GROWTH CORRELATIONS AND COMPETITIVE RELATIONSHIPS BETWEEN YIELD COMPONENTS OF SELECTED VARIETIES OF THE DRY BEAN

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M. W. Adams
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ABSTRACT

GROWTH CORRELATIONS AND COMPETITIVE RELATIONSHIPS BETWEEN YIELD COMPONENTS OF SELECTED VARIETIES OF THE DRY BEAN

By

Hassan Hojat

Growth processes of plants and their specialized organs have been under study for a long time, each researcher approaching the subject with the prevalent methodology in his area of specialization at the time of investigation. The approach taken up in the present study is by means of fitting the incremental data of leaflet and pod growth in two groups of field bean varieties,differing in leaf sizes,to the Gompertz growth equation. No attempt has been made to attribute a specific physiological function to any of the three parameters of the asymptotic curve. However, it has been assumed that the metric values of $\underline{b}$ parameters of leaflet and pod growth curves of varieties grown under constant environmental conditions belong to normally distributed populations. Parameter $\underline{b}$ is a measure of scale or spread of the curve along the time axis and denotes the rate of change in relative growth rate or the rate of approach to asymptotic value. Treating the $\underline{b}$ parameters of leaflet and pod growth curves as metric traits with normal distribution lends them to statistical analysis. Significant differences were found between $\underline{b}$ parameters of leaflet and pod growth curves of the eight varieties. This parameter could be used not only to

differentiate the growth patterns of the organs of distinct groups of varieties but it could also distinguish any of the varieties demonstrating a distinct growth pattern of its organs. Generally the small leaf varieties showed a remarkable similarity in the form of growth and rate curves of their leaflets and pods and proximity of the average maximum growth rates of these organs while the large leaf varieties were more divergent with different forms of rate curves for leaflets and pods and a higher maximum growth rate for leaflets as compared to pods. Highly negative correlation between the b parameters of leaflets and pods in the large leaf group signified different orders of priority for utilization of growth resources in leaflet and pod growth of the constituent varieties of this group.

The assumption of organ homology between leaflets, pods, and seeds is based on the premise that all these organs, regardless of their particular functions as photosynthetic, reproductive, and storage entities, are essentially similar in structure. Pods and seeds are modified leaves in the sense that the elongated ovary is anatomically similar to a leaf and contains the seeds which are in turn mainly composed of cotyledons. These are storage organs functionally and modified leaves structurally. So, in addition to being regulated by organ-specific genes, they are influenced by a common gene set. Positive and reasonably high correlations between average maximum growth rate of leaflets and pods on one hand and seed size on the other hand substantiate this hypothesis.

Furthermore, highly significant positive correlations between leaflet growth rate and leaflet sizes provide additional evidence, though a highly positive correlation between pod growth rate and pod length is only present in the large leaf group.

The correlations between mature leaflet, pod, and seed sizes in the small, medium, and large leaf groups were predominantly positive, reasonably substantial and occasionally significant regardless of location or the level of competition between plants. In other words, the influence of the common set of genes regulating the size of these homologous organs did not have a decisive role as compared to the organ-specific genes and non-genetic factors.

The correlations between the three components of yield in field beans in the three groups of varieties generally follow the pattern described by Adams (1967) though no clear trend was visible as to the influence of location or inter-plant competition levels on these correlations for any of the three groups of varieties.

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By

Hassan Hojat

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To the memory of
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INTRODUCTION

The analysis of growth in higher plants is a complex subject. It deals with a constellation of characters and their interrelationships, making the analysis more problematic since any particular approach deals with one or a few facets of a subject eventually related to the whole developmental history of the plant. From the earliest periods when Sachs described the "Grand Period of Growth" to the present, different disciplines of biology have used the techniques and methods available to them in order to shed some light on different aspects of a complex problem. The study of plant growth processes has been taken up by plant morphologists, plant anatomists, plant physiologists, plant geneticists, and plant breeders in different times with certains theories and concepts having gained currency and predominance in each period.

From the first decades of the 20th century different growth equations have been developed, and relevant metrical data dealing with the increase in height, weight, length, volume, and surface of a plant or its organs in time have been fitted to them in order to gain, hopefully, a better understanding of the processes which give rise to the particular shape of growth curves. These quantitative methods deal with the parameters of growth curves and their ability to distinguish between different patterns of growth and by this to distinguish different genetic constitutions, even though environmental influences in the broad sense make the detection of genetic differences very difficult. The most commonly used growth curves in the case of higher plants are different forms of autocatalytic (logistic) expressions and the Gompertz Growth Equation. In the present study, the Gompertz curve with three parameters was fitted to the leaflet and pod growth data taken from two sets of varieties grouped according to the size of their leaves. The parameter $\underline{b}$, which denotes the rate of change in the relative growth rate or the rate of approach to the asymptotic value, was treated as a metric value and the mean values of this parameter for different varieties were compared. Since the absolute rate of growth during the growth period first rises, reaches a maximum and then declines until it approaches zero, it was considered important to calculate correlations between the rates of leaflet and pod growth on one hand, and yield, its components, and mature leaflet and pod sizes on the other hand. This was done on the assumption that the time period in which the rate was at or near its maximum represents the maximum utilization of resources (metabolites) either in increasing the size of the principal organ of photosynthesis and consequently increasing the source capacity or extending the sink capacity in order to utilize the resources directed from source to sink. The general intent has been the analysis of possible interactions between pod and leaf growth rates and pursuit of relevant explanations for this relationship, and the impact it has on yield and its components under different environmental conditions.

REVIEW OF LITERATURE

Growth has been defined as a process of increasing size, complexity and substance in an organism or any of its organs through time (28, 30). Change in size is the most conspicuous characteristic which occurs in terms of length, area or volume (6). Changes in dry weight and leaf area have been widely used in studies of plant growth, although change in length is also taken as an index of growth of plant parts and organs such as internodes, roots and fruits.

Growth of an organ or organism in time often follows the form of an s-shaped or sigmoid curve. The initially slow increase in size at the beginning of the elongation or expansion process enters the phase of exponential growth, with a constant relative rate which follows the "compound interest law" of Blackman (7). The next phase consists of linear growth with a constant absolute rate. Eventually, in the third phase, the growth rate declines gradually until growth ceases. Sigmoid curves have a point of inflection which varies in position depending on the specific equation used. This is the point of maximum growth rate at which the increase in growth rate ceases and the decrease begins. Weight or height of plants, leaf area, and length of root and shoot follow this pattern of growth (7, 28, 36).

Internal and external factors determine the longitudinal growth rate of a plant or any of its parts, although there is a genetically determined limit for growth rate regardless of how favorable environmental conditions become (33).

The growth of leaves commences with a phase in which cell division in leaf primordia has precedence over cell elongation. Cell division under constant conditions continues at an approximately constant relative rate until the leaf emerges from the bud. The average rate of cell division continues to decline after unfolding until the leaf reaches .25 to .75 its final size. After unfolding, the rate of cell expansion increases and this, combined with cell division, rapidly increases the leaf size until the final size is attained. Both Monocotyledonous and Dicotyledonous leaves demonstrate this pattern of growth with reasonable consistency in constant environments (21).

The processes of cell division and cell expansion cannot be clearly separated in time. They occur simultaneously for a considerable portion of the leaf expansion period. Dale and Sunderland (9, 32) investigated the growth of leaves of lupin (Lupinus albus), sunflower (Heliantus annus) and the dry bean (Phaseolus vulgaris). Their observations confirmed this point although the latter part of leaf development in beans appeared to be dominated by cell expansion.

Watada and Morris (35) studied the growth pattern of snap bean fruits and found it to be sigmoid. Four days following anthesis the pod weight and length started to increase until the maximum length was reached about the thirteenth day. This growth occurred mainly due to the enlargement of fleshy endocarp.

There have been many growth equations developed over the past 50 years. Those used widely at the present time are the Von Bertalanffy equation, the logistic equation, and different forms of the Gompertz equation (10).

All these curves are asymptotic at their two ends to the base lines $W = o$ and $W = K$, respectively.

The Von Bertalanffy equation was developed upon the physiological premise that growth rate is the end result of a balance between the rates of catabolism and anabolism (12). This curve was generally used in animal growth studies in which catabolism and anabolism could be more accurately defined. Richards developed a more generalized form of the equation in which by changing the value of a constant, both logistic and Gompertz equations could be arrived at (27, 34). The autocatalytic or logistic function is a 3-parameter symmetrical sigmoid curve with the inflection point located midway between the upper and lower asymptotes. Pearl and Reed (23) arrived independently at this function for explaining human population increases. It has been widely used in both studies of human population growth and growth studies in higher plants and their parts and organs.

The Gompertz function, which was used by actuaries for a long time in order to describe population increases, is a 3-parameter asymmetrical sigmoid curve with a point of inflection before the midpoint at K/e or 0.3679 the upper asymptote.

Wright (38) revived this equation and suggested its use in the study of biological growth. Weymouth, McMillin and Rich (36) used this curve in the study of shell growth of razor clam and obtained an excellent fit to experimental data. They attached no biological meaning to the inflection point of the curve. Winsor (37) discussed the possibilities and limitations of this curve for the purpose of growth studies.

The Gompertz function, though commonly used in animal growth and population studies, has not been widely applied to the growth of higher plants.

Laird, Taylor and Barton (19) derived a form of the Gompertz equation based on previous experimental observations made on animals, indicating an almost exponential decay of the specific growth rate over time. They advanced the following hypothesis:

> "the major part of the growth of the normal organism from conception to early maturity is the resultant of two genetically determined processes whose magnitudes are defined by exponential coefficients; these processes operate on an initial mass to determine 1) the magnitude of the initial exponential proliferation of the system and 2) the magnitude of the exponential decay of this primary exponential growth rate."

Laird and Howard (20) demonstrated that the Gompertz equation was proper and suitable to fit the weight growth data of an average mouse from two to ten weeks of age. They further demonstrated that the differences between growth curve parameters in mice were related to sex, level of heterozygosity, and maternal influence. They stated that a sigmoid curve is indispensible for description of the growth of animals and their parts and organs. Furthermore, they argued that the growth curves of distantly related animals such as cows, mice, and chickens are different only in scale and can be superimposed due to the similarity in pattern. Therefore the growth parameters responsible for the differences of scale must be acted upon by genetic factors.

They suggested that three growth parameters may be genetically determined and species-specific. These are the initial specific growth rate, its rate of exponential decay, and the initial weight.

In a later study, Kidwell, Howard and Laird (18) suggested the possibility of treating "the estimated parameters of a mathematical expression of the weight-time relation, i.e. a 'growth model', as metric traits, amenable to the usual analytic methods of quantitative genetics." They recognized that the model would not be of any value in genetic studies if only an insignificant portion of the variance of the growth parameters were found to have a genetic origin. The results of a diallel analysis of all possible crosses between four inbred lines of mice, in which weight data from two to ten weeks of age were fitted to the Gompertz equation and the growth parameters were treated as metric traits, proved to be ambiguous and failed to provide clear-cut proof for the hypothesis put forward.

Amer and Williams (3) used a Gompertz equation for the study of growth in area of Pelargonium leaves. These leaves reached the maximum growth rate in one week but continued to grow for eight weeks. The asymmetry of the curve, thus, was pronounced and a logistic equation seemed to be inappropriate. Although the Gompertz equation, permitting only a slight asymmetry, did not seem to match the strong asymmetry of the data, Amer and Williams used the equation ($Y = Ka^{b^t}$) quite satisfactorily. There were three different watering regimes for plants of Pelargonium zonale in this experiment. These regimes had a pronounced effect on parameter K and to a lesser degree on parameter a, but parameter b remained reasonably constant under widely divergent watering regimes and this led them to conclude that parameter b might be species-specific for Pelargonium zonale.

Plant breeders are turning increasingly away from single-objective selection, and more toward selecting for multiple goals. This is particularly the case where the breeder has adopted the plant design approach to achieve optimum performance, the most widely known of such approaches being that described by Donald (10). Plant designs, or ideotypes, largely involve selecting for a combination or package of both morphological and physiological traits that, in the judgement of the breeder, will lead under specified environmental-management conditions to superior performance. But herein lies a problem -- that of association between favorable and unfavorable characteristics. With several objectives in mind, each influenced by at least one to possibly several genes, some association is expected. Johnson, Robinson, and

Comstock (16) pointed out the importance of correlations, favorable and unfavorable, in soybean improvement. Yap and Harvey (39) discussed a similar situation in barley. Recently, Peet, Bravo, Wallace and Ozbun (24) noted the association in dry beans involving several morpho-physiological characteristics. Stebbins (29) based his fundamental cause of "developmental correlations" among traits in plants upon pleiotropy -- a gene or a set of genes regulating certain basic metabolic and/or developmental process(es) that lead to several traits being affected. It is expected that traits associated due to pleiotropy would be developmentally related. A simple example is the length and width of a leaf. Adams (1) postulated developmental associations between components of the yield system. The basis of this "component compensation" was the sequential demand for metabolites needed for growth and development by successive components of the yield system, where the demand was directed at common metabolites of a limited source. Component compensation was shown (4, 5, 8, 14, 15, 17, 25) to be widespread among grain crops.

Duarte and Adams (11) pointed out a common kind of developmental association in grain legumes, namely, the correlation between number of pods per plant and number of leaves. Since both these metrical characters are functions of number of nodes, or axillary positions, this correlation is explicable. Stebbins (29) and Grant (13) might see this as a case of pleiotropy -- the genes affecting node number thus being also responsible for leaf number and pod number potential.

In beans, Duarte and Adams (11) also observed a significant positive relationship between leaflet size and seed size. They could not postulate a direct morphological-developmental basis for this relationship, but did suggest the possibility that the relationship depended upon homology of organ systems. It is possible that leaves and seeds are, therefore, dependent upon a common gene system regulating the size of homologous organs. It was stated that the amount of photosynthate produced by a leaf, the amount per unit of time being proportional to its size, could be a regulating factor on the size of seed produced in the raceme borne in the axil of that leaf. Grant (13) postulated the concept of multifactorial linkage where with numerous genes involved in the expression of each of several traits, and a limited number of chromosomes or linkage groups, there will be a strong tendency for some of the traits to associate in inheritance -- to vary together from one generation to the next. With time and opportunity for breaking up of linkage groups new associations will form, but the multifactorial nature of the genetic base of each trait will tend to resist abrupt and drastic change in the association. This system provides a kind of cohesiveness to certain character associations that may be of positive fitness value to some wild populations.

Materials and Methods

Fourteen varieties of the field bean, divided into three groups on the basis of leaf size (five with large leaves, four with medium leaves, and five with small leaves), were planted in two replications in East Lansing during the summer of 1970. Plant spacing within rows was 10 centimeters and rows were 70 centimeters apart. Measurements of leaflet and pod growth were made on randomly selected plants of 4 varieties with large and 4 varieties with small leaves in order to study the comparative rates of continuous growth. This non-destructive method, in spite of the apparent difficulties and the care which should be taken to avoid damaging young growing plant parts, is preferable to the destructive sampling method which involves selection and tagging of very young leaves and pods, taking into consideration the approximate equivalence of length, and harvesting them in different time intervals for measurements, and averaging of the samples. The length of the middle leaflet of the first and second leaves appearing on the main axis of each of five plants and also the length of three to five normally developing pods (with more than two seeds) per each selected plant were measured, beginning at the time of appearance and continuing in two-day intervals until growth had ceased. The precision was to the nearest millimeter. Final yield (W) and its three components, namely, average number of pods per plant (X), average number of seeds per pod (Y), and average seed weight (Z) were also measured on one meter harvested sections of each plot. The same varieties were planted in Gratiot County, Michigan, under three levels of competition. Four replications of closely spaced plants in the row (10 centimeters) and four replications of wide spacing (30 centimeters) were grown. In two of the replications of closely-spaced plants half of the length of plots was shaded with semi-translucent plastic screens to reduce the light intensity. Size of five fully expanded leaves and ten mature pods per plot was measured. Yield and its components were also measured.

Leaf and pod growth data were fitted to a Gompertz growth curve which is generally given as

$$Y = \underline{K}\underline{a}^{\underline{b}^t}$$

and is fitted in its logarithmic form

$$\text{Log } Y = \text{Log } \underline{K} + \text{Log } \underline{a} \cdot \underline{b}^t,$$

where Y is the measured length at time t, $\underline{K}$ is the upper asymptote or the value of Y at t = t∞, $\underline{a}$ is the difference between the Y value and the upper asymptote when t = 0, and $\underline{b}$ is a measure of change or the rate constant which represents the ratio between successive increments of growth and is a declining ratio of increase.

Parameter $\underline{b}$ is the most important of the three parameters and signifies that each difference between successive logarithmic values of the dependent variable is a constant percentage of the preceding difference.

For calculation of the three parameters the data were divided into three groups each consisting of n observations. Then the Log K, Log a, and b values were calculated from the following expressions:

$$\text{Log } \underline{K} = \frac{1}{n} \frac{(\Sigma_1 \log Y)(\Sigma_3 \log Y) - (\Sigma_2 \log Y)^2}{(\Sigma_1 \log Y + \Sigma_3 \log Y - 2\Sigma_2 \log Y)}$$

$$\text{Log } \underline{a} = (\Sigma_2 \log Y - \Sigma_1 \log Y) \frac{b-1}{(b^n - 1)^2}$$

$$\underline{b} = \left[\frac{\Sigma_3 \log Y - \Sigma_2 \log Y}{\Sigma_2 \log Y - \Sigma_1 \log Y}\right]^{\frac{1}{n}}$$

For all experiments, the correlations r_{ZL}, r_{LP}, r_{PZ}, r_{PY}, r_{XY}, r_{XZ}, r_{YZ}, r_{XW}, r_{YW}, and r_{ZW} were calculated where X, Y, and Z are components of yield, W; L is the length of a fully expanded leaflet and P is the length of a mature pod.

The correlations between average maximum leaflet and pod growth rates and yield, its components, and mature leaflet and pod lengths for both variety groups were also calculated.

RESULTS AND DISCUSSION

A summary of leaflet and pod growth data of the eight varieties and the data related to yield, its components, and mature leaflet and pod measurements is given in the appendices.

The estimated values of the three parameters of the Gompertz curve are summarized in Table 1 for leaves and in Table 2 for pods. Although at first a method of averaging the growth curves was tried for both leaflet and pod growth, the following disadvantages were inherent in the application of this method.

The average of several Gompertz curves only approximates a Gompertz curve and does not precisely represent a real curve. By averaging several curves the existing variation in the experimental material would be reduced drastically and consequently the decrease in the available degrees of freedom makes significance tests very insensitive to small differences. The measurements on leaflets and pods of different plants could not begin at exactly the same stage of growth due to time limitations. Because of this displacement in time, the average curve (averaged over several leaflets or several pods) would not represent the actual process of growth in length because each data point on the curve represents the mean of several measurements whose magnitudes differ by as much as three centimeters.

TABLE 1. Estimated parameters of the Gompertz curve fitted to the data for leaflet growth.

Variety	replication	b	K	a	Variety	replication	b	K	a
Charlevoix	I	.4716	13.3660	.1331	8247 Cranberry	I	.4654	10.0554	.1165
		.4198	11.2642	.1360			.4534	11.3423	.0732
		.4352	10.7746	.1539			.4709	10.9623	.0871
		.4033	10.6488	.1252			.4837	10.9119	.0692
		.4886	13.3199	.1191			.4903	12.3310	.0958
	II	.4039	9.6427	.1444		II	.4463	12.1255	.0884
		.4866	12.5314	.0858			.4284	11.7004	.0737
		.3773	9.6272	.1420			.5401	12.6911	.0514
		.5055	8.2376	.1812			.4829	10.8393	.0698
		.5015	8.6080	.2546					
Manitou	I	.4412	11.5851	.1639	Swedish Brown	I	.6023	12.5314	.0771
		.4244	11.5771	.1171			.6177	16.2930	.0550
		.4118	11.0611	.1147			.4972	10.4160	.0627
		.3913	12.0420	.1463			.4836	13.0768	.0546
		.3902	12.3481	.1116			.4506	10.5390	.0575
	II	.4676	10.8893	.1464		II	.5630	12.7204	.1233
		.4327	12.3027	.0918			.5127	13.0888	.0599
		.4174	10.5536	.1563			.5375	9.6073	.1738
		.3953	13.2526	.1318			.6275	13.3598	.0600
		.3940	14.6589	.1193			.6090	10.5148	.1011

TABLE 1 (Cont'd.)

Variety	repli- cation	b	K	a	Variety	repli- cation	b	K	a
Navy-01	I	.4332	8.0538	.1520	Navy-03	I	.4512	8.3695	.1680
		.3383	8.7257	.1830			.4416	8.2832	.0829
		.3619	8.3157	.1912			.4179	9.4558	.1205
		.4066	8.0242	.2689			.3804	8.3253	.1486
		.4242	8.1527	.1235			.4114	9.3476	.1327
	II	.4438	8.7842	.0992		II	.4253	8.0445	.1750
		.4240	8.8634	.1029			.4937	7.9195	.1630
		.4116	9.1517	.1136			.4239	9.1538	.1533
		.4179	9.0532	.1231			.3774	9.4276	.1336
		.4623	8.7096	.0966					
Navy-02	I	.4292	9.9609	.1594	Navy-04	I	.4553	8.5763	.1671
		.4345	8.2414	.2550			.4654	9.2109	.1217
		.4251	8.6576	.1247			.4947	8.6477	.1328
		.4794	9.2470	.0983			.5280	9.3519	.0925
		.4228	8.8552	.1247			.5269	9.1601	.0796
	II	.4287	9.6805	.0800		II.	.5184	7.9287	.1675
		.4453	10.0092	.0783			.4613	9.2811	.1934
		.4462	9.2854	.1162			.4493	10.0369	.1004
		.4317	9.2790	.0842			.5015	9.8446	.0968
		.4675	9.0928	.0931			.5044	9.2363	.1473

TABLE 2. Estimated parameters of the Gompertz curve fitted to the data for pod growth.

Variety	replication	b	K	a	Variety	replication	b	K	a
Charlevoix	I	.5825	16.8500	.0644	8247 Cranberry	I	.5748	9.9747	.1191
		.5840	12.3709	.1243			.5892	10.5950	.1043
		.5398	12.1675	.1318			.6454	10.8019	.1406
		.6356	13.9573	.0906			.5819	12.2462	.0897
		.5959	14.6352	.1123			.5649	10.3681	.1447
	II	.5354	14.3714	.0969		II	.6084	10.6561	.1488
		.5577	14.9348	.0863			.5269	9.5587	.1573
		.5909	15.3603	.1035					
		.5321	13.2984	.1091					
Manitou	I	.5921	13.0858	.1199	Swedish Brown	I	.4072	9.3325	.2282
		.5538	12.7703	.1669			.5282	9.2918	.2043
		.5923	13.1160	.1631			.4492	10.3753	.2046
		.6717	15.0418	.1193			.4177	9.6405	.2196
		.5825	12.7879	.1519			.4643	8.2604	.2752
	II	.5990	13.4184	.1244		II	.4769	9.5918	.2414
		.5858	13.9669	.1136			.4561	8.6636	.2282
							.4679	8.3560	.3223
							.4797	8.9784	.2812

TABLE 2 (Cont'd.)

Variety	replication	b	K	a	Variety	replication	b	K	a
Navy-01	I	.4599	7.6366	.3944	Navy-03	I	.4546	7.9396	.3583
		.4587	8.6417	.4013			.5092	9.2087	.3141
		.4659	7.5388	.4046			.4424	8.0334	.3680
		.4447	7.8361	.3275			.3871	8.1152	.3504
		.4507	7.0275	.4256			.4179	8.6238	.3686
	II	.3738	7.9104	.3574		II	.4196	7.8253	.3364
		.4216	7.1170	.4606			.4047	8.4217	.3213
		.4379	7.0194	.4988			.3483	8.3081	.2914
							.4738	8.7680	.2985
							.3978	8.0168	.3784
Navy-02	I	.4492	9.0532	.2775	Navy-04	I	.4152	8.3445	.1431
		.4492	8.8532	.2692			.4217	8.3426	.1786
		.4821	8.7761	.2946			.4016	8.1320	.1675
		.4808	8.9764	.3002			.4243	8.3560	.1152
		.4208	8.6338	.2664					
	II	.4141	8.3272	.3037					
		.5242	9.3433	.2890					
		.4906	8.2718	.3387					
		.3938	8.7218	.2645					
		.3988	7.4131	.4104					

For the above reasons, curves were individually fitted to the data from each leaflet and pod. The estimated parameters of these Gompertz curves were then treated as metric traits for statistical analysis. The assumption was made that estimated b parameters of the curves of individual leaflets or pods were normally distributed. The same assumption could be made about parameters K and a. Among the three parameters of the Gompertz curve, K is the parameter of final size and its value fluctuated around the final value obtained by actual observations. Parameter a was the parameter of time origin or a measure of location, related to the point at which the first measurement was made. If $a < 1/e$, the measurements started before the time the maximum absolute growth rate was reached and, as such, the rate curve would rise, reach the maximum point and then fall. If $a > 1/e$, the measurements started after the point of maximum absolute rate had passed and the growth rate curve would fall from the beginning. Parameters K and a were more or less self-evident and their comparison did not furnish much more information about the varieties concerned. The parameter b was the important one. If we write the equation in the following form:

$$\frac{dy}{dt} = -(\ln \underline{b})\, Y\, (\ln \underline{K} - \ln Y)$$

the relationship of the absolute rate of growth (dy/dt) to b and to the asymptotic value (K) becomes apparent. Parameter b gives an indication of the extent to which growth rate at any moment is dependent upon the size at that moment and the difference between this size and the final size, given that conditions remain constant.

Figures 1 through 8 represent the observed and fitted curves of leaflet and pod growth of three varieties with large leaves, namely Charlevoix (dark red kidney), Cranberry 8247, and Swedish Brown, and also a variety with small leaves (Navy-04) and the corresponding observed rate curves of these varieties. For each variety the measured leaflet and pod were located on the same plant. For the purpose of comparison, the observed growth and rate curves of a leaflet and a pod from each of these varieties are shown together in Figures 9 through 12. There was a reasonably close approximation between observed and estimated curves of leaflet and pod growth of these varieties. In the Figures comparing observed growth curves of leaflets and pods, the leaflets of Charlevoix and Cranberry varieties are slightly longer than pods. In the navy bean variety the mature lengths of leaflet and pod were very close. The pattern of leaflet and pod growth in these varieties was also very similar. In Swedish Brown the pod was shorter than the leaflet and their growth patterns were somewhat different, the leaflet reaching a higher maximum growth rate than the pod and declining in rate less abruptly than the pod. As the comparison of the rate curves demonstrated, the maximum growth rate of leaflets in all varieties reaches a higher level than the maximum growth rate of pods, though this difference was more pronounced in the large leaf varieties than in the navy bean variety. This trend held

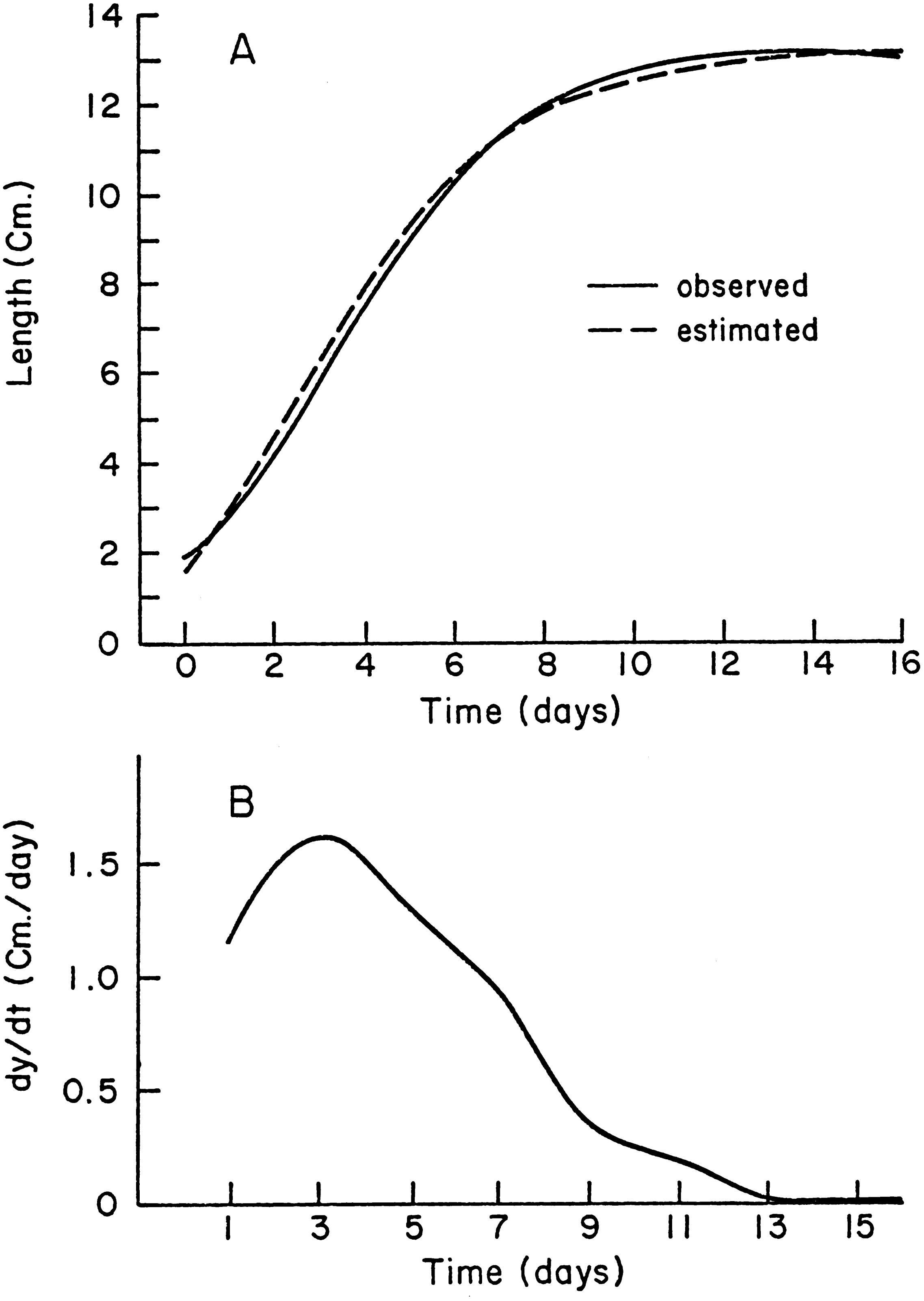

Fig. 1. Observed and estimated growth curves (A) and observed rate curve (B) of a Charlevoix leaf.

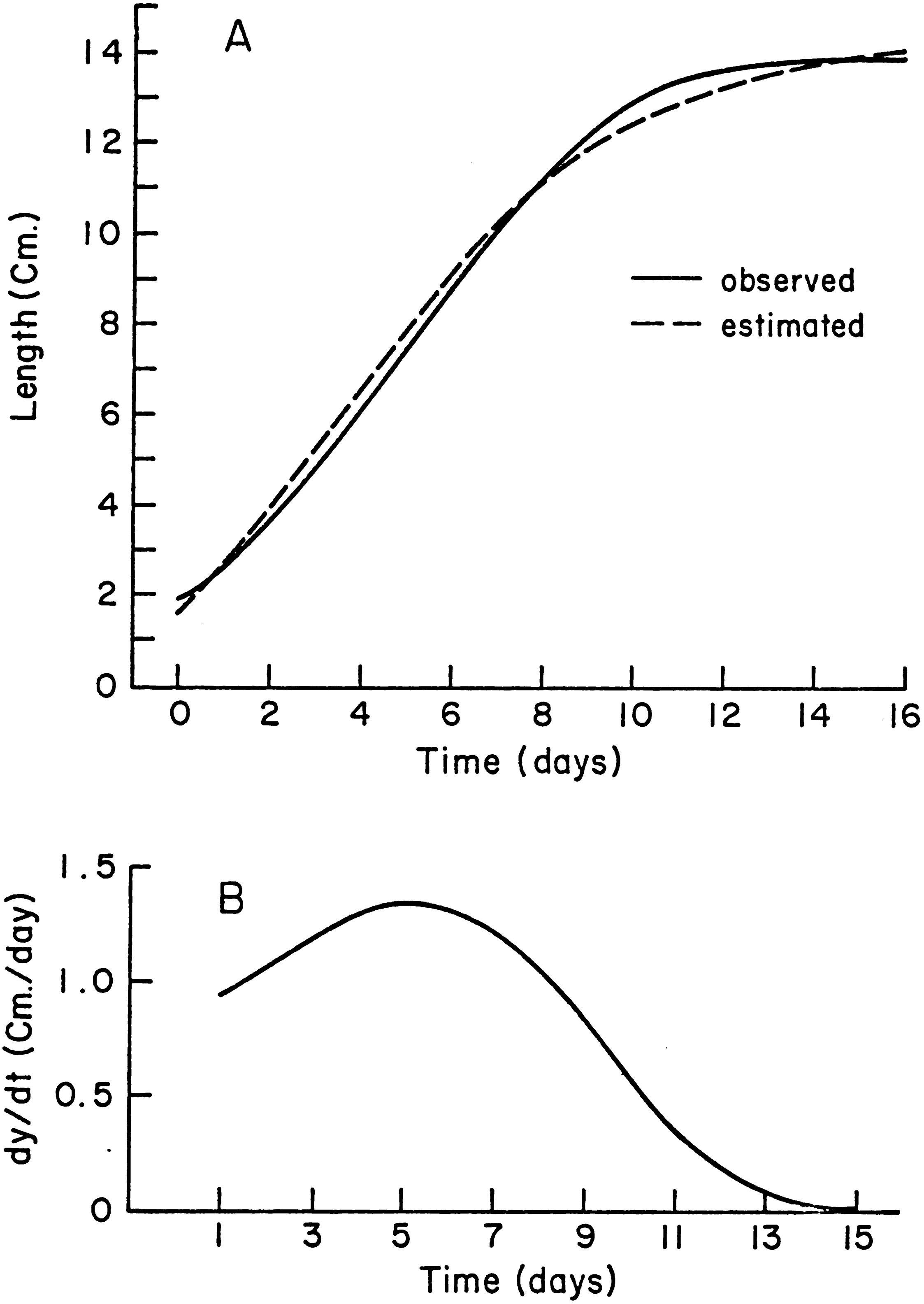

Fig. 2. Observed and estimated growth curves (A) and observed rate curve (B) of a Charlevoix pod.

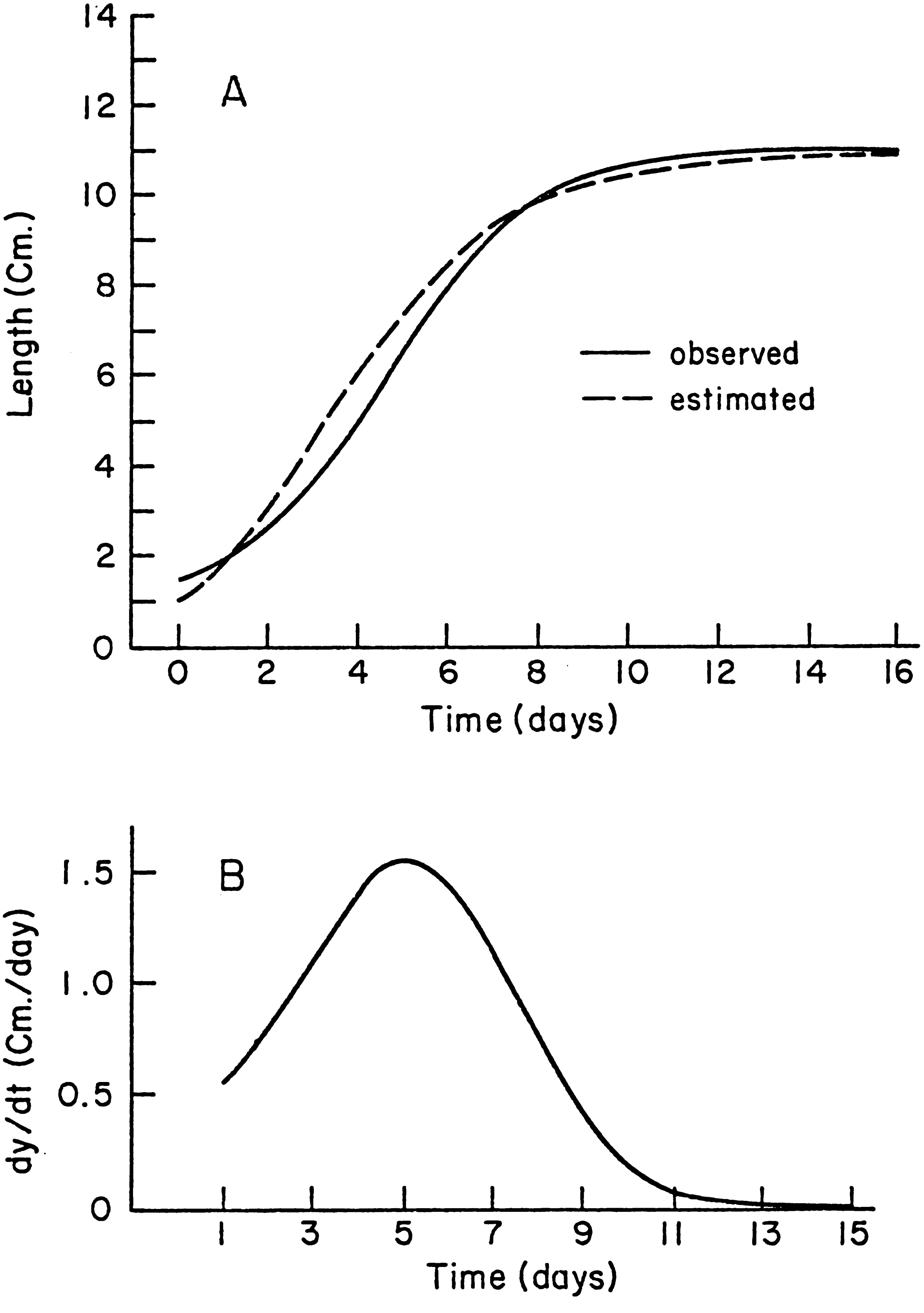

Fig. 3. Observed and estimated growth curves (A) and observed rate curve (B) of a Cranberry 8247 leaf.

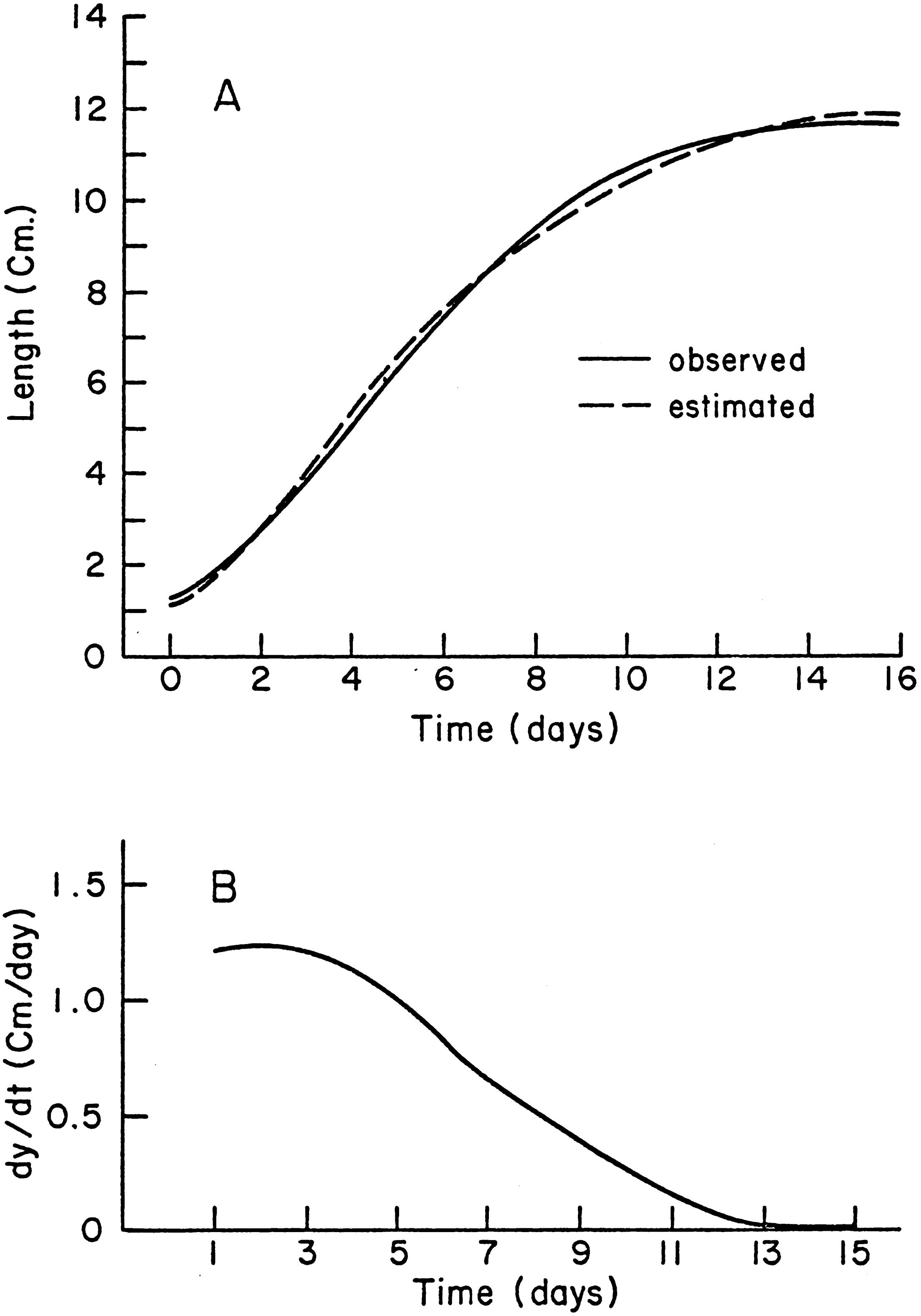

Fig. 4. Observed and estimated growth curves (A) and observed rate curve (B) of a Cranberry 8247 pod.

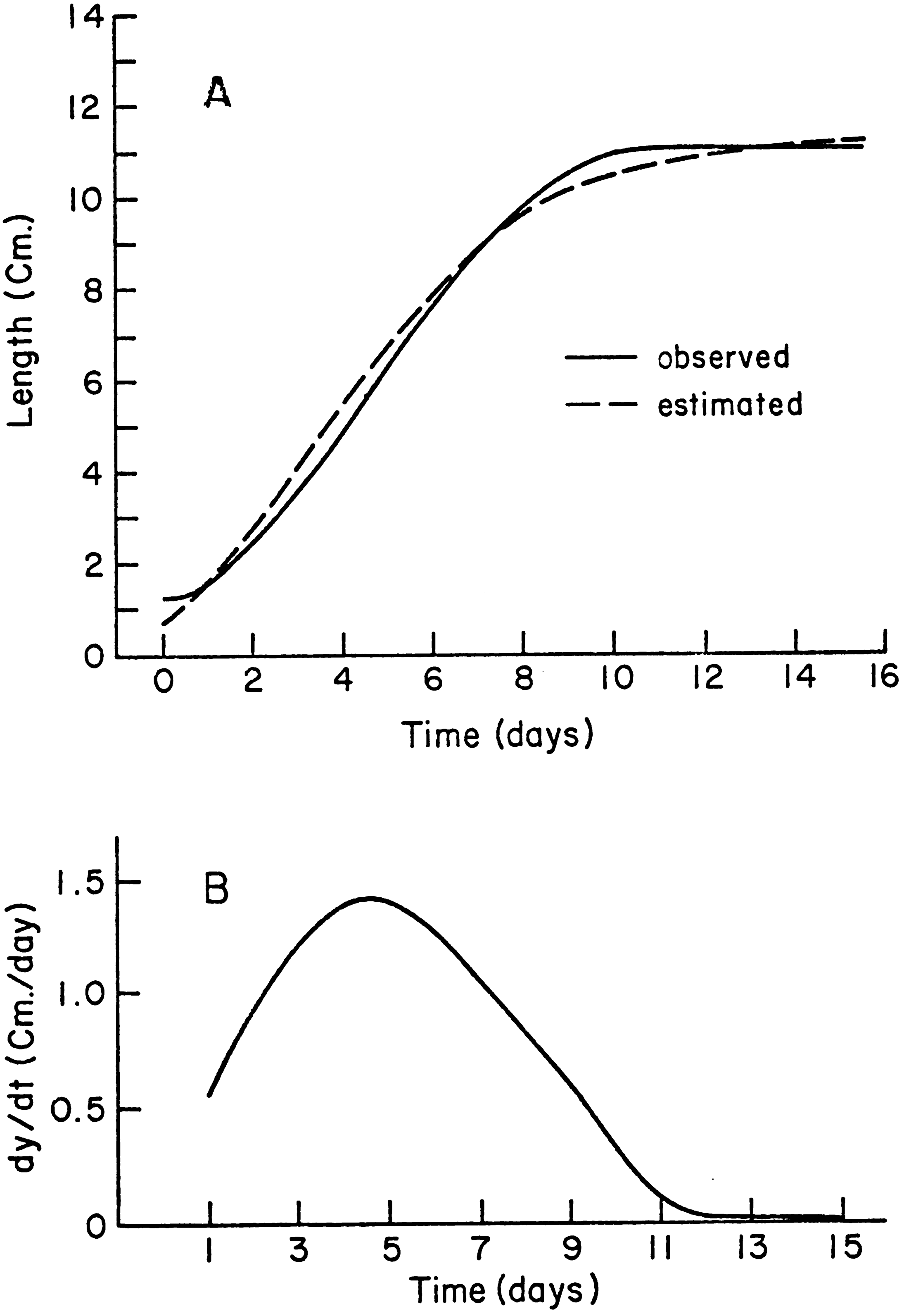

Fig. 5. Observed and estimated growth curves (A) and observed rate curve (B) of a Swedish Brown leaf.

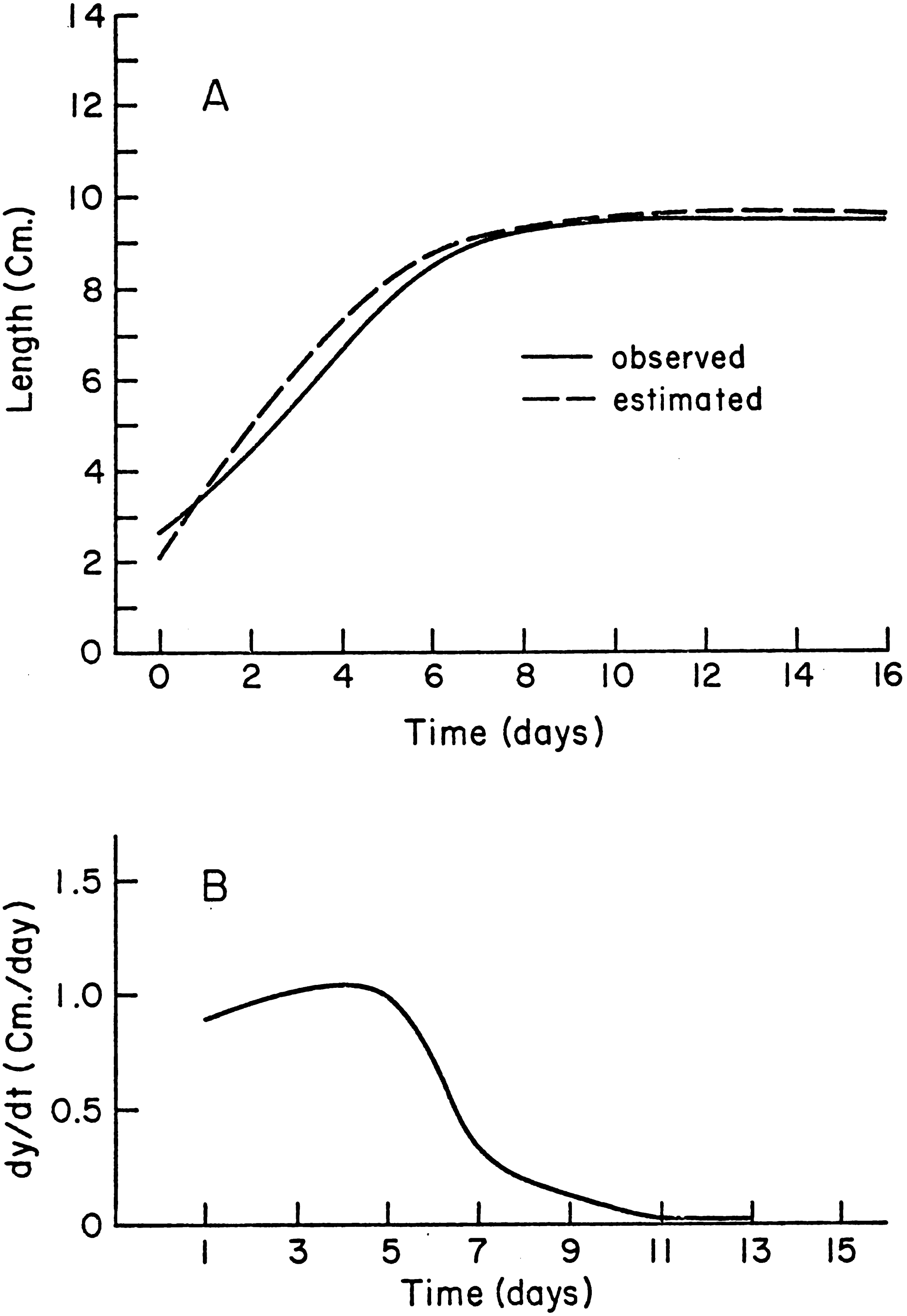

Fig. 6. Observed and estimated growth curves (A) and observed rate curve (B) of a Swedish Brown pod.

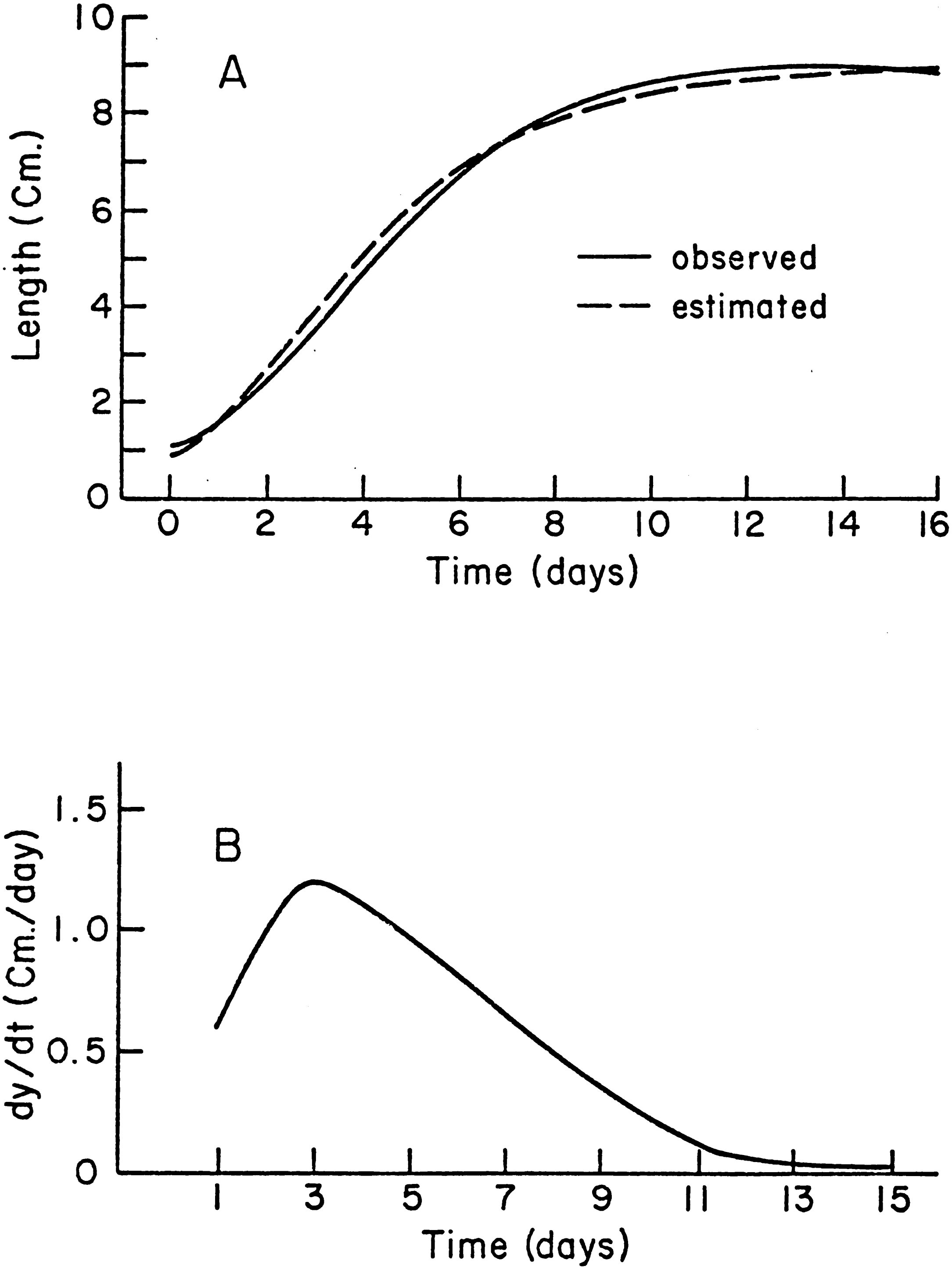

Fig. 7. Observed and estimated growth curves (A) and observed rate curve (B) of a Navy-04 leaf.

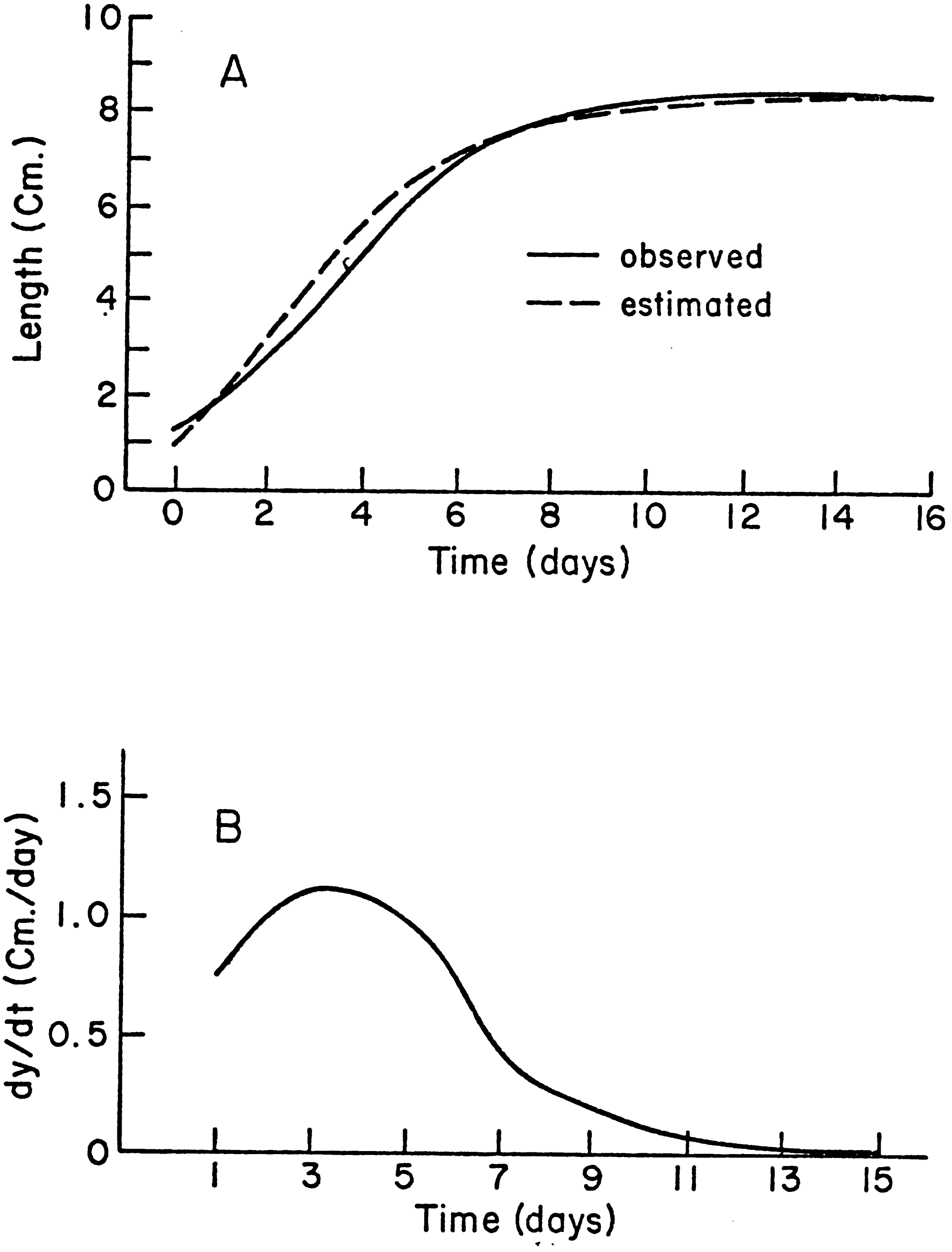

Fig. 8. Observed and estimated growth curves (A) and observed rate curve (B) of a Navy-04 pod.

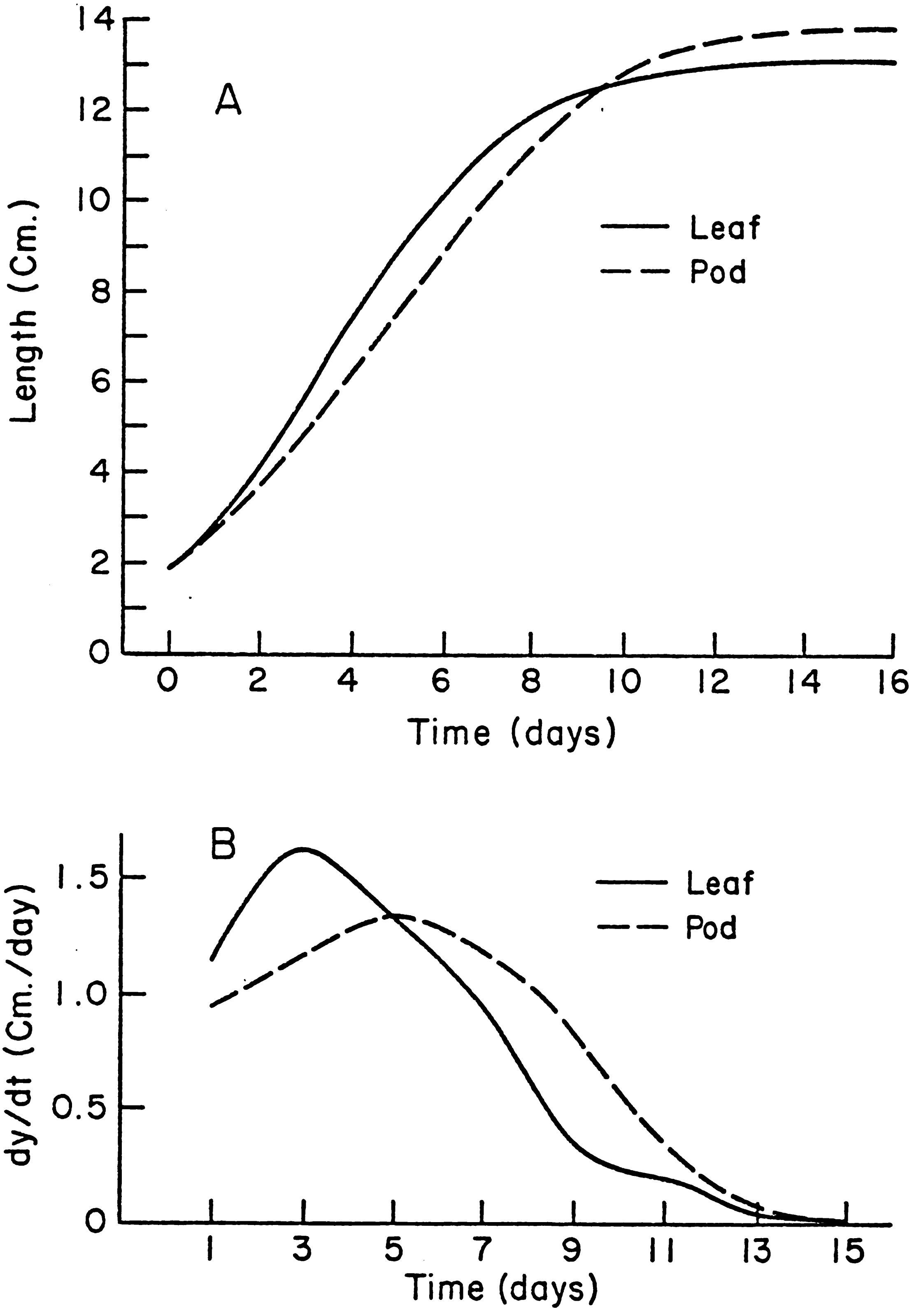

Fig. 9. Observed growth (A) and rate (B) curves of Charlevoix leaf and pod.

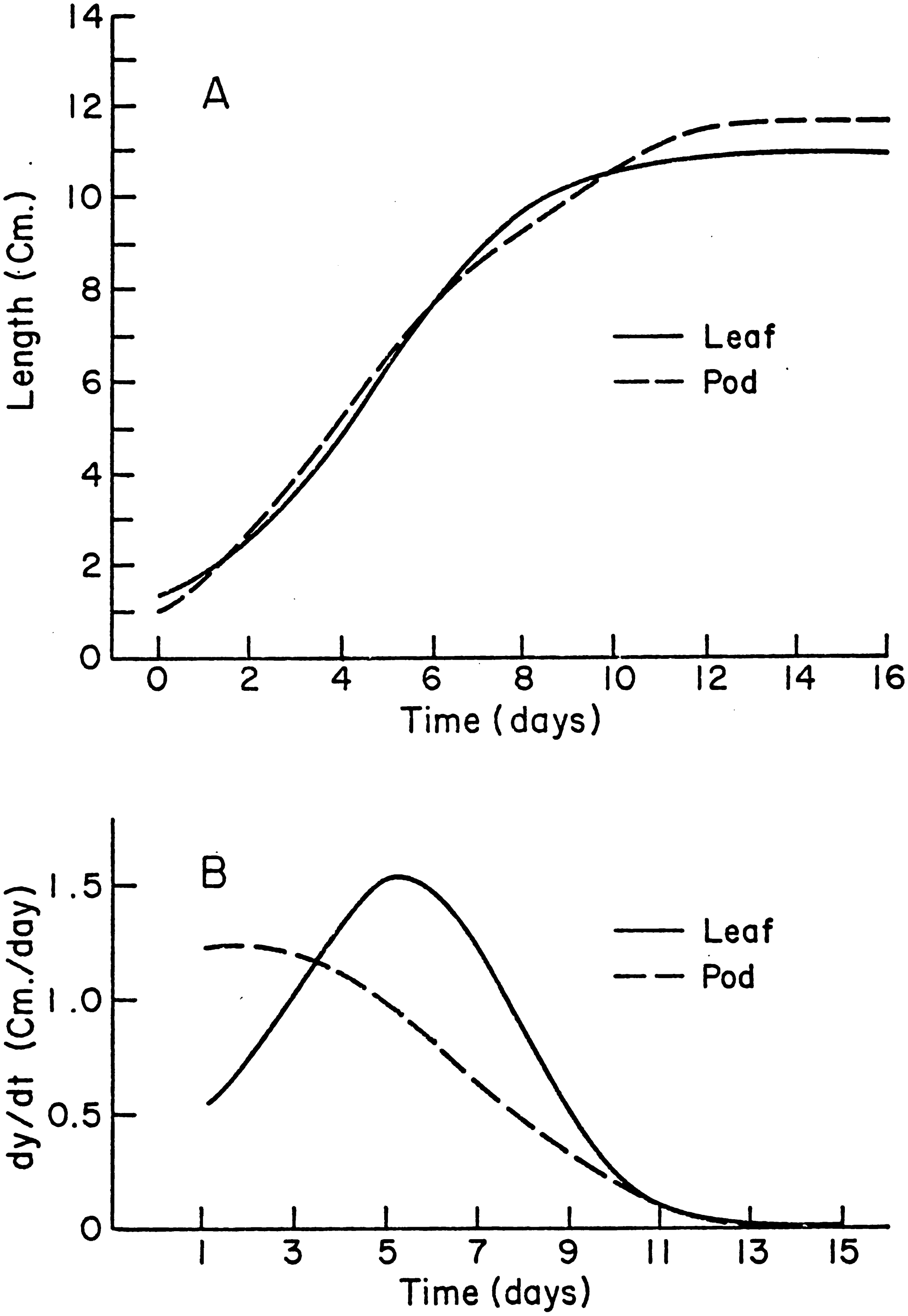

Fig. 10. Observed growth (A) and rate (B) curves of Cranberry 8247 leaf and pod.

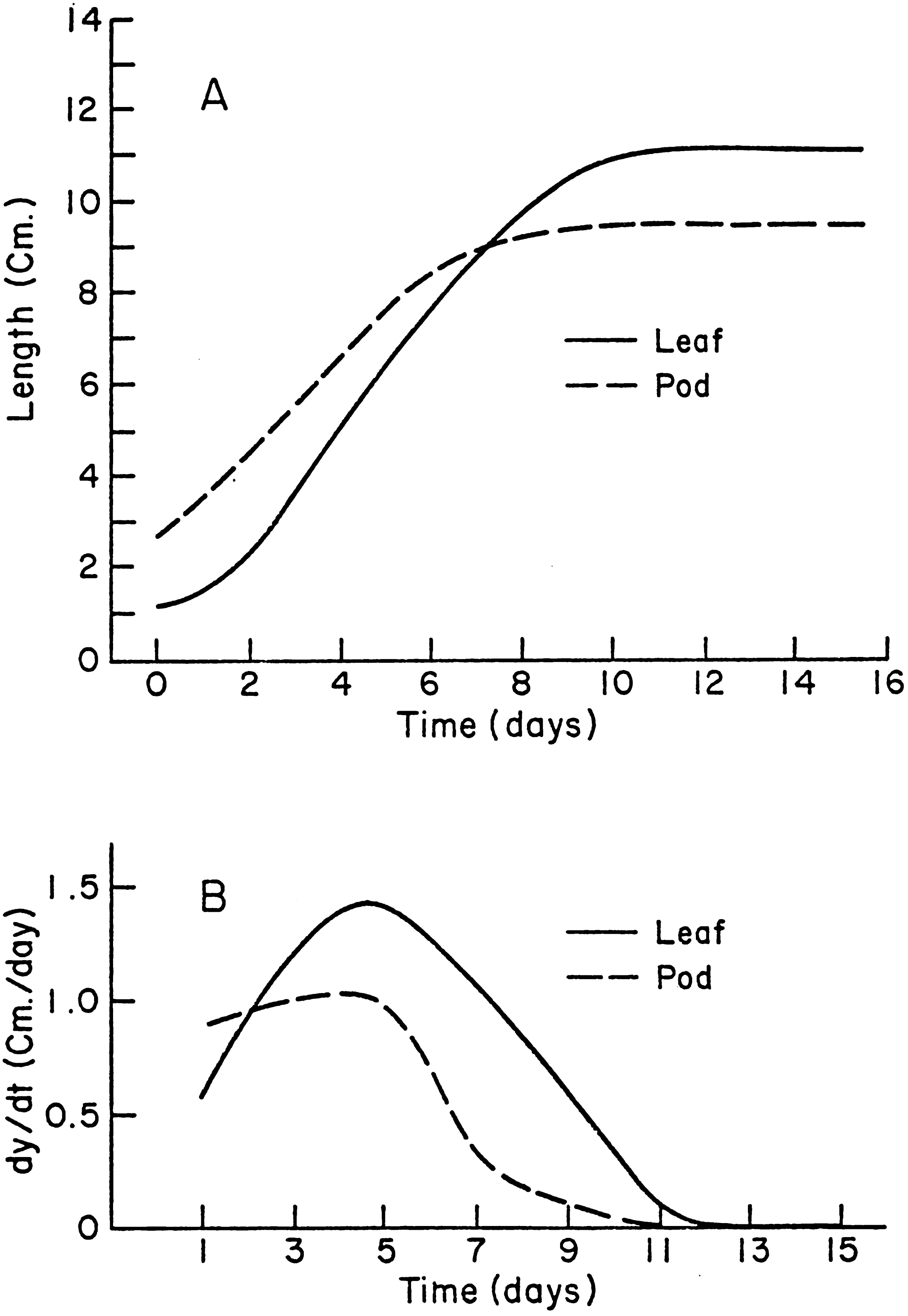

Fig. 11. Observed growth (A) and rate (B) curves of Swedish Brown leaf and pod.

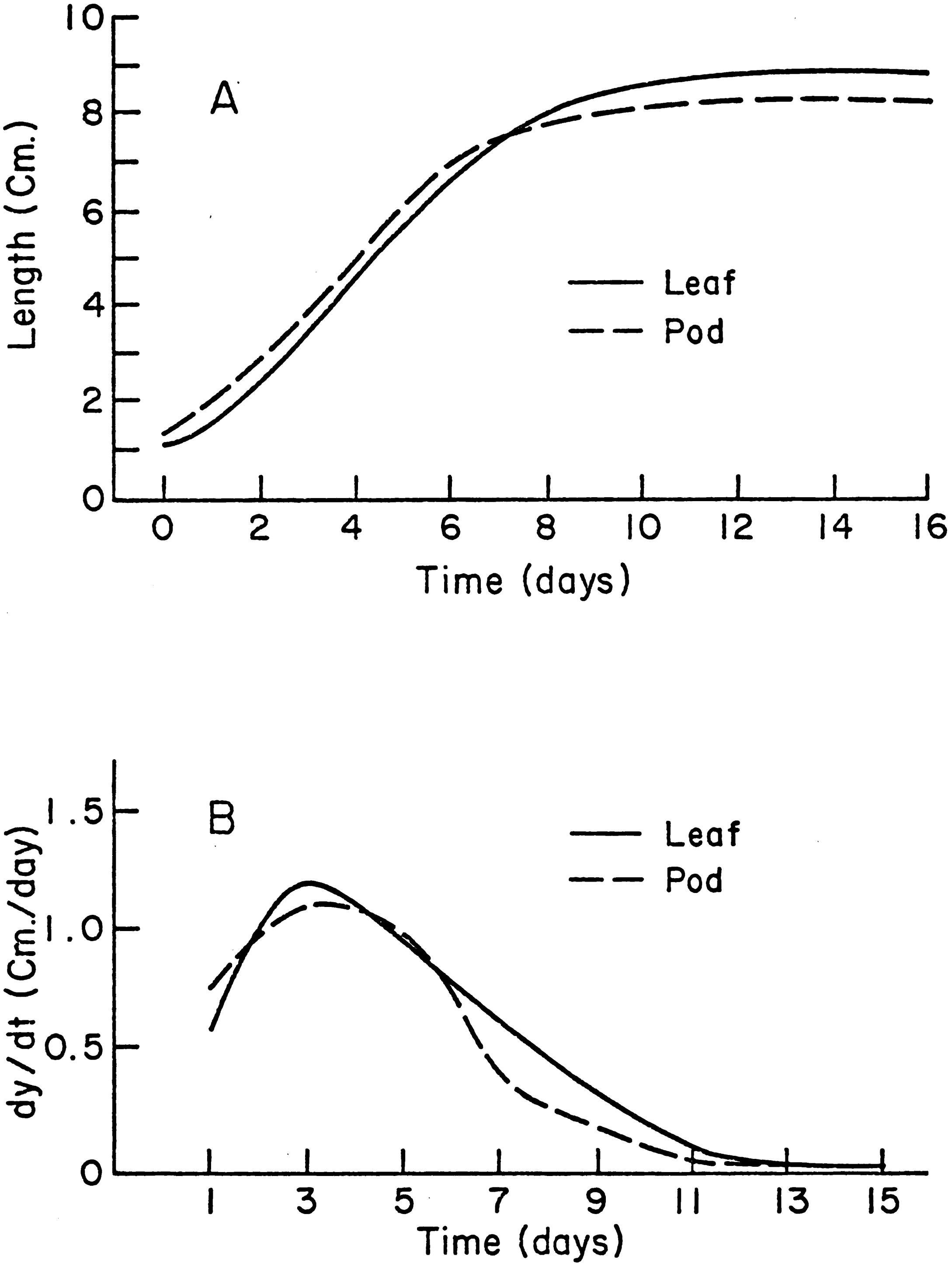

Fig. 12. Observed growth (A) and rate (B) curves of Navy-04 leaf and pod.

true for the four large leaf and the four small leaf varieties with only a few exceptions.

The analysis of variance for the b parameters of leaflet growth curves (Table 3) and pod growth curves (Table 4) of the eight varieties demonstrated significant differences (at the .01 level) among varieties for this parameter in both leaflet and pod growth. Block effect was only significant in the case of pod growth (at the .05 level). This may be due to a more sensitive response of pod development to small environmental differences since the experimental plots were located in a homogeneous field as far as the cultural practices were concerned and all indications are that block differences in soil condition were not substantial.

The high level of significance observed for the variety effect in the analysis of variance made a multiple-range test of differences between variety means of b parameters feasible. The means of b parameters of leaflet and pod growth curves of the two groups of varieties are as follows:

	Leaflets	Pods
Charlevoix	.4493	.5726
Manitou	.4165	.5967
Cranberry 8247	.4734	.5845
Swedish Brown	.5500	.4608
Navy-01	.4173	.4391
Navy-02	.4410	.4503
Navy-03	.4247	.4255
Navy-04	.4903	.4157

For the comparison of mean b parameters, Tukey's multiple-range test, which is a conservative one, was employed. Table

TABLE 3. Analysis of variance for b parameters of leaflet growth curves.

Source	df	SS	MS	F-ratio	level of significance .05	.01
Blocks	1	.0033	.0033	2.20	4.00	7.08
Varieties	7	.1445	.0206	13.73**	2.17	2.29
Block x varieties	7	.0038	.0005			
Sampling error	62	.0913	.0015			
Total	77	.2429				

$**P \leq .01$

TABLE 4. Analysis of variance for b parameters of pod growth curves.

Source	df	SS	MS	F-ratio	level of significance .05	.01
Blocks	1	.0100	.0100	7.14*	4.08	7.31
Varieties	7	.3110	.0444	31.71**	2.18	2.99
Block x varieties	7	.0008	.0001			
Sampling error	48	.0676	.0014			
Total	63	.3894				

$**P \leq .01$

$* P \leq .05$

5 shows the differences between the means of b parameters of leaflet growth curves of four large leaf and four small leaf varieties. The differences are generally small and only three of them show significance at the .05 level. These include the one between Swedish Brown and Manitou within the large leaf group and between Swedish Brown and Navy-01 and Navy-03, which belong to the second group. Swedish Brown is an early bush type variety. Manitou is also a determinate variety while the two Navy Bean varieties are late vines. Examination of the means for b shows that Swedish Brown possesses the highest value for the above parameter. Since b is a measure of the magnitude of decline in the rate, Swedish Brown approaches the mature size at a higher rate than all other varieteis. Differences between Swedish Brown and three of the small leaf and two of the large leaf varieties are considerably high (Table 5). This might be an indication of the higher rate of photosynthetic efficiency in this variety. In other words, Swedish Brown leaves grow at a higher rate than do those of the other varieties. There are no sizable or significant differences between varieties making up the small leaf group.

The difference between the means of b parameters of pod growth curves of the same varieties are presented in Table 6. Here the size of differences is much larger and the number of significant differences considerably higher, with the distinction that the direction of differences among the large leaf varieties has been reversed. While in the case of

TABLE 5. Differences between the means of *b* parameters for leaflet growth.

	Manitou	Cranberry 8247	Swedish Brown	Navy-01	Navy-02	Navy-03	Navy-04
Charlevoix	.0328	.0241	.1007	.0320	.0083	.0246	.0410
Manitou		.0569	.1335*	.0008	.0245	.0082	.0738
Cranberry 8247			.0766	.0561	.0324	.0487	.0169
Swedish Brown				.1327*	.1090	.1253*	.0597
Navy-01					.0237	.0074	.0730
Navy-02						.0163	.0493
Navy-03							.0656

* $P \leq .05$

TABLE 6. Differences between the means of b parameters for pod growth.

	Manitou	Cranberry 8247	Swedish Brown	Navy-01	Navy-02	Navy-03	Navy-04
Charlevoix	.0241	.0119	.1118	.1335*	.1223*	.1471**	.1569**
Manitou		.0122	.1359*	.1576**	.1464**	.1712**	.1810**
Cranberry 8247			.1237*	.1454**	.1342*	.1590**	.1688**
Swedish Brown				.0217	.0105	.0353	.0451
Navy-01					.0112	.0136	.0234
Navy-02						.0248	.0346
Navy-03							.0098

**$P \leq .01$

* $P \leq .05$

leaflets Swedish Brown has the highest b value, in the case of pods it shows the lowest. Within the large leaf group large differences were observed between Swedish Brown on one hand, and Charlevoix, Manitou, and Cranberry 8247 on the other, the last two values showing significance at the .05 level. The differences between Charlevoix, Manitou, and Cranberry 8247 and all four varieties of the small leaf group are significant or highly significant. The differences between Swedish Brown and the Navy bean varieties, unlike the case of leaflets, are neither sizable nor significant. There were no substantial or significant differences among varieties of the small leaf group.

Comparison of Table 5 and Table 6 demonstrates that the differences between the b parameters of varieties with small leaf for both leaflet growth and pod growth are very small and always non-significant. This is an indication of the similarity of growth process of the small leaf varieties. These varieties are similar in their mature leaflet and pod sizes, the pattern of growth, and finally the rate of decline of growth rate as the mature size is approached. In spite of the divergent leaf sizes of the two groups of varieties, when comparing them, the only sizable difference is that between Swedish Brown and three of the small leaf varieties. However, for pods the difference between Swedish Brown and the small leaf varieties is negligible. In other words the high rate of approach to mature size demonstrated by the leaves of Swedish Brown is not repeated in the process of pod development in this variety. Consequently Swedish Brown pods reach the mature size at almost the same rate that is characteristic of the pods of the small leaf varieties. The same reasoning holds true for the large leaf group. Within the large leaf group the mean b parameter of Swedish Brown leaflets is considerably larger than that of Charlevoix and Manitou and somewhat larger than Cranberry 8247. But this pattern is reversed for the case of pods and the latter varieties show considerably larger b values than that of Swedish Brown. It can be stated that the comparatively high rate of approach to mature leaf size observed in Swedish Brown does not imply that the same process would be true for pod growth in that variety. Therefore, Swedish Brown pods reach their mature size more slowly than do the pods of the other three large leaf varieties. This may be associated with the lesser re-mobilization and utilization of stored starch in this variety as compared to Charlevoix (2).

Another interesting point is the difference between the leaflet b parameters of Charlevoix, Manitou, and Cranberry 8247 on one hand and the leaflet b parameters of the four small leaf varieties on the other hand as contrasted to the corresponding difference between pod b parameters of the two groups. While in the first instance the differences are negligible, in the second instance all the differences are significant or highly significant.

It could be argued that while the rates of approach of leaflets to the mature size in Charlevoix, Manitou, and

Cranberry 8247 are very similar to the corresponding rates in the small leaf varieties, when comparing pod growth between these two groups, the pods of the three large leaf varieties reach the mature size considerably faster than do the pods of the small leaf varieties. In the case of Swedish Brown the reverse of this holds true. While its leaflets reach maturity with a rate higher than most small leaf and large leaf varieties, its pods approach the mature size with almost the same rate as the pods of the small leaf varieties. Large and mostly significant differences between pod $\underline{b}$ parameters of Charlevoix, Manitou, and Cranberry 8247 and Swedish Brown clearly demonstrate this point since the pod $\underline{b}$ parameter of Swedish Brown has almost the same size of the $\underline{b}$ parameters as the small leaf varieties.

The correlation between $\underline{b}$ parameters of leaflets and pods within each of the two groups of varieties was calculated in order to understand the pattern of correlated growths of these organs. For the large leaf group it was $r = -.6084$ and highly significant (at the .01 level). For the small leaf group it was -.1202 and nonsignificant. Thus the rate of approach to the mature size in leaflets and pods of the large leaf varieties is not the same. Generally, lower rates of decline in the growth rate of leaflets in approaching the mature size was associated with an opposite trend in pods. In other words, for Charlevoix, Manitou, and Cranberry 8247 varieties the lower rate of approach to the asymptote by the leaves was associated with a substantially higher rate of approach to maturity by the pods. This process was reversed for Swedish Brown, in the sense that the high rate of approach to maturity in leaves was associated with a low rate of pod elongation to maturity.

The growth rates

The maximum absolute growth rates of leaflets and pods were considered in order to investigate the nature and the degree of their association. When all the eight varieties were pooled together, the overall correlation between maximum growth rates of leaflets and pods was $r = .3822$ and highly significant (at the .01 level). However, when the two groups of varieties were taken separately this significant correlation disappeared. For the large leaf group the correlation was $r = .0171$ and for the small leaf group it was $r = .0668$, both nonsignificant. This discrepancy could be explained as follows: combination of two distant clusters of points, each with a small value of correlation coefficient, could result in some sizable value for this coefficient in the combined data. Examination of the plotted data for the maximum growth rates of leaves and pods in two groups of large and small leaf varieties revealed such a relationship.

Since the two groups of varieties differ in terms of growth rates, the correlations between average maximum growth rates of leaflets (Table 7) and pods (Table 8) and yield and its components and mature leaflet and pod lengths were calculated for both groups and are summarized in Table 9.

TABLE 7. Average maximum growth rates of leaflets (cm./day).

Variety		Charlevoix	Manitou	Cranberry 8247	Swedish Brown	Navy-01	Navy-02	Navy-03	Navy-04
Rep	I	1.65	1.75	1.57	1.69	1.10	1.28	1.24	1.19
	II	1.31	1.82	1.62	1.38	1.28	1.30	1.18	1.26

TABLE 8. Average maximum growth rates of pods (cm./day).

Variety		Charlevoix	Manitou	Cranberry 8247	Swedish Brown	Navy-01	Navy-02	Navy-03	Navy-04
Rep	I	1.33	1.33	1.04	1.06	.82	.92	.94	1.10
	II	1.60	1.45	.95	.91	.90	.90	.89	

TABLE 9. Correlation between average maximum leaflet and pod growth rates and yield, its components, leaflet size, and pod size.

		4 large leaf varieties	4 small leaf varieties
X vs.	leaflet rate	.2678	.2162
	pod rate	-.6766*	-.3789
Y vs.	leaflet rate	-.4641	.7665*
	pod rate	.2008	.2885
Z vs.	leaflet rate	.3159	.6882*
	pod rate	.7715**	.3139
W vs.	leaflet rate	.5285	.6982*
	pod rate	-.3220	-.1497
L vs.	leaflet rate	.9102**	.8047**
	pod rate	-. -	-
P vs.	leaflet rate	.1952	.7140*
	pod rate	.9369**	-.0108

**P $\leq$ .01

* P $\leq$ .05

Correlation between growth rates and pod number

For both groups the leaflet rate showed positive correlation values in the lower middle range, although they were nonsignificant. The pod growth rate showed sizable negative correlations with X (pod number) for both groups and in the case of the large leaf group was significant at the .05 level. The negative correlation between pod growth rates and the X component, especially in the large leaf group with higher maximum growth rate, underlines the importance of competition for environmental resources and the negative impact of the rate of growth of pods on the formation and development of other pods, the latter being at an earlier stage of growth.

Correlation between the growth rates and seeds per pod

In the large leaf group the leaflet growth rate shows a sizable negative correlation with the Y component, but for the small leaf group this correlation was positive and significant, demonstrating an opposite direction of association as compared to the first group. On the other hand, the pod growth rates produced positive and similar correlations in the lower medium range with the Y component for both groups.

Correlation between the rates and seed size

This relationship was a positive one for both groups and both rates though its degree varied. It was significant between leaflet rate and seed size of the small leaf group and highly significant between pod growth rate and the Z component of the large leaf varieties.

Correlation between growth rates and yield

For leaflet rates this was positive and high for both groups and significant for the small leaf group. The opposite was found for pod growth rate which showed negative and low correlations for both groups.

Correlation between leaflet growth rate and fully expanded leaf size

This was a positive and highly significant correlation for both groups. If the final size of leaflets under constant environmental conditions is a genetically determined character, being developmentally linked with the rate and duration of growth though not necessarily determined by them, this large and highly significant correlation between the growth rate and final size may be an indication of the primacy of favorable environment at the stage of maximum rate of leaf growth.

Correlation between the rates and mature pod size

The pattern of this association was very similar to the one observed for seed size. Its degree varied from highly positive to zero. For leaflet rates it was low with the large leaf group, but high and significant for the small leaf group. Pod rates showed a highly significant correlation with pod size within the large leaf group while no correlation was present within the small leaf group.

Comparing the two groups for the correlation between maximum leaflet growth rate and yield and its components, the general trend was a positive one except for the case of seeds per pod in the large leaf group. In the large leaf group the positive association of maximum rate with pod number and seed size was countervailed by a negative correlation with seeds per pod. This results in a reasonably high correlation with yield. In other words, the high rate of leaf growth exerted its positive influence on yield through an increase in pod number and seed size but not in number of seeds per pod. In the small leaf varieties the association between maximum leaflet growth rate and the three yield components was always positive and in the case of seeds per pod and seed size was significant. The correlation with yield was also significant. Here the maximum rate of leaf growth positively influenced yield mainly through an increase in the number of seeds per pod and seed sizes while its influence on pod number was moderately positive. Thus, the high rate of leaf growth in the small leaf varieties plays a much more important role in determining the final yield than in the large leaf varieties. The association between maximum leaflet rate and mature leaflet sizes in both groups was positive and highly significant. Since the maximum size of leaf for each variety is genetically determined, and a function of rate and duration of growth, this high correlation might be an indication that optimal environmental conditions and availability of nutrients would strongly influence yield through acceleration of rate of leaf growth which makes it possible for leaves to reach their mature size in a shorter period of time and become fully active sources of metabolites.

The association between leaflet growth rate and pod length was positive for both groups and significant for the small leaf varieties. The pattern was similar to the correlation between leaflet rate and leaflet length but much stronger in the small leaf group. One possible reason for this discrepancy is that the varieties comprising the small leaf group were much more uniform in growth habits and leaf and pod sizes than varieties of the large leaf group. So the positive association between rate and the sizes of leaflets and pods was more consistent.

Considering the associations between maximum pod growth rate and the yield system, the correlation with pod number was negative and considerably large for both groups, the one for the large leaf group, which had a higher maximum growth rate, being significant. This underlines the importance of competition for the sources of nutrients. Since within the nutritional unit defined by Adams (1) young pods have the lowest priority in competition for nutrients, the high growth rate of those pods which have passed the first stages of growth exerts a negative impact on formation and development of the pods at a very early stage of development. This impact occurs through appropriation of the major portion of resources available, cutting the flow of metabolites to the young pods and causing them to abort. This matter was substantiated in a study by Subhadrabandhu (31) of Black Turtle Soup, Michelite, and Seafarer cultivars of dry bean. The chance of development to full maturity for the pods of all three cultivars was greater when they developed from earlier borne flowers. The high growth rate of these pods was the cause of cessation in further growth of pods initiated later.

The correlation between maximum pod growth rate and number of seeds per pod in both groups was positive but not large or significant. The speed of pod elongation did not have a strong bearing on the number of fertilized ovules retained within pods because of the lower order of priority they have in appropriating available nutrients for full development.

The association between maximum pod growth rate and seed size was positive in both groups and highly significant for the large leaf group. This might be a corollary of the previous correlation, the one between the rate and number of seeds per pod. Since the average maximum pod growth rate of the large leaf group was higher than that of the small leaf group, the pods of the former group reached their full length sooner and a greater portion of metabolites became available for seed development while the pods of the latter group reached their full length later and a lesser part of nutrients could be appropriated for seed enlargement. This argument holds true only if a genetic basis is assumed for the magnitude of the maximum rate. The correlation between average maximum pod growth rate and seed yield in both groups was negative though nonsignificant. This could be explained on the basis of generally high negative correlations between the maximum pod growth rate and the number of pods per plant, which, due to the primacy of pod number in yield determination, negates the small positive impact of maximum pod growth on the number of seeds per pod and its more substantial positive effect on seed size.

The correlation between maximum pod growth rate and pod length was positive and highly significant for the large leaf group and near zero for the small leaf group. Here the contrast between leaflet and pod growth rate correlations with mature pod size is worth noticing. It was the small leaf group which had positive and significant correlation of the leaflet rate with pod size, while the large leaf group showed a small positive correlation with this rate. In the large leaf group the average maximum grwoth rate of pods had an association of the same degree and direction with the mature pod size as the average maximum leaflet rate of the small leaf group. Since the same pattern was present in the case of rate correlations with seed size, in the large leaf group of varieties the average maximum pod growth rate was strongly associated with pod size and seed size while in the small leaf group it was the average maximum leaflet rate which was highly correlated with pod size and seed size.

Correlations between yield, its components, and final leaflet and pod sizes

Phenotypic correlations calculated were as follows:

r_{LB}: Between fully expanded leaflet length and its breadth.

r_{LP}: Between leaflet length and mature pod length.

r_{LZ}: Between leaflet length and seed size.

r_{PZ}: Between pod length and seed size.

r_{PY}: Between pod length and seeds per pod.

r_{XY}: Between pod number and seeds per pod.

r_{XZ}: Between pod number and seed size.

r_{YZ}: Between seeds per pod and seed size.

r_{XW}: Between pod number and yield of seed.

r_{YW}: Between seeds per pod and yield of seed.

r_{ZW}: Between seed size and yield of seed.

These were calculated for the three leaf size groups and are presented in four tables (Tables 10-13). Table 10 and Table 11 show correlations between leaflet and pod sizes and seed size and seed number and also correlation between leaflet length and breadth, the latter only for the Gratiot County experiments. Table 12 and 13 show correlations between yield and its components. Test 23 and Test 25A had the same planting regime (row and plant spacing), but the former was planted in East Lansing while the latter was planted in Gratiot County. Since the level of inter-plant competition for both of these experiments was the same, they are compared

TABLE 10. Correlations involving leaflet size, pod size, seed size, and seeds per pod compared for the effect of environmental change.

Correlation	Experiment	Large-leaf varieties	Medium-leaf varieties	Small-leaf varieties
r_{LP}	23A	.0683	.0933	.2573
	25A	.4875*	.1935	.4150
r_{LZ}	23	.1175	.4616	.3914
	25A	.1099	.4696*	.3252
r_{PZ}	23	.7112**	-.6178	.3427
	25A	.3407	.1071	.1752
r_{PY}	23	.1598	.8245**	.2790
	25A	.6983**	-.0522	.1090

**$P \leq .01$

* $P \leq .05$

TABLE 11. Correlations involving leaflet size, pod size, seed size, and seeds per pod compared for the effect of different competition regimes.

Correlation	Experiment	Large-leaf varieties	Medium-leaf varieties	Small-leaf varieties
r_{LB}	24	.8673**	.8151**	.8454**
	25A	.8450**	.5833**	.8707**
	25B	.7706**	.6183**	.7698**
r_{LP}	24	.3164	.2218	-.0619
	25A	.4875*	.1935	.4150
	25B	.7626*	.4053	.5694
r_{LZ}	24	.4526*	.4186	.6460**
	25A	.1099	.4696*	.3252
	25B	.4889	.2439	.2537
r_{PZ}	24	.3525	-.2381	-.2336
	25A	.3407	.1071	.1752
	25B	.8154**	.1481	-.0444
r_{PY}	24	.4839*	.3885	.2727
	25A	.6983**	-.0522	.1090
	25B	-.3877	.2827	.3763

** $P \leq .01$

* $P \leq .05$

TABLE 12. Correlations between yield and its components compared for the effect of environmental change

Correlation	Experiment	Large-leaf varieties	Medium-leaf varieties	Small-leaf varieties
r_{XY}	23	-.1063	.7080*	-.0629
	25A	-.5998**	-.1518	-.4721*
r_{XZ}	23	-.5790*	-.6433*	-.3466
	25A	-.2429	-.2672	-.0063
r_{YZ}	23	-.3963	-.4878	.1692
	25A	-.3902	-.2581	-.3939
r_{XW}	23	.9051**	.7316*	.7318**
	25A	.4483	.8069**	.4957*
r_{YW}	23	-.1354	.6753*	.2819
	25A	-.2255	.1630	-.3128
r_{ZW}	23	-.2228	.0078	.3265
	25A	.5470*	.0766	.7720**

**P≤ .01

* P≤ .05

TABLE 13. Correlation between yield and its components compared for the effect of different competition regimes.

Correlation	Experiment	Large-leaf varieties	Medium-leaf varieties	Small-leaf varieties
r_{XY}	24	-.5519*	-.0208	-.6286**
	25A	-.5998**	-.1518	-.4721*
	25B	.6012	-.1762	.0896
r_{XZ}	24	-.3266	-.6385**	.6445**
	25A	-.2429	-.2672	-.0063
	25B	-.8157**	-.3852	-.5787
r_{YZ}	24	-.2051	-.3111	-.6818**
	25A	-.3902	-.2581	-.3939
	25B	-.4706	-.5417	-.5172
r_{XW}	24	.8339**	.7072**	.9225**
	25A	.4483	.8069**	.4957*
	25B	.4130	.6976*	.6912*
r_{YW}	24	-.4143	.3249	-.5224*
	25A	-.2255	.1630	-.3128
	25B	.5420	-.2847	-.0045
r_{ZW}	24	.0947	-.0895	.8391**
	25A	.5470*	.0766	.7720**
	25B	.0642	.2144	.2424

**$P \leq .01$

* $P \leq .05$

for the study of environmental differences. Test 24, test 25A, and test 25B on the other hand were all planted in Gratiot County and shared the same environment; each represents one distinct level of competition (wide plant spacing, close plant spacing, close spacing with shade, respectively) and therefore are compared for the effect of stress levels upon correlations.

Correlation between leaf length and breadth

Calculated for only one location, this correlation was always positive and highly significant. The factors determining the length and width of leaflets in varieties of all groups were strongly associated.

Correlation between leaf length and pod length

This correlation was generally positive and higher in degree in Gratiot County as compared to East Lansing. In Gratiot there was also a general trend of increase in the magnitude of correlation accompanied with the increase in severity of stress, the highest values observed for all groups in the artificial shading experiment. Thus, the correlation showed the tendency to vary rather widely in degree from one location to another with the same density of planting having always considerably higher values in Gratiot County. This correlation varied in magnitude from group to group, location to location, and across different stress regimes ranging from zero to .76. The expression of this positive association was environmentally determined. It could be argued that in Gratiot County the environment was much more favorable for its expression. This is demonstrated by the coefficients of the large leaf group, with a value close to zero in East Lansing, but in Gratiot County generally substantial and in two cases significant.

Correlation between leaflet length and seed size

This correlation was always positive. The degree of correlation remained unchanged for each of the three groups while in Gratiot County it varied within each group by the change in the competition level. The plants in the wide spacing experiment had large coefficients for all three groups varying from significant to highly significant, indicating that this positive association was best manifested at lower intensities of competition. The plants in the small leaf group had the highest correlation coefficient.

Correlation between pod length and seed size

Unlike the previous correlation,the correlation between pod length and seed size varied in sign and magnitude from location to location and also across competition levels. The large leaf group always showed positive and in two cases high and highly significant correlations. These two occurred in closely planted experiments, one in East Lansing, another one in Gratiot County with artificial shading. For the large leaf group this correlation appeared to be positive and environmentally influenced.

Correlation between pod length and seeds per pod

From location to location the correlations between pod length and seeds per pod were mostly positive, but they varied widely in degree from group to group, ranging from zero to .82 and highly significant. Across the stress regimes the correlations were generally positive, but fluctuated in magnitude, except for the large leaf group under shade which showed a negative correlation. The large leaf group showed wide fluctuation in magnitude and sign ranging from .70 to -.39 across locations and stress regimes. It had significant correlations for widely spaced and closely spaced experiments in Gratiot County. The medium leaf group had coefficient values varying from zero to .82 with no clear trend. The small leaf group had always positive, but mostly low correlation coefficients.

Correlation between pod number and seeds per pod

This correlation was predominantly negative. The large leaf group across locations varied from slightly negative to highly negative and significant. Across stress regimes the coefficients varied from highly negative and significant to highly positive, the last one being in the shading experiment. The medium leaf correlations fluctuated across locations from highly positive and significant to slightly negative while in different competition regimes they varied from zero to the low negative range. The small leaf group across locations varied from zero to negative and highly significant. Across competition levels the coefficients varied from zero to negative and highly significant, the size of the negative correlation decreasing with the increase in the severity of competition.

Correlation between pod number and seed size

Excepting one occasion, this correlation was negative but highly varied in degree for all groups according to location or competition levels. It was significant in East Lansing and highly significant in Gratiot County under shading. For the medium leaf group the East Lansing value was significant while in Gratiot the wide spacing experiment showed a highly significant value. The small leaf group showed a positive and highly significant value in the wide spacing experiment which was in contrast to the rest of the correlations. Overall, the plants in the East Lansing experiment showed higher values for all groups. In Gratiot County experiments the large leaf and the small leaf groups showed a substantial increase in the degree of negative correlation in shade.

Correlation between seeds per pod and seed size

This correlation was generally negative except for the small leaf group in East Lansing which was slightly positive. Fluctuations across locations and competition levels were not great. Across competition levels the large and medium leaf groups showed a trend of increasing degree with intensification of stress and the small leaf group showed higher values than the other three groups at different competition levels, one being significant. The shading experiment had a value in the medium range for all groups.

Correlation between pod number and yield

This correlation was always positive and mostly significant. This correlation was very consistent in its sign across location and competition levels. The East Lansing experiment had a higher degree of correlations than the same experiment in Gratiot County. The wide spacing experiment showed the highest magnitude for all groups and was always highly significant. The large leaf group demonstrated a distinct response to intensification of competition by a gradually decreasing coefficient trend.

Correlation between seeds per pod and yield

This correlation showed no clear trend in sign or degree across locations or competition levels. The medium leaf group values varied from low positive towards low negative with increase in stress level. Large and small leaf groups showed an opposite trend.

Correlation between seed size and yield

This correlation was mostly positive with the highest values belonging to the small leaf group. Only the large leaf group in East Lansing showed a small negative correlation. The number of correlations close to zero was substantial. Overall, the large leaf group had contradictory signs across locations and no clear trend across stress regimes. The medium leaf group showed generally no correlation across locations or competition levels except for the shading experiment having a small positive one. The small leaf group coefficients, though varying considerably in magnitude by change in environment, had large and highly significant values for both wide and close spacing experiments but a small and nonsignificant one for the shading experiment.

SUMMARY AND CONCLUSIONS

There have been numerous attempts to define specific physiological meaning for the parameters of growth curves. Specifically, those parameters which are measures of scale or spread of the growth curve along the time axis (parameter b in the Gompertz curve) and which determine the general pattern of growth or the shape of the curve have been extensively studied. These attempts have not been successful. It has not been possible to associate any of the parameters of growth curves with any particular physiological function. Nevertheless, growth curves provide an economical summary of growth data. In fitting the data to any particular growth function, some of the variation in the actual measurements is lost, however, the estimated parameters of growth of any genotype or its organs can be treated as metric traits. This assumption has been made in the present study. Furthermore, it has been assumed that any significant differences between the parametric values of growth of the same organs on different genotypes can be attributed to genetic effects.

In comparing two groups of field bean varieties, one group consisting of large leaf and another of small leaf varieties, grown under similar environmental conditions, significant differences were found between b parameters of leaf growth curves. This was in contrast to the findings of

Amer and Williams (3) who found reasonably constant b parameters for leaves of Pelargonium zonale plants grown under different watering regimes. Amer and Williams imply that this parameter is species-specific. From the present study it appears that this parameter is not species-specific in field beans. Furthermore, it could be used in differentiating among groups of varieties of varying leaf sizes. This differentiation was even more pronounced when the significant differences between the b parameters of pod growth curves of the two groups of field bean varieties were taken into consideration.

One of the objectives of the present study was to elaborate on the basis of expected relationships between the sizes of organs, such as leaflet, pod, and seed. Duarte and Adams (11) reported a significant path correlation between leaflet size and seed size in lines derived from a cross between the variety Michelite with small leaves and small seeds and the variety Algarrobo which is a mottled kidney bean with large leaves and large seeds. The explanation they offered was based on the assumption of organ homology, that in the plant's ontogeny pods are modified leaves, and that seeds which are composed mainly of cotyledons may also be considered modified leaves. Each of these organs is homologous to the other and they should all be regulated to some extent by a common set of genes. Clearly, having different functions as photosynthetic, reproductive, and storage organs, these organs are also subject to genetic and non-genetic influences different from those exerted by the common set of genes. On the basis of this reasoning, the growth curve parameters of leaflets and pods are expected to show some degree of correlation but not necessarily complete correlation. The magnitude of this correlation would depend upon the relative contribution of the common set of genes versus the specific set of genes regulating the particular function of each of the two organs. There was a highly negative association between b parameters of leaflet and pod growth curves of large leaf varieties. Closer inspection showed that lower b parameters of leaflet growth curves of Charlevoix, Manitou, and Cranberry 8247 were associated with higher b values of pod growth in these varieties, while for Swedish Brown the reverse was true. Since b is a measure of decline in the rate of growth of leaflet or pod, it could be inferred that in kidney and cranberry beans the partition of growth resources - water, carbohydrates, growth hormones, proteins - is regulated to favor pod and seed development at the expense of leaf development. In Swedish Brown leaf development is favored over pod development. Swedish Brown pods are unusually short, with fewer seeds per pod, for a variety of its seed size class. The contrast between red kidney Charlevoix and Swedish Brown in leaflet and pod growth pattern may be associated with the recent finding (2) that starch remobilization from root and lower stem is more restricted in Swedish Brown than in Charlevoix. Clearly, in Swedish Brown the restricted pod development was not a result of deficiency in carbohydrates. The competition between leaf and pod must have been for some other resources. An alternative explanation is regulation of growth at genetic and hormonal levels. No clear-cut evidence for either system of regulation is presently available.

In the small leaf group the *b* parameters of leaflet and pod growth curves differed very little (Figure 12). Here, it could be implied that both organs were competing for growth materials on an equal basis. Consequently the rate of approach to the asymptote for both organs is very similar. Although the general form of the leaflet and pod growth curves was similar in both large leaf and small leaf varieties (Figures 9, 10, 11, 12), the growth rates of leaflets consistently exceeded the growth rate of pods in the large leaf varieties. These varieties differ in the time point at which the leaflet and pod growth rates are the greatest. In the small leaf varieties the growth and rate curves of leaflets and pods were very similar.

A highly significant correlation was found between the average maximum growth rates of leaflets and pods when both groups of varieties were taken together. However, within each group this correlation became zero. This means that the significant correlation was due to group differences; large leaf varieties having longer pods and the small leaf varieties having shorter pods. If the objective of a breeding program is to develop a variety with small leaves and long pods the data analyzed in the present study would not be sufficient and measurements on a genetically-segregating population would be required.

Leaflet growth rates were positively correlated with pod number in both large leaf and small leaf groups. Pod growth rates were negatively correlated with pod number. The higher the growth rate of pods, the smaller the number of pods. The simplest explanation is based on competition for carbohydrates and proteins between pods which are at different stages of growth and the priority of rapidly developing pods in appropriating the available nutrients. The correlations between leaflet and pod growth rates and seed sizes were positive for both groups. This could be explained on the ground that seed size, the seed being composed mainly of storage leaves or cotyledons, is a reflection of leaf growth rates. That is, leaves whether photosynthetic, reproductive (as pods), or storage (as seeds) are regulated in their growth by a common set of genes due to their homologous nature. In spite of the specific functions of these organs, the basis of the positive association is strong enough to be expressed by the positive correlations. This interpretation requires that the growth rate of a leaflet be correlated with its mature size. This correlation was in fact positive and highly significant for both groups of varieties. Pod growth rates also had a highly significant correlation with mature pod length in the large leaf group, but not in the small leaf group. This correlation was absent in the small leaf group, probably because all varieties belonging to this group were so similar that there was little or no variation in pod growth rates and their mature lengths.

In general, leaflet growth rates were positively correlated with yield. This may be interpreted as either the effect of a favorable environment influencing both yield and growth rates, or as an indication that high leaflet growth rates are a sign of plant vigor which in turn results in high yield.

As far as the interaction between mature leaflet, pod, and seed sizes is concerned, the correlation coefficients listed in Table 10 should be taken into consideration. Among eighteen correlations involving leaflet size, pod size, and seed size, only three were statistically significant and only one was high enough ($r_{PZ} = .71$) to account for 50% of the variation in seed size. However, all but one of the correlations were positive. The same correlations from other experiments are presented in Table 11. Again the correlations among the three organs even under different competition levels were nearly always positive and though relatively high in magnitude only occasionally significantly higher than zero. It could be concluded that the effect of common genes regulating growth of these homologous organs, though substantial, plays a relatively minor role as compared to the effect of genes regulating specific functions of these organs and the influence of non-genetic factors. Therefore, the breeder has a relative freedom that would allow him to select for a desired combination of leaflet, pod, and seed sizes. This might not be true across the extreme types of these traits, but certainly the expectation should hold within the limits of more narrow size combinations. Here, there is enough flexibility in the developmental systems to allow for some recombination between genes controlling organ sizes. Generally, the basic correlations attributed to organ homology of leaflet, pod, and seed by Duarte and Adams (11) were confirmed in the present study. Correlation patterns previously described among yield components themselves (1) were also confirmed in this study. As has been found in many grain legumes, the correlation of pod number with yield was always positive and almost always significant, pod number being the single most important component of yield.

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APPENDICES

Appendix A

Measurements of leaflet and pod lengths in centimeters taken in 48-hour intervals

R_1: First replication

R_2: Second replication

Table A-1. Charlevoix leaflets.

		Time (day)																	
		0		2		4		6		8		10		12		14		16	
Plant No.	Leaf No.	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	2.2	-	4.4	-	8.1	-	10.6	-	12.3	-	12.8	-	13.2	-	13.2	-	13.2	-
1	2	1.7	1.9	3.4	3.5	7.1	6.5	8.7	8.4	9.5	9.2	10.0	9.5	10.0	9.6	10.0	9.5	10.0	9.5
2	1	-	1.7	-	2.9	-	5.8	-	9.0	-	11.1	-	12.1	-	12.3	-	12.3	-	12.3
2	2	2.0	-	4.0	-	7.4	-	9.6	-	10.6	-	11.1	-	11.2	-	11.2	-	11.2	-
3	1	2.3	2.2	4.0	4.2	6.5	6.6	9.0	8.5	10.3	10.1	10.5	10.6	10.7	10.8	10.7	10.8	10.7	10.8
3	2	-	1.8	-	3.7	-	6.9	-	8.9	-	9.0	-	9.5	-	9.5	-	9.5	-	9.5
4	1	1.6	2.0	2.8	3.0	5.7	4.6	8.8	6.4	10.5	7.4	11.2	8.0	11.6	8.1	11.6	8.1	11.6	8.1
4	2	1.8	-	3.6	-	7.2	-	9.2	-	10.1	-	10.5	-	10.6	-	10.6	-	10.6	-
5	1	1.9	2.3	4.2	4.2	7.5	6.0	10.1	7.1	12.0	8.0	12.7	8.3	13.1	8.5	13.1	8.5	13.1	8.5
5	2	2.2	-	4.2	-	7.5	-	9.5	-	10.5	-	10.9	-	11.2	-	11.2	-	11.2	-

Table A-2. Manitou leaflets.

Plant No.	Leaf No.	Time (day) 0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	2.2	-	4.7	-	7.8	-	9.7	-	11.0	-	11.3	-	11.5	-	11.5	-	11.5	-
1	2	2.1	1.8	4.2	3.9	8.4	7.2	10.3	9.0	11.1	10.0	11.8	10.3	12.0	10.7	12.1	10.8	12.1	10.8
2	1	2.0	1.9	3.6	3.2	6.9	6.4	9.6	9.7	10.9	11.6	11.4	12.1	11.5	12.2	11.5	12.2	11.5	12.2
2	2	1.8	2.1	3.8	4.5	7.6	7.5	10.0	9.8	11.4	10.9	11.8	12.0	12.0	12.4	12.0	12.8	12.0	12.8
3	1	1.7	2.3	3.1	4.8	6.5	8.8	10.8	11.5	13.7	12.5	14.8	12.8	15.0	12.9	15.0	12.9	15.0	12.9
3	2	1.8	2.1	3.5	4.0	7.0	7.3	9.4	9.3	10.4	10.0	10.9	10.2	11.0	10.5	11.0	10.5	11.0	10.5
4	1	2.3	2.3	4.7	4.9	8.3	8.9	10.5	11.8	11.7	12.4	11.9	13.1	12.0	13.2	12.0	13.2	12.0	13.2
4	2	1.9	2.3	4.2	5.1	8.2	9.6	10.2	11.9	10.8	12.5	10.9	12.6	11.0	12.7	11.0	12.7	11.0	12.7
5	1	1.8	2.3	4.2	5.3	7.8	9.6	10.9	12.6	12.9	14.1	13.3	14.5	13.5	14.6	13.5	14.6	13.5	14.6
5	2	2.0	2.3	4.0	4.7	8.0	8.0	10.7	9.9	11.8	10.5	12.2	11.0	12.3	11.1	12.3	11.1	12.3	11.1

Table A-3. Cranberry 8247 leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	-	1.8	-	3.1	-	5.9	-	9.3	-	11.3	-	11.9	-	12.0	-	12.0	-	12.0
1	2	1.4	1.1	3.2	2.0	6.1	4.1	8.0	6.9	9.1	9.4	9.7	10.9	9.8	11.1	10.0	11.6	10.0	11.6
2	1	1.5	1.5	2.4	2.8	5.3	5.7	8.6	9.1	10.2	11.0	11.1	11.5	11.2	11.6	11.2	11.6	11.2	11.6
2	2	1.5	1.0	2.5	2.3	5.0	4.4	7.7	7.3	9.2	9.5	9.8	11.0	10.4	11.2	10.4	11.8	10.4	12.1
3	1	1.6	-	2.7	-	4.9	-	8.0	-	10.0	-	10.7	-	10.8	-	10.8	-	10.8	-
3	2	1.4	-	2.2	-	5.4	-	9.3	-	11.5	-	12.3	-	12.7	-	12.7	-	12.7	-
4	1	1.5	1.3	3.3	1.9	5.8	4.0	9.0	7.0	11.0	9.7	11.3	10.9	11.4	11.1	11.4	11.1	11.4	11.1
4	2	1.4	1.2	2.1	1.9	4.5	3.9	7.9	7.4	9.5	10.2	10.3	11.5	10.7	12.0	10.7	12.2	10.7	12.2
5	1	1.8	1.4	3.1	2.1	5.8	3.6	8.8	6.0	11.0	9.1	12.0	10.5	12.1	10.7	12.1	10.7	12.1	10.7
5	2	1.5	1.1	2.4	2.4	5.0	5.0	8.7	7.7	10.5	9.6	11.4	10.3	11.8	10.5	12.0	10.7	12.0	10.7

Table A-4. Swedish Brown leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	1.3	2.1	2.4	3.3	4.1	5.8	6.8	8.3	9.0	10.5	10.7	11.7	11.5	12.2	11.6	12.2	11.6	12.2
1	2	1.2	1.5	2.3	2.3	4.7	4.7	7.6	8.6	9.7	10.9	11.0	12.2	11.1	12.7	11.1	12.8	11.1	12.8
2	1	1.3	1.5	2.4	2.5	4.2	4.5	7.4	7.5	11.2	9.6	13.3	11.0	14.5	11.6	14.7	11.6	14.7	11.6
2	2	1.2	1.4	2.4	2.3	4.7	4.7	7.1	8.6	8.9	10.9	10.3	12.2	10.7	12.7	11.3	12.7	11.3	12.7
3	1	1.6	1.4	2.7	2.3	3.7	4.1	7.9	6.6	9.1	8.1	9.4	8.9	9.6	9.2	9.6	9.2	9.6	9.2
3	2	1.1	1.7	2.0	3.5	4.1	6.1	7.0	7.4	9.1	8.2	9.8	8.9	10.1	9.1	10.2	9.5	10.2	9.5
4	1	1.4	1.1	2.3	2.1	4.7	3.5	8.7	6.2	11.5	8.9	12.7	10.6	12.8	11.7	12.8	12.0	12.8	12.0
4	2	1.2	1.1	2.2	1.9	4.9	3.9	8.9	6.3	10.6	8.3	11.4	9.6	11.9	9.9	11.9	10.5	11.9	10.8
5	1	1.9	1.4	3.0	2.4	5.3	3.7	8.6	5.8	10.8	7.9	11.6	9.1	11.8	9.6	11.8	9.8	11.8	9.8
5	2	1.1	1.6	2.1	3.3	4.5	5.9	8.0	8.2	9.4	9.7	10.1	10.4	10.4	10.7	10.4	11.1	10.4	11.1

Table A-5. Navy-01 leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	1.7	1.3	2.9	2.4	5.0	4.9	6.7	6.9	7.7	8.2	7.9	8.6	8.0	8.7	8.0	8.7	8.0	8.7
1	2	1.4	1.1	3.2	2.6	5.8	5.3	7.4	7.3	8.0	8.7	8.2	9.2	8.3	9.4	8.3	9.4	8.3	9.4
2	1	2.1	1.6	3.8	2.9	6.1	5.1	7.8	7.3	8.5	8.3	8.5	8.6	8.5	8.7	8.5	8.7	8.5	8.7
2	2	1.8	1.2	3.9	2.8	6.3	5.4	7.3	7.3	7.6	8.3	7.7	8.7	7.8	8.8	7.8	8.8	7.8	8.8
3	1	-	1.3	-	2.6	-	5.1	-	7.5	-	9.0	-	9.6	-	9.7	-	9.7	-	9.7
3	2	1.9	1.3	4.0	3.1	6.4	6.1	7.7	7.7	8.1	8.7	8.2	9.0	8.3	9.1	8.3	9.1	8.3	9.1
4	1	2.5	1.6	4.3	3.0	6.1	5.5	7.3	7.6	7.8	8.6	7.9	8.9	8.0	9.0	8.0	9.0	8.0	9.0
4	2	-	1.8	-	4.3	-	7.1	-	8.6	-	9.1	-	9.2	-	9.3	-	9.3	-	9.3
5	1	1.4	1.3	2.3	2.3	4.8	4.4	7.2	6.6	8.5	8.0	9.0	8.5	9.1	8.6	9.1	8.6	9.1	8.6
5	2	1.3	-	2.8	2.3	5.2	5.0	6.9	6.7	7.6	7.6	8.0	7.8	8.1	8.0	8.1	8.0	8.1	8.0

Table A-6. Navy-02 leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	2.1	1.2	3.8	2.1	6.4	4.6	8.4	7.3	9.5	8.6	9.8	9.1	9.9	9.3	9.9	9.3	9.9	9.3
1	2	1.2	1.1	2.8	2.6	5.8	5.4	7.8	7.7	8.8	9.0	9.2	9.5	9.3	9.6	9.3	9.6	9.3	9.6
2	1	2.5	1.3	4.2	2.3	5.8	5.1	7.2	7.6	8.0	9.3	8.1	9.8	8.2	9.9	8.2	9.9	8.2	9.9
2	2	1.5	1.3	3.3	3.2	6.1	6.3	7.7	8.3	8.6	9.2	8.9	9.4	9.0	9.5	9.0	9.5	9.0	9.5
3	1	1.9	1.6	3.2	2.9	5.0	5.0	6.8	7.3	7.8	8.8	8.1	9.1	8.2	9.2	8.2	9.2	8.2	9.2
3	2	1.3	1.3	2.8	3.1	6.3	6.3	7.2	8.1	8.2	9.0	8.5	9.2	8.6	9.4	8.6	9.5	8.6	9.5
4	1	1.5	1.5	2.8	2.6	5.1	5.2	6.9	7.2	8.0	8.6	8.3	8.9	8.5	9.0	8.5	9.0	8.5	9.0
4	2	1.2	-	2.5	2.2	5.0	5.1	7.0	7.4	8.2	8.6	8.9	9.1	9.1	9.2	9.1	9.2	9.1	9.2
5	1	1.5	1.3	3.0	2.5	5.5	4.9	7.3	7.3	8.5	8.8	8.7	9.3	8.8	9.5	8.8	9.5	8.8	9.5
5	2	-	1.1	-	2.6	-	4.8	-	7.0	-	8.2	-	8.7	-	8.9	-	9.0	-	9.0

Table A-7. Navy-03 leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	1.9	-	3.1	-	5.2	-	6.9	-	7.9	-	8.2	-	8.3	-	8.3	-	8.3	-
1	2	1.2	-	2.6	-	5.3	-	7.1	-	8.0	-	8.4	-	8.5	-	8.5	-	8.5	-
2	1	1.9	1.8	3.2	3.2	5.4	5.5	6.8	6.9	7.8	7.7	8.1	7.9	8.2	8.0	8.2	8.0	8.2	8.0
2	2	1.0	1.2	2.1	2.5	4.6	4.8	6.5	6.9	7.6	8.3	8.1	8.8	8.2	8.9	8.2	9.1	8.2	9.1
3	1	1.7	2.0	3.0	3.6	5.7	6.1	7.9	8.2	9.0	9.1	9.3	9.3	9.4	9.4	9.4	9.4	9.4	9.4
3	2	-	1.4	-	3.3	-	4.6	-	6.3	-	7.1	-	7.6	-	7.8	-	7.8	-	7.8
4	1	1.4	1.9	2.7	3.5	5.3	5.7	7.7	7.7	8.9	8.8	9.1	9.0	9.2	9.1	9.2	9.1	9.2	9.1
4	2	1.5	-	3.5	-	6.0	-	7.4	-	8.1	-	8.2	-	8.3	-	8.3	-	8.3	-
5	1	1.9	1.6	3.1	3.1	5.7	6.0	7.9	8.5	9.0	9.9	9.2	10.2	9.3	10.3	9.3	10.3	9.3	10.3
5	2	1.2	1.5	2.8	3.8	5.9	6.9	7.8	8.4	8.8	9.1	9.2	9.3	9.3	9.4	9.3	9.4	9.3	9.4

Table A-8. Navy-04 leaflets.

Plant No.	Leaf No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
1	1	1.9	1.7	3.2	2.8	5.3	4.3	7.0	6.0	8.1	7.1	8.4	7.5	8.5	7.7	8.5	7.8	8.5	7.8
1	2	1.1	1.5	2.2	3.0	4.6	5.1	6.3	6.4	7.4	7.1	8.0	7.3	8.1	7.5	8.1	7.7	8.1	7.7
2	1	1.8	1.1	3.2	2.0	5.3	3.9	6.9	6.1	7.8	7.6	8.0	8.6	8.1	9.0	8.1	9.2	8.1	9.2
2	2	1.3	1.8	3.0	4.3	5.8	6.6	7.4	7.8	8.3	8.6	8.9	9.1	9.1	9.2	9.1	9.2	9.1	9.2
3	1	1.8	1.7	3.2	3.3	5.4	6.0	7.0	8.0	7.9	9.2	8.2	9.6	8.3	9.7	8.3	9.7	8.3	9.7
3	2	1.3	-	2.8	2.8	5.3	5.8	6.7	8.2	7.6	9.2	8.3	9.5	8.5	9.8	8.5	10.0	8.5	10.0
4	1	-	1.3	2.4	2.4	4.2	4.7	6.4	6.6	7.8	7.7	8.7	8.2	9.0	8.4	9.1	8.5	9.1	8.5
4	2	1.7	1.2	4.0	2.5	6.7	5.3	8.2	7.2	9.1	8.5	9.7	9.3	9.8	9.5	9.8	9.7	9.8	9.7
5	1	1.0	1.7	2.1	2.9	3.8	5.5	6.1	7.0	7.6	8.3	8.5	8.8	8.8	9.0	8.9	9.1	8.9	9.1
5	2	1.1	1.8	2.3	4.3	4.7	6.6	6.6	7.8	7.9	8.6	8.6	9.1	8.8	9.2	8.8	9.2	8.8	9.2

Table A-9. Manitou and Charlevoix pods.

Variety	Plant No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Charlevoix	1	1.3	1.7	3.0	3.5	6.3	7.1	9.3	9.9	12.6	12.1	14.4	12.9	15.4	13.7	15.9	14.0	15.1	14.0
	2	1.7	1.7	3.3	3.3	6.1	6.1	7.9	9.5	9.8	12.1	11.0	13.1	11.6	14.0	11.8	14.4	11.8	14.4
	3	1.9	1.9	3.8	3.6	6.1	6.5	8.4	9.3	10.4	12.0	11.5	13.1	11.8	14.1	11.8	14.6	11.8	14.6
	4	1.3	1.8	3.0	3.6	5.2	6.5	7.2	9.3	9.5	11.4	11.3	12.1	12.4	12.7	12.6	13.0	12.6	13.0
Manitou	1	2.3	2.0	3.1	3.4	5.1	6.0	8.6	8.4	9.8	10.4	11.3	11.5	12.2	12.6	12.4	12.6	12.4	12.6
	2	2.2	1.8	4.7	3.8	7.2	6.0	9.2	9.2	10.8	10.8	11.9	11.8	12.2	13.2	12.4	13.2	12.4	13.2
	3	2.4	2.0	4.4	3.2	6.3	5.9	8.6	8.7	10.6	11.1	11.9	-	12.4	-	12.5	-	12.5	-
	4	2.2		3.2		5.3		7.7		9.7		11.6		12.9		13.2		13.2	
	5	2.3		3.8		6.4		8.7		10.4		11.3		12.2		12.2		12.2	

Table A-10. Swedish Brown and Cranberry 8247 pods.

Variety	Plant No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Cranberry 8247	1	1.5	1.8	2.8	3.1	4.1	5.0	6.1	6.7	8.1	8.4	9.3	9.2	9.5	9.8	9.5	10.1	9.5	10.1
	2	1.3	1.9	2.8	3.2	4.1	5.1	6.3	7.0	8.2	8.6	9.4	8.9	9.9	9.2	10.0	9.4	10.0	9.4
	3	1.6		3.0		4.6		6.2		7.7		8.9		9.6		9.9		9.9	
	4	1.3		2.7		5.1		7.4		9.4		10.6		11.4		11.6		11.6	
	5	1.9		3.2		4.8		7.0		8.6		9.6		9.9		10.0		10.0	
Swedish Brown	1	2.6	2.7	4.5	4.6	6.8	6.3	8.3	8.2	9.1	8.8	9.2	9.4	9.3	9.5	9.3	9.5	9.3	9.5
	2	2.2	2.3	3.9	4.1	5.3	5.9	7.2	7.3	8.2	8.3	8.9	8.5	9.1	8.6	9.1	8.6	9.1	8.6
	3	2.6	3.0	4.6	4.5	6.8	6.4	8.9	7.5	9.7	7.8	10.2	8.2	10.3	8.3	10.3	8.3	10.3	8.3
	4	2.7	2.9	4.5	4.6	6.6	6.2	8.6	7.8	9.2	8.3	9.5	8.8	9.5	8.9	9.5	8.9	9.5	8.9
	5	2.4		4.2		6.4		7.0		8.0		8.1		8.2		8.2		8.2	

Table A-11. Navy-01 and Navy-02 pods.

Variety	Plant No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Navy - 01	1	3.2	3.3	4.9	5.1	6.0	6.2	6.9	7.6	7.4	7.7	7.5	7.8	7.6	7.9	7.6	7.9	7.6	7.9
	2	3.6	3.4	5.5	5.2	7.1	5.9	7.8	6.8	8.4	6.9	8.5	7.0	8.6	7.1	8.6	7.1	8.6	7.1
	3	3.3	3.5	4.8	5.3	5.9	6.0	6.8	6.7	7.3	6.8	7.4	6.8	7.5	7.0	7.5	7.0	7.5	7.0
	4	3.0		4.5		5.7		7.0		7.6		7.7		7.8		7.8		7.8	
	5	3.1		4.7		5.9		6.5		6.8		6.9		7.0		7.0		7.0	
Navy - 02	1	2.9	3.2	4.6	4.7	6.7	5.8	8.0	7.6	8.6	8.1	8.9	8.2	8.9	8.3	8.9	8.3	8.9	8.3
	2	2.7	3.1	4.6	4.7	6.4	6.0	7.8	7.3	8.4	8.9	8.7	9.1	8.8	9.2	8.8	9.2	8.8	9.2
	3	3.0	3.2	4.7	4.6	5.9	5.9	7.4	7.0	8.4	8.0	8.6	8.1	8.7	8.2	8.7	8.2	8.7	8.2
	4	3.2	3.0	4.8	4.7	6.0	6.0	7.6	8.1	8.6	8.4	8.8	8.6	8.8	8.7	8.8	8.7	8.8	8.7
	5	2.7	3.2	4.5	5.3	6.4	6.0	7.7	7.0	8.4	7.2	8.5	7.3	8.5	7.4	8.5	7.4	8.5	7.4

Table A-12. Navy-03 and Navy-04 pods.

Variety	Plant No.	Time (day)																	
		0		2		4		6		8		10		12		14		16	
		R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Navy - 03	1	3.2	3.2	4.9	4.7	5.8	5.6	7.1	7.2	7.7	7.6	7.8	7.7	7.9	7.8	7.9	7.8	7.9	7.8
	2	3.2	3.5	4.7	5.0	6.7	6.1	7.7	7.8	8.6	8.2	9.0	8.3	9.1	8.4	9.1	8.4	9.1	8.4
	3	3.3	3.2	4.7	4.8	6.5	6.1	7.3	8.0	7.8	8.1	7.9	8.2	8.0	8.3	8.0	8.3	8.0	8.3
	4	3.2	3.3	4.9	4.6	6.8	5.7	7.7	7.5	7.9	8.4	8.0	8.6	8.0	8.7	8.0	8.7	8.0	8.7
	5	3.5	3.4	5.5	5.3	6.8	6.3	8.0	7.6	8.4	7.8	8.5	7.9	8.6	8.0	8.6	8.0	8.6	8.0
Navy - 04	1	1.7		3.0		5.2		7.1		8.0		8.2		8.3		8.3		8.3	
	2	1.8		3.6		5.7		7.2		8.0		8.2		8.2		8.2		8.2	
	3	1.7		3.4		5.7		7.1		7.9		8.0		8.1		8.1		8.1	
	4	1.3		2.8		5.0		7.0		7.8		8.2		8.3		8.3		8.3	

Appendix B

Values, by replication, of yield and yield-related characteristics.

Large leaf group: Charlevoix, Manitou, Michigan Improved Cranberry, Cranberry 8247, Swedish Brown

Medium leaf group: Yellow Eye, Great Northern, Merithew, Perry Marrow, Red Mexican

Small leaf group: Navy-01, Navy-02, Navy-03, Navy-04, Navy-05

X = Number of pods per one meter of plot.
Y = Number of seeds per pod.
Z = Single seed weight in grams.
W = Seed yield in grams per one meter of plot.
L = Leaflet length in centimeters.
B = Leaflet width in centimeters.
P = Pod length in centimeters.

Table B-1. Test 23, East Lansing.

Variety	Rep.	X	Y	Z	W	L	P
Charlevoix	1	85	3.55	.4441	134	11.73	13.5
	2	66	4.00	.4735	125	9.83	13.5
Manitou	1	100	3.25	.4862	158	12.24	12.3
	2	93	3.40	.5471	173	11.92	12.8
Michigan Improved Cranberry	1	104	3.25	.4320	146	10.01	10.6
	2	151	3.00	.4636	210	11.00	10.8
Cranberry 8247	1	116	3.50	.3842	156	11.05	10.4
	2	105	3.40	.4118	147	11.53	10.1
Swedish Brown	1	167	4.00	.3234	216	11.64	10.1
	2	116	3.50	.3744	152	10.98	8.6
Yellow Eye	1	109	4.05	.3760	166	12.51	10.3
	2	122	4.00	.3873	189	12.01	10.0
Great Northern	1	179	4.50	.2843	229	9.41	10.5
	2	167	4.65	.2820	219	10.02	10.8
Merithew	1	140	4.00	.2750	154	11.09	10.6
	2	142	4.55	.2430	157	11.49	10.6
Perry Marrow	1	137	3.80	.3150	164	8.97	10.1
	2	126	3.75	.2942	139	9.03	10.0

Table B-1 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	P
Navy - 01	1	285	4.50	.1146	147	8.09	7.9
	2	373	4.95	.1159	214	8.93	8.1
Navy - 02	1	245	5.05	.1568	194	8.74	8.7
	2	254	5.15	.1384	181	9.41	8.8
Navy - 03	1	319	5.00	.1404	224	8.60	8.6
	2	246	5.10	.1227	154	8.67	8.4
Navy - 04	1	214	4.95	.1293	137	8.77	8.1
	2	240	4.80	.1441	166	8.97	8.4
Navy - 05	1	248	5.20	.1279	165	8.93	7.3
	2	244	4.60	.1488	167	8.84	7.7

Table B-2. Test 24, Gratiot County.

Variety	Rep.	X	Y	Z	W	L	B	P
	1	75	4.30	.3411	110	11.90	9.54	11.1
Charlevoix	2	93	4.90	.3292	150	11.50	8.82	12.0
	3	111	4.95	.2512	138	11.80	10.08	11.3
	4	100	4.30	.3628	156	12.96	9.58	11.2
	1	76	4.05	.4191	129	12.72	9.92	11.3
Manitou	2	92	4.20	.4063	157	13.00	9.34	11.2
	3	89	4.30	.4547	174	13.12	10.00	10.9
	4	74	4.55	.3475	117	11.32	9.04	11.4
Michigan	1	98	3.70	.3447	125	9.22	7.32	8.3
Improved	2	135	4.20	.3316	188	10.34	7.76	8.6
Cranberry	3	180	3.75	.3467	234	11.50	8.32	7.8
	4	139	4.15	.3328	192	9.24	7.38	8.8
	1	133	4.10	.2861	156	12.46	9.60	8.8
Cranberry	2	103	3.35	.2753	95	11.16	9.40	8.1
8247	3	184	3.20	.3601	212	12.20	10.56	9.3
	4	159	4.00	.2596	163	10.56	8.12	9.8
	1	111	4.25	.3052	144	12.70	8.88	8.7
Swedish	2	102	3.70	.3233	122	11.68	9.22	8.7
Brown	3	113	4.70	.2957	157	11.72	9.38	9.0
	4	128	4.60	.3108	183	12.68	10.52	9.1

Table B-2 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
Yellow Eye	1	101	4.95	.2760	138	11.18	9.04	9.5
	2	90	5.20	.2692	126	11.50	8.06	9.3
	3	95	4.55	.3008	130	12.24	9.04	8.8
	4	103	4.60	.3039	144	11.10	8.46	9.2
Great Northern	1	136	6.50	.1912	169	9.72	7.68	10.7
	2	153	5.60	.1926	165	9.52	8.12	9.4
	3	114	5.70	.2355	153	9.22	7.78	9.8
	4	168	5.60	.2338	220	9.98	8.28	9.7
Merithew	1	175	4.90	.1644	141	10.44	8.16	9.4
	2	169	5.15	.1792	156	11.16	9.10	10.0
	3	154	4.25	.2108	138	10.56	8.76	9.0
	4	192	4.00	.2135	164	11.02	8.90	9.5
Perry Marrow	1	106	4.60	.2584	126	9.34	8.08	9.7
	2	130	4.35	.2140	121	9.18	8.20	9.5
	3	209	4.60	.2268	218	10.64	9.40	9.5
	4	98	4.25	.2617	109	9.50	8.70	9.4
Red Mexican	1	135	5.00	.1556	105	8.58	7.20	8.8
	2	138	5.05	.2353	164	8.44	7.06	8.3
	3	184	5.10	.2312	217	10.04	8.54	8.5
	4	127	5.10	.2023	131	7.74	6.44	8.5

Table B-2 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
	1	238	5.15	.0922	113	8.34	6.54	7.2
Navy - 01	2	187	5.45	.0834	85	8.40	6.88	7.2
	3	166	5.40	.0814	73	7.96	6.82	7.0
	4	372	4.25	.1271	201	10.02	8.10	6.8
	1	247	5.20	.1098	141	8.95	7.15	8.3
Navy - 02	2	259	5.30	.1020	140	9.40	8.00	8.1
	3	341	5.10	.1219	212	9.34	7.34	8.4
	1	189	5.80	.0930	102	8.06	6.48	7.5
Navy - 03	2	184	5.35	.0853	84	8.86	6.86	7.7
	3	197	5.45	.0913	98	9.14	7.46	7.7
	4	230	5.10	.1014	119	9.14	7.66	8.2
	1	274	5.15	.1176	166	9.78	7.50	7.7
Navy - 04	2	206	5.60	.1075	124	9.94	7.64	7.7
	3	226	5.35	.0926	112	8.84	6.98	8.4
	4	232	6.20	.0820	118	8.60	7.04	7.6
	1	208	5.00	.1221	127	9.20	7.70	6.7
Navy - 05	2	253	5.60	.1172	166	9.02	7.52	7.7
	3	260	5.35	.0906	126	9.00	7.20	7.7

Table B-3. Test 25A, Gratiot County.

Variety	Rep.	X	Y	Z	W	L	B	P
Charlevoix	1	78	5.35	.2924	122	10.52	8.36	12.6
	2	74	4.35	.2982	96	10.32	8.48	11.4
	3	77	4.65	.3966	142	11.48	8.94	12.3
	4	90	4.20	.3624	137	10.66	8.28	11.5
Manitou	1	67	4.90	.3168	104	10.92	8.94	11.4
	2	121	4.25	.3734	192	10.56	7.60	11.8
	3	102	4.15	.4063	172	12.04	9.70	11.7
	4	86	4.50	.4186	162	11.80	8.88	11.9
Michigan Improved Cranberry	1	108	3.40	.3649	134	9.04	6.82	7.9
	2	102	4.05	.2953	122	8.12	6.54	8.5
	3	123	4.20	.3136	162	9.82	7.18	8.8
	4	139	2.95	.4268	175	8.46	7.24	8.5
Cranberry 8247	1	148	4.00	.1926	114	10.76	9.54	9.0
	2	132	4.45	.2554	150	11.38	10.20	9.8
	3	118	4.45	.2780	146	9.90	8.82	9.6
	4	108	4.10	.3794	168	11.64	9.30	9.7
Swedish Brown	1					11.18	8.46	
	2	119	4.10	.3054	149	10.90	8.44	8.3
	3	110	4.05	.3075	137	10.70	9.34	8.2
	4	110	3.75	.3103	128	11.38	8.74	7.8

Table B-3 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
Yellow Eye	1	96	4.35	.2514	105	9.38	7.32	8.3
	2	98	4.95	.2371	115	10.74	8.28	9.0
	3	106	4.90	.2638	137	11.20	8.84	8.8
	4	131	4.20	.2781	153	10.94	8.00	8.1
Great Northern	1	121	5.40	.1714	112	8.34	7.12	9.1
	2	112	5.85	.1480	97	8.12	7.28	9.4
	3	142	5.70	.2335	189	9.38	7.96	8.6
	4	157	5.60	.2104	185	10.00	8.90	8.6
Merithew	1	136	4.15	.1984	112	9.40	8.68	8.8
	2	227	4.00	.1971	179	10.76	9.10	9.3
	3	154	5.15	.2307	183	10.86	9.12	9.3
	4	160	4.25	.2176	148	9.88	8.76	8.6
Perry Marrow	1	108	4.75	.2203	113	8.72	7.54	9.6
	2	118	4.40	.2619	136	8.82	7.76	9.2
	3	178	4.55	.2482	201	8.60	8.78	9.4
	4	120	4.20	.2401	121	9.88	8.88	9.1
Red Mexican	1	125	4.55	.2286	130	7.92	6.72	8.2
	2	131	5.30	.1700	118	8.02	7.08	8.4
	3	227	4.60	.2078	217	8.20	7.64	8.1
	4	149	5.25	.1969	154	8.04	7.32	8.4

Table B-3 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
Navy - 01	1	185	4.95	.0841	77	7.56	6.38	6.7
	2	220	5.60	.0820	101	7.50	6.20	7.2
	3	323	4.60	.1137	169	8.80	7.36	6.7
	4	281	5.05	.0712	101	8.32	7.50	6.8
Navy - 02	1	156	5.50	.1084	93	8.12	6.72	7.9
	2	236	5.45	.1026	132	9.06	7.76	7.4
	3	242	4.90	.1214	144	9.30	7.86	7.9
	4	243	5.00	.1374	167	9.96	7.94	6.4
Navy - 03	1	128	6.00	.0794	61	7.88	6.32	7.5
	2	236	5.40	.0949	121	8.70	6.88	7.6
	3	230	5.10	.1228	144	8.76	6.86	7.2
	4	231	5.35	.1044	129	9.96	8.04	7.8
Navy - 04	1	206	5.30	.0934	102	9.28	7.88	7.4
	2	165	6.00	.0889	88	8.36	6.64	7.4
	3	276	5.30	.1039	152	9.84	7.64	8.0
	4	215	5.40	.1068	124	9.44	7.66	7.6
Navy - 05	1	248	6.25	.0903	140	8.08	6.66	6.9
	2	211	5.30	.1082	121	8.24	7.10	6.5
	3	241	5.40	.1322	172	7.88	7.02	6.8
	4	204	5.55	.1025	116	8.40	6.62	7.5

Table B-4. Test 25B, Gratiot County.

Variety	Rep.	X	Y	Z	W	L	B	P
	3A	84	3.90	.4121	135	11.48	8,94	10.3
Charlevoix	3B	76	4.65	.3594	127	11.48	8.94	12.4
	4A	81	4.15	.2737	92	10.66	8.28	11.7
	4B	64	5.45	.2985	104	10.66	8.28	12.5
	3A	71	4.10	.4328	126	12.04	9.70	11.4
Manitou	3B	66	3.95	.4526	118	12.04	9.70	11,7
	4A	65	4.00	.4385	114	11.80	8.88	11.3
	4B	48	4.25	.4412	90	11.80	8.88	11.7
Michigan	3A	82	3.80	.3113	97	9.82	7.18	8.4
Improved	3B	106	3.80	.3401	137	9.82	7.18	8.9
Cranberry	4A	-	-	-	-	8,46	7.24	-
	4B	89	4.55	.2914	118	8.46	7.24	10.0
	3A	101	4.00	.3267	132	9.90	8.82	9.3
Cranberry	3B	110	4.35	.2564	127	9,90	8.82	9.7
8247	4A	107	4.35	.2621	122	11,64	9.30	9.8
	4B	92	4.75	.2838	124	11.64	9.30	10.3
	3A	105	4.80	.2837	143	10.70	9.34	8.1
Swedish	3B	110	4.25	.3016	141	10.70	9.34	8.4
Brown	4A	94	4.30	.2845	115	11.38	8.74	9.1
	4B	99	3.60	.2862	102	11.38	8.74	8.2

Table B-4 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
Yellow Eye	3A	101	4.80	.2702	131	11.20	8.84	9.0
	3B	108	4.90	.2759	146	11.20	8.84	8.9
	4A	79	4.60	.2889	105	10.94	8.00	9.3
	4B	102	4.30	.2668	117	10.94	8.00	8.2
Great Northern	3A	130	6.10	.1740	138	9.38	7.96	9.8
	3B	130	6.06	.1373	108	9.38	7.96	10.1
	4A	94	5.65	.2146	114	10.00	8.90	9.5
	4B	102	5.35	.1942	106	10.00	8.90	10.2
Merithew	3A	152	4.70	.2044	146	10.86	9.12	9.6
	3B	157	4.30	.2089	141	10.86	9.12	9.5
	4A	115	4.80	.1884	104	9.88	8.76	9.5
	4B	118	4.80	.2048	116	9.88	8.76	9.5
Perry Marrow	3A	138	4.10	.3005	170	8.60	8.78	9.6
	3B	110	4.50	.2869	142	8.60	8.78	9.4
	4A	63	3.60	.2778	63	9.88	8.88	8.2
	4B	68	3.90	.2715	72	9.88	8.88	8.5
Red Mexican	3A	151	4.65	.1894	133	8.20	7.64	7.5
	3B	146	5.05	.1926	142	8.20	7.64	8.6
	4A	79	5.10	.1812	73	8.04	7.32	8.3
	4B	84	4.10	.2236	77	8.04	7.32	8.0

Table B-4 (Cont'd.)

Variety	Rep.	X	Y	Z	W	L	B	P
Navy - 01	3A	188	5.50	.0890	92	8.80	7.36	7.0
	3B	153	5.25	.0921	74	8.80	7.36	7.1
	4A	189	6.30	.0705	84	8.32	7.50	7.7
	4B	159	5.30	.0783	66	8.32	7.50	7.1
Navy - 02	3A	195	6.15	.0859	103	9.30	7.86	8.5
	3B	209	5.30	.1065	118	9.30	7.86	8.8
	4A	143	6.00	.1096	94	9.96	7.94	7.9
	4B	116	5.50	.1082	69	9.96	7.94	6.7
Navy - 03	3A	188	5.50	.1006	104	8.76	6.86	8.0
	3B	154	5.45	.1048	88	8.76	6.86	7.7
	4A	144	5.60	.0980	79	9.96	8.04	8.2
	4B	134	5.25	.0981	69	9.96	8.04	8.1
Navy - 04	3A	181	5.35	.0898	87	9.84	7.64	7.6
	3B	188	5.90	.0875	97	9.84	7.64	8.2
	4A	127	5.60	.1069	76	9.44	7.66	8.0
	4B	110	4.90	.0946	51	9.44	7.66	7.6
Navy - 05	3A	201	5.60	.1066	120	7.88	7.02	7.0
	3B	239	5.55	.0973	129	7.88	7.02	7.2
	4A	150	5.30	.0956	76	8.40	6.62	7.6
	4B	143	4.80	.0962	66	8.40	6.62	7.5