Yield-Tenderness Relationships in 'Dark Skinned Perfection' Peas[1]

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Abstract. Maturity effects on yield of fresh peas (*Pisum sativum* L.) were identified by yield-tenderometer measurements. A percent yield-tenderometer reading relationship was shown to be a useful means for yield adjustment to a common maturity—100 tenderometer reading. Analysis of random error in the predicted percent yield, as a function of tenderometer reading, indicates the need to plan harvests within the 90 to 110 tenderometer range. Alternatively, the yield-tenderometer reading relationships show the possible magnitude of errors incurred in comparing green pea yields when no adjustment is made for dissimilar tenderometer ratings.

Improved techniques are needed for determining and comparing fresh pea (*Pisum sativum* L.) yields. Expressions of fresh pea yields are generally not precise because of harvest at a growth stage when fresh pea wt is increasing rapidly while tenderness may decrease even more rapidly. Pea yields may increase as much as 900 kg/ha daily when growth conditions are favorable. Such a yield increase often causes yield differences between treatments only because the treatments affected maturity. Examples of such treatments are comparisons involving cultivars, tillage, fertilizer, irrigation, or herbicides.

The need for comparing yields of processing peas at a common tenderometer rating, such as 100, has been suggested repeatedly, but, unfortunately there is little published information. Yield and tenderness are inversely related; i.e., yield increases as tenderness decreases (tenderometer readings increase). However, changes in yield and tenderometer readings are generally not a linear function of time (2, 3, 4, 6). Yield increases per unit of increase in tenderometer readings are generally greater when tenderometer values are below 100 to 120 than at higher tenderometer values. Hagedorn et al. (1) reported an unusual linear relationship between yield and tenderometer reading up through readings of 150.

Adjustments of absolute yield to a common base of 100 tenderometer reading is complicated, because temporal changes in yield and tenderometer reading vary between years, fields, and cultivars. Some of the factors influencing increase of fresh pea wt and associated change in tenderness are temperature, wind, humidity, available soil moisture, and soil fertility. However, temperature and moisture are the dominating factors. Yield differences produced by these factors, along with seasonal and field variations preclude direct adjustments of yield based on tenderness rating, i.e., *x* pounds of peas per unit change in tenderometer reading. Norton et al. (4) presented yield-tenderness relationships indirectly in terms of percent yield at a given tenderometer reading. The method for adjusting fields was developed by H. K. Schultz and M. W. Carstens. They used the yield at 100 tenderometer reading as 100 percent yield. Kramer (2) and Sayre (7) used percent of maximum yield as their expression of the observed yields at various tenderometer readings.

Our objectives were to emphasize the need for comparing yields of fresh peas at a common tenderometer reading, and to present additional data in support of the Norton et al. (4) method for adjusting yields.

Methods and Procedures

Dark Skinned Perfection peas were grown in 17 field experiments from which fresh pea yields and tenderness evaluations were made. The experiments were conducted on or near the Columbia Basin Research Center, Pendleton, Oregon. Seeding rates varied from about 130 to 230 kg/ha, in row spacings varying from 15 to 20 cm. Plant environment varied considerably because the data were collected during 11 years from experiments testing fertilizers, herbicides, and tillage—all 3 factors alone or in various combinations. All experiments were dryland, except 2 which were irrigated. In the dryland experiments, about 61 percent of the evapotranspiration was derived from soil water stored prior to pea planting. Longterm rainfall averages during the growing season for peas are 3.9, 3.7, 3.4, and 3.5 cm, respectively, for March, April, May, and June at the Columbia Basin Research Center. Corresponding average monthly temperatures are 6.1, 10.0, 13.3, and 17.2°C.

Fresh pea harvests were made to provide tenderometer readings below 100 at the earliest harvest, near 100 at the middle harvest, and above 100 at the latest harvest. Usually 3 or more harvests were necessary and the interval between harvests was generally 1 or 2 days in each of the 17 experiments. Harvests in the dryland experiments occurred in late June and only rarely in early June, while those under irrigation occurred about 5 days later.

From the data obtained in each experiment, pea yield at 100 tenderometer reading was interpolated. Then the ratio of measured to interpolated yield at 100 tenderometer reading was used to obtain "percent yield" (when multiplied by 100). All percent yields and corresponding tenderometer readings were plotted to obtain a scattergram of percent yield versus tenderometer reading, from which a least squares fit was made using the model: $Y = a + b X + c X^{1/2}$, where Y is percent yield, X is tenderometer reading; a, b, and c are parameters to be estimated statistically.

Results and Discussion

Six experiments typify green pea development observed in the 17 experiments. They are presented herein (Figs. 1, 2, and 3) because their greater number of harvests more precisely defined trends. These relationships were typical, also, of those found in the literature.

Yields varied from experiment to experiment, but yields within experiments were usually nonlinear functions of time (Fig. 1). In some experiments rates of yield change (change in slope) were positive throughout all harvests, while in others they became negative soon after the harvest series was initiated.

Tenderometer readings increased as a function of time (Fig. 2), but the tenderometer readings increased more rapidly after tenderometer readings had reached 100. An exponentially increasing tenderness function of time was suggested for both dryland and irrigated peas in Fig. 2.

Pea yields are distinctly nonlinear functions of tenderometer reading (Fig. 3). Field to field variation also caused large separation of curves. These 2 features of the yield-tenderness curves emphasize a critical need for comparing experimental yields within an experiment on a common tenderometer rating basis. We have not found a feasible direct adjustment of yields.

Pea yields expressed as a percent of the yield expected at 100 tenderometer are plotted versus tenderometer reading (Fig. 4), and the estimated equations are shown separately for irrigated and

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[1] Received for publication December 12, 1974. Contribution from the Oregon Agricultural Experiment Station in cooperation with the Agricultural Research Service, USDA. OR Agr. Expt. Sta. Techn. Paper No. 3891.

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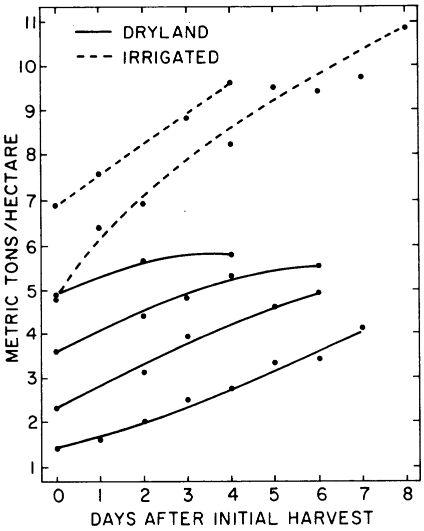

Fig. 1. Yield versus time of harvest for fresh peas in 6 typical experiments.

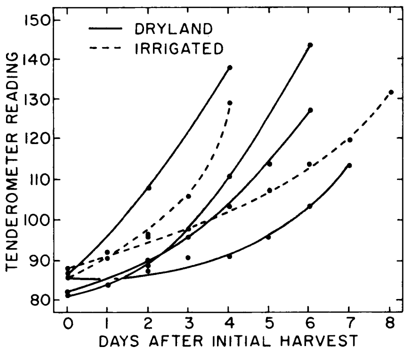

Fig. 2. Tenderometer of fresh peas as affected by time of harvest in 6 typical experiments.

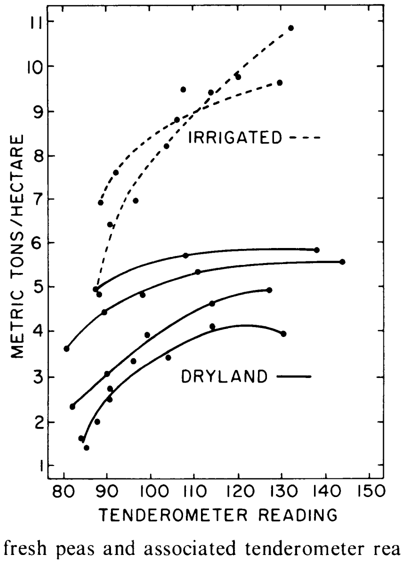

Fig. 3. Yield of fresh peas and associated tenderometer reading in 6 typical experiments.

dryland peas. These equations (Fig. 4) were slightly modified for easy use in adjusting percent yield when tenderometer readings were not 100. The modification involved estimation of Y at 100 tenderometer using equations in Fig. 4. This estimate of Y was then designated as the mean of Y when the mean of X was designated as 100. The equations are shown as follows:

Dryland peas: $(Y\text{-}97.21) = -14.134\ (X\text{-}100) + 315.14\ (X^{1/2}\ \text{-}10)$

Irrigated peas: $(Y\text{-}100.43) = -8.405\ (X\text{-}100) + 200.00\ (X^{1/2}\ \text{-}10)$

In these equations, Y is percent yield to be calculated, and X is observed tenderometer reading.

The scatter diagram of Fig. 4 (a composite over the 17 experiments) can be used to adjust yields to a common maturity (100 tenderometer). Such a calibration adjusts for maturity differences. However, the increasing scatter in Fig. 4 as the tenderometer reading deviates from 100 suggests strongly that harvests should be planned to achieve tenderometer readings within the 90 to 110 range. Ordinarily in regression, where the variance of the dependent variable is assumed independent of the independent variable, the precision of predicted dependent variable decreases as the dependent variable becomes larger or smaller than the mean (5). The scatter distribution in Fig. 4 shows a variance dependent on tenderometer reading. We have combined this variance estimate with that of regression in Table 1 to emphasize the true variability characteristics of the calibration in Fig. 4, and the need to plan harvests within the 90 to 110 tenderometer range.

The curves and data points for dryland and irrigated peas were

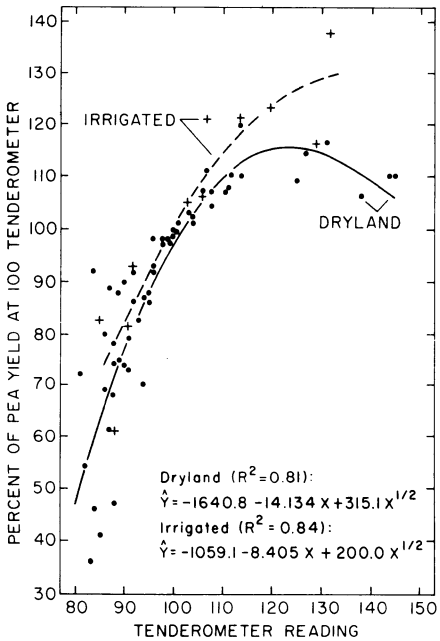

Fig. 4. Percent yield-tenderometer reading relationship for 'Dark Skinned Perfection' pea in irrigated and dryland experiments.

Table 1. Expected random error in estimating a percent-pea-yield at different ranges of tenderometer.[z]

Tenderometer range	$\sigma_{\hat{y}}$	Weighing factor	Estimated true $\sigma_{\hat{y}}$
80–85	8.8[y]	2.1[x]	18.5[w]
85–90	8.7	1.9	16.6
90–95	8.7	0.4	3.5
95–100	8.6	0.4	3.3
100–105	8.6	0.2	1.5
105–110	8.7	0.5	4.5
110–115	8.7	0.5	4.5
115–120	8.8	1.4	12.3

[z] Computations were made using regression composited over irrigated and dryland conditions.

[y] $\sigma_{\hat{y}}$ is the random error expected from multiple regression assuming a variance of y independent of x.

[x] *Weighing factor* is a ratio in which the numerator is the standard error of estimate within the indicated tenderometer range and the denominator is the standard error of estimate for the whole tenderometer range. This ratio approximates the nonuniform variance of percent pea yield at different tenderometer readings.

[w] Estimated true $\sigma_{\hat{y}}$ is the product, (weighing factor) ($\sigma_{\hat{y}}$).

maintained separate in Fig. 4. Above about 110 tenderometer reading the percent yields separate distinctly. This separation of yields indicates a major influence of available soil water on the development of fresh peas in their later stages of growth. We suggest that this factor be carefully evaluated for experiments where irrigation or stored soil water is an experimental variable.

In passing, we note the failure of an appealing normalization procedure involving both yield and tenderometer reading. For each experiment, the maximum and minimum yield or tenderometer readings were noted and the normalized observation computed as $(u-u_{min})/(u_{max}-u_{min})$. The symbol u indicates the variable to be normalized. Nearly the whole range of normalized yield was noted for normalized tenderometer readings <0.5. Furthermore, there was much scatter providing little basis for a calibration.

Norton et al. (4) and Sayre (7) point out that 1 scale is not applicable to all pea cultivars. Norton et al. (4) add that the use of a well-developed scale for 1 cultivar to adjust another cultivar may introduce less error than using a scale developed from only a few points. Information presented in Fig. 4 is consistent with earlier results (1, 2, 4, 7) showing a similar relationship between percent yield and tenderometer readings in the range of 90 to 110. Percent yields changed between 1 and 2 percentage units with each unit change in tenderometer reading.

Experience by the authors indicates that fresh pea yield comparison at a common maturity is essential to good research. Harvesting each treatment at 2 or more times and interpolating the yield at 100 tenderometer is preferred. When only 1 harvest is possible, yields can be adjusted to 100 tenderometer by using a percent yield-tenderometer scale (Fig. 4) which provides more reliable data than merely using the unadjusted yields.

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Influence of the Multiflora-Grandiflora Genotypes of Petunia on Seed Germination, Seedling Growth, and Elemental Foliar Composition[1]

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Abstract. Three sets of *Petunia hybrida* Vilm. lines were used with each set comprised of the 3 genotypes, multiflora (*gg*), grandiflora (*GG*), and heterozygote (*Gg*). Seed germination was consistently high for the hybrid *Gg* (92%), intermediate for *gg* (77%) and low for *GG* (45%). The fresh and dry wt of 28-day-old seedlings was inconsistent but the *Gg* hybrid was the most vigorous at 49 days followed by the *gg* and *GG* genotypes. No differences were observed in N, P, K, Na, Mn, Fe, Cu, Zn, or Al in vegetative leaves of the 3 genotypes. Differences in Ca, Mg, and B occurred, but they were not uniform with respect to genotype or to genotypes within a set. Calcium and Mg were generally highest in *gg* and lowest in *GG*. Boron in 1 of 2 experiments showed the same pattern. The physiological roles of the observed differences in elemental composition with respect to chlorophyll composition, sugar metabolism, and vigor as indicated by an increase in fresh and dry wt, in the 3 genotypes are discussed.

Petunia cultivars are classified by plant and flower characteristics either as grandiflora or multiflora. Multiflora plants generally have dark green foliage, a large number of small flowers with small calyces and long, narrow sepals and slender filaments; in contrast, the typical grandiflora has light green foliage, fewer flowers, and calyces with short, broad sepals and short, thick anther filaments (6). It has been shown (1, 6, 12) that the grandiflora and multiflora types are determined by the *G* and *g* alleles, at a single locus respectively, and the homozygous *GG* showed degrees of sub-lethality due, perhaps, to low chlorophyll content. In addition, Bianchi (1) observed a certation effect which he concluded arose by linkage of self-sterility alleles with those determining flower size.

Reimann-Philipp (12) found no linkage between the self-sterility alleles and flower size and abscribed the reduced number of seeds to a zygotic lethal factor *l* (normal allele *L*) which often reduced fertilization in *l* pollen grains; so its function could also be explained as certation. He concluded that the low number of grandiflora homozygotes was due to sublethality of the genotype *GG* caused by a chlorophyll defect linked to the zygotic lethal factor. Ewart (6) also concluded that lethal and sub-lethal alleles may be closely linked with *G* resulting in a class of weak homozygous dominant petunias. He suggested also, that alleles of gene(s) controlling vigor may interact with the large flower-viability gene linkage.

Seidel (13) showed that the *G* locus determining large flower in superbissima petunias (tetraploids) and in diploid grandifloras was the same. The genes determining flower size in *P. hybrida* grandiflora and in *P. axillaris* were found by Chlebowski (3) to be at the same locus. Petals with green margins in *P. hybrida* grandiflora and *P. hybrida* vulgaris (multiflora) also appeared to be linked with the grandiflora character (4). This linkage, like that involving lethality and fimbriate borders (4), is not universal to the species but is found only in certain genetic lines. Ewart (personal communication) indicated the linkage between *G* and the lethal gene(s) has been broken in breeding lines.

Hence, the grandiflora character is a monogenic inherited characteristic resulting from action of the genes *G* and *g* which control, by some as yet unknown physiological action, the flowering and growth type of petunia plants. We undertook to determine the influence of

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[1] Received for publication December 14, 1974. MI Agricultural Experiment Station Journal No. 7052.