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EFFECTS OF MAXIMUM TEMPERATURE AND AGE ON FLOWERING AND SEED PRODUCTION IN THREE BEAN VARIETIES

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Statistical studies on five bean varieties, California Red, Sutter Pink, Pinto, Red Kidney, and Small White, planted at 2-week intervals from late May to late July over a four-year period indicated that yields increased up to mid-June, remained high through mid-July, and then declined in late July for four of the five varieties. The exception was Small White which did not mature in the mid-July planting some years and never in late-July plantings. Significant differences were obtained in varietal yields.

Correlation studies of data from tagged flowers on three varieties over a three-year period were made.

Significant positive correlations were obtained between per cent set and beans per pod in all varieties.

Significant negative correlations were obtained between age of plants and per cent set, and age of plants and beans per pod in all varieties.

Significant negative correlations were obtained between per cent set and maximum temperatures the day before, the day of, and the day after bloom in Small White and Sutter Pink. In California Red these correlations were too low to be significant.

The negative correlations between maximum temperature and beans per pod were smaller than between maximum temperature and per cent set, and only in Sutter Pink were they significant. Beans per pod in California Red were not affected by temperature.

California Red gave the highest yields, highest per cent set and highest beans per pod. In all three measures Sutter Pink ranked second and Small White third.

Advancing age of plants was more effective in reducing per cent set than were increasing temperatures.

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EFFECTS OF MAXIMUM TEMPERATURE AND AGE ON FLOWERING AND SEED PRODUCTION IN THREE BEAN VARIETIES[1]

FRANCIS L. SMITH[2] and RICHARD H. PRYOR[3]

THERE IS A general feeling among bean growers that high temperatures at blooming time have a deleterious effect on flower set and seed production. This has been shown to be the case in some experimental studies (Davis, 1945; Lambeth, 1950; Van Shank and Probst, 1958; and Wolf, 1942). In the present study, the effects of temperature and age were correlated with per cent set and beans per pod. Data were taken over a period of about 4 months for three years.

REVIEW OF LITERATURE

In field experiments with white pea beans in Michigan, Davis (1945) studied the effect of maximum temperature on per cent set. He used the average maximum for the day of bloom and the day after. The simple correlation of per cent set versus maximum temperature was –.5962. The r value for maximum temperature versus relative humidity was –.4664; for per cent set versus relative humidity the r value was .4653. With relative humidity held constant, the correlation of per cent set and temperature was –.5192, but with temperature held constant the correlation of per cent set versus relative humidity was .2523, which was not significant. The regression equation indicated that approximately 57 per cent of the blossoms set seed if the maximum temperature did not exceed 75° F. For each degree above 75 there was a reduction of approximately 2 per cent in set of pods. Davis found no consistent annual response of field beans to fertilizer treatment and attributed this largely to the overpowering effect of high temperatures during the flowering period. The relationship of yields and leaf areas was not consistent. Van Shank and Probst (1958) concluded from studies with soybeans in climatically controlled chambers that day temperature is the first factor in limiting flower formation, and not until it is sufficiently high does the night temperature exert a limiting effect. In field tests a relationship existed between rising temperatures and increased shedding of the flowers. Lambeth (1950) in Missouri studied the effect of mean daily temperature and mean

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daily humidity on per cent set of Tendergreen snap beans with nitrogen levels of 80, 180, and 380 pounds per acre. The correlation between per cent set and mean daily temperature at the 80-pound level was –.6241, at 180 pounds it was –.5728, and at 380 pounds it was –.3699. The first correlation is significant at the 1 per cent level, the second at the 5 per cent level and the third is not significant. The correlations between per cent set and average daily humidity were positive but were too low to be statistically significant. In a comparison of seed set of lima bean varieties, Lambeth (1950) found Henderson Bush was more adaptable to environmental factors than Fordhook 242. Wolf (1942) compared plants of poor and good set of seed in Henderson Bush. He analyzed the soil in the area where the plants were grown. Good seed set was associated with higher concentrations of available calcium and nitrate nitrogen in the main stem.

METHODS

Yields. The flowering studies reported in this paper were made on bean plants in a date-of-planting experiment extending over a four-year period. Five varieties of common beans, California Red, Sutter Pink, Pinto, Red Kidney, and Small White, were planted at 2-week intervals from early May to late July. At each of the eight dates, the five varieties were planted in 4-row plots 30 feet long, and replicated six times. Yields were taken from the two center rows.

Flower Tagging. The flowers on the plants in the guard rows were tagged by tying a piece of red yarn about 5 inches long on the pedicel of the open flower. The first flowers that appeared on the first planting were tagged in one replication. The next date another replication was used. The schedule of sampling was twice each week at 3- and 4-day intervals in 1958 and 1959. In 1960, the samples were made three times a week at 2-, 2-, and 3-day intervals. Since there were twelve guard rows of each variety at each planting, twelve samples could be taken. If more than twelve flower samples were taken, another color of string was used in rows which had been sampled earlier. The lower limit of a sample was 20 flowers and the upper was 100. A recording thermometer was installed with the bulb about 9 inches from the soil surface; it was protected from direct sunlight by strips of boards. For the statistical studies, the maximum temperature the day before bloom, the day of bloom, and the day after bloom was taken from the recorded disks for each flower-sampling date. Two varieties, California Red and Small White, were sampled in 1958 because they represented the most and least productive of the five varieties. In 1959 and 1960, Sutter Pink was included in flower studies.

DEFINITIONS OF TERMS

Per cent set (F) was determined by dividing the number of tagged pods that matured in each sample by the number of flowers that were tagged.

Beans/pod (S) was determined by dividing the number of mature seeds obtained from the tagged pods by the number of pods.

Age (A). Since there was a great variation in the age of plants when the first flowers appeared in different varieties, in different plantings, and in different years, the date of the first flowers tagged on a given variety and planting date was considered as the first day and this date was subtracted from the date of all later samples from this planting to give the age. In 1958 the samples were obtained as long as 53 days after first flower in Small White and 64 days after first flower in California Red. In 1959 the oldest sample was 89 days after first flower in Small White, 53 days in California Red, and 57 days in Sutter Pink. In 1960, the late samplings were eliminated; the oldest flowers sampled were 41 days after first flower in Small White, 27 days in California Red, and 31 days in Sutter Pink.

Maximum Temperature. In this study, three maximum temperatures of each sampling day were used. The maximum temperatures were for the day before bloom (T_1), the day of bloom (T_2), and the day after bloom (T_3).

The data of each flower sample were set up in tables with the variety, the year, the age, the per cent set and the beans per pod. Three arrangements of the data were made to get the corresponding maximum temperatures for the day before bloom, the day of bloom, and the day after bloom. Correlations were calculated for each variety and each year. In 1958 there were 83 samples of Small White and 85 of California Red. In 1959 there were 61 Small White, 45 California Red, and 75 Sutter Pink dated flower samples. In 1960 there were 124 flower samples of Small White, 133 of California Red, and 148 of Sutter Pink. In this report all data from all years were combined for each of the three varieties.

RESULTS

Yield. The essential features of the yield data were summarized in an article in *California Agriculture* (Smith and Pryor, 1961). The analysis of variance made of five varieties, six replications, and eight plantings per season for four years showed that F values exceeded the 1 per cent level for every variable and for all the interactions except those involving replications.

In figure 1 the four-year average yields, expressed in pounds per acre, of the five varieties at each planting date are shown graphically. California Red consistently yielded higher than the other varieties while the Small White yield was lowest. The graph also shows that increases in yields expressed in pounds per acre were obtained for four varieties with each succeeding planting from early May until mid-June. There was a high plateau between mid-June and mid-July. The plantings made in the latter part of July yielded less. The July plantings of Small White failed to mature seed in some years. The maximum yields were made on plantings between mid-May and mid-June. The average yields for all varieties and all plantings were 2,035 pounds per acre in 1955, 1,673 in 1956, 2,000 in 1958, and only 996 in 1959. A study of the temperature records showed that in 1959 the maximum temperatures were higher than normal from June 15 to July 31. It is thought that the poor yields obtained in the first five planting dates that year were associated with the high temperatures that occurred in this 6-week period.

Length of Prebloom Stage. The average number of days in the prebloom stage showed remarkable varietal differences based on three years' data.

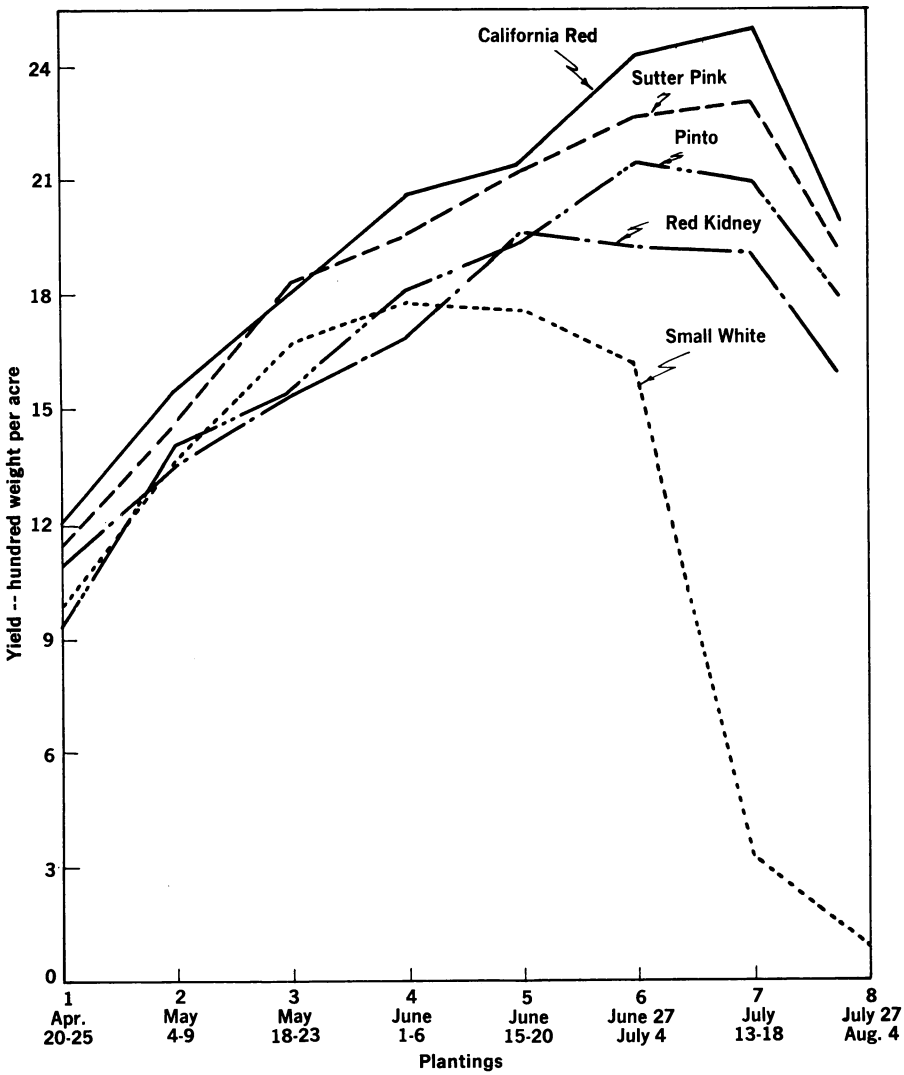

Figure 1. Four-year yield record of five varieties at eight planting dates.

Small White required 57.2, California Red 53.2, and Sutter Pink 40.0 days from planting to the appearance of enough flowers for an adequate sample.

A study of the length of the prebloom stage in the different plantings was made. Only 22 to 27 samples were available for each variety. Correlations were calculated between planting date and the number of days required to bloom. The data indicate that each year the preblooming period in California Red was reduced in the later plantings. In Small White the length of the prebloom stage was not affected by planting date. In the two-year study with Sutter Pink, the length of the prebloom stage was only slightly reduced by later planting dates.

Correlations Between Per Cent Set (F) vs. Beans per Pod (S). Simple correlations were calculated between per cent set (F) and the number of beans per pod (S). The correlations of the three varieties are as shown in table 1.

California Red is more efficient in the per cent of flowers set and the number of seed produced. Small White is the least efficient. The relationship of these two measures of production is shown in the high correlations, all significant at the 1 per cent level. These are illustrated graphically in figure 2 in which the regression lines are drawn for each variety. In the regression lines the mean of the two variables is indicated by a triangle. Although the correlation is not as high for Small White as for California Red, the rate of change in the regression line of $\hat{S}$, in relation to F is much more pronounced. Between the ranges of 10 and 50 per cent set, California

TABLE 1

CORRELATIONS OF PER CENT SET (F) AND BEANS PER POD (S)

Variety	Number of samples	$\bar{f}$	$\bar{s}$	r_{FS}	Regression equation of $\hat{S}$
Small White	268	21.79	3.08	.4369**	$2.30 + .0359_F$
California Red	263	34.48	3.58	.4557**	$2.90 + .0198_F$
Sutter Pink	223	31.85	3.24	.4327**	$2.67 + .0180_F$
LSD 5 per cent		3.29	.17		
LSD 1 per cent		4.34	.23		

Red increased the beans per pod from 3.1 to 3.7, Sutter Pink from 2.7 to 3.4, and Small White from 2.6 to 3.9. These correlations and regression lines indicate that the factors which influence per cent set also influence beans per pod. By comparing the yields shown in figure 1 with the data on per cent set and beans per pod in table 1, it is evident that California Red is the most efficient in all three measures, Sutter Pink next, and Small White is the least efficient.

Correlations of Age of Plants (A) versus Per Cent Set (F). The observation that flowers appearing on older plants usually had a very low per cent set led to correlation studies between age of plants and per cent set. Age, as indicated above, is defined as the number of days from the appearance of first flowers. The correlations of age versus per cent set for the three varieties are shown in table 2.

The correlations are all negative and highly significant. The regression lines (figure 3) indicate that Small White produces fertile flowers over a longer period than the other varieties, and Sutter Pink has the shortest period of productive bloom. The first flowers of California Red had 45 per cent set, while 40 days later they had only 19 per cent. In Sutter Pink the two values were 43 and 10, and in Small White they were 29 and 12.

Correlation of Age of Plants versus Beans per Pod. The effect of age on beans per pod is shown in table 3. These correlations are also all negative and highly significant. The regression lines of age versus beans per pod are shown in figure 4. The regression line indicates that the first flowers of California Red produced 3.8 beans per pod, while those which appeared 40 days

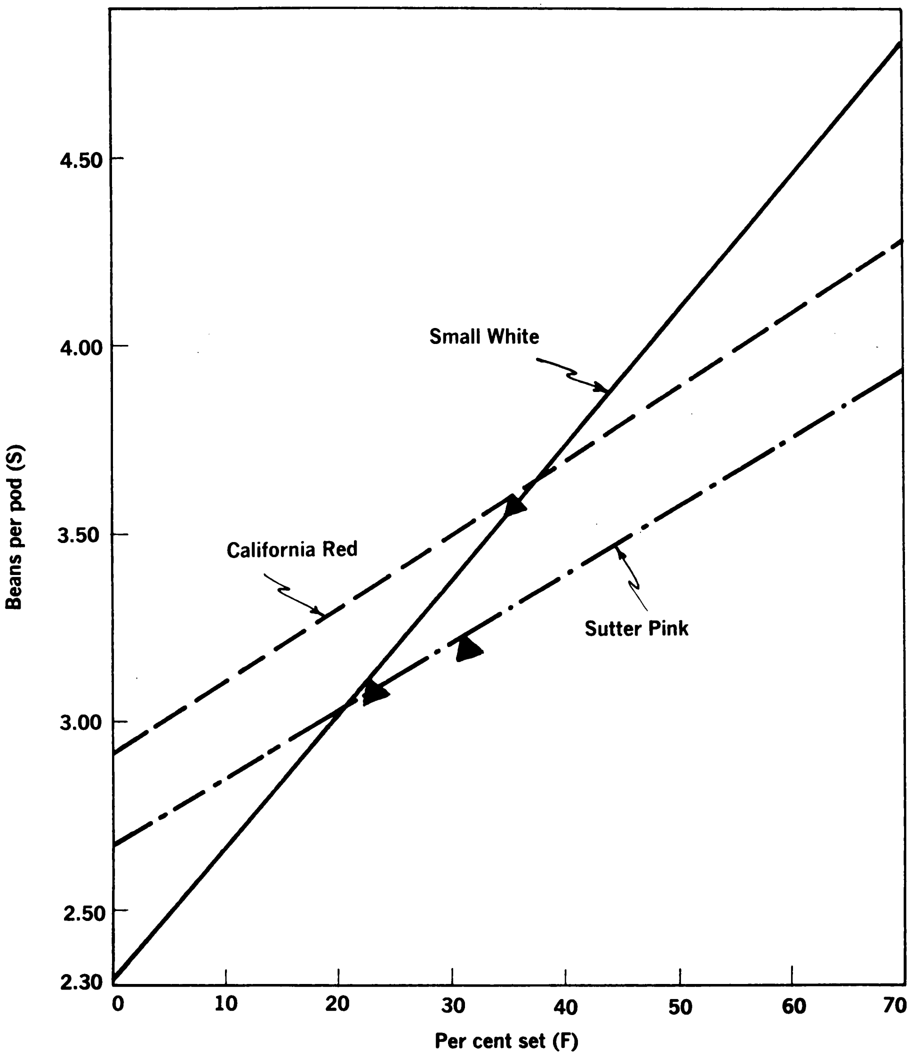

Figure 2. Regressions of per cent set versus beans per pod for three varieties.

TABLE 2

EFFECT OF AGE† ON PER CENT SET‡

(correlations and regressions)

Variety	Number of samples	$\bar{a}$	$\bar{f}$	r_{AF}	Regression equations of $\hat{F}$
Small White	268	19.75	21.79	−.3606**	29.97 − .4140$_A$
California Red	263	16.30	34.48	−.4122**	45.27 − .6617$_A$
Sutter Pink	223	15.43	31.85	−.4735**	44.49 − .8191$_A$
LSD 5 per cent		2.25	3.29		
LSD 1 per cent		2.96	4.24		

† A = age.
‡ F = per cent set.

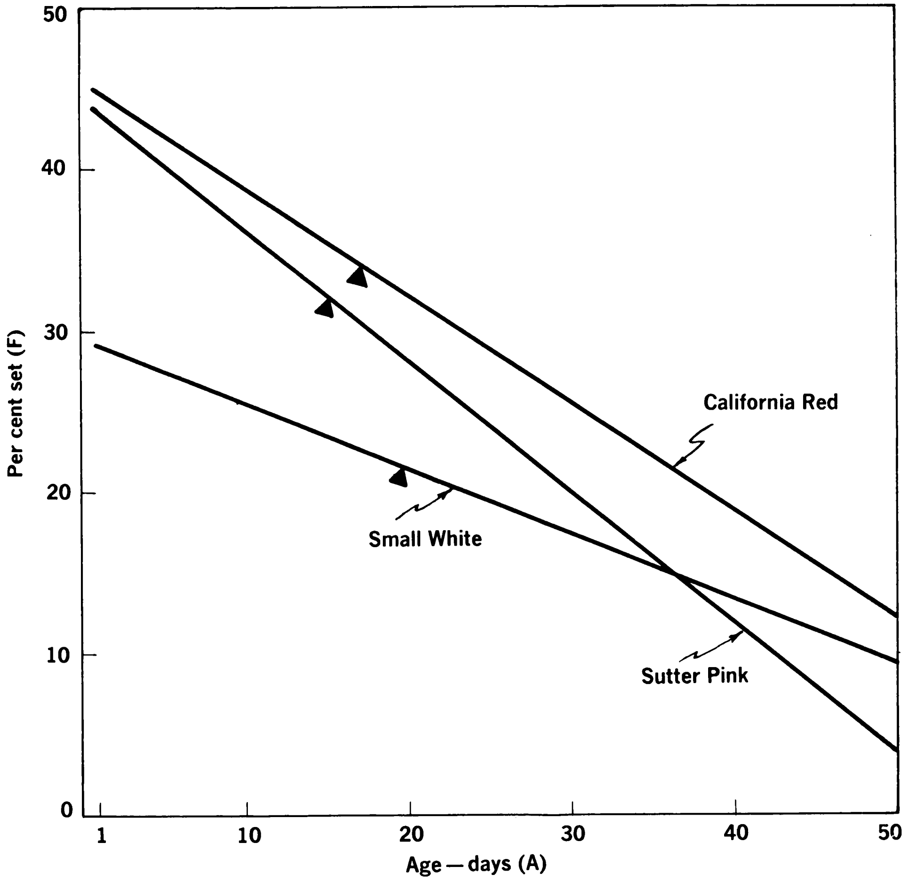

Figure 3. Regressions of age versus per cent set for three varieties.

TABLE 3

EFFECT OF AGE† ON BEANS PER POD‡

(correlations and regressions)

Variety	r_{AS}	Regression equation of $\hat{S}$
Small White	−.3991**	3.74 − .0332$_A$
California Red	−.3079**	3.93 − .0214$_A$
Sutter Pink	−.3392**	3.61 − .0243$_A$

† A = age.
‡ S = beans per pod.

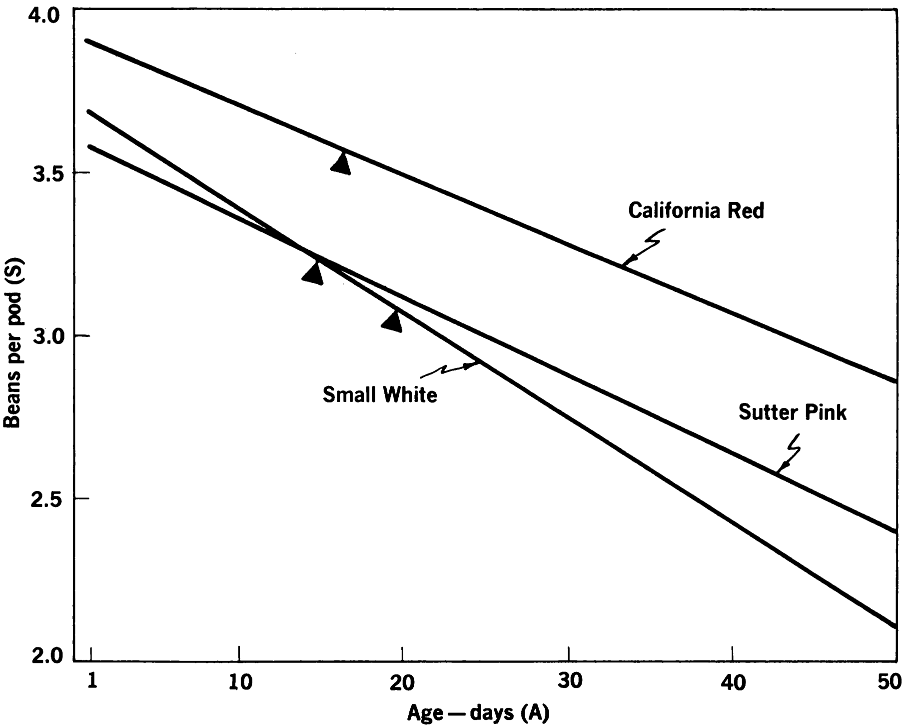

Figure 4. Regressions of age versus beans per pod for three varieties.

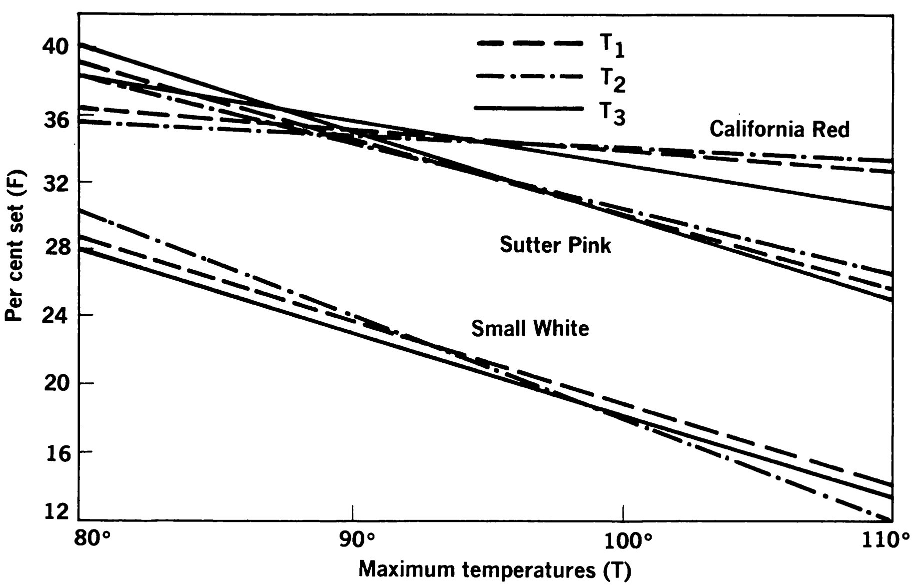

Figure 5. Regressions of maximum temperature versus per cent set for three varieties.

later had only 3.0. In Sutter Pink the values for the two ages were 3.7 and 2.8 beans per pod, and in Small White they were 3.6 and 2.4. These studies indicate that the flowers which appear first have a greater chance of survival to maturity and produce more beans per pod than those which appear later.

Correlations of Maximum Temperature (T) versus Per Cent Set (F). Correlations were calculated to study the effects of maximum temperature on the fruiting of the varieties. Three correlations were calculated for each variety: maximum temperature of day before bloom (T_1), maximum temperature for day of bloom (T_2), and maximum temperature day after bloom (T_3) with per cent set (F). The data for the three years are summarized in table 4.

TABLE 4
EFFECT OF MAXIMUM TEMPERATURE† ON PER CENT SET‡
(correlations and regressions)

Temperatures	Varieties		
	Small White	California Red	Sutter Pink
Day before bloom r_{T_1F}	−.2910**	−.0464	−.1951**
Regression of $\hat{F}$	67.24 − .4831T_1	45.72 − .1190T_1	74.83 − .4455T_1
Day of bloom r_{T_2F}	−.3439**	−.0437	−.1824**
Regression of $\hat{F}$	76.68 − .6064T_2	43.80 − .0989T_2	69.04 − .3861T_2
Day after bloom r_{T_3F}	−.2141**	−.1200	−.2247**
Regression of $\hat{F}$	62.18 − .4275T_3	62.46 − .2949T_3	79.97 − .4967T_3

† T_1 = day before bloom; T_2 = day of bloom; T_3 = day after bloom.
‡ F = per cent set.

These correlations indicate that high temperatures at blooming time reduce per cent set.

The effect of maximum temperature on all three days was significant on Small White and Sutter Pink but not on California Red. The regressions are shown graphically in figure 5. The regression lines show that between 80° and 110° F on the day of bloom (T_2) the per cent set in California Red was reduced from 36 to 33, in Sutter Pink from 38 to 27, and in Small White from 30 to 12. The regression lines of $\hat{S}$ and T_1 and T_3 show approximately the same trends.

The range of maximum temperature for the sampling days was 76° to 114° F in 1958, 70° to 116° F in 1959, and 78° to 110° F in 1960.

Correlations of Maximum Temperature (T) versus Beans per Pod (S). Correlations were calculated for temperature versus beans per pod. The results are summarized in table 5.

The correlations of temperature with beans per pod were much lower than with per cent set. The only significant correlations were with Sutter Pink. The effect of temperature on California Red was very slight and for all three dates the correlations were positive. The regressions of temperature versus beans per pod are shown graphically in figure 6. For the day of bloom (T_2), California Red produced 3.41 beans per pod at 80° F and 3.75 at

TABLE 5

EFFECT OF MAXIMUM TEMPERATURE† ON BEANS PER POD‡

(correlations and regressions)

Temperatures	Varieties		
	Small White	California Red	Sutter Pink
Day before bloom $r_{T_1 S}$	$-.0504$	$.1103$	$-.1533$*
Regression of $\hat{S}$	$3.65 - .0061T_1$	$2.42 + .0123T_1$	$4.64 - .0145T_1$
Day of bloom $r_{T_2 S}$	$-.0865$	$.1140$	$-.1736$**
Regression of $\hat{S}$	$4.11 - .0110T_2$	$2.52 + .0112T_2$	$4.76 - .0157T_2$
Day after bloom $r_{T_3 S}$	$-.0087$	$.0756$	$-.2681$**
Regression of $\hat{S}$	$3.21 - .0014T_3$	$2.81 + .0081T_3$	$5.64 - .0248T_3$

† T_1 = day before bloom; T_2 = day of bloom; T_3 = day after bloom.
‡ S = beans per pod.

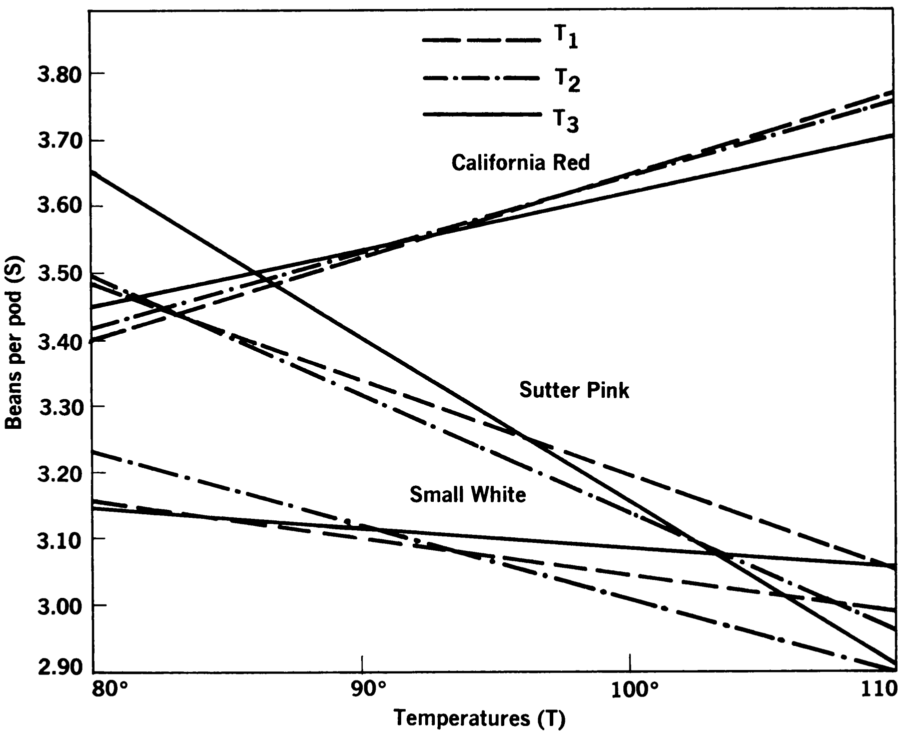

Figure 6. Regressions of maximum temperature versus beans per pod for three varieties.

110° F. Small White was reduced from 3.22 to 2.90. Sutter Pink, the only one which showed significant correlations, was reduced from 3.50 to 2.97. The regressions of $\hat{S}$ with T_1 and T_3 were similar.

Partial Correlations. An effort was made to study the effects of temperature with age constant, and age with temperature constant on per cent set and beans per pod. This was done by using partial correlation methods described in a textbook on statistical methods (Snedecor, 1956). The correlations of age with temperature constant were $r_{A\,F.T}$ and $r_{A\,S.T}$. The correlations of temperature with age held constant were $r_{T\,F.A}$ and $r_{T\,S.A}$. Partial correlations for the three temperatures with age, per cent set, and beans per pod are given in table 6. The partial correlations $r_{A\,F.T}$ are higher for Small

TABLE 6

PARTIAL CORRELATIONS OF $r_{A\,F.T}$, $r_{T\,F.A}$, $r_{A\,S.T}$ AND $r_{T\,S.A}$

Item	Varieties		
	Small White	California Red	Sutter Pink
$r_{A\,F.T_1}$ †	−.4035**	−.4106**	−.4629**
$r_{A\,F.T_2}$ ‡	−.4065**	−.4133**	−.4687**
$r_{A\,F.T_3}$ §	−.3856**	−.4169**	−.4906**
$r_{T_1\,F.A}$	−.3451**	.0226	−.1699*
$r_{T_2\,F.A}$	−.3922**	−.0317	−.1662*
$r_{T_3\,F.A}$	−.2574**	−.1382	−.2143**
$r_{A\,S.T_1}$	−.3972**	−.2957**	−.3623**
$r_{A\,S.T_2}$	−.4319**	−.3060**	−.3319**
$r_{A\,S.T_3}$	−.4069**	−.3079**	−.3239**
$r_{T_1\,S.A}$	−.0772	.0644	−.1346*
$r_{T_2\,S.A}$	−.1203	.1082	−.1573*
$r_{T_3\,S.A}$	−.0402	.0748	−.2474**

† Day before bloom.
‡ Day of bloom.
§ Day after bloom.

White than the simple correlations shown in table 2. They are not appreciably changed for the other varieties. The partial correlations $r_{A\,S.T}$ showed the same effect. The partial correlations $r_{T\,F.A}$ for Small White were larger than the simple $r_{T\,F}$ correlations shown in table 4. The insignificant correlations of $r_{T\,F}$ of California Red were not changed much in the partial correlations $r_{T\,F.A}$. In Sutter Pink, however, all the partial correlations $r_{T\,F.A}$ were lower than the simple ones. The partial correlations $r_{T\,S.A}$ shown in table 6 were slightly higher for Small White than the simple correlations $r_{T\,S}$ shown in table 5. The $r_{T\,S.A}$ values for the other varieties are slightly lower than the simple correlations $r_{T\,S}$.

The maximum temperature had more effect on per cent set than on beans per pod. Varietal differences were demonstrated. In all varieties age had a marked influence on both per cent set and beans per pod.

TABLE 7
PARTIAL REGRESSION EQUATIONS

Variety equation	Day before bloom	Day of bloom	Day after bloom
Per cent set ($\hat{F}$)			
Small White	$70.54 - .4365T_1 - .3891_A$	$83.11 - .5710T_2 - .3922_A$	$65.36 - .3779T_3 - .3985_A$
California Red	$54.87 - .1019T_1 - .6607_A$	$51.45 - .0659T_2 - .6600_A$	$71.83 - .2805T_3 - .6589_A$
Sutter Pink	$76.58 - .3442T_1 - .7466_A$	$75.49 - .3250T_2 - .7995_A$	$81.58 - .3881T_3 - .7862_A$
Beans per pod ($\hat{S}$)			
Small White	$4.70 - .0101T_1 - .0338_A$	$5.07 - .0141T_2 - .0338_A$	$4.25 - .0054T_3 - .0334_A$
California Red	$2.73 + .0128T_1 - .0216_A$	$2.76 + .0123T_2 - .0211_A$	$3.21 + .0076T_3 - .0215_A$
Sutter Pink	$4.71 - .0115T_1 - .0235_A$	$4.90 - .0136T_2 - .0227_A$	$5.69 - .0215T_3 - .0240_A$

From the data it was possible to calculate three-dimensional regression planes. The equations for these are given in table 7. The first part of the table gives the equations for per cent set for the three varieties, the second part the equations for beans per pod. Of the 18 equations presented in table 7, six were drawn on three-dimensional graphs. These are for per cent set and beans per pod for each of the three varieties with the maximum temperature the day of bloom. These graphs are shown in figures 7 to 12. The target on each graph represents the intersections of the means of the three variables.

Figures 7, 8, and 9 show the combined effect of age and temperature on the per cent set of Small White, California Red and Sutter Pink. For these drawings the range of temperature was from 80° to 110° F. The range in age was 1 to 50 days. For Small White (fig. 7) the per cent set was reduced 19 per cent in the age range and 13 per cent in the temperature range, making a total of 32 per cent.

For California Red (fig. 8) the per cent set was reduced 32 per cent in the age range and only 3 per cent in the temperature range, making a total of 35 per cent. For Sutter Pink (fig. 9) the per cent set was reduced 36 per cent in the age range and 11 per cent in the temperature range with a total of 47 per cent.

In figures 10, 11, and 12 the combined effects of age and temperature are shown on beans per pod for the three varieties. For Small White (fig. 10) the reduction in the age range was 1.7 beans per pod and the reduction in the temperature range was 0.3, making a total of 2.0. In California Red (fig. 11) there was a slight increase of 0.3 beans per pod at the higher temperature range, but in the age range there was a reduction of 1.1, so that the total reduction was only 0.8 beans per pod. For Sutter Pink (fig. 12) there was a reduction of 1.1 beans per pod in the age range and 0.4 in the temperature range, making a total reduction of 1.5. These drawings show graphically that age had a more marked effect on both per cent set and beans per pod than temperature had. But temperature was effective in markedly reducing the per cent set, especially in the Small White and Sutter Pink varieties.

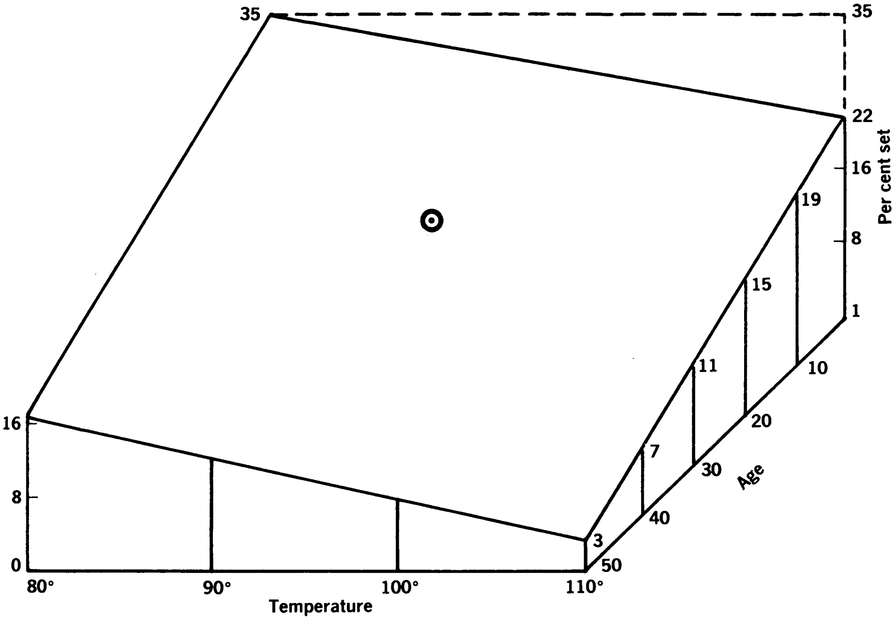

Figure 7. Partial regression of age and maximum temperature the day of bloom versus per cent set in Small White.

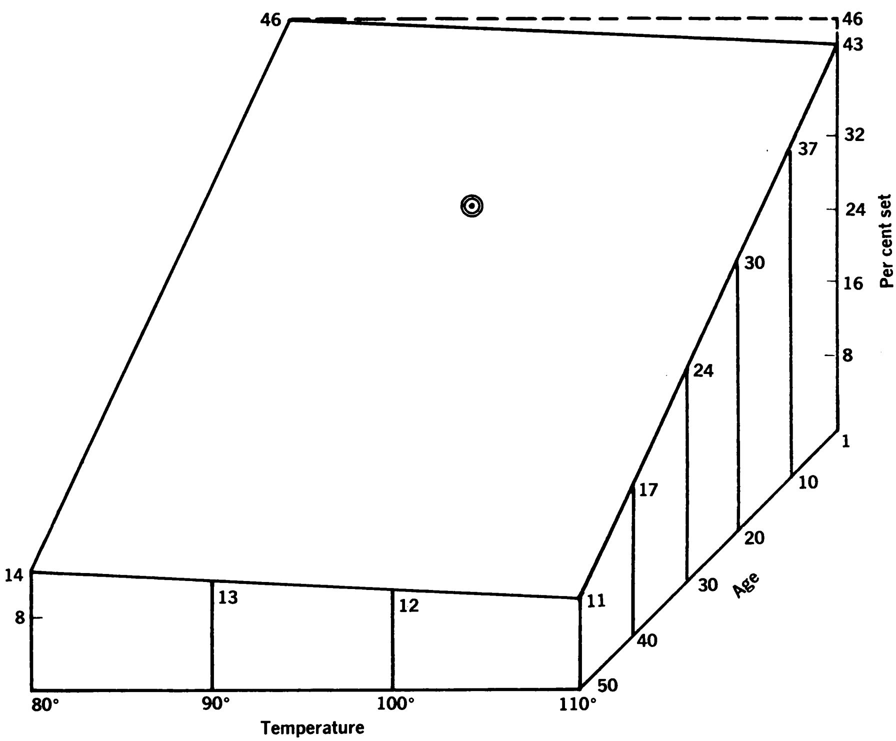

Figure 8. Partial regression of age and maximum temperature the day of bloom versus per cent set in California Red.

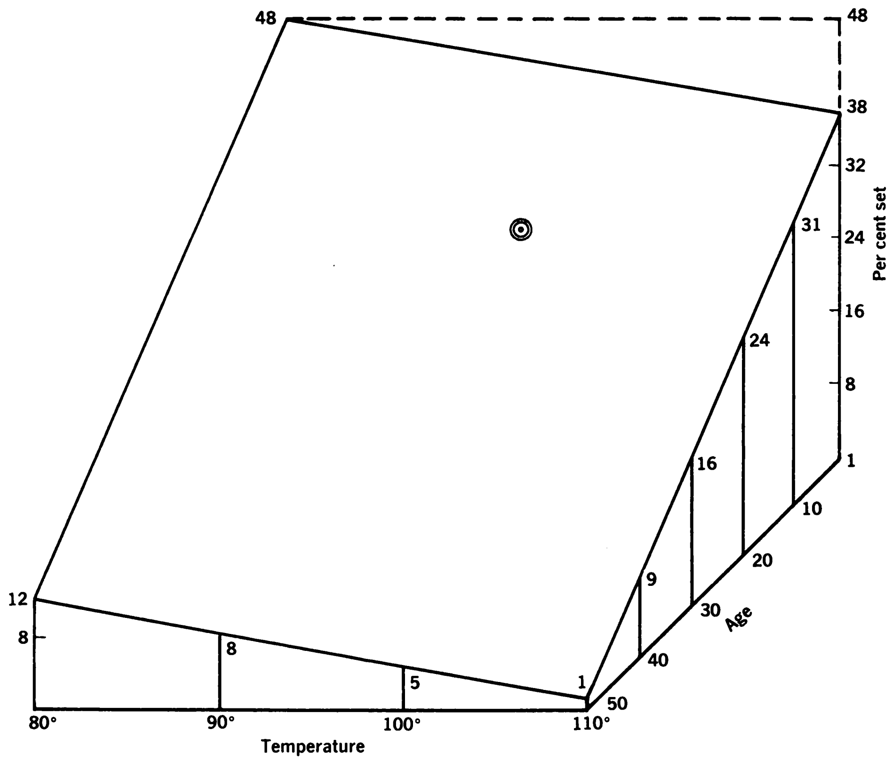

Figure 9. Partial regression of age and maximum temperature the day of bloom versus per cent set in Sutter Pink.

Another method was used to study the effects of temperature. If high temperature is effective in reducing per cent set or beans per pod, this should be shown by comparing samples taken on cooler days with those taken on warmer days. For this purpose, samples taken on days with maximum temperatures below 90° F were compared with those taken when maximum temperatures were above 100° F. In order to eliminate the effect of age, each measure of per cent set and beans per pod was corrected for age of one day by using the regression equations.

The study on per cent set is shown in table 8 for temperatures of the day before bloom and the day after bloom. There is a significant decrease in both Small White and Sutter Pink for the warmer days. In California Red the difference was not significant for the day before bloom and was significant at only the 5 per cent level for the day after bloom. These are in accord with the results of the partial correlations of $r_{T\ F.A}$.

Data from table 7 were used to calculate the values of $\hat{F}$ and $\hat{S}$ for 85° (for the $<90°$ F group) and 105° F (for the $>100°$ F group). (These regression values were inserted in table 8.)

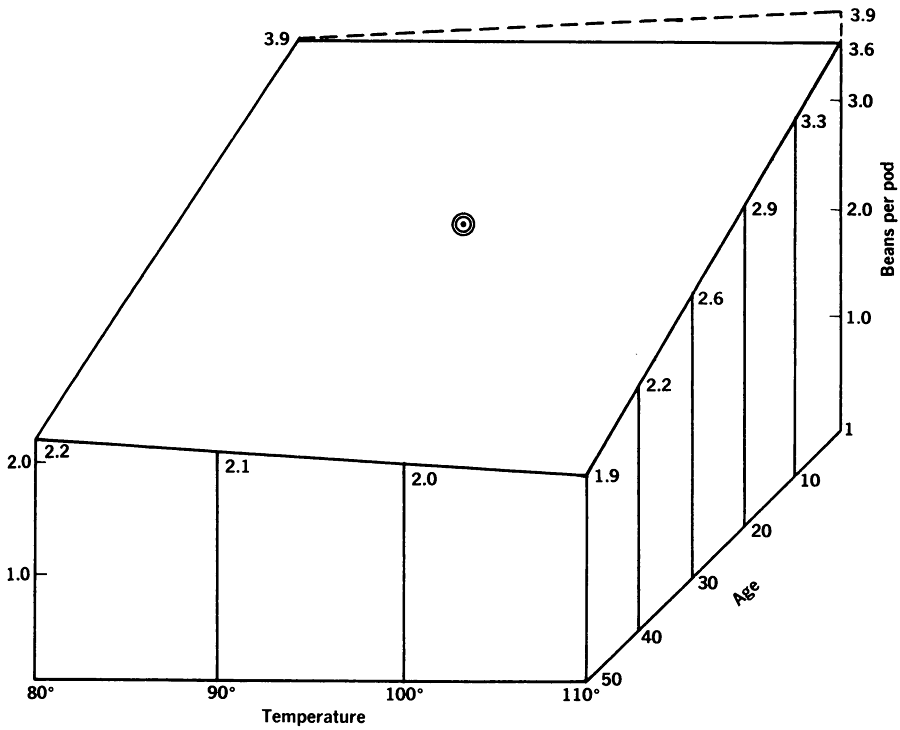

Figure 10. Partial regression of age and maximum temperature the day of bloom versus beans per pod in Small White.

TABLE 8

PER CENT SET AT MAXIMUM TEMPERATURES BELOW 90°F AND ABOVE 100°F
(corrected for age)

Variety	*N*	Maximum temperatures less than 90°F Per cent set	*N*	Maximum temperatures greater than 100°F Per cent set	Difference
			Day before bloom		
Small White	69	35.07	52	20.81	14.26**
Regression calculation		33.05		24.32	8.73
California Red	71	47.15	63	41.84	5.31
Regression calculation		45.55		43.51	2.04
Sutter Pink	56	46.57	73	39.70	6.87**
Regression calculation		46.58		39.69	6.89
			Day after bloom		
Small White	74	36.50	59	28.83	7.67**
Regression calculation		32.84		25.28	7.56
California Red	78	47.19	67	41.00	6.19*
Regression calculation		47.38		41.71	5.62
Sutter Pink	51	48.47	68	39.28	9.19**
Regression calculation		47.80		40.04	4.76

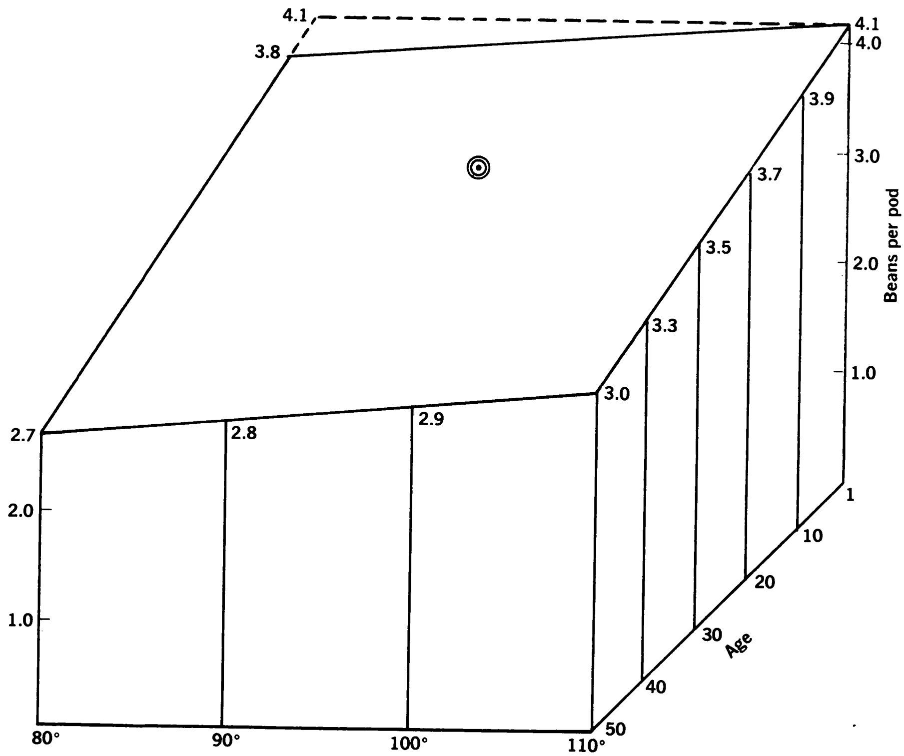

Figure 11. Partial regression of age and maximum temperature the day of bloom versus beans per pod in California Red.

The observed means of per cent set can be compared with the calculated values from the regression equations. The regression values usually show less spread between the two groups than the mean values, but they are in remarkable agreement, especially when it is realized that less than half of the total number of observations were used in this test. All the trends were alike.

Similar calculations were made for beans per pod in which cooler and warmer days were compared. These data are shown in table 9. The calculated values of the beans per pod at 85° F and 105° F from the regression equations are shown with the observed means. As in per cent set, the warmer days decreased beans per pod but the differences were less marked. The observed and calculated values show the same trend in all but one case: Small White the day after bloom.

In this study as in the correlations, the effect of temperature on the beans per pod was signicant in only Sutter Pink.

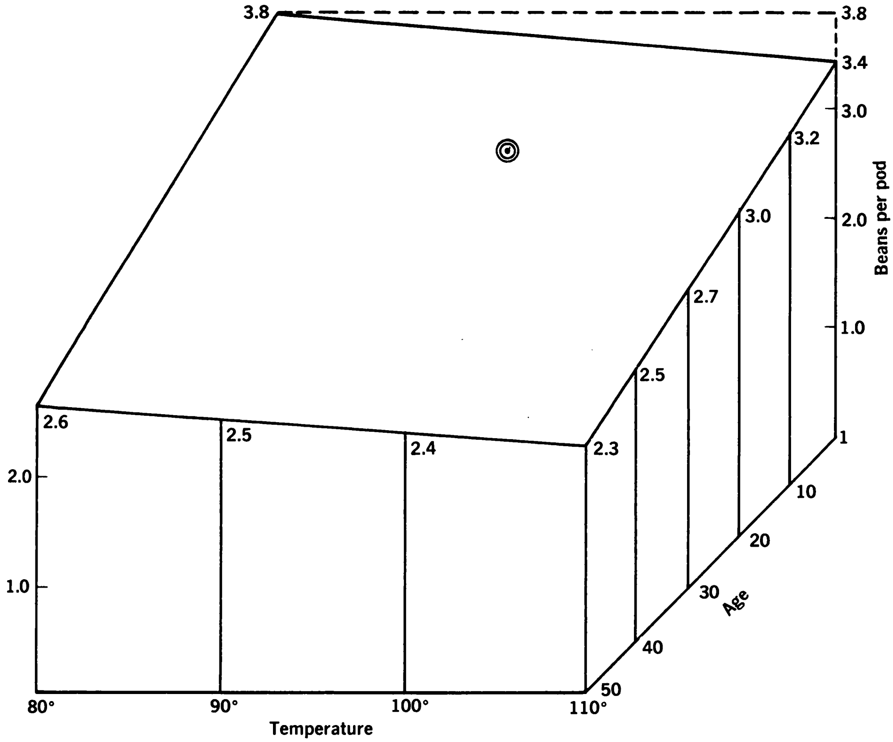

Figure 12. Partial regression of age and maximum temperature the day of bloom versus beans per pod in Sutter Pink.

TABLE 9

BEANS PER POD AT MAXIMUM TEMPERATURES BELOW 90°F AND ABOVE 100°F

(corrected for age)

Variety	*N*	Maximum temperatures less than 90°F Beans/pod	*N*	Maximum temperatures more than 100°F Beans/pod	Difference
	Day before bloom				
Small White	69	3.71	52	3.43	0.28
Regression calculation		3.81		3.61	0.20
California Red	71	3.85	63	4.01	−0.16
Regression calculation		3.80		4.05	−0.25
Sutter Pink	56	3.66	73	3.37	0.29*
Regression calculation		3.71		3.48	0.23
	Day after bloom				
Small White	74	3.86	59	3.88	−0.02
Regression calculation		3.76		3.65	0.11
California Red	78	3.89	67	4.01	−0.12
Regression calculation		3.83		3.99	−0.16
Sutter Pink	51	3.75	68	3.35	0.40**
Regression calculation		3.84		3.41	0.43

SUMMARY

Yield records in a four-year test are reported in which five varieties were planted at 2-week intervals between early May and late July. The varieties were California Red, Sutter Pink, Pinto, Red Kidney, and Small White. The record of yields was based on six replications of each variety on each planting date or a total of 960 plots. The first four of the five varieties mentioned above showed the same general pattern. The yields increased from the early-May plantings to mid-June. There was a high plateau from mid-June to mid-July, while for the last date of planting in late July yields were lower. Small White, a slow-maturing variety, did not ripen in the last planting.

Three varieties, California Red, Sutter Pink, and Small White, were chosen to make studies of flower set and beans per pod in 1958, 1959, and 1960 in the date-of-planting experiments. Dated tagged flower samples ranged from 20 to 100 flowers. A recording thermometer was installed in the field so that the effect of temperature and age of plants at flowering could be studied. The data were analyzed by varieties for the three-year period covering about 4 months per season. There were 263 flower samples of California Red, 225 of Sutter Pink and 268 of Small White. Three temperatures were correlated with per cent set and beans per pod: the maximum temperature of the day before bloom, the day of bloom, and the day after bloom.

The three varieties were in the same order for yield, per cent set and beans per pod. The average yields for all plantings were: California Red, 1,965 pounds per acre; Sutter Pink, 1,873; and Small White, 1,197. The three-year average per cent sets for the three varieties were: California Red, 34.5; Sutter Pink, 31.9; and Small White, 21.8. The three-year averages of beans per pod were: California Red, 3.58; Sutter Pink, 3.24; and Small White, 3.08. Consistent positive correlations, all highly significant, were found between per cent set versus beans per pod in all three varieties. Consistent negative correlations were found in all three varieties between age versus per cent set and age versus beans per pod. Correlations between maximum temperature of the day before, the day of, and the day after bloom versus per cent set were negative in all varieties. The correlations in California Red were too small to be significant, but in Small White and Sutter Pink they were all significant at the 1 per cent level.

Correlations between maximum temperatures versus beans per pod were not as high as those versus per cent set. The only significant *r* values were in Sutter Pink. They were all negative and two were significant at the 1 per cent level. The number of beans per pod, then, is not as sensitive a measure as per cent set.

Partial correlations were calculated, some in which temperature was held constant and others in which age was held constant. The values of *r* were changed but little in the partial correlations. Three-dimensional regression equations were calculated for each variety for per cent set and beans per pod with each temperature. These indicated that age depressed production more than temperature did. Since both acted in the same direction, the combination of the two was easy to demonstrate in three-dimensional graphs.

Sampling dates were chosen in which the maximum temperatures were below 90° F or above 100° F. The per cent set and beans per pod were corrected for age and the averages were calculated. In general the study substantiated the correlation studies: that higher temperature reduced the per cent set in Small White and Sutter Pink but not in California Red, and that higher temperatures reduced the beans per pod in Sutter Pink only.

The data collected and assimilated give some statistical proof corroborating a number of opinions held by experienced bean growers.

1. For maximum yields the date of planting in the Sacramento Valley was limited to about one month from mid-June to mid-July. If planted earlier, the yields were considerably lower, and if planted later, there was a danger that the fall rains might begin before the crop was harvested. Only one of the varieties (Small White) used in these experiments was not adapted to the area. It failed to mature when planted on July 30, and in some years the planting in mid-July failed to mature.

2. The first blooms were important for dry-bean production. The later flowers had a much higher mortality.

3. These studies indicated that high temperatures reduced the per cent of flowers that set seed and also the number of beans per pod. Two of the three varieties showed this consistently. California Red, however, was not as affected by high temperatures. The per cent set was only slightly reduced, and the beans per pod showed no significant effect.

4. If plants were in bloom on days of high temperatures, there was a high mortality of the flowers and fewer beans per pod. Since these days cannot be predicted at planting time, it would seem that spreading the planting over a week or two might increase the chances of high yields. Plants would be at different stages during possible hot periods so that the entire crop would not be vulnerable.

5. The per cent set was a more precise measure of production than beans per pod. This seems logical because the potential range in per cent set is 0–100 while in beans per pod it is only 1–6. Beans per pod also did not account for the many flowers which fail to set any seed.

6. There were marked varietal differences in per cent set and beans per pod. The unadapted variety, Small White, not only yielded the least but was significantly less efficient in both per cent set and beans per pod. On the other hand, the best-yielding variety, California Red, also had the highest per cent set and beans per pod of the three varieties in the flower studies.

7. This study did not produce information on the daily rate of flower production or indicate when in the life cycle of the plants the major part of the crop of pods is produced. To do this adequately, one would have to tag all the flowers on a sample of plants throughout the flowering season.

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Statistical studies on five bean varieties, California Red, Sutter Pink, Pinto, Red Kidney, and Small White, planted at 2-week intervals from late May to late July over a four-year period indicated that yields increased up to mid-June, remained high through mid-July, and then declined in late July for four of the five varieties. The exception was Small White which did not mature in the mid-July planting some years and never in late-July plantings. Significant differences were obtained in varietal yields.

Correlation studies of data from tagged flowers on three varieties over a three-year period were made.

Significant positive correlations were obtained between per cent set and beans per pod in all varieties.

Significant negative correlations were obtained between age of plants and per cent set, and age of plants and beans per pod in all varieties.

Significant negative correlations were obtained between per cent set and maximum temperatures the day before, the day of, and the day after bloom in Small White and Sutter Pink. In California Red these correlations were too low to be significant.

The negative correlations between maximum temperature and beans per pod were smaller than between maximum temperature and per cent set, and only in Sutter Pink were they significant. Beans per pod in California Red were not affected by temperature.

California Red gave the highest yields, highest per cent set and highest beans per pod. In all three measures Sutter Pink ranked second and Small White third.

Advancing age of plants was more effective in reducing per cent set than were increasing temperatures.