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YRB

THE DEVELOPMENT OF WITHIN-YEAR FORECASTING MODELS FOR WINTER WHEAT

RESEARCH AND DEVELOPMENT BRANCH

RESEARCH DIVISION

STATISTICAL REPORTING SERVICE

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THE DEVELOPMENT OF WITHIN-YEAR FORECASTING MODELS FOR WINTER WHEAT

BY

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ACKNOWLEDGEMENT

I would like to thank the Kansas SSO's staff for providing expert supervision of the data collection.

INTRODUCTION

The increased dependence of world markets on United States' grain production has augmented the need to improve our pre-harvest production forecasts. Therefore, in recent years, the Research Division of the Statistical Reporting Service has been conducting research on an additional objective yield forecasting system to supplement the present yield forecasting system for various grain crops.

The present system generates monthly yield forecasts by inserting current year data into models developed from past years' data. Current year data include objective plant counts and fruit measurements and farmers' subjective opinions about expected yield. The system being research provides forecasts at any time after plant pollination by developing a model based solely on current year plant data collected up to the desired forecasting time. Current year plant data include the time since a phenological event occurred, such as time since flowering in wheat, and the associated weight accumulation of the kernels or a function of the kernels, such as the wheat head.

Research was conducted during 1976 in Kansas. The primary objective of this research was to determine the appropriate dependent and independent variables, if any, for forecasting winter wheat yield. To forecast yield per wheat head, the dependent variables tested were oven dried head weight, oven dried kernel weight, undried head weight and undried kernel weight. To forecast wheat heads per acre, the dependent variable tested was the ratio of surviving heads to total heads clipped in the field. The independent variables investigated for forecasting yield per wheat head and wheat heads per acre were days since full head emergence and days since flowering occurred. The secondary objective was to examine the possibility of clipping fewer wheat heads in the field and making less frequent field visits to obtain the occurrence dates of full head emergence and flowering.

SAMPLE DESIGN

A simple random selection of 13 winter wheat fields from the south-central crop reporting district in Kansas constituted the sample. The 13 fields were drawn from the winter wheat objective yield survey fields, which were selected by a systematic random sample from the December Enumerative Survey. Nine varieties were represented in the 13 sample fields.

Within each sample field, two units were randomly located. Within each unit, 50 stalks were identified with a numbered tag. In all, 1,300 stalks were in the sample.

DATA COLLECTION

There were three phases to the data collection. The first phase involved obtaining the dates that full head emergence and flowering occurred for each of the 1,300 stalks. Because of the rapid maturation of winter wheat after stalks have jointed, sample fields were visited every two or three days beginning the last week of April and ending the last week of May so that the occurrence dates could be accurately determined. The second phase began the last week of May after flowering had occurred for most stalks and kernel formation had commenced. Weekly visits were made to the fields until harvest, and 6 randomly selected heads in each unit were clipped and mailed to the laboratory each visit. For each clipped head, the independent variables, days since full head emergence and flowering, were now known since the clipping and occurrence dates were available.

In the third phase, measurements, counts, and weighings before and after oven drying were performed in the laboratory on the clipped heads to obtain the various dependent variables.

MODELS

Three models were examined to determine the most reliable forecasting variables. These models are:

(1) $$y_i = \frac{\alpha}{1 + \beta\rho^{t_i}} + u_i$$

$i = 1,2,\ldots,n$

α, β and ρ = parameters

$\alpha>0$, $\beta>0$, $0<\rho<1$

u_i = error term

t_i = independent variable

y_i = dependent variable

(2) $$\frac{y_i}{f(t_i)} = \frac{1}{f(t_i)}\left[\frac{\alpha}{1 + \beta\rho^{t_i}} + u_i\right]$$

$i = 1,2,\ldots,n$

α, β and ρ = parameters

$\alpha>0$, $\beta>0$, $0<\rho<1$

$f(t_i)$ = functional relationship between the absolute value of the residuals and t_i

$\frac{u_i}{f(t_i)}$ = error term

t_i = independent variable

$\frac{y_i}{f(t_i)}$ = dependent variable

$$(3)\quad y_i = \frac{\alpha}{1 + (\alpha - 1)\rho^{t_i}} + u_i$$

$i = 1,2,\ldots,n$

α and ρ = parameters

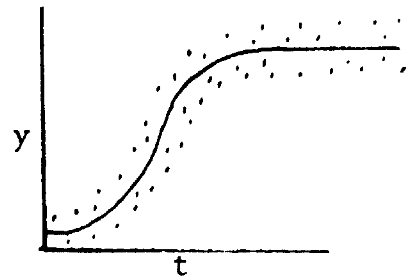
$\alpha \geq 1,\ 0 < \rho < 1$

u_i = error term

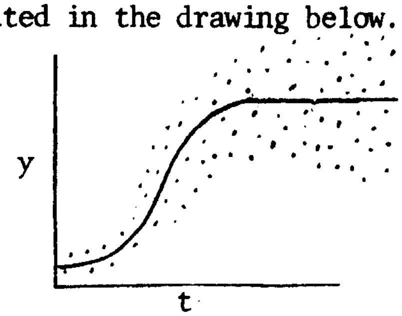
t_i = independent variable

y_i = dependent variable

Model 1 is commonly referred to as the logistic growth model and was utilized when the assumption of constant variances was not violated. That is, the spread of the data around the estimated model was not significantly different for different values of t_i. This concept is expressed pictorially below.



Model 2 is a weighted logistic growth model and was used when the assumption of constant variances was violated. That is, the spread of the data around the estimated model was significantly different for different values of t_i. This concept is illustrated in the drawing below.



For models 1 and 2, t_i was the time since full head emergence or flowering in days, and y_i was the undried or dried kernel or head weight in grams. For a desired forecasting date, model 1 or model 2 was used to forecast the undried or dried kernel or head weight at harvest. The forecast given by any of these dependent variables would then have to be converted to kernel weight at the standard 12% moisture, which represents yield per head.

Model 3 is referred to as the logistic survival model. For this model, t_i was the time since full head emergence or flowering in days, and y_i was the ratio of surviving heads to the total heads based upon all heads to be clipped in the field during the weekly visits. This model was used to forecast the percent of heads that will survive until harvest. This survival percentage is then multiplied by an estimate of heads per acre determined earlier in the season to obtain a forecast of heads per acre at harvest.

In summary, model 1 or 2 will forecast yield per head, and model 3 will forecast heads per acre. The two forecasts are then combined to provide yield per acre.

DATA ANALYSES

Tables in Appendix A and figures in Appendix B will be referenced during the discussion of the results from the data analyses. Each table displays for each weekly cutoff date the model used, the number of observations, the estimated relative sampling error for each parameter, the forecast and the forecast as a percent of the estimated harvest weight. Data were analyzed for each cutoff date in order to determine how early a reliable forecast could be provided. Each figure shows the data and estimated model for a given cutoff date.

Is time since full head emergence or flowering a more reliable independent variable?

Intuitively, time since flowering would seem to be more appropriate to forecast kernel weight since initial values of time should approximate as closely as possible the beginning of kernel formation. Time since full head emergence would seem to be more appropriate to forecast head weight since initial time values should approximate the beginning of head formation. Other potential time variables, such as time since head swelling in the sheath, are too difficult to reliably identify, and therefore were not considered.

Regardless of weather disturbances, such as hail, or scheduling of visits, full head emergence can always be observed. However, hail or heavy rain could detach the anthers or flowers from the head, or field visits could be scheduled in such a manner that flowers would have fallen off between visits because of rapid head maturation. Therefore, in rare instances, flowering would not be identifiable.

Comparison of these time variables was somewhat inappropriate since field clippings began after most heads had flowered rather than after most heads had fully emerged. Therefore, no data for kernel or head weight were present for small values of time since full head emergence.

Examination of the relative standard errors for the parameters and forecasts in Tables 1 and 2 for the dependent variable, dried kernel weight, shows that time since flowering is the preferred time variable. However, if flowering was unidentifiable for some reason, full head emergence could have been accurately used as the independent variable. Again, because of the form of the logistic growth model, flowering would be more realistic.

Inspection of Tables 3 and 4 for the dependent variable, dried head weight, also shows that time since flowering is more reliable, especially with respect to the consistency of the forecasts.

In summary, these data show flowering to be the better time variable. However, full head emergence should be retained in the data collection for another year to verify this result.

Is it necessary to oven dry the head or kernels?

Undried kernel and head weight were each fit to the logistic growth model for each cutoff date with time since flowering. Undried kernel weight fits the model well for early cutoff dates, but the forecasts are very high. On later visits, the fits get worse, and the forecasts are still high. Undried head weight fits the model poorly throughout the season, and these forecasts are also high. Figures 1 and 2 show the estimated model and data for undried kernel weight and undried head weight, respectively, for the given cutoff dates. These figures show that the disparity in moisture content during the growing season affected the data fits and forecasts. In order to provide accurate forecasts and reliable data fits, the moisture content must be kept constant throughout the growing season, which is done by oven drying. Therefore, undried kernel weight and undried head weight are inappropriate dependent variables.

Is oven dried head weight or oven dried kernel weight a better dependent variable?

Two reasons favoring the use of dried head weight are: (1) The number of heads sent to the laboratory could be tripled if dried head weight was chosen, because the tedious task of extracting kernels to determine dried kernel weight would be eliminated. (2) The weighted model (model 2) was required for most cutoff dates for dried kernel weight, but was never necessary for dried head weight. A weighted model is undesirable since various approaches for modifying the data can be applied. Associated with the various approaches are various forecasts.

A method was developed for modifying the data when required for dried kernel weight so that the assumption of constant variances was not violated.[1/] Figure 3 shows the estimated model for all data when dried kernel weight was the dependent variable. Figure 4 displays the spread of these data around the estimated model for all values of time since flowering. Notice that the variance was not constant. Figure 5 shows a plot of the absolute value of the residuals and time since flowering. According to the method that has been referenced, the functional relationship, $f(t_i)$, between the absolute value of the residuals and time since flowering is used to correct the violation concerning the variance. Since at time equals zero, no kernel weight has accummulated, it was assumed that the functional relationship would pass through the origin. Further examination of Figure 5 demonstrates that a linear function would be appropriate. Therefore, for model 2 on page 3:

$$f(t_i) = \delta t_i \quad ; \quad i = 1,2,\ldots,n$$

t_i = time since flowering (days)

δ = slope coefficient between the absolute value of the residuals and time since flowering

Comparison of dried kernel and head weight was made with respect to the preferred time variable, time since flowering. Tables 1 and 3 illustrate

[1/] Dwight A. Rockwell, Nonlinear Estimation, Research and Development Branch, Research Division, Statistical Reporting Service, U.S. Department of Agriculture, Washington, D. C., 1975.

that the estimated relative sampling errors for the parameters were smaller for the dependent variable, dried kernel weight. However, the forecasts were much better for dried head weight. Since reliable early season forecasts are being sought, dried head weight is the preferred dependent variable. Figures 6 through 10 show the data fit for each cutoff date. The horizontal line in each figure represents the estimated harvest weight.

Is it possible to send fewer heads to the laboratory and still obtain an accurate representation of dried head weight?

A double sampling approach was utilized to determine if fewer heads could be sent to the laboratory to be oven dried without impairing the accuracy of the oven dried head weight. This approach involves the following four steps: (1) Instead of sending a sample of size n to the laboratory, send a sample of size n´ such that n´ < n. (2) While making head clippings in the field on the n´ stalks, cheaply obtain stalk characteristic data on n stalks. (3) Determine if a strong relationship exists between the oven dried head weight and the stalk characteristic data from the n´ samples. (4) If a strong correlation exists, use this correlation and the stalk characteristic data from the n samples to adjust the oven dried data from the n´ samples to represent a sample size of n. If n´ is large and the correlation is high, fewer heads need be sent to the laboratory for oven drying.

Fertile spikelet count and head length were collected from 12 randomly selected stalks per field to determine if a refinement of the oven dried head weight from 6 stalks per field was practical. A fertile spikelet was defined as a spikelet that appeared to have kernel formation within it. The head measurement was made from the base of the lowest spikelet to the top of the highest spikelet.

Table 5 displays the correlation coefficient of each stalk characteristic with dried head weight for weekly intervals of time since flowering. Data were divided into weekly intervals so that the number of observations for each correlation coefficient would be sufficient. Time since flowering was used because flowering was previously determined to be the appropriate independent variable. Fertile spikelet count and head length were each highly correlated with dried head weight. For the purpose of illustration, the fertile spikelet count will now be used to refine the dried head weight from the smaller sample to represent the larger sample. A refinement of dried head weight could also have been made using the head length. Again, fertile spikelet count was chosen only for illustrating the refinement method.

The refinement was made by: $\bar{H}_L = \bar{H}_S + \hat{\beta}(\bar{F}_L - \bar{F}_S)$ where $\bar{F}_L$ is the mean value for the fertile spikelet count in the larger sample for each time interval, $\bar{H}_S$ and $\bar{F}_S$ are the mean values for dried head weight and fertile spikelet count, respectively, in the smaller sample for each time interval, $\hat{\beta}$ is the slope coefficient between dried head weight and fertile spikelet count in the smaller sample for each interval of time, and $\bar{H}_L$ is the double sampling regression estimator of dried head weight for the larger sample for each time interval.

It must be noted that the regression estimator is biased, particularly for small samples. Therefore, our refinements are questionable. In future research, the bias of the regression estimator could be reduced since sample sizes will be much larger.

Table 6 shows the relative standard error of each parameter and the forecast for each cutoff date using the refinement. Comparison with the unrefined data in Table 3 shows that the relative standard errors for the parameters are very similar. However, the forecasts are not as consistent with the refined variable. Despite the inconsistency of the forecasts when the refinement was made with fertile spikelet count, fertile spikelet count and head length should be examined in future research because of their strong correlation with dried head weight. Hopefully, the number of heads clipped can then be reduced.

Can an accurate occurrence date of flowering for each stalk be obtained with fewer field visits?

Fields were visited every two or three days to accurately obtain the occurrence dates of full head emergence and flowering for the 1,300 stalks. If this forecasting system were operational, survey expenses would be very high. Also, the repeated visits to the fields would increase the possibility of damaging parts of the fields. Therefore, to reduce survey expenses and the possibility of field damage, data were examined as if the fields were visited once a week.

The selected variables, dried head weight and time since flowering, were fit to the model with all the data to determine if the estimated model was unfavorably affected using the modified time variable. If it was not adversely influenced, weekly field visits will be proposed.

Comparison of the estimated relative sampling error of each parameter shows that the parameter errors fluctuates only slightly when the occurrence dates of flowering were derived from weekly field visits. This is shown on the following page.

Method	$\hat{\sigma}_{\hat{\alpha}}/\hat{\alpha}$ %	$\hat{\sigma}_{\hat{\beta}}/\hat{\beta}$ %	$\hat{\sigma}_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
Every 2 or 3 days	7.68	41.89	4.38	.761	98.3
Once a week	8.01	42.95	4.36	.764	98.7

Therefore, weekly field visits will be made in future research.

Can moisture content in the ripe kernels after the research oven drying be determined so that the kernel weight can be adjusted to the standard 12% moisture?

The standard oven drying method for winter wheat set forth by the Grain Division, Consumer and Marketing Service, USDA, was designed to remove all moisture from ripe kernels. This method is not appropriate for immature kernels, because the oven temperature would burn them. Therefore, it was necessary to develop a research oven drying method that would not burn immature kernels and would be consistent for all growth stages of the kernels. Therefore, the research oven drying method was designed to dry all kernels for 48 hours at a temperature of 140°F.

Since the oven temperature was lower for the research method, some moisture remained in the kernels after drying. It was necessary to determine how much moisture was removed by the standard and research methods at harvest so that the dried kernel weight could be adjusted to zero percent moisture.

Tests illustrated that the dry matter percentages for the standard and research methods were 88.2% and 92.6%, respectively. Obviously, some moisture remained in the ripe kernels dried by the research method. Therefore, the adjustment to zero percent moisture is 88.2/92.6 = .952.

Divide this adjustment factor by .88 to obtain the 12% moisture.

Can a survival model be used to forecast heads per acre?

When the units were located at the end of April, an estimate of stalks per acre was obtained. This estimate was adjusted to heads per acre by assuming that heads that did not flower would not survive. The adjustment was:

$$\frac{\text{Estimated heads}}{\text{Acre}} = \left[\frac{\text{Estimated stalks}}{\text{Acre}}\right]\left[\frac{\text{Total heads flowered}}{\text{Total heads}}\right] \quad (4)$$

Enumerators classified stalks either as surviving or dead in the field when clippings began. Therefore, for each field on each weekly visit a survival ratio was obtained for the flowered heads. The logistic survival model was then used to forecast the survival ratio. The dependent variable was the survival ratio and the independent variable was time since full head emergence or flowering.

Tables 7 and 8 display the estimated relative sampling errors for the parameters and the survival ratio forecast for each cutoff data for time since flowering and full head emergence, respectively. Both time variables perform very well. The forecasted survival ratio generated by the logistic survival model is the multiplied by (4) to provide the forecast of heads per acre at harvest.

CONCLUSIONS

Dried head weight was found to be the most promising dependent variable. Flowering is the preferred time variable. The head length and fertile spikelet count may be beneficial for refining dried head weight so that a larger percentage of the population can be represented. Fields need only be visited once a week to accurately obtain the flowering time. The conversion of kernel weight to 12% moisture can be reliably made. Finally, heads per acre at harvest can be accurately forecasted.

RECOMMENDATIONS

The use of growth and survival models to forecast yield per head and heads per acre, respectively, appear to have much promise. Future research should expand from the crop reporting district to the state to fully test this methodology. A sample of 50 fields is proposed. This sample size should be sufficient to determine if different models are necessary for different varieties or groups of varieties. The performance of the model may improve if a separate model is generated for each varietal stratum. Also, the correlations of head length and fertile spikelet count with dried head weight may improve with stratification. With a statewide sample it could be determined if models need be different for different geographic locations. Alternate oven drying methods should be tested on immature wheat to determine the best oven temperature and drying time. Finally, a method of converting dried head weight to dried kernel weight at the standard 12% moisture will have to be investigated.

Table 1: Growth model fit for each cutoff date given that y = dried kernel weight (grams)

t = time since flowering (days)

Cutoff Date	Model	n	$\hat{\sigma}_{\hat{\alpha}}/\hat{\alpha}$ %	$\hat{\sigma}_{\hat{\beta}}/\hat{\beta}$ %	$\hat{\sigma}_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
5-22-76	1	10	47.01	32.94	9.88	.268	47.8
5-28-76	1	23	46.94	52.26	10.26	.305	54.4
6-4-76	2	36	20.17	27.24	3.99	.433	77.2
6-11-76	2	49	10.82	25.57	2.87	.522	93.0
6-18-76	2	59	8.27	24.89	2.46	.579	103.2
6-25-76	2	67	6.75	24.12	2.26	.576	102.7

Table 2: Growth model fit for each cutoff date given that y = dried kernel weight (grams)

t = time since full head emergence (days)

Cutoff Date	Model	n	$\hat{\sigma}_{\hat{\alpha}}/\hat{\alpha}$ %	$\hat{\sigma}_{\hat{\beta}}/\hat{\beta}$ %	$\hat{\sigma}_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
5-22-76	1	10	80.19	44.58	8.47	.333	59.4
5-28-76	1	23	17.65	124.10	10.30	.234	41.7
6-4-76	2	36	17.84	44.25	3.91	.425	75.8
6-11-76	2	49	11.18	51.57	3.57	.512	91.3
6-18-76	2	59	8.62	52.93	3.30	.554	98.8
6-25-76	2	67	6.94	50.08	2.99	.557	99.3

Table 3 : Growth model fit for each cutoff date given that y = dried head weight (grams)

t = time since flowering (days)

Cutoff Date	Model	n	$\hat{\sigma}_{\hat{\alpha}}/\hat{\alpha}$ %	$\hat{\sigma}_{\hat{\beta}}/\hat{\beta}$ %	$\hat{\sigma}_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
5-22-76	1	10	-	-	-	-	-
5-28-76	1	23	135.99	156.26	10.37	.754	97.4
6-4-76	1	36	77.14	75.47	7.94	.772	99.7
6-11-76	1	49	20.34	26.70	4.50	.821	106.1
6-18-76	1	59	9.73	42.61	4.88	.763	98.6
6-25-76	1	67	7.68	41.89	4.38	.761	98.3

Table 4 : Growth model fit for each cutoff date given that y = dried head weight (grams)

t = time since full head emergence (days)

Cutoff Date	Model	n	$\hat{\sigma}_{\hat{\alpha}}/\hat{\alpha}$ %	$\hat{\sigma}_{\hat{\beta}}/\hat{\beta}$ %	$\hat{\sigma}_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
5-22-76	1	11	-	-	-	-	-
5-28-76	1	24	178.36	203.37	7.26	.789	101.9
6-4-76	1	37	48.68	37.87	5.54	.692	89.4
6-11-76	1	50	32.51	27.60	3.37	.954	123.3
6-18-76	1	60	12.25	54.29	4.23	.767	99.1
6-25-76	1	68	9.10	54.82	3.89	.759	98.1

Table 5 : Correlation Coefficient of Each Stalk Characteristic with Dried Head Weight.

Cutoff Date	n	Days Since Flowering	Stalk Characteristic	
			Fertile Spikelets	Head Length
6-25-76	34	[0,7)	.77	.83*
	67	[7,14)	.70*	.69
	56	[14,21)	.66	.68*
	68	[21,28)	.69*	.62
	40	[28,35)	.82*	.80
	45	≥ 35	.76*	.59
6-18-76	34	[0,7)	.77	.83*
	67	[7,14)	.70*	.69
	56	[14,21)	.66	.68*
	65	[21,28)	.64*	.58
	36	[28,35)	.80*	.78
	14	≥ 35	.77*	.64
6-11-76	34	[0,7)	.77	.83*
	67	[7,14)	.70*	.69
	53	[14,21)	.64	.67*
	56	[21,28)	.62*	.42
	21	≥ 28	.84*	.60
6-4-76	34	[0,7)	.77	.83*
	63	[7,14)	.72*	.69
	47	[14,21)	.60	.69*
	24	≥ 21	.50*	.44
5-28-76	27	[0,7)	.77	.79*
	55	[7,14)	.73*	.69
	21	≥ 14	.78	.79*
5-22-76	22	[0,7)	.77	.78*
	20	≥ 7)	.78*	.61

* Stalk characteristic with better correlation

Table 6 : Growth model fit for each cutoff date given that y = dried head weight (grams)

t = time since flowering (days)

x = fertile spikelet count

Cutoff Date	Model	n	$\sigma_{\hat{\alpha}}/\hat{\alpha}$ %	$\sigma_{\hat{\beta}}/\hat{\beta}$ %	$\sigma_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated harvest weight
5-22-76	1	10	-	-	-	-	-
5-28-76	1	23	-	-	-	-	-
6-4-76	1	36	38.77	34.07	7.98	.651	84.1
6-11-76	1	49	29.75	25.13	4.24	.908	117.3
6-18-76	1	59	10.22	39.17	4.44	.783	101.2
6-25-76	1	67	7.19	42.57	4.31	.757	97.8

Table 7 : Survival model fit for each cutoff date given that $y = \frac{\text{surviving heads}}{\text{total heads}}$

t = time since flowering (days)

Cutoff Date	Model	n	$\sigma_{\hat{\alpha}}/\hat{\alpha}$ %	$\sigma_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated survival ratio
5-22-76	3	10	2.51	0.0	.965	99.8
5-28-76	3	23	1.25	0.0	.976	100.9
6-4-76	3	36	0.84	0.0	.982	101.6
6-11-76	3	49	0.89	0.0	.978	101.1
6-18-76	3	59	0.78	0.0	.978	101.1
6-25-76	3	67	0.97	0.0	.965	99.8

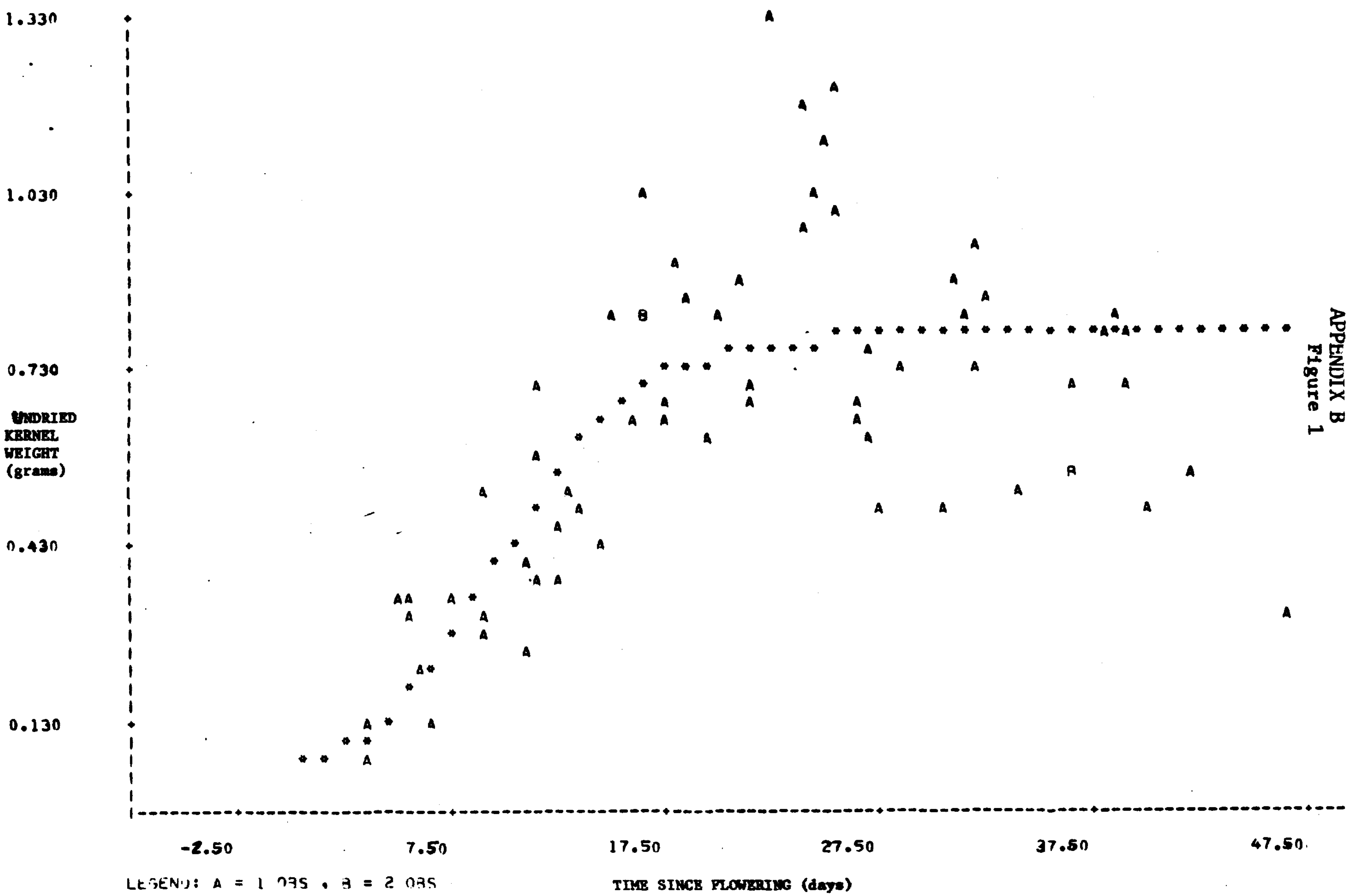
Table 8 : Survival model fit for each cutoff date given that $y = \frac{\text{surviving heads}}{\text{total heads}}$

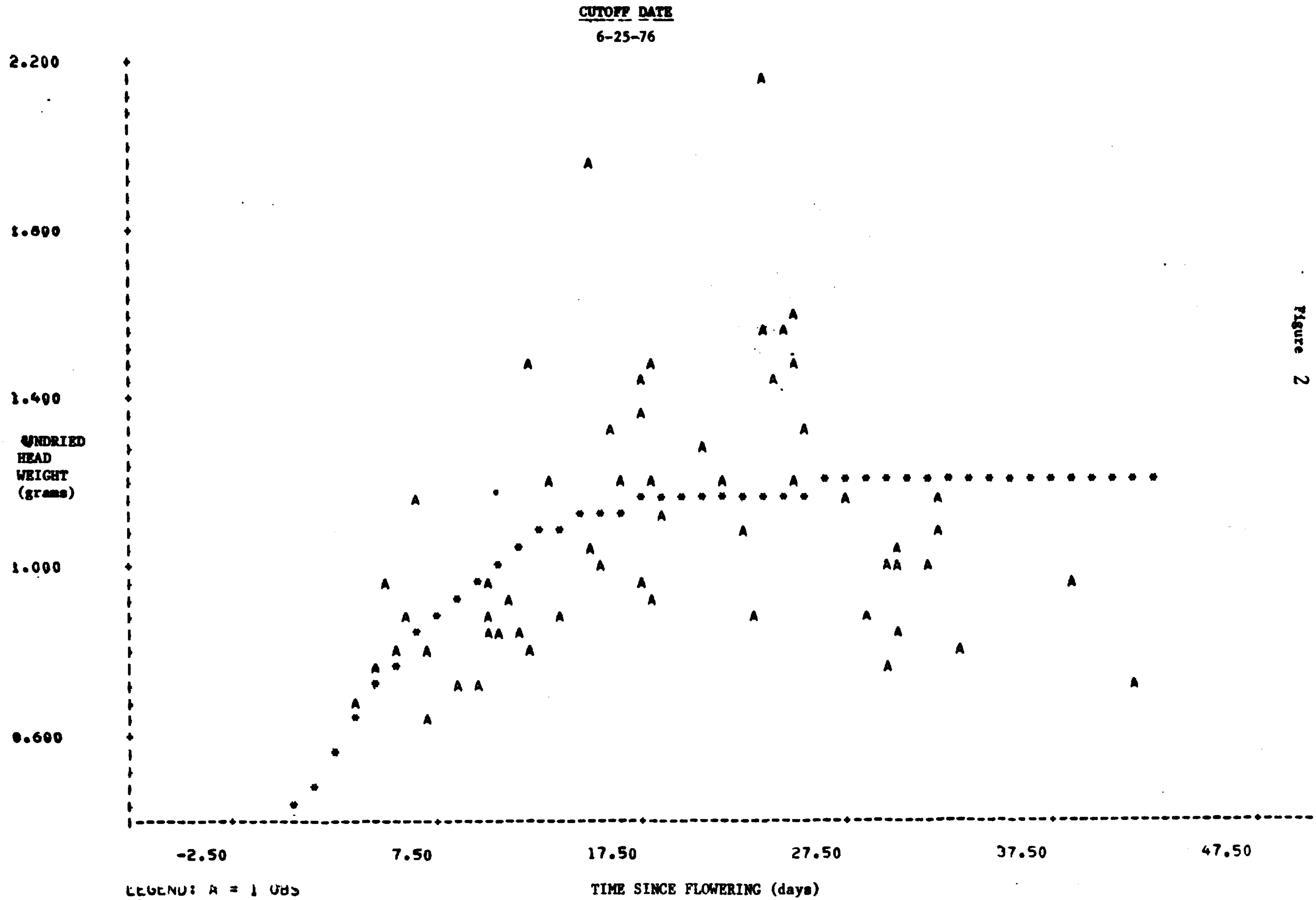
t = time since full head emergence (days)

Cutoff Date	Model	n	$\sigma_{\hat{\alpha}}/\hat{\alpha}$ %	$\sigma_{\hat{\rho}}/\hat{\rho}$ %	Forecast	% of estimated survival ratio
5-22-76	3	11	2.06	0.0	.980	101.3
5-28-76	3	24	1.38	0.0	.974	100.7
6-4-76	3	37	0.98	0.0	.975	100.8
6-11-76	3	50	0.95	0.0	.973	100.6
6-18-76	3	60	0.83	0.0	.974	100.7
6-25-76	3	68	0.86	0.0	.967	100.0

APPENDIX B
Figure 1

CUTOFF DATE
6-18-76




CUTOFF DATE
6-25-76
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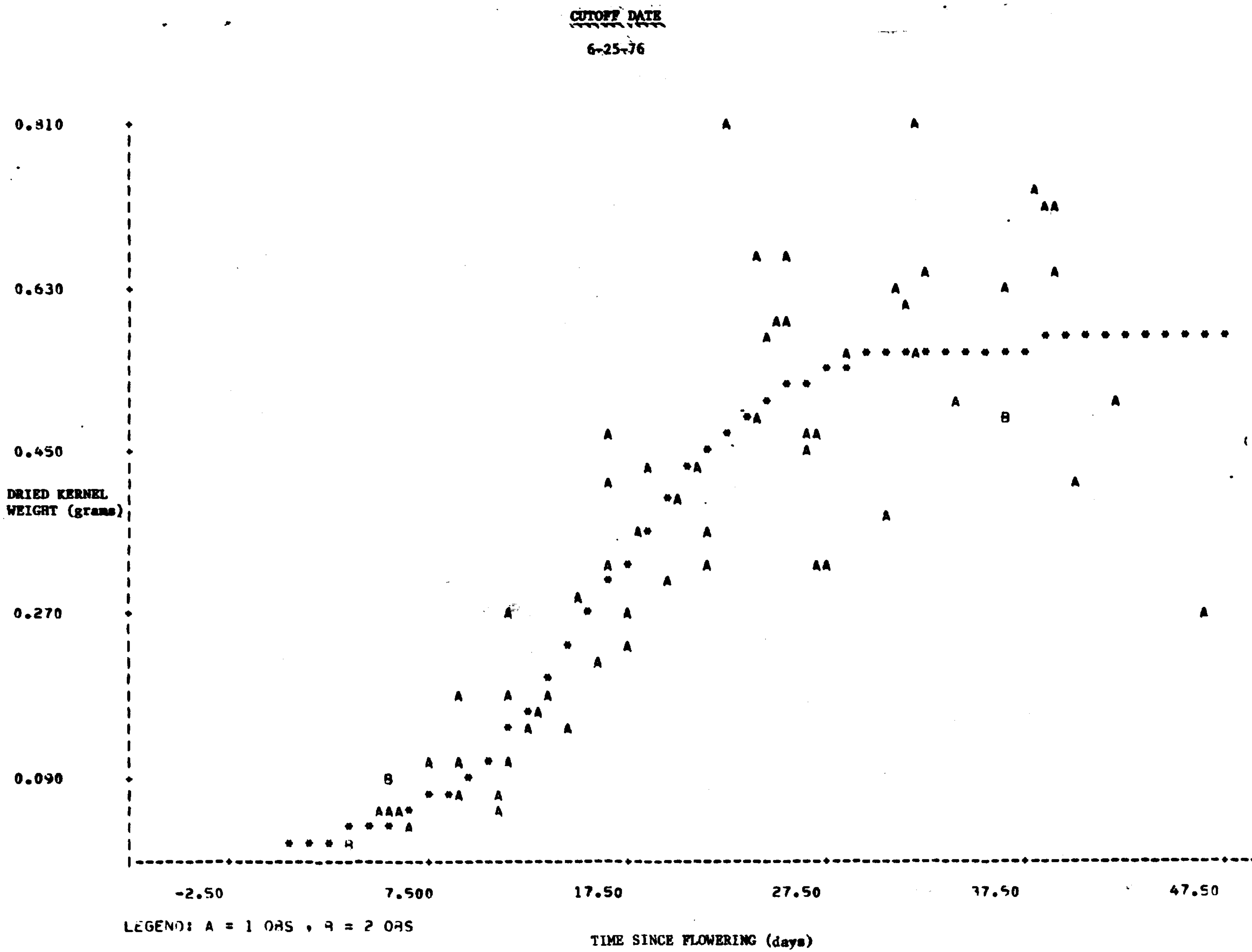
1.800
1.400
1.000
0.600
UNDRIED
HEAD
WEIGHT
(grams)
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS
TIME SINCE FLOWERING (days)

Figure 2


CUTOFF DATE
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0.630
0.450
0.270
0.090
DRIED KERNEL WEIGHT (grams)
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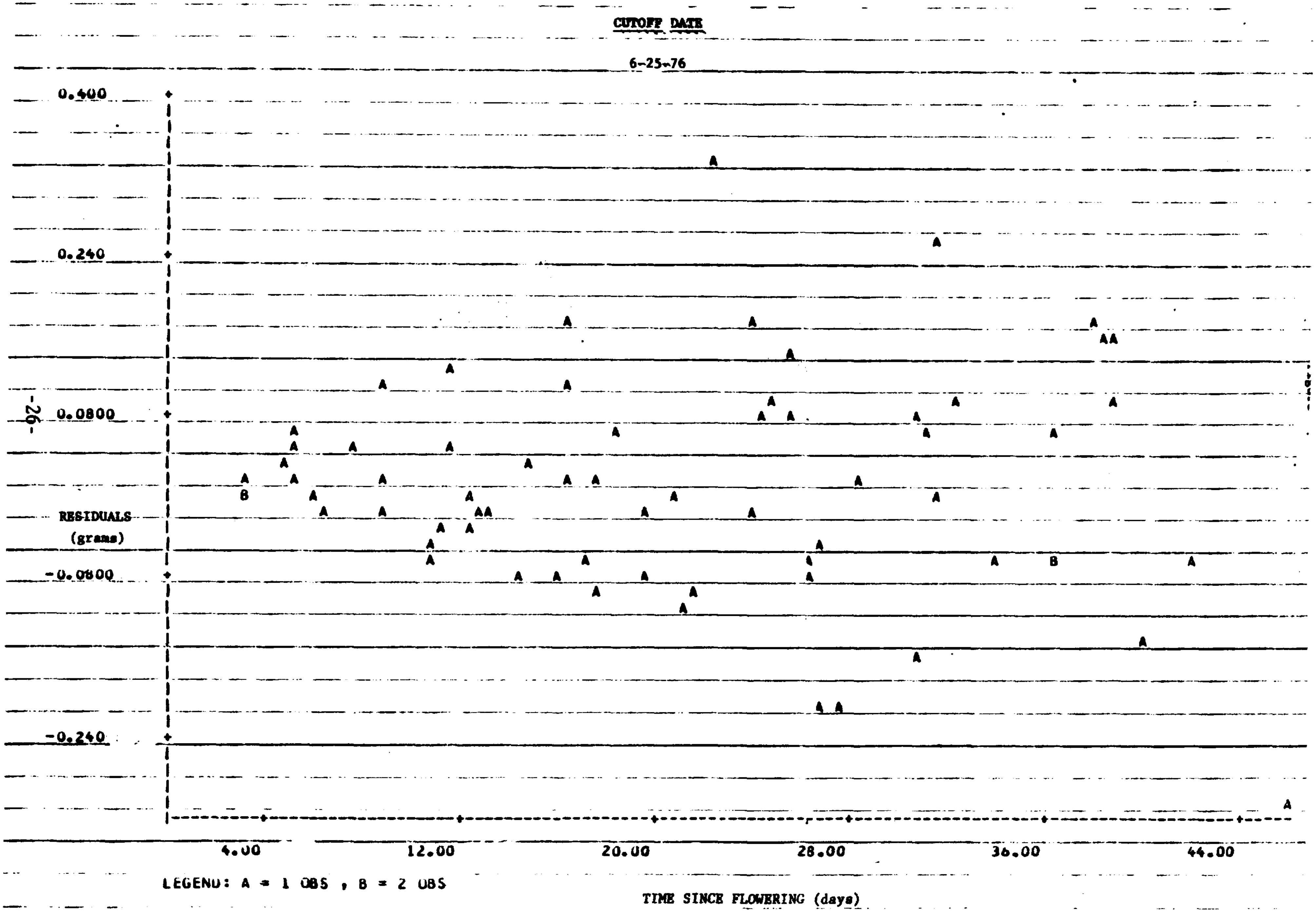
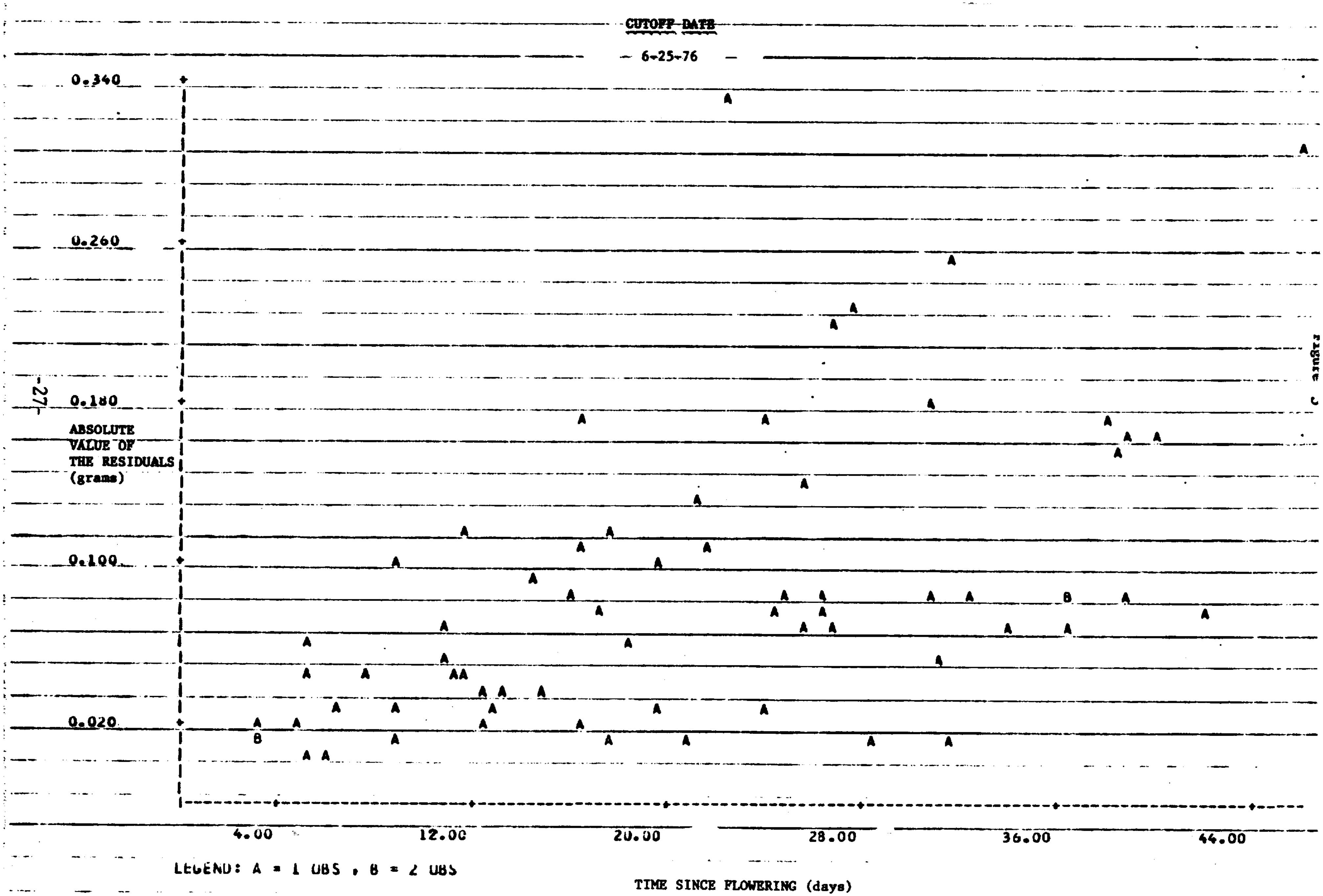
7.500
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)


CUTOFF DATE
6-25-76
0.400
0.240
0.0800
-0.0800
-0.240
RESIDUALS
(grams)
4.00
12.00
20.00
28.00
36.00
44.00
TIME SINCE FLOWERING (days)
LEGEND: A = 1 OBS , B = 2 OBS


CUTOFF DATE
6-25-76
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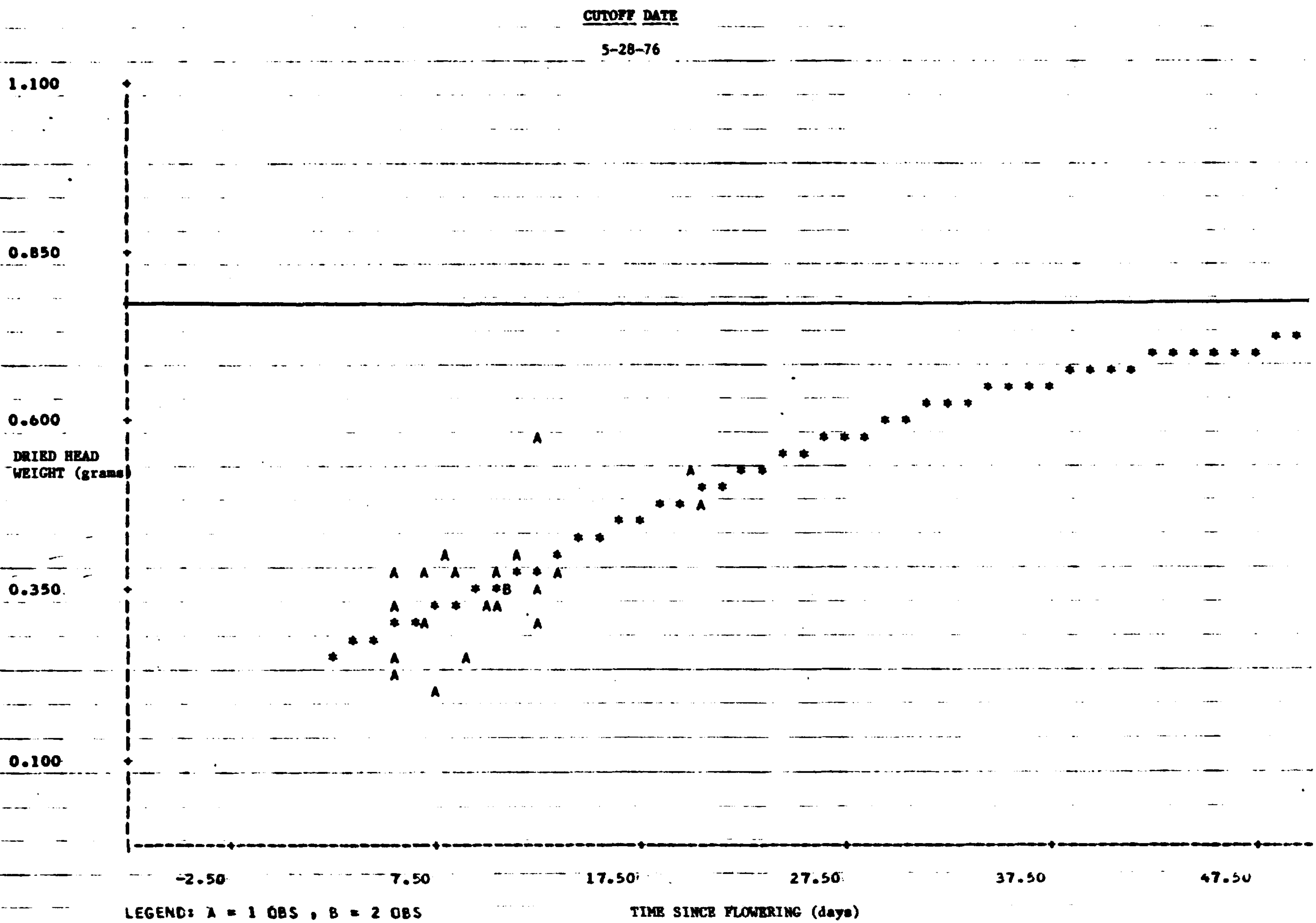
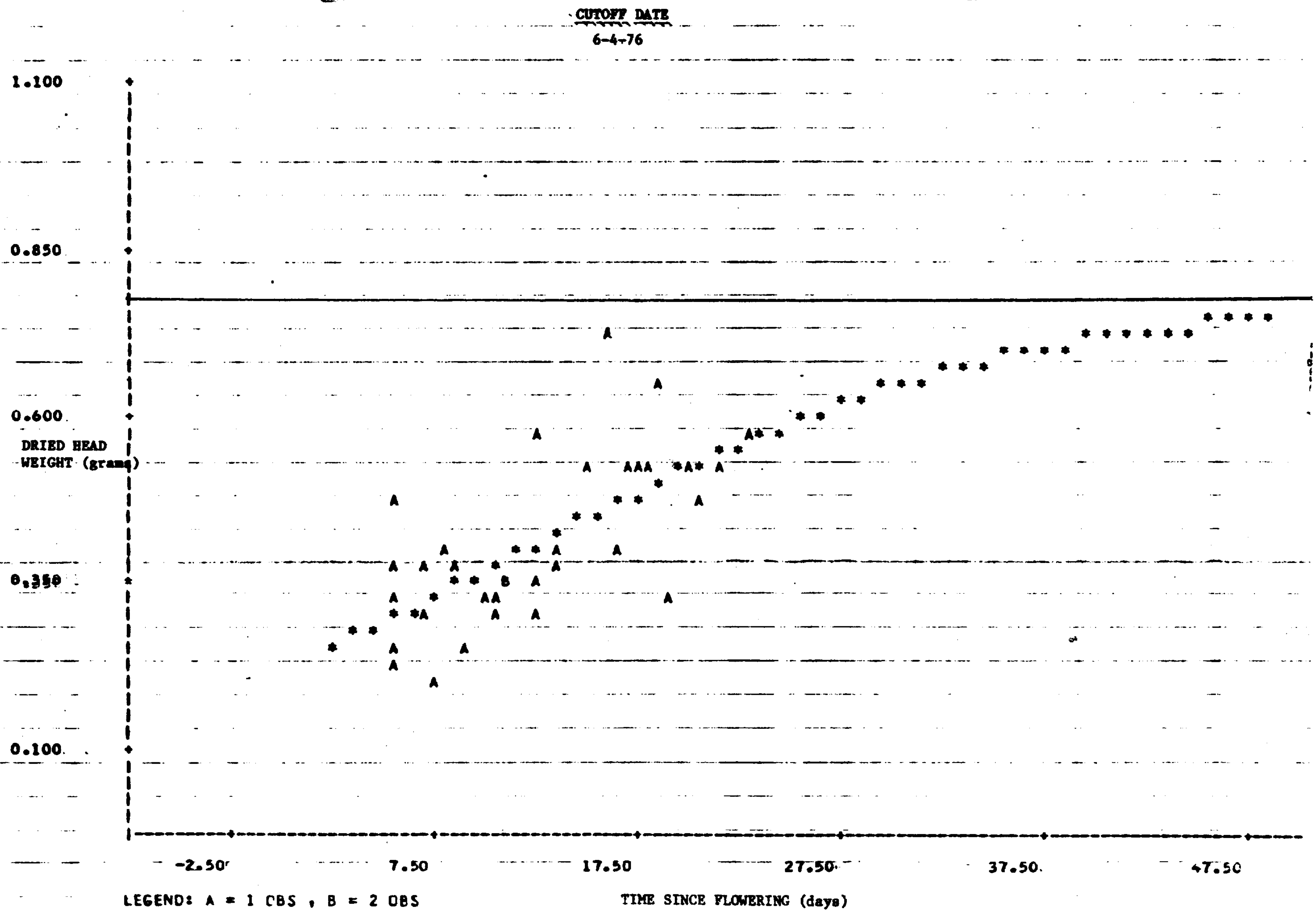
0.260
0.180
0.100
0.020
ABSOLUTE VALUE OF THE RESIDUALS (grams)
4.00
12.00
20.00
28.00
36.00
44.00
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)

Figure



CUTOFF DATE
5-28-76
1.100
0.850
0.600
0.350
0.100
DRIED HEAD WEIGHT (grams)
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)



CUTOFF DATE
6-4-76
1.100
0.850
0.600
DRIED HEAD WEIGHT (grams)
0.350
0.100
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)

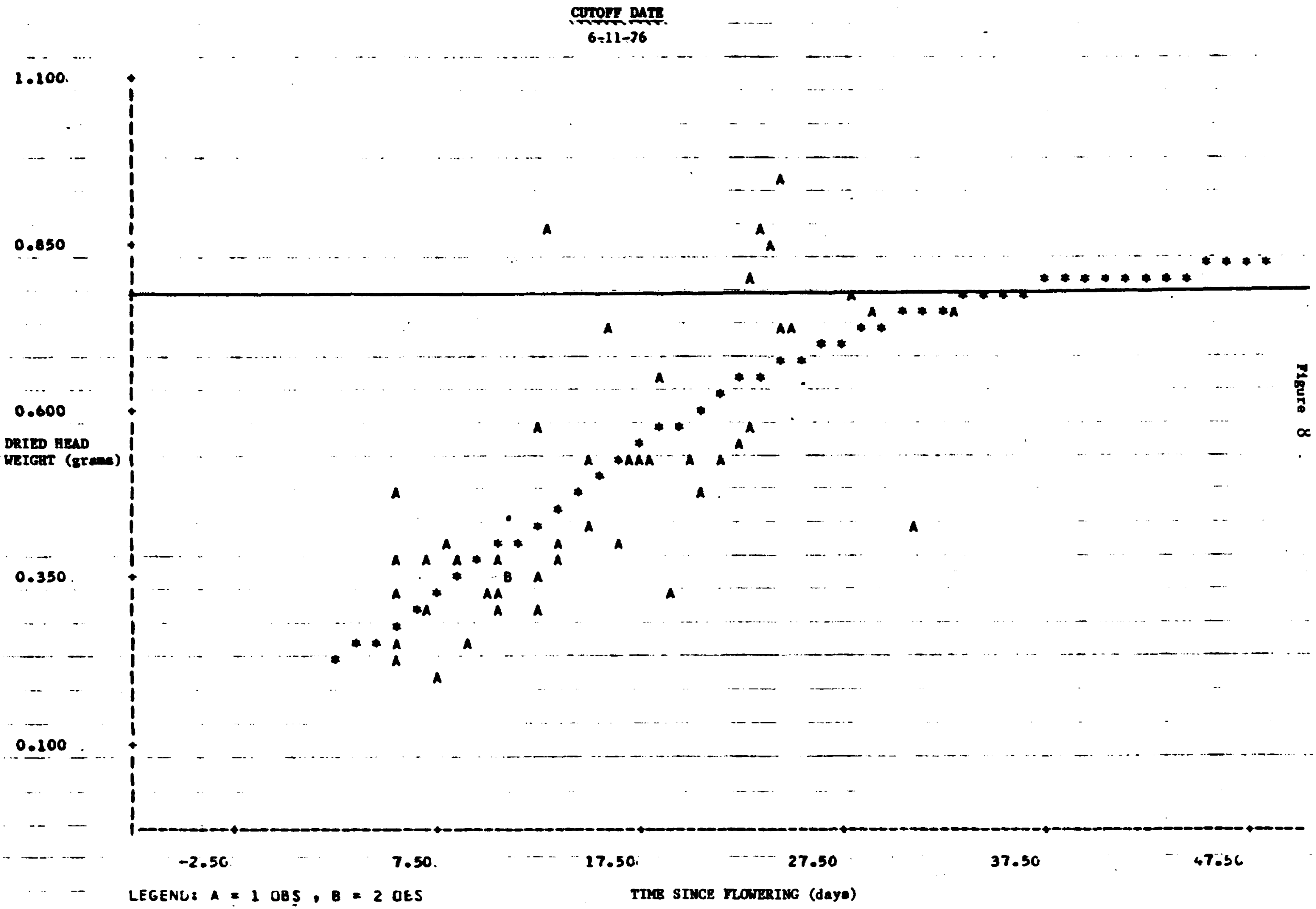

CUTOFF DATE
6-11-76
1.100
0.850
0.600
0.350
0.100
DRIED HEAD WEIGHT (grams)
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)

Figure 8

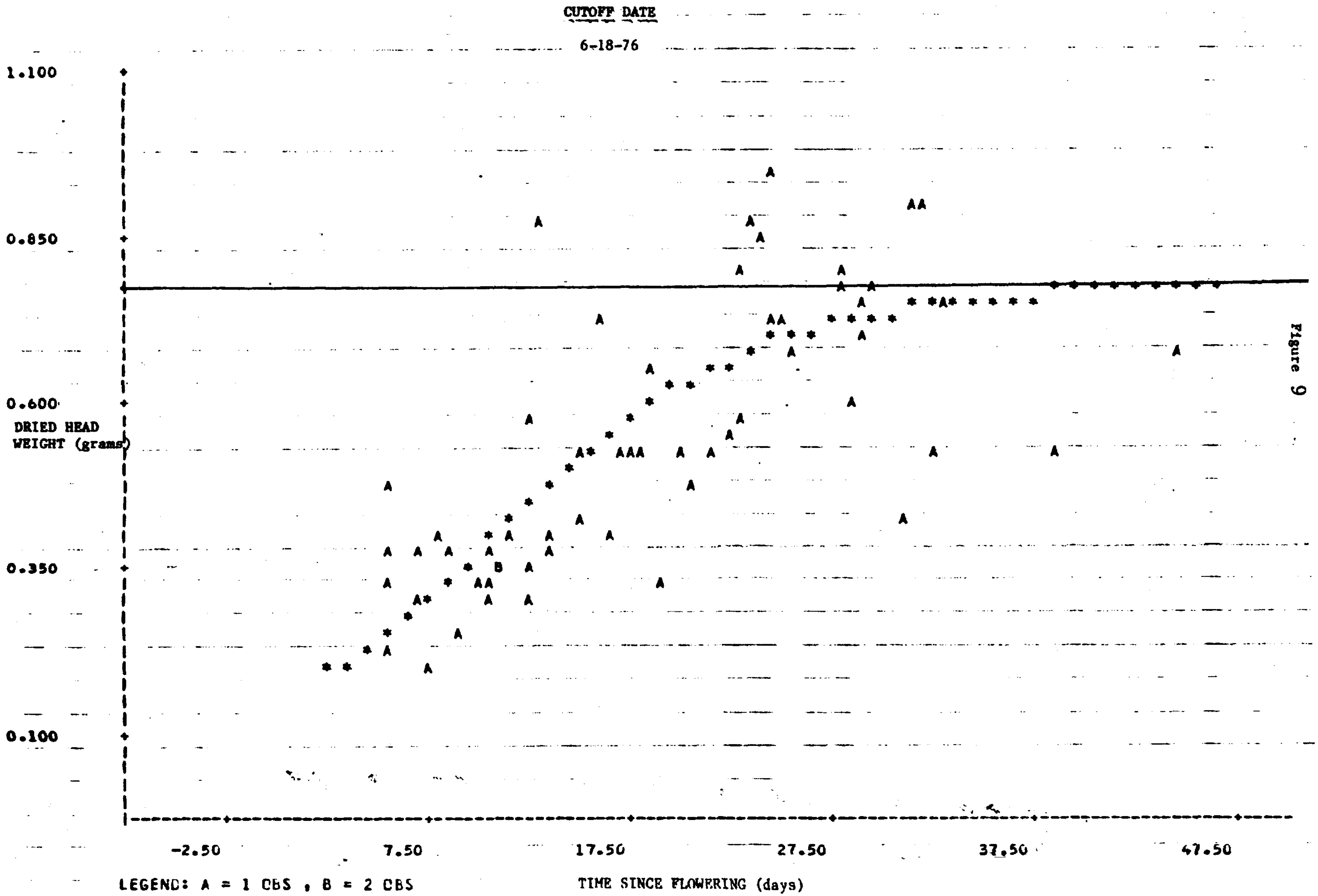

CUTOFF DATE
6-18-76
1.100
0.850
0.600
0.350
0.100
DRIED HEAD WEIGHT (grams)
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)

Figure 9

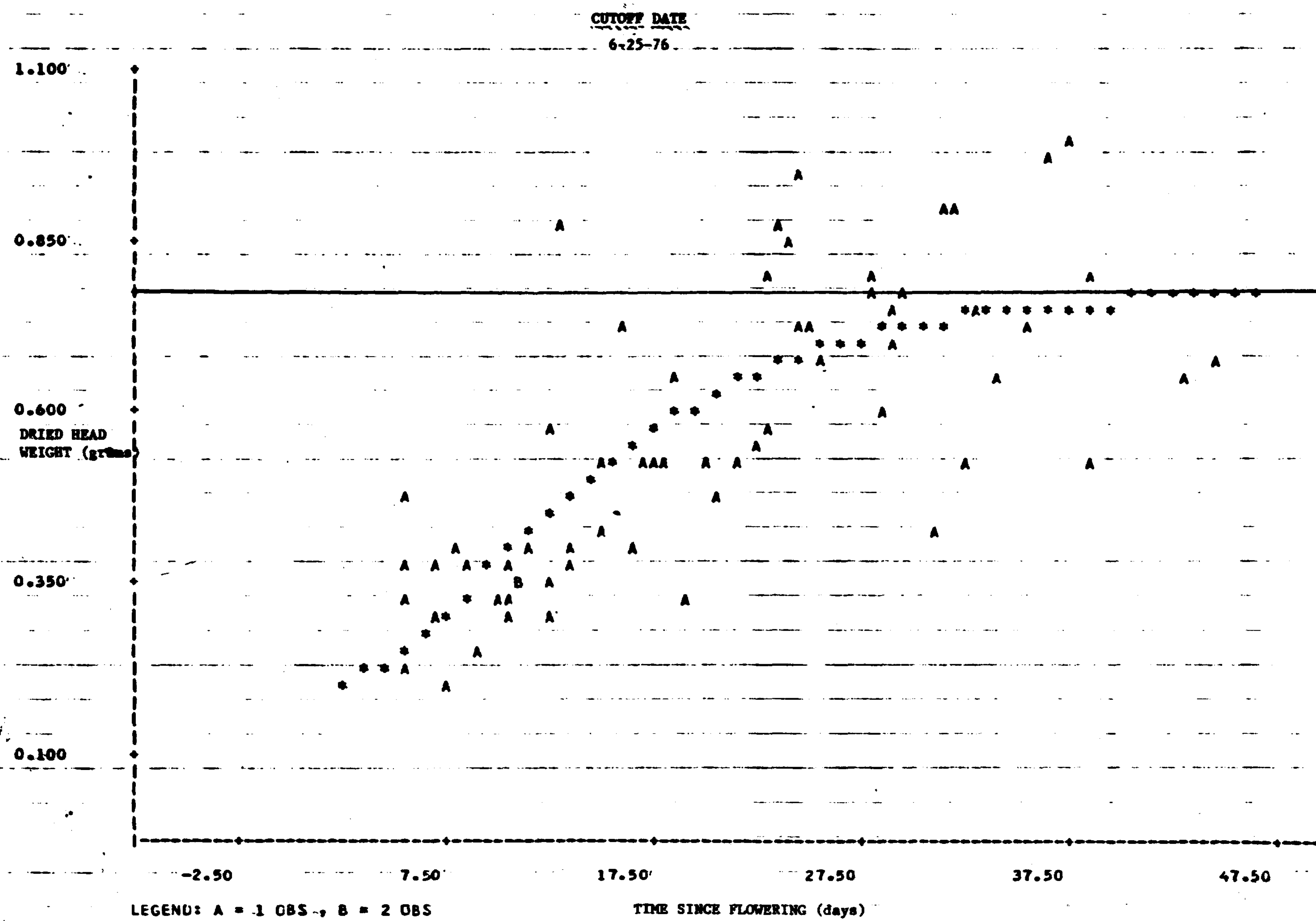

CUTOFF DATE
6-25-76
1.100
0.850
0.600
0.350
0.100
DRIED HEAD
WEIGHT (grams)
-2.50
7.50
17.50
27.50
37.50
47.50
LEGEND: A = 1 OBS , B = 2 OBS
TIME SINCE FLOWERING (days)

Figure 10