerase activity in *P. ginseng* that was demonstrated here suggests that telomere length and telomerase activity might play essential roles in directly or indirectly regulating the life span of *P. ginseng*.

**Methods**

**Sample collection.** Ginseng samples of known age were collected from the Ji’an and Fusong districts of Jilin Province, China, in mid-August, 2010 and 2013 (Table 1). Samples of the main root (1 cm below the rhizome, known as “ginseng lutoz”) in China, leaf, stem, secondary root and seeds were frozen in liquid nitrogen and stored at −80°C until use.

**Chromosome preparation and in situ hybridization.** Adventitious roots were induced from callus of *P. ginseng* by cultured in the MS rooting medium for 14 d. Adventitious root tips were used as a source of metaphase chromosomes, and the digoxigenin–dUTP nick (Roche, Penzberg, Germany) tag sequence (CCCTAAAT)₅ was used as a chromosome probe, as previously described. Slides were removed immediately after immersion in 1 × PBS (containing 0.2% Tween) and dipped in 1 × blocking buffer (Boehringer, Ingelheim, Germany) at 37°C for 30 min. After drying, each slide was placed in 50 × blocking buffer containing 2 μl of a FITC-conjugated anti-digoxin antibody (anti-Dig FITC, Boehringer, Ingelheim, Germany), covered by the telomerase mechanism or/and the ALT mechanism. The correlation between telomere length and telomerase activity in *P. ginseng* of different harvest times was evaluated on HPLC fingerprints and principal component analysis. *Nat. Prod. Res.* 27, 851–854 (2013).

**Kim, N. et al.** Nontargeted metabolomics approach for age differentiation and structure interpretation of age-dependent key constituents in hair roots of *Panax ginseng*. *J. Nat. Prod.* 75, 1777–1784 (2012).

**Azaña, R. V. & Taylor, F. J. Are Pyrodinium blooms in the Southeast Asian region recurring and spreading? A view at the end of the millennium. *Amar. 38*, 356–364 (2001).

**Kipling, D., Wilson, H. E., Thomson, E. J. & Cooke, H. J. YAC cloning *M. musculus* telomeric DNA: physical, genetic, in situ and STS markers for the distal telomere of chromosome 10. *Hum. Mol. Genet.* 4, 1007–1014 (1995).

**Olovnikov, A. M. Telomeres, telomerase, and aging: origin of the theory. *Exp. Gerontol.* 31, 443–448 (1996).

**Harley, C. B., Fuchter, A. B. & Greider, C. W. Telomeres shorter during aging of human fibroblasts. *Nature. 345*, 458–460 (1990).

**Olovnikov, A. M. A theory of marginotomy. The incomplete copying of template margin in enzymic synthesis of polynucleotides and biological significance of the phenomenon. *J. Theor. Biol.* 41, 181–190 (1973).

**Watson, J. D. Origin of concatemeric T7 DNA. *Nat. New Biol.* 239, 197–201 (1972).

**Murray, B. G., Friesen, N. & Hesslop-Harrison, J. S. Molecular cytogenetic analysis of Podocarpus and comparison with other gymnosperm species. *Ann. Bot.* 89, 483–499 (2002).

**Allopp, R. C. et al. Telomere length predicts replicative capacity of human fibroblasts. *Proc. Natl. Acad. Sci. U. S. A.* 89, 10114–10118 (1992).

**Hastie, N. D. et al. Telomere reduction in human colorectal carcinoma and with aging. *Nature. 346*, 866–868 (1990).

**Izzo, C., Hamer, D. J., Bertozzi, T., Donnellan, S. C. & Gilanders, B. M. Telomere length and age in pinnipeds: The endangered Australian sea lion as a case study. *Mar. Mammal Sci.* 27, 841–851 (2011).

**Pauliny, A., Wagner, R. H., Augustin, J., Szep, T. & Blomqvist, D. Age-independent telomere length predicts fitness in two bird species. *Mol. Ecol. 15*, 1681–1687 (2006).

**Kilian, A., Stiff, C. & Kleinhoft, A. Barley telomeres shorten during differentiation but grow in callus culture. *Proc. Natl. Acad. Sci. U. S. A.* 92, 9555–9559 (1995).

**Fulcher, D. S., McKnight, T. D. & Shippen, D. E. Characterization and developmental patterns of telomerase expression in plants. *Proc. Natl. Acad. Sci. U. S. A.* 93, 14422–14427 (1996).

**Riha, J., Kajurski, J., Siroky, J. & Vysokt, B. Developmental control of telomere lengths and telomerase activity in plants. *Plant Cell.* 10, 1691–1698 (1998).

**Broun, P., Canal, M. W. & Tankely, S. D. Telomeric arrays display high levels of heritable polymorphism among closely related plant varieties. *Proc. Natl. Acad. Sci. U. S. A.* 89, 1354–1357 (1992).

**Flanary, B. E. & Kletetschka, G. Analysis of telomere length and telomerase activity in tree species of various life-spans, and with age in the balsam fir *Pinus longaeva*. *Biorogentrol.* 6, 101–111 (2005).

**Richards, E. J. & Ausubel, F. M. Isolation of a higher eukaryotic telomere from Arabidopsis thaliana. *Cell.* 53, 127–136 (1988).

**Ganal, M. W., Lapitan, N. L. & Tanksley, S. D. Macrostructure of the tomato telomeres. *Plant Cell.* 5, 87–94 (1993).

**McKnight, T. D., Fitzgerald, M. S. & Shippen, D. E. Plant telomeres and telomerase: A review. *Biochemistry.* 62, 1224–1231 (1998).

**Ho, I. S. & Leung, F. C. Isolation and characterization of repetitive DNA sequences from *Panax ginseng*. *Mol. Genet. Genomics.* 266, 951–961 (2002).

**Göhring, J., Fulcher, N., Jacak, J. & Riha, K. TeloTool: a new tool for telomere length measurement from terminal restriction fragment analysis with improved probe intensity correction. *Nucleic Acids Res.* 42, e21 (2014).

**Grant, J. D. et al. Telometric: a tool providing simplified, reproducible measurements of telomeric DNA from constant field agarose gels. *Biotechniques.* 31, 1314–1316, 1318 (2001).

**Huang, L., Xiao, P., Guo, L. & Gao, W. Molecular pharmacogenomics. *Sci. China Life Sci.* 53, 643–652 (2010).
31. Liu, D. et al. Comparative analysis of telomeric restriction fragment lengths in different tissues of Ginkgo biloba trees of different age. J. Plant Res. **120**, 523–528 (2007).
32. Mather, K. A., Jorm, A. F., Parslow, R. A. & Christensen, H. Is telomere length a biomarker of aging? A review. J. Gerontol. A. **66**, 202–213 (2011).
33. Watson, J. & Ríha, K. Telomeres, aging, and plants: from weeds to Methuselah—a mini-review. Gerontology. **57**, 129–136 (2010).
34. Song, H., Liu, D., Li, F. & Lu, H. Season-and age-associated telomerase activity in Ginkgo biloba. Mol. Biol. Rep. **38**, 1799–1805 (2011).
35. Liu, D. et al. Dynamic changes of telomeric restriction fragment (TRF) lengths in cells during the developmental process from embryos to seedlings and a comparison with the embryonal calli in Ginkgo biloba L. Forest. Stud. China. **9**, 127–131 (2007).
36. Zentgraf, U., Hinderhofer, K. & Kolb, D. Specific association of a small protein with the telomeric DNA–protein complex during the onset of leaf senescence in Arabidopsis thaliana. Plant Mol. Biol. **42**, 429–438 (2000).
37. Aronen, T. & Rynänen, L. Variation in telomeric repeats of Scots pine (Pinus sylvestris L.). Tree Genet. Genomes. **8**, 267–275 (2012).
38. Aronen, T. & Rynänen, L. Silver birch telomeres shorten in tissue culture. Tree Genet. Genomes. **10**, 67–74 (2014).
39. Zhou, B. et al. Ginsenoside Rg1 protects human fibroblasts against psoralen- and UVA-induced premature senescence through a telomeric mechanism. Arch. Dermatol. Res. **304**, 223–228 (2012).
40. Zhou, Y. et al. Changes of telomere and telomerase in effect of ginsenoside Rg1 to delay hematopoietic stem cell senescence. J. Chin. Mater. Med. **36**, 3172–3175 (2011).
41. Zhao, C. et al. Roles of telomere and telomerase in the process of ginseno-side Rg1 protection against tert-butyl hydroperoxide-induced senescence in WI-38 cells [J]. Chin. Pharmacol. Bull. **1**, 61–66 (2005).
42. Dong, X. X. et al. Ginkgo biloba extract reduces endothelial progenitor-cell senescence through augmentation of telomerase activity. J. Cardiovasc. Pharm. **49**, 111–115 (2007).
43. Kurata, N. & Omura, T. Karyotype analysis in rice, 1: A new method for identifying all chromosome pairs. Japan. J. Genet. **53**, 251–255 (1978).
44. Chaffey, N. J. Wood formation in trees: cell and molecular biology techniques (CRC Press, Florida, 2004).
45. Kim, N. W. et al. Specific association of human telomerase activity with immortal cells and cancer. Science. **266**, 2011–2015 (1994).
46. Bradford, M. M. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem. **72**, 248–254 (1976).
47. Nakamura, K. et al. Comparative analysis of telomere lengths and erosion with age in human epidermis and lingual epithelium. J. Invest. Dermatol. **119**, 1014–1019 (2002).
48. Rogers, S. O. & Bendich, A. J. Plant Molecular Biology Manual 73–83 (Springer Press, Heidelberg, Germany, 1989).
49. Flanary, B. E. & Streit, W. J. Telomeres shorten with age in rat cerebellum and cortex in vivo. J. Anti. Aging Med. **6**, 299–308 (2003).
50. Flanary, B. E. & Streit, W. J. Progressive telomere shortening occurs in cultured rat microglia, but not astrocytes. Glia. **45**, 75–88 (2004).

**Acknowledgment**

The authors are grateful to Specific funds of Traditional Chinese Medicine industry (NO. 201407003) and Key Projects in the National Science & Technology Pillar Program (NO. 2012BAIZ9B02).

**Author contributions**

J.L. conducted experiments and data analysis. C.J. conducted data analysis and wrote the paper. H.P. collected the majority of the samples provided the case information and conducted experiments. Q.S. and X.G. conducted the FISH experiments. Y.Y. designed experiments and revised the paper. L.H. designed experiments, performed data analysis and wrote the paper.

**Additional information**

Competing financial interests: The authors declare no competing financial interests.

**How to cite this article:** Liang, J. et al. Analysis of the age of Panax ginseng based on telomere length and telomerase activity. Sci. Rep. **5**, 7985; DOI:10.1038/srep07985 (2015).

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in the credit line; if the material is not included under the Creative Commons license, users will need to obtain permission from the license holder in order to reproduce the material. To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-nd/4.0/