BIOLOGICAL AND CYTOLOGICAL FOUNDATION FOR BETTER GINSENG TO MORE PEOPLE

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Both in Eastern Asia and Eastern North America, since the time immemorial, people have gathered ginseng, taking it first as a food to assuage hunger and to alleviate fatigue, and later using it as a medicine. In the over populated area of the natural range of ginseng in Eastern Asia, forests were destroyed, and ginseng was exterminated with the trees. However, in the less populated areas of higher altitudes and also of higher latitudes, different species of ginseng still grow, from the Eastern Himalayan Region thence northeastward to Chinese Northeast, Korea, Russian Far East, and Japan. Two species grow in Eastern North America. The commercially important species at present are *Panax ginseng* C. A. Meyer, *P. wangianus* Sun (Sanchi), and *P. quinquefolius* L. The major portion of the market material is produced in ginseng farms or sanchi plantations. The price of this material is too high for the general public.

My personal interest in ginseng is focused on the economic botany of the species, in other words, ginseng and human welfare. My recent study concerns the biology and the cytology of ginseng, for such information would enhance the production of better ginseng for more people. The results of some of my investigations are summarized in this report.

Observations on the Biology of Ginseng

Ginseng is becoming an increasingly important commercial crop and a subject for popular writings. Fanciful statements for exciting the reading public appear in many books. An understanding of the essential structure (morphology) of ginseng may help growers to communicate, and writers to reduce dubious statements. It is true that some of the morphological terms are available in textbooks of botany, but they are generally unfamiliar to growers and users of ginseng.

General Aspects of Ginseng: All the species of ginseng are deciduous perennial herbs, the aerial portion of which becomes yellow at the end of the growing season, dies and disappears subsequently. The underground portion of the plant persists. It consists of the root-system and the stem. The primary root of ginseng is fleshy in all the species. This fleshy taproot lasts only for few years in *Panax japonicus* and related species with large quantity of oleanane-type triterpene, and for many (up to 65)[1] years in *P. quinquefolius* and related species rich in dammarane-type triterpenes. Species with short-life taproots have fibrous adventitious roots growing at the nodes of the

[1]Burkill, I. H. in Kew Bull. 1902: 5. 1902.

underground stems (the rhizomes).

Seedling of Ginseng: A seedling is a young plant that develops soon after the germination of a seed. In most botanical textbooks, the point of attachment of the seed-leaf (cotyledon) is used to show the axis of the seedling. The portion that grows upward from this point is called the stem, and the portion that grows downward is called the primary root. In most herbaceous plants, a stem emerges aboveground to produce leaves and branches. In ginseng, the stem portion is extremely short, and it remains underground. A trifoliolate or triparted leaf (rarely two simple leaves) emerges aboveground. The strong white hypocotyl elongates and penetrates the soil, and it becomes part of the fleshy taproot which has numerous branches (secondary and tertiary roots and rootlets) at the lower portion (Fig. 1).

Juvenile Ginseng Plants: The length of the juvenile period of ginseng depends upon the environment in which it grows. In plantations ginseng begins to show flower buds at the age of three and it generally flowers when four-year old. In nature, a plant may remain juvenile for many years (see below). Normally people estimate the age of a ginseng plant by counting the scars left by the deciduous aerial portion. Juvenile and weak plants leave smaller scars than the strong flowering plants, and in such cases, it is hard to assess the true age of wild ginseng.

There is an obvious phase change in the aerial portion of juvenile ginseng. In plantations, an one-year old ginseng has a trifoliate leaf. A two-year old plant has two palmately compound leaves, each with 3, 4, or 5 leaflets (Fig. 1). The third year old plant may have three palmately compound leaves, and a poorly developed flowering branch (inflorescence), which may or may not produce flowers.

The underground portion of ginseng is relatively stable and specifically specialized. The juvenile taproots of the majority of the species are cylindric at first and gradually become carrot-like, with lateral branches at the distal portion especially. The taproot of the Dwarf Ginseng in eastern North America is oblong (Fig. 1-c), and as it grows in thickness, it gradually becomes spherical.

The rhizome of juvenile ginseng are slender, and with obscure scars. As the plant increase in size and vigor, the scars gradually become more prominent.

Mature ginseng: Most reports, illustrations, and herbarium speciments concern mature ginseng. In the summer of 1942 I spent three months botanizing in the virgin forests and alpine meadows of the Ch'ung-lai Range (Long. 102°30'E, Lat. 31–32°N). From my locale guide, a medicine collector, I learned different species of wild ginseng. In his 1960 and 1963 expedition to the Eastern Himalayan Region, Professor H. Hara of the University of Tokyo made careful field studies of the populations of ginseng in that region. Information in his 1970 report on the Asiatic species of the genus *Panax* is most enlightening. This significant report helps us to understand

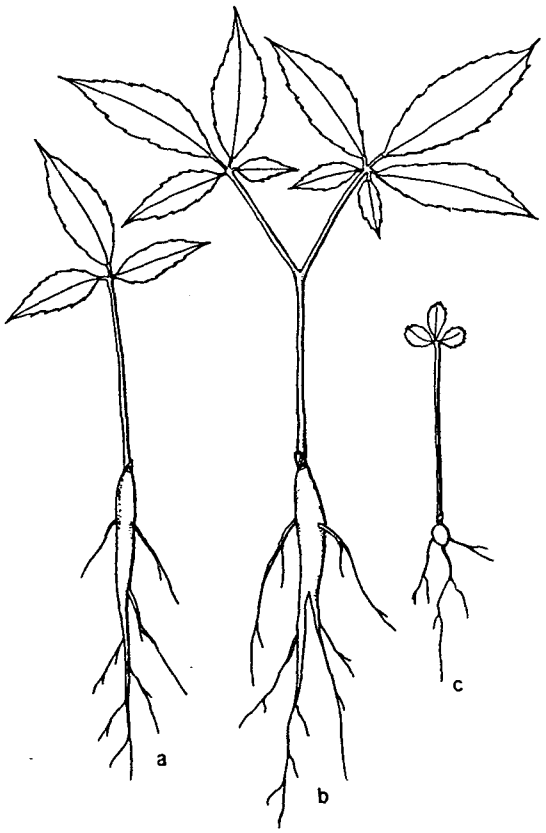

Fig. 1.

mature ginseng. However, systematic botanists and economic botanists often take different views in the application of scientific names. The former, in trying to show relationships, choose to use very long names, such as *Panax pseudo-ginseng* Wall. subsp. *japonicus* (C. A. Meyer) Hara var. *japonicus*, while the latter prefer short names with fewer words, such as *P. japonicus* C. A. Meyer. Likewise, for *P. pseudoginseng* Wall. subsp. *himalaicus* Hara var. *bipinnatifidus* (Seem.) Li, an economic botanists chooses to use *P. bipinnatifidus* Seem. In this article I take the latter view. The discussion on the mature plant is subdivided into the underground and the aerial organs.

1. The Underground Organs: The subterranean portion of a ginseng consists of the root and the rhizome. The root-system of a ginseng varies according to the species. The shape of the taproot of species with persistent primary root is affected by the habitat. A plant which grows in light soil

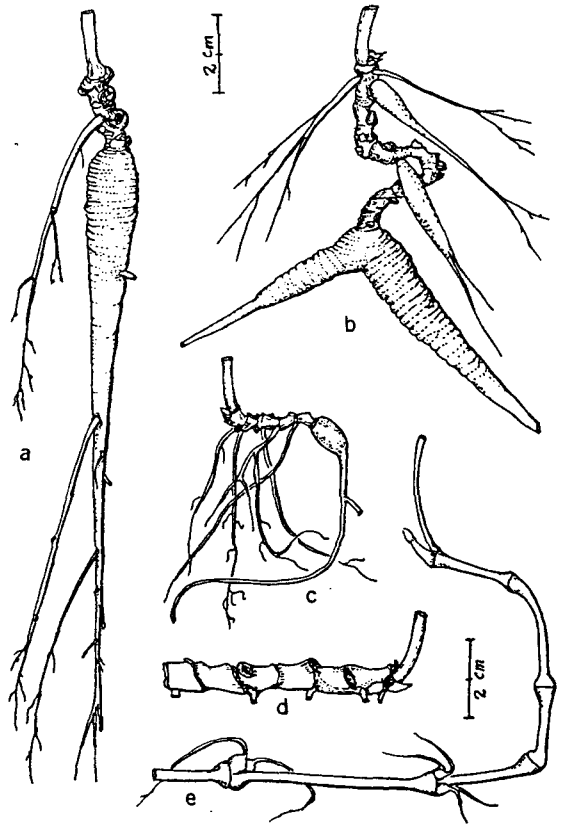

Fig. 2.

formed by the debris accumulated between large boulders lying along the banks of the stream, has straight taproot 15–20 cm. long, branched only at the distal end (Fig. 2-a). On the other hand when a plant grows in soil over a rock or with stones or roots, it branches early, with the branches grow against the object (Fig. 2-b). It seems that such a situation also stimulate the formation of more adventitious roots and some of them can become considerable fleshy. The surface of old fleshy root or the older portion of it is wrinkled, due to the increment of the diameter of the portion concerned. In *P. japonicus*, after the decay of the taproot, the plant is furnished with numerous fibrous adventitious roots (Fig. 2-c). In the Eastern Himalayan and Chinese species with creeping slender rhizomes, tubers are formed at the thickened nodes, and at the distal end of each tuber there is a filiform root with branches and perals (Fig. 2-e). Some of the tubers are spherical, reminding one of the fleshy root of *P. trifolius* (Dwarf Ginseng).

The *rhizome* of mature ginseng is erect in *P. trifolius*, creeping in *P. japonicus*, and *P. bipinnatifidus* and related forms, suberect (Fig. 2-a) or creeping (Fig. 2-b) in *P. quinquefolius* and wild *P. ginseng*. In nature, much humus is added to the forest floor annually. Adventitious roots are produced progressively upward (Fig. 2-b) to prop the slender rhizome. Cultivation has greatly modified the length and shape of the rhizome of ginseng, making it shorter and thicker. Such character enhance better market price. As the plant becomes older, the diameter of the rhizome increases slightly. The rhizome of most species of ginseng is terminated by a dormant bud covered by scales. In *P. quinquefolius* the terminal bud is actively developing and elongating (Fig. 2-e) at flowering time. The rhizome of a mature plant of Japanese Ginseng *(P. japonicus)* is creeping, with short and stout internodes and it contains much reserved food.

2. The Aerial Organs: The aerial portion of mature ginseng has been described in floras (Fernald 1950), and revisions (Li 1942). In these publications, the aerial portion is interpreted as a simple stem bearing a whorl of palmately com-

pound leaves. At present, on account of the position of the bud, some botanists argue that the rhizome of ginseng should be regarded as a sympodium and the entire aerial growth as a leaf with an epiphyllous flowering umbel. For three reasons I maintain the former interpretation that the aerial portion is a stem which bears leaves and inflorescence. In complying with well known publications is to avoid confusion to my readers. Secondly, there is hardly any information on the developmental changes of the subapical bud and the anatomy of the aerial organs. Finally, many specimens of *P. japonicus, P. pseudo-ginseng,* and some cultivated *P. ginseng* have branched inflorescences. In such a manner, ginseng is similar to peony which has only one bud on the rhizome, except in peony the aerial stem has distinct notes and internodes.

In order to save space, in this discussion, general information available in common publications on the aerial portion of ginseng is omitted. Here the variability in the vegetative organs and in the breeding system are emphasized. The aerial organs of ginseng is very variable. The age of the individual plants and the environmental factors make much of the difference. Some genetic mechanisms account for other disparity.

The *number of aerial growth* of ginseng is usually one. This limited-growth is probably due to the effect of environmental conditions. Being an undergrowth of deciduous forest, ginseng grows in rather disadvantageous condition with weak light and competition of water and nutrient from the tree roots and the associated herbs and shrubs. Under this condition, ginseng normally produce one aerial shoot annually, However specimens with two flowering shoots do occur in nature, and often in cultivation. A specimen collected from the dry rocky wooded hillside in Middlefield, Massachusetts (*Fernald and Long 10080,* in Gray Herbarium) has a flowering shoot with four leaves and a flowering peduncle 12 cm. long, and a second shoot with two leaves and a flowering peduncle 3 cm. long. In ginseng plantations two-shoot plants are common. In order to have product for better price, one of the shoots is often nipped off.

The *number of leaves to a plant* also varies with the age of the plant and its growth condition. The count of a random selection of 50 flowering specimens growing in six states of New England shows that 4% of them have 2 leaves, 64% of them have 3 leaves, and 32% of them have four leaves. The number of *leaflets* to a leaf also varies, more so in *P. trifolius* than in *P. quinquefolius.* A random selection of 100 flowering plants of *P. trifolius* from New England has this count: 13% with 3 leaves, all having 3 leaflets; 77% 3 leaves each with 3, 4, or 5 leaflets; and 10% of them have 3 leaves, all having 5 leaflets. The shape and size of the leaflets of the species are also very variable, from suborbicular in young plants to lancelate in tall large plants, and from 1.5 cm. long and 0.7 cm. wide to 6 cm. long and 1.5 cm. wide. In dry area with poor soil the plants bearing male flowers are 2–3 cm. tall, while larger plants with female flowers are 15 cm. tall. Comparing with the spherical root and the erect rhizome with membranous persistant scales, the aerial portion of the species is effected by the environmental condition while the underground portion is rather stable. The leaflets of *P. trifolius* are shortly petiolulate or sessile, and the *apexes* are roundish to acute. The leaflets of *P. quinquefolius* are obovate, distinctively petiolulate, with the middle one as large as 15.5 cm. long and 8 cm wide. The small middle leaflets are about 7 cm. long, 4 cm. wide. The *base* are all roundish and the apexes all acuminate. Some specimens from the Himalayan Region and Yunnan are copiously *bristly* on the surface.

The *flowering peduncle* of a plant and the *inflorescence* it carries are affected by the age and the vigor of that plant before it passes its prime period of life. Regarding this prime period of ginseng, we still have much to learn yet. However, from the observations of ginseng growers we know that *P. ginseng* begins its *prime period of life* under cultivation at the age of four, and it reaches the peak of this prime period at six. We have no experimental evidence concerning the prolongation of the peak yet, but we know that on pass-

ing the peak period, certain internal changes affect the structure and physiology of the plant and it becomes less resistant to fungal attack. With this understanding and giving the allowance for the effect of the age and vigor of the plant, we know that the *length of the peduncle is a stable character for a species*. The method of detecting the effect of age and vigor is to measure the relative length of the petioles and the peduncle of the same plant and get the ratio. The *flower bud and the leaves of a mature plant unfold from a mixed bud simultaneously*. The effect of age and vigor to the growth of the petioles and peduncle should be about the same. By applying this method, we find that *P. quinquefolius* is a *short-peduncle species* with 44% of the random selected samples having peduncles slightly longer than the petioles but never twice as long as the latter, 20% of the plants having peducles about equal their petioles, and 36% of them having peduncles shorter than the petioles. On the other hand, *P. trifolius,* and *P. japonicus* are both *long-peduncle species*. In *P. trifolisus* the length of the peduncles is evidently correlated with the sex of the flower, i.e., the female plants have shorter peduncles and pedicels, and the male plants have longer peduncles and pedicels. A random selection of 100 plants shows that 60% of them have pedunclels 2 to 2.5 times longer than the petioles, 20% of them have peduncles 1–1.5 times longer than the petioles, and 20%of them have peduncles 3–4 times longer than the petioles. The 20% of the short-peduncle plants all bear female flowers, while the 20% long-peduncle plants all bear male flowers, and the 60% of the medium-length peduncles mostly bear male flowers. In *P. japonicus* the peduncles are 3 to 6 times longer than the petioles of the same plant.

In 1709, Pierre Jartoux, a Jesuit Missionary from France hired by the Emperor of China to construct maps of the Chinese Northeast, ate some fresh ginseng and reported its effect with a drawing of the plant, showing a branched inflorescence. In the late 1820s, Nathaniel Wallich also observed branched inflorescences in *P. pseudoginseng*[2]. Branched inflorescence in *P. japonicus* is common in nature. Approximately 54% of the Japanese samples in Gray Herbarium have branched inflorescences. Some samples of *P. quinquefolius* also show a tendency of branching (Figs. 3 a-b). However, in these species the result of branching is not the formation of normal panicles of unbels as it is found in *P. japonicus* and *P. pseudoginseng*. In *P. quinquefolius* a single flower or a small umbel may diverge from the base of the peduncle (Fig. 3-b), or an umbellet may be put forth from the center of the major umbel (Fig. 3-a).

The nature of the flowers of ginseng varies with the species. Professor M. L. Fernald observed that the American species have "Flowers dioeciously polygamous" (Fernald 1950). For the Asiatic species Professor H. Hara observed that the flowers are hermaphrodite or male. Both kinds of flowers are on different individuals, or often mixed in a single umbel. Actually the shape and size of the flower parts, such as the hypanthium, disc, style, and anther are all subject to variation effected by the sexuality of the flower. In the hermaphrodite flowers, two styles condition is common, and 3 or 4 styles condition is occasional. These styles are usually free and recurved, or slightly united at the base. In male flowers, the hypanthium is small and the styles short and often united to form a single column. The petals are oblong and deciduous. The fertile anthers are oblong.

In *P. trifolius* the plants are unisexual and the flowers are morphologically specialized. The male flowers are white, on longer pedicels (5–6 times longer than the obconic hypanthia, Fig. 3-c), with filiform erect filaments exposing the oblong anthers in the air, and a short columnar style. The female flowers are pink, on short pecicels about equal or slightly longer than the length of the urn-shaped hypanthia (Fig. 3-d), devoid of stamens, and normally with 3 carpels and 3 distinct recurved styles.

The *ripe fruit* of ginseng are either red, greenish yellow, or ivory white. In the Himalayan Region, plants with bright red fruits black at the apex have been observed. In Korean ginseng planta-

[2]Wallich, N. 1831. Plantae Asiaticae Rariores 2: t. 137: also S. Y. Hu, 1978. Ecology, Phytogeography and ethnobotany of ginseng. Proc. 2nd Int. Gins. Symp. 153. fig. 3.

tions a cultivar with yellowish or ivory fruits has been selected. The red and ivory fruits of ginseng are fleshy and berry-like. The fruit of *P. trifolius* is yellowish green and it never become fleshy. As the carpels turn from green to yellow, they separate and drop off readily. On account of the pitted endocarp, a dry fruit of *P. trifolius* appears reticulate on the outside.

A *seed* of ginseng is similar to that of holly in structure and physiology. First, the structure which is normally called a ginseng seed is not a ture seed, but a seed enclosed in a lignified leathery pitted bag with a tiny apical opening (*germination pore*). In holly this structure is called a pyrene, which is defined as a seed embedded in the woody endocarp of the fruit. This endocarp protects the enclosed true seed in similar manner as the shell of a snail to to the soft gastropod. It has a tiny opening on the adaxial side of the apical and, below the base of the style (Fig. 3-e). This aperture provides a gateway for the entrance of the pollen tube to the embryo sac, a pathway of communication for nutrient supply from the mother plant to the developing seed, and a passage for water to enter the seed during germination. Secondly, as in holly, when the fruits of ginseng are ripe, and detach from the parent plant, the embryo in the seed is poorly developed. It takes many months for the seed to nature after the fruit drops to the ground. The shape, size, and surface structure of the pyrenes of ginseng are specifically significant. Wu, Tsai and Feng (1975) used the length and width of seeds as key criteria for distinguishing closely related species. The largest pyrenes of ginseng are found in "Sanchi", which are subglobular-trigonous, 5–8 mm. long and 5–6 mm. across the middle. The pyrenes of *P. trifolius* are subpyriform-trigonous, 3–4 mm. long, 2 mm. wide across the middle, and with a pitted (alveolate) surface (Fig. 3-e).

Ecological Observations: All the species of ginseng grow in the shade of undisturbed deciduous florests. However, the behavior of various species is different. For example, in eastern North America, *Panax quinquefolius* grows on damp but well drained soil. It requires a rather long period of dormancy. It resumes growth in middle June when

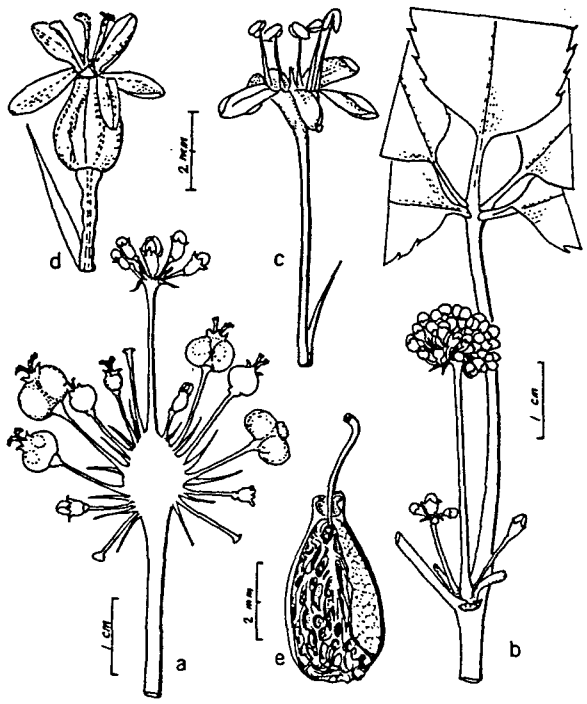

Fig. 3.

the leaves of the forest-trees are fully expanded and consequently the intensity of light is low. In contrast, *P. trifolius* grows abundantly on wet flat land, sometimes in the margin of swamps close to small streams. Its winter bud becomes active in late April, when the leaves of trees just emerge. Consequently the species grows in relatively strong light and low temperature. By the time the leaves of the trees and shrubs are fully grown, the plants have flowered, and the fruits of the species are mature. It is evident that *P. trifolius* requires a short dormancy, and it is more cold resistent, light tolerant, wet forbearing and fast growing. In a similar growing condition of the greenhouse, *P. trifolius* resumes growth in early March, and is in full bloom by March 25, while *P. ginseng* begins to emerge from the soil, and *P. quinquefolius* is in deep dormancy.

The observation of a colleague, Peter Del Tredici, on a natural population of *P. quinquefolius* is interesting. In an undisturbed forest of northwestern Connecticut, annual visits were made for a period of seven years, and data of 25 plants of American ginseng in a quadrat of 1 meter square were

taken. At the end of the period, 36% of the original plants survived, and one juvenile plant was added to the quadrat. Of the surviving plants in the plot, four (16%) grew more vigorously than before, for they had either more leaves or more flowers than seven years ago. Two of the plants (8%) were unchanged, and three of them (12%) had reduced vitality for they bore less leaves or flowers than before. This is a case where the population has a high death rate (64% over seven years), and a very low establishment rate. High death rate of *P. quinquefolius* has also been observed in a garden in Needham, Massachusetts, where a couple of thousand plants 4- to 7-years' old disappears in three years. Fungal attack was the contributing factor.

The Cytology of Ginseng

The DNA-containing bodies in the nuclei of plants responsible for the determination and transmission of the hereditary characteristics of the species are the chromosomes. The chromosome of ginseng was first investigated by Hajime Matsuura and Tihara Sutô in 1935. They reported that the pollen mother-cell of cultivated *P. japonicus* has n = 24, and concluded that the species is a tetraploid. They observed that the chromosomes are spherical and slightly non-uniform in size. Sugiura (1936) reported n = 22 in *P. ginseng* while Harn and Whang (1963) observed n = 24 in the species. For *P. quinquefolius* Taylor reported 2n = 22 in 1967 while Blair in 1975 counted n = 24. Blair described the karyotype, reporting two long chromosomes with a mean length of 4.0 μm, and two very small ones with a mean length of 1.8 μm. The measurements of the remaining 44 chromosomes vary in between. In 1971 Sachiko Kurosawa first reported the chromosome count of a diploid species, *P. psueoginseng*, n = 12.

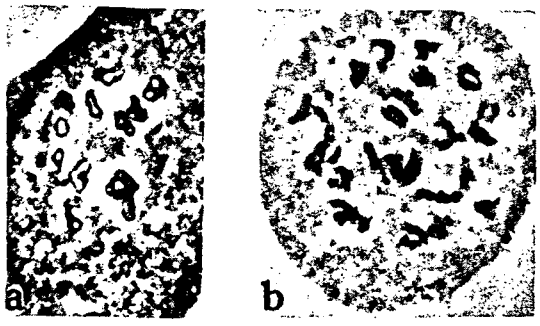

Fig. 4.

My friend, Lily Rüdenberg, investigated the young flower buds of *P. trifolius* and of *P. quinquefolius*. The material was treated with 3:1 alcohol/acetic acid for 12 hours and stained in aceto-carmine. It was discovered that *P. trifolius* is a diploid with n = 12, and *P. quinquefolius* is a tetraploid with n = 24 (Fig. 4).

Conclusion and Discussion

The data and illustrations presented in this article are conclusive that diversity of morphological characters, variation in chromosome numbers, difference to ecological requirements, and disparity in behavior exist among different species of ginseng. Both various diploid species and tetraploid species occur in Eastern Asia and Eastern North America. In the American diploid species, *P. trifolius*, we have observed certain superior characteristics such as hardiness, quick growing habit, more tolerant to stronger light, and capacity to with stand wetter soil than the cultivated tetraploid species, *P. ginseng* and *P. quinquefolius*.

The future of having better ginseng for more people is clear. Through scientific agriculture with the emphasis on the breeding and selection of high quality lines and mutants of ginseng, good cultivars can be established. The initial steps should be the crossing of paired Asian and American diploid and tetraploid species, selecting the off-springs and evaluating the progeny. Further programs may be carried in doubling the chromosome number of *P. trifolius*, and in crossing the offsprings with *P. ginseng* and *P. quinquefolius* so that the superior characteristics of short dormancy, cold resistence, and light and wet tolerance may be introduced to the species which are already important commercially. Likewise, the application of tissue culture of haploid material of *P. ginseng* and *P. quinquefolius* to produce apomicts and then cross them with *P. trifolius* for its good genetic factors, may achieve the same goal.

Ginseng was first collected by the prehistori-

cal people as food to assuage hunger. As the supply dwindled it gradually shifted to be an expensive tonic enjoyed only by the affluent people and the royal families. Actually the major volume of Chinese consumption of ginseng is still in form of food, drink and masticatory. I believe in growing better ginseng for more people, and of taking ginseng off the medicinal closet and placing it in the market for the common people to put it in their shopping bags. In a Korean style banquet of the Second International Ginseng Symposium which took place in September 1978, the invited guests were served sliced fresh ginseng as carrot and celery used in western dinners. Such use of ginseng should be spread throughout the world. The responsibility of providing better ginseng for more people can be shared cooperatively by ginseng research institutions in Korea, China and USA, the native homes of various species of the genus *Panax* Linn. Collaboration in ginseng research and the practice of scientific agriculture for bringing the price down should be our keynote, and better ginseng for more people is our goal.

Chairman: Now the time is open to discussion.

Tanaka: Thank you for your exiting paper. I'd like to ask you one question. How about the shape of the underground part of Panax trifolius? Just like Panax quinquefolium?

Hu: The root of Panax trifolius is like a little chesnut. It's round, hard and it grows fast.

Tanaka: How about the chemical constituents, for instance, saponin or other compounds?

Hu: To bring trifolius into scientific meeting, this is the first time. And your question will lead you to the future finding of the chemical constituents of trifolius. Nobody so far as I know, may be Dr. Duke know, as far as I know, nobody has worked on the chemical constituents. And one fellow in Philadelphia who want to work on the trifolius he wants five pounds of roots and the people who knows that five pounds of roots we have to harvest the whole forest. So, nobody has seen this specimen. I just point out in this meeting that we have something with the superior power to adapt with the nature and there is much for botanists to work on it.

Literature Cited

1. Blair, A. 1975. Karyotypes of five plant species with disjunct distributions in Virginia and the Carolines. Am. Journ. Bot. **62(8)**: 833–837.
2. Burkill, I. H. 1902. Ginseng in China. Kew Bull. **1912**: 4–11.
3. Fernald, M. L. 1950. Gray's Manual of Botany. lviii. 1632. Am. Book. N. Y. pp. 1977–1978 on ginseng.
4. Hara, H. 1970. On the Asiatic species of the genus *Panax*. Journ. Jap. Bot. **45(7)**: 197–212.pls. X-XII.
5. Harn, C. and J. Whang. 1963. Development of female gametophyte in *Panax ginseng*. Kor Journ. Bot. **6**: 3–6.
6. Hisauchi, K. 1953. On the root of *Panax japonicum*. Journ. Jap. Bot **28(12)**: 369–371. figs. 1–3.
7. Hoo G. and C. J. Tseng. 1973. On the Chinese species of *Panax* Linn. Acta Phytotax. Sin. **11(4)**: 431–438.
8. Hu, S. Y. 1978. Ecology, phytogeography and ethnobotany of ginseng. Proc. 2nd Int. Gins. Symp. 149–157.
9. Hu, S. Y., L. Rūdenberg and P. Del Tredici. 1980. Studies of American ginseng. Rhodora **82**: (in press).
10. Kurosawa, S. 1971. Cytological studies on some Eastern Himalayan plants and their related species. Bull. Univ. Mus. Univ. Tokyo **2**: 355–364.
11. Lewis, W. H. 1980. American ginseng: a forest crop. 1–8. Missouri Department of Conservation.
12. Li, H. L. 1942. The Araliaceae of China. Sargentia **2**: 1–134. pp. 116–119 on *Panax*.
13. Matsuura, H. and T. Sutô. 1935. Contribution to the idiogram study in phanerogamous plants I. Jour n.Fac. Sci. Hokkaido Univ. **5(5)**: 33–75.
14. Seemann, B. 1868. Revision of the natural order Hederaceae. Journ. Bot Brit. For. **6**: 52–58.
15. Sugiura, T. 1936. A list of chromosome numbers in Angiospermous plants II. Proc. Imp. Acad. Tokyo **12**: 144–146.
16. Taylor, R. L. I.O.P.B. chromosome number report. Taxon **16**: 566 (ed. Lôve).
17. Wallich, N. 1831. Plantae Asiaticae Rariores **2**: 30–32. *t. 137.*
18. Wu, C. Y., H. T. Tsai, and K. M. Feng. 1975. Triterpenoids from *Panax* Linn. and their relationship with taxonomy and geographical distribution. Acta Phytotax. Sin. **13(2)**: 29–48.

APPENDIX

Explanation of the Illustrations

Figure 1. Juvenile ginseng or seedlings: a. An one-year old plant of *Panax quinquefolius* showing the trifoliolate aerial portion with an axillary bud, and the fleshy taproot with secondary and tertiary branches. b. A two- or three-year old juvenile plant with pentafoliolate leaves, a short rhizome with a terminal bud, and the fleshy taproot and its branches. c. A juvenile plant of *P. trifolius* showing the oblong-subglobose fleshy taproot with its branches, an erect rhizome, and a trifoliolate leaf with suborbicular or obovate leaflets.

Figure 2. The subterranean organs of various species of ginseng: a. The elongated root of *P. quinquefolius* which grows in compost between boulders, showing the straight taproot branched at the distal portion and a suberect rhizome (*C. H. Knowlton, July* 1939). b. A strongly branched root of *P. quinquefolius* which grows on rocky area, showing many adventitious roots and a bending and creeping rhizome (*C.W. Jenks* 1884). c-d. The creeping and stout rhizomes of *P. Japonicus,* showing a relatively young plant with a thick stout fleshy taproot retained in c (redrawn from Hisauchi 1953), and an older plant with thicker rhizome and no taproot in d (*Maximowicz* 1861). e. The slender creeping rhizome of *P. bipinnatifidus,* showing the elongated internodes, enlarged nodes (some with tubers), and a stalked terminal bud (*T. T. Yu* 8573).

Figure 3. Variations in the inflorescences and flowers of ginseng: a-b. Some unusual inflorescences in *P. quinquefolius*. a. A diagramatic sketch of an umbel showing an umbellet growing from the center (*B. F. Bush* 5921). b. The apex of the aerial portion of a plant showing the position of the leaves and the major umbel, and the divergence of a diminutive umbel and a single flower in the axils of bracts at the base of the peduncle (*Fernald and Long 10081*). c-d. Flowers of *P. trifolius*. c. A male flower showing the basal bract, slender and elongated pedicel (6 times longer than the obconic calyx tube), the petals, fertile stamens with filiform filaments, and the columnar rudimentary style (*G. F. Moore 33*). d. A female flower showing a bract, the stout and short pedicel (about equal to the length of the urn-shaped hypathium), and three distinct recurved styles (*W. H. Tiffery,* July 1964). e. One-third of a mature fruit of *P. trifolius* showing the persistent calyx and style, the pitted endocarp on the adaxial side, an apical germination pore located at the base of the style, and portion of the reticulate exocarp (*A. S. Pease 16418*).

Figure 4. Chromosomes of the American species of ginseng: a. The chromosomes of a microsporocyte of a diploid species, *P. trifolius,* n = 12. b. The chromosomes of a microsporocyte of a tetraploid species, *P. quinquefolius,* n = 24 (courtesy of Mrs. Lily Rüdenberg.)