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Characteristics of Third Year American Ginseng Root Yields for Lytton, British Columbia, Canada

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Abstract□ The statistical characteristics of three year old American ginseng (*Panax quinquefolium L.*) root yields from Lytton, British Columbia, Canada are presented. Ginseng root yield is related to plant density, with the highest yields generally obtained from the sites with the highest plant densities. However, these higher yields are made up of a larger proportion of smaller roots while the proportion of larger roots remains almost constant throughout the range of plant densities sampled. Further, it is suggested that relatively small samples can provide significant insight into crop performance and growth.

Keywords□ *Panax quinquefolium* L., yield, plant density.

Introduction

Production of American ginseng now occurs in regions outside the native range of the plant in North America.[1] The knowledge of ginseng production in these areas is limited. An understanding of the statistical characteristics of ginseng root growth may provide insight into the growing environments and resulting production.

The purpose of this paper is to report on the growth and yield characteristics of three year old American ginseng roots. Attention will be given to the frequency distributions of roots grown at high plant densities, the relationship between plant densities and yield, and the relationship between dry and fresh root weights. In addition, an examination of optimum sample size will be considrred.

Methods

Data and study sample sites

Data was collected on a large commercial ginseng farm located near Lytton, British Columbia, Canada (50°17'N, 121°34'W). The ginseng was planted in the fall of 1982 and the roots sampled at the termination of their third growing season (September 19 and 20, 1985). Modern North American production techniques were utilized in the cultivation.

The size of the garden under investigation is 135 m by 155 m with the beds varying in width from 1.25-1.35 m and running the length of the garden in a north-south direction. The garden beds were covered with 50 to 100 mm of loose straw mulch and shade was provided by a black polypropylene shade canopy suspended 2 m above the ground.[2] The garden was sown at a density of 134 kg of seed per hectare with seed obtained from different sources. This resulted in the high planting density that is customary in North American production.

The data was obtained by sampling ten randomly selected sites in the garden. Each site was 0.5 m of bed length and all roots were removed by hand. The roots were immediately washed free of soil and weighed (to the nearest 0.1g) to obtain fresh root weights. For two of the sample sites, the roots were then dried at 70 °C for 72 h and re-weighed to obtain the dry root weights.

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Results and Discussion

Distribution of ginseng root fresh weights

Frequency histograms for the population and individual sample site data show that the distribution of ginseng root fresh weights are all positively skewed (Fig. 1 and 2). These positively skewed distributions are indicative of normal growth patterns of plants grown in high density populations.[3]

Due to the positive skewness, it is necessary to normalize the distribution of root fresh weight data using a log (1+x) transformation.[4] A constant of 1 is added to the root fresh weight as several roots did not have a measurable weight at the 0.1 g level. Frequency histograms, using the long (1+x) transformation, produce near normal distributions for both the population and individual sample site data (Fig. 1 and 2). The skewness before and after the transformation of the population data are 1.073 and -0.453, and the kurtosis before and after the transformation are 1.207 and -0.301 respectively.

Table 1 summarizes the sample site statistics derived from the normalized data (mean root fresh weight and standard deviation) as well as characteristics about the individual site (number of plants per site, plant density, site yield and yield).

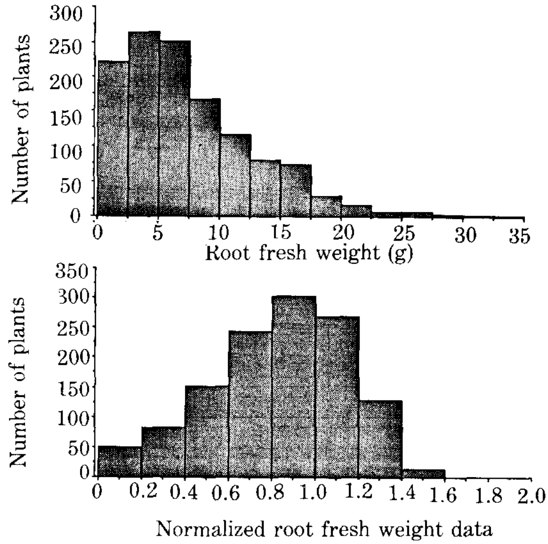

Fig. 1. Frequency histogram of actual ginseng root fresh weight data and transformed root fresh weight data for the population.

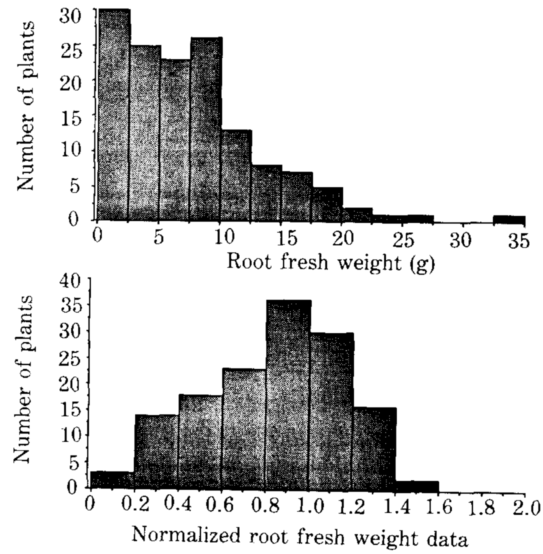

Fig. 2. Frequency histogram of actual ginseng root fresh weight data and transformed root fresh weight data for sample site 7.

Relationship between ginseng root weight and density of plants

It is apparent from Table 1 that mean fresh root weight at each sample site is related to plant density. There is in fact a strong negative correlation at the 0.05 probability level using Spearman's rank correlation comparing the plant density and the mean fresh root weight. Generally, the greater the plant density, the smaller the mean root fresh weight in this garden.

A simple linear regression of ginseng root yield versus plant density is presented in Fig. 3. The best fit line indicates that yield increases with increasing plant densities. While the regression line suggests that higher plant densities result in higher yields, an r^2 of 0.345 implies that the relationship between ginseng yield and plant density is not strong. Because of the low r^2 value, it cannot be determi with any degree of certainty whether the maximum yield is attained. Maximum yield could be confirmed with a subsequent experiment utilizing more sample sites over a wider range of plant densities.

While plant density affects yield, density also affects individual ginseng root weight at each sample

Table 1. Summary of third year gingeng root fresh weight data from Lytton, British Columbia, Canada

Sample site	Number of plants per site	Site yield (g)	Plant density (plants m^{-2})	Yield (g m^{-2})	Mean root fresh weight* (g)	Standard deviation* (g)
1	114	890.2	168.9	1318.8	6.34	0.94
2	76	819.5	112.6	1214.1	7.77	1.34
3	123	721.8	182.2	1069.3	4.23	1.20
4	131	770.3	194.1	1141.2	4.56	1.00
5	131	889.1	194.1	1317.2	5.34	0.99
6	100	777.2	148.1	1151.4	6.33	0.91
7	142	1083.1	210.4	1604.6	5.77	1.10
8	156	1065.9	231.1	1579.1	5.35	0.95
9	153	1109.1	226.7	1643.1	5.86	0.90
10	110	1035.2	163.0	1533.6	7.47	0.98
Total	1236	–	–	–	-	–
Average	123.6	916.1	183.1	1357.2	5.70**	1.05**

* Values calculated from log(1 + x) normalized data.
**Values calculated from population log(1 + x) normalized data.

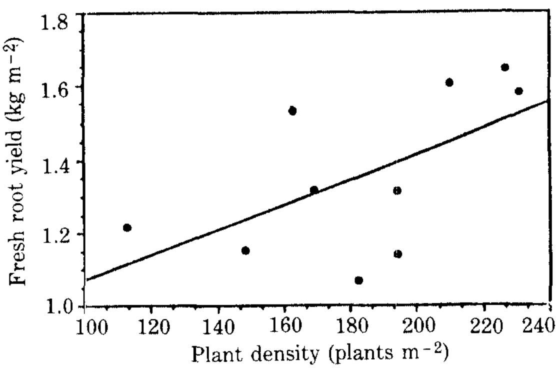

Fig. 3. Sample site fresh root yield versus plant density. The best fit line is given by $y = 0.003x + 0.722$, $r^2 = 0.345$, $n = 10$.

site. To establish a plant density effect on individual root weight, the roots were categorized into two groups, roots weighing 15.0 g or greater and roots weighing less than 15.0 g. The number of plants in the two groups were then plotted against plant density (Fig. 4). This relationship clearly establishes that plant density affects the distribution of root weight. Roots which weigh less than 15.0 g show a very strong linear relationship ($r^2 = 0.955$) with plant density, while roots which weigh equal to or more than 15.0 g indicate a weak negative correlation with an r^2 of 0.044 between root weight and plant density.

The effect of plant density with therefore increase the yield up to a certain density. However, if individual root size is of importance, the number of larger roots will remain fairly constant while the smaller roots tend to increase linearly with increasing plant density.

When the roots weighing less than 15.0 g are further categorized into groups with a 5.0 g interval, further details are apparent (Fig. 4). The trend line for the heavier roots, greater or equal to 10.0 g but less than 15.0 g, show that there is a slight increase in root numbers at higher plant densities. The trend line (hand-fitted) for the other two categories are notably different. The number of smaller roots, roots which weigh less than 5.0 g, appear to increase exponentially with increasing plant densities. The trend line for roots weighing greater or equal to 5.0 g but less than 10.0 g increase in number up to a plant density of approximately 200 plants m^2 where it then begins to level off. It can be generalized that the yields in higher plant densities are made up of a similar number of large roots, but more importantly, by a larger number of small roots.

Konsler and Shelton[5] who studied the effects of

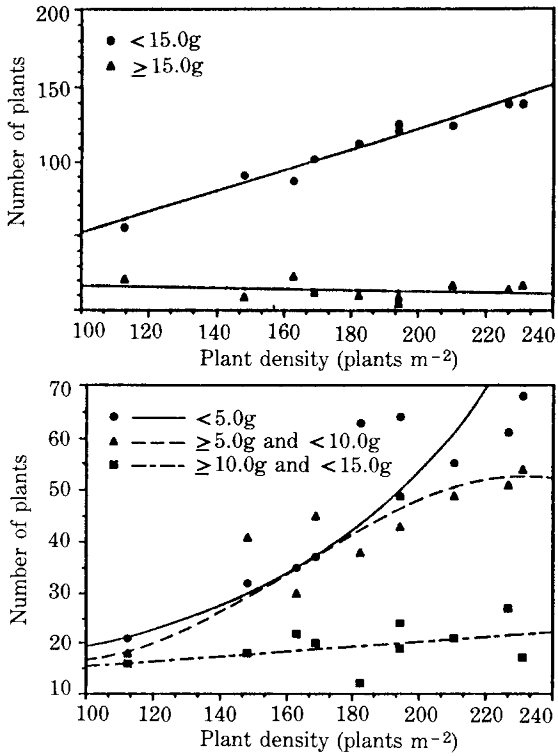

Fig. 4. The relationship between the number of plants and plant densities for various fresh root weight categories. For the upper graph, the root weight categories are: <15.0g; ≥15.0g. For the lower graph, the root weight categories are: <5.0g; ≥5.0g and <10.0g; ≥10.0g and <15.0g.

plant spacing on cultivated ginseng, found that there is a well defined density effect on overall yield. For three year old ginseng, Konsler and Shelton report a fresh weight yield of 1.38 and 1.07 kg m^{-2} for plant densities of 258 and 86 plants m^{-2} respectively. These results are consistent with the average fresh root yield and average plant density of 1.36 kg m^{-2} and 183.1 plants m^{-2} respectively for this site.

Characteristics of fresh weights at each sample site

The foregoing presentation has shown that the mean fresh root weight at each sample site is related to plant density. The mean fresh root weights, which range from a high of 7.77 g at sample site 2 to a low of 4.23 g at sample site 3, are given in Table 1. These sites which contain high or low mean ginseng root values skew the population

Table 2. ANOVA of the 10 sample sites

Source	DF	Sum squares	Mean square	F-test
Between	9	4.97	0.552	5.91
Within	1227	114.57	0.093	
Total	1236	119.54		

p=0.0001

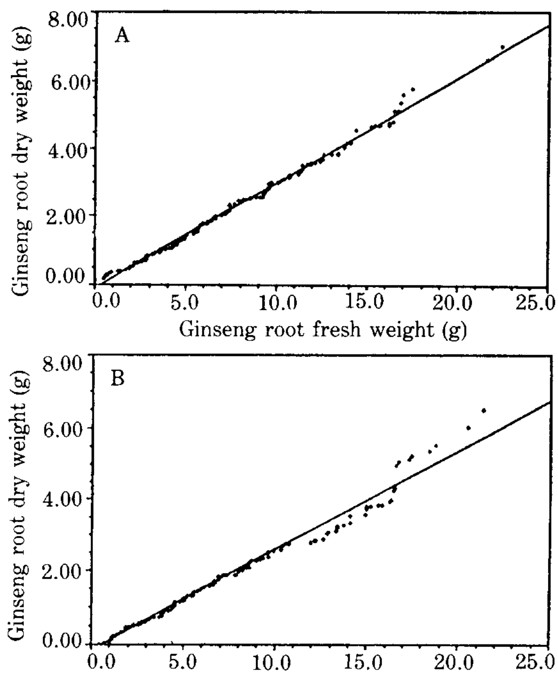

Fig. 5. Relationship between root dry weight and root fresh weight for sample sites 8 and 9. (A) The site 8 best fit line is $y=0.306x-0.248$, $r^2=0.970$, $n=156$. (B) The site 9 best fit line is $y=0.294x-0.092$, $r^2=0.994$, $n=153$.

data by weighting disproportionately the population data with either high or low values. This would give an erroneous estimator of the population standard deviation of root fresh weight, s(an unbiased estimator of σ), and also the mean population root fresh weight, $\bar{y}$(an unbiased estimator of μ).

To determine whether any of the mean root fresh weight at each sample site is significantly different from one another, a fixed-effects one-way Analysis of Variance was performed on the 10 sites. The results are shown in Table 2. The one-way

Table 3. Regression results of dry versus fresh ginseng root weights for sites 8 and 9

Site	N	Intercept	Slope	r	r^2	F-value	SE
8	156	−0.248	0.306	0.985	0.970	4859	0.271
9	153	−0.092	0.294	0.997	0.994	23524	0.113

ANOVA reveals that the mean root fresh weight at each sample site was highly significant, with an F-ratio of 5.91, 9 degrees of freedom and $p = 0.0001$. This finding is not surprising as it has already been established that plant density and mean fresh root weight are related.

The relationship between dry and fresh ginseng root weights

The relationship between fresh and dry ginseng root weight is of vital importance to ginseng producers since ginseng root is sold in the dried state. A scatter plot of ranked root dry weight versus ranked root fresh weight for sites 8 and 9 is shown in Fig. 5. The best fit line is the ratio of average dry root weight to average fresh root weight. The slope of the best fit line gives an accurate estimate of the weight of the dry root as a percentage of the fresh root weight. A least-squares fit analysis of dry versus fresh ginseng root weight was performed for sites 8 and 9. These results are shown in Table 3.

The significance of the beta values and the high r^2 suggest that fresh ginseng root weight is a good predictor of dry weight. Based on this analysis, one can expect fresh roots to lose approximately 70% of their weight in the drying process.

Optimum sample size

A common problem in any study involving sampling from a large population is selecting a sample size which can give meaningful results. One of the problems in selecting the size of samples for ginseng is the lack of ginseng data, particularly statistical data. The high commercial value of the ginseng root also compounds the problem of selecting the number of samples taken since a large sample would represent a significant monetary loss to the producer. As a consequence, in this study, a sample size of 10 clusters out of an estimated 22,610 clusters was used for the field sampling.

The experimental site under study (a commercial planting) consists of 85 beds of ginseng, each bed having an actual length of 133 m and a width of about 1.25-1.35 m. Each sample size (cluster) is 0.5 m in length and approximately 1.30 m in width. The total number of sample sites in this garden, the population size, is calculated by dividing the total area of the beds (14,696.5 m^2) by the sample area (0.65 m^2), and is estimated to be 22,610 sites.

The sample size selected should be large enough to provide a certain level of sampling error or precision (standard error). If the sample size is too large, then excess time and resources would have been wasted in obtaining too high a precision. Likewise, if the sample size is too small, time and resources is wasted because the specified level of precision had not been achieved.

The equation for selecting an optimal cluster size for single-stage cluster sampling is given by Scheaffer *et al.*[6)]

$$n = \frac{N\sigma_c^2}{0.25NB^2\bar{M}^2 + \sigma_c^2} \qquad (1)$$

where n is the required sample size for an interval estimate of population mean μ, N is the number of clusters in the population, σ_c^2 is the population variance of the samples, B is the bound of error of estimation, and $\bar{M}$ is the average cluster size of the population. Since the population variance of the clusters σ_c^2 and the average cluster size of the population $\bar{M}$ cannot be readily determined, they can be estimated by the estimators, s_c^2, the variance of the sampled clusters and $\bar{m}$, the average cluster size for the sample. The sample variance of the clusters s_c^2 is given by

$$s_c^2 = \frac{\sum_{i=1}^{n} (y_i - \bar{y}m_i)^2}{n-1} \qquad (2)$$

where y_i is the total of all observations in the ith cluster, $\bar{y}$ is the sample mean ($\Sigma y_i / \Sigma m_i$), and m_i is the number of elements in the ith cluster.

Normally, σ_c^2 and $\bar{M}$ would have been estimated by a prior survey or by a preliminary sample. The use of the sample cluster variance and average cluster size in equation 1 will show whether our sample size of 10 is adequate to achieve a specified bound of error of ± 5% of μ_t, the mean of the transformed data.

If the bound of error of estimation is set at ± 5% of μ_t ($\mu_t = 0.8261$), $B = 0.0413$, $N = 22{,}610$, $s_c^2 = 61.47$ and $\bar{\bar{m}} = 123.6$, the required cluster size is 9.43 or 10 clusters. Our sample size of 10 clusters is therefore large enough to provide an estimate of the population mean with a bound of error of ± 5% of μ_t.

The optimum sample size is not determined by the size of the population but rather by the variance of the cluster totals. Even though it had been previously determined that some of the clusters are significantly different in terms of the cluster means, the variation of the cluster totals was small enough to yield a sample size of 10 clusters (about 0.044% of the population).

Conclusions

American ginseng grown at Lytton, British Columbia have root fresh weight frequency distributions which are positively skewed, a normal occurance in density stressed plant populations. This data was normalized for analysis by using a long (1 + x) transformation.

Root fresh weight yields were found to be directly related to the plant density. The yield of high and low plant densities are made up of a similar number of large roots. As plant density increases, a higher proportion of the yield is made up of an increased number of smaller roots.

The dry root weight was found to be about 30% of the fresh root weight for third year ginseng grown at Lytton. The sample size of 10 at this site was sufficient to give an estimate of the population mean with a bound of error of ± 5%. This was only possible due to the small differences in the variance of the clusters.

Acknowledgements

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Literature Cited

1. Proctor, J.T.A. and Bailey, W.G.: *Ginseng: Industry, Botany, and Culture.* Horticultural Reviews, **9**, pp. 187-236 (1987).
2. Stathers, R.J. and Bailey, W.G.: Energy Receipt and Partitioning in a Ginseng Shade Canopy and Mulch Environment. *Agricultural and Forest Meteorology,* **37**, pp.1-14 (1986).
3. Harper, J.L.: *Population Biology of Plants.* Academic Press. San Francisco. pp.151-194 (1977).
4. Silvertown, J.W.: *Introduction to Plant Population Ecology.* Longman Publishers. New York. pp.123-130 (1982).
5. Konsler, T.R. and Shelton, J.E.: Plant Spacing, Mulches and Soil Effects on Cultivated American Ginseng (*Panax quinquefolium* L.). *Proceedings of the Sixth North American Ginseng Conference,* J.T.A. Proctor (ed.), University of Guelph, Ontario, Canada, pp.23-49 (1984).
6. Kleinbaum, D.G. and Kupper, L.L.: *Applied Regression Analysis and other Multivariate Methods.* Duxberry Press. Boston. pp.244-282 (1978).