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LABELING RESEARCH IN SUPPORT OF THROUGH-THE-SEASON AREA ESTIMATION

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16. Abstract

This report documents work done to support the development of Landsat-based through-the-season labeling procedures for corn and soybeans. A model for predicting labeling accuracy within key time periods throughout the growing season is outlined. Two methods for establishing the starting point of one key time period, viz., early season, are described. In addition, spectral-temporal characteristics for separating crops in the early season time period are discussed.

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LABELING RESEARCH IN SUPPORT OF THROUGH-THE-SEASON AREA ESTIMATION

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1.0 INTRODUCTION AND RESEARCH GOALS

The Large Area Crop Inventory Experiment (LACIE) demonstrated the usefulness of Landsat data for crop identification measurements in support of area estimation without a ground sample stage. In particular, LACIE area estimation procedures were for estimation of small grain acreages in areas where ground data would not be available. The LACIE small grains procedures were end-of-season procedures. That is, the LACIE procedures depended upon the full set of crop season acquisitions in order to perform the crop type labeling operation with sufficient accuracy. During the LACIE Transition Program, and in the subsequent AgRISTARS Project, there was a desire to not only extend the LACIE-like technology to crop types other than small grains, but also to more directly address the need for a continual through-the-season estimation capability. Through-the-season capability was most desirable to all potential users of the technology, since crop production indications prior to the end-of-season would allow for more effective management and planning within the agrobusiness community and commodities market.

The crop types selected for the extension of the LACIE-like technology were corn and soybeans. The particular foreign areas of interest for application of the technology were Argentina and Brazil. Therefore the work described in this report was directed toward corn and soybean crop types. The ultimate goal of the work was to develop corn and soybean crop type labeling procedures to be used in support of a through-the-season area estimation technology. It was envisioned that a through-the-season capability would be developed that would allow for the estimation of crop acreages at any time in the growing season. This may mean that more than one pre-end-of-season labeling procedure would need to be developed for use in different periods within the growing season. At the least, it was felt that the particular point in the season at which an estimate was desired would affect the operating parameters of any labeling procedure. Therefore, a further goal of this research was to come to understand the dynamics of crop separability as the growing season progressed.

2.0 GENERAL APPROACH

There were three phases planned in the overall approach to developing through-the-season labeling procedures. These three phases were:

First Phase: Determination and Description of Summer Crop Type Separation Characteristics Throughout the Growing Season

Second Phase: Development of Labeling Guidelines for Pre-End-of-Season Labeling of Corn and Soybeans

Third Phase: Development of Labeling Procedures to Support a Through-the-Season Area Estimation Procedure

Briefly in the first phase--Determination and Description of Summer Crop Type Separation Characteristics Throughout the Growing Season--the research would focus on determining what, if any, crop type or crop group characteristics could be observed within Landsat data that would be useful in uniquely identifying the crop types or at the very least the crop groups of interest. In addition, the expected improvement in labeling accuracy as the growing season progressed was to be evaluated and some mechanism for determining or for controlling the setting of the operating parameters at various periods in the growing season was to be investigated.

The second phase of research--Development of Labeling Guidelines--would formulate consistent labeling guidelines for the separation of corn and soybeans throughout the growing season. Clearly formulated guidelines would then allow labeling procedures to be designed in support of specific through-the-season area estimation procedures being developed.

The third phase--Development of Labeling Procedures--was to proceduralize the labeling guidelines into a consistent logical processing of the data either by an analyst, machine, or both interactively, similar to the proceduralization effort undertaken in the design of the Corn/Soybean Baseline Procedure C/S-1.[1]

This document will report on the progress of the first phase of the research. At present no plans exist to continue with the other two phases due to termination of support for this effort.

3.0 THROUGH-THE-SEASON MODEL OF LABELING ACCURACY

3.1 GENERAL MODEL CONCEPT

There are four characteristics observable in multitemporal Landsat data that are most useful in determining the crop type or crop group identification of an agricultural feature. These characteristics are: (1) a temporal characteristic which pertains to the development of a feature's vegetation canopy through time, i.e., what time of year is a green vegetation canopy observable for the feature as opposed to bare ground; (2) a spectral characteristic which refers to the value of a given spectral variable, or to the relative relationship between two or more spectral variables for a given feature; and (3) two spatial characteristics, one which refers to the geometric attributes of a given feature such as the nature of a feature's boundary, and the other which refers to the areal distribution of similar and dissimilar features within the area of analysis. The most important characteristic for crop identification is the temporal characteristic. The temporal characteristic allows the separation of crop groups within a region, or more precisely, is used to define the various crop groups within the region. In order to support evaluation of the temporal characteristic, collateral data in the form of crop calendars are needed. Indeed, the most important piece of collateral data for crop type analysis is crop calendar data. The crop calendar data provides information about when crops within a given region are likely to be or are (if a real time crop calendar is used) in any given biostage.

From past research and experience, the spectral response of many vegetation biostages are familiar and generally known. Therefore a spectral crop calendar can be generated from phenological crop calendar data. This spectral crop calendar model allows an analyst or programmed decision algorithm to judge the most likely crop type or cover class label to assign to a given feature in a given set of multitemporal, spectral data such as Landsat data.

The logic process by which a labeling target's observed characteristics are evaluated can be illustrated by the list of "important questions" in Table 1. The ability to answer the important questions in a deterministic manner is dependent upon the temporal set of acquisitions available for analysis. It can be appreciated that as the crop growing season starts, there is little or no spectral data available to answer any of the questions. As the season progresses, however, more data become available and more of the "important questions" can be answered. The accuracy of any labeling analysis task is a function of the temporal sequence of acquisitions available. Thus, it can be understood that the labeling accuracy increases as a function of time. Note, however, that some questions can only be answered after a discrete event has occurred. For example, question 2a ("When does the maximum value for the green vegetation indicator occur?"): This question cannot be answered until some time AFTER the occurrence of the maximum value because a relative maximum can only be identified after the value of the green vegetation indicator has started to decrease again. This time delay in ability to answer a specific question relative to the occurrence of some events says that the labeling accuracy function relative to time is not a smoothly increasing function, but is a function which increases in steps. The plot of this function through the crop growing season would have several plateaus where the labeling accuracy would remain fairly constant until sufficient data had been received that would allow the answering of additional "important questions." (A graphical representation of this model is shown in Figure 1.) The above description of the model of labeling accuracy has ignored the question of data dropout and the use of multiyear labeling procedures or estimators. If multiyear labeling procedures or estimators were employed, the value for A_o (initial value for labeling accuracy at the start (t_o) of a given crop year) would probably be higher (indicated by A_m). The labeling accuracy function would then proceed to perform generally as described above except for the increased accuracy levels expected from the use of multiyear data. Data dropout would have the effect of prolonging the length of various labeling accuracy plateaus until such time as sufficient data became available to answer additional "important questions."

With the above-described Labeling Accuracy Model as a basis, the Through-the-Season labeling research effort sought to accomplish the following objectives in Phase One:

(1) Determine the specific identification characteristics that could be used to uniquely identify summer crop types (corn/soybean) or crop group to the highest accuracy level possible within any given accuracy plateau;

(2) Determine a means of specifically identifying when each of the accuracy plateaus started and ended for the corn/soybean situation.

3.2 SPECIFIC THROUGH-THE-SEASON MODEL OF LABELING ACCURACY FOR CORN/SOYBEANS IN U.S. CORN BELT AND PERIPHERY

The accuracy plateaus described in the general Through-the-Season labeling model need to be more definitively described for the specific corn/soybean situation. This was done based on when each of the important questions from Table 1 could be answered during the Corn/Soybean Summer Crop growing season in the U.S. Corn Belt and Corn Belt Periphery. Figure 2 shows the specific characterization of the Labeling Accuracy Model for the Corn/Soybean Summer Crops in the Corn Belt Area. Use of multiyear data or data dropout were ignored for the present. The C/S-1 (Corn/Soybean Baseline Procedure) Summer Crop biowindows and the potential and actual separation windows have also been delineated on the specific model representation. As can be seen, C/S-1 is actually a mid-season procedure based on the occurrence of the actual separation window in the mid-season of the model. Since the DFS stratification in C/S-1 can be done with a minimum set of two acquisitions--one acquisition from the very early or pre-season time period and one acquisition from the very early to mid-season time period--C/S-1 can operate as a mid-season procedure. Partly because of the above reason and partly due to efficiency of approach, the decision was made to concentrate on the early season plateau in the initial efforts toward developing a Through-the-Season labeling logic.

Therefore the specific objectives of this initial Through-the-Season effort were:

(1) to determine when t_2 occurred - for the Corn/Soybean situation,

  (i) investigate how the occurrence of t_2 could be predicted operationally (i.e. real time during an actual Through-the-Season Estimation Effort)

(2) to determine what characteristics or attributes of corn/soybeans, summer crops, and others were useful in separating

  (i) summer crops from other (at the least)
  (ii) corn and soybeans from other summer crops and from each other if possible.

4.0 DATA ANALYSIS METHODS

4.1 DATA SET

4.1.1 Segment Selection

The Through-the-Season labeling guidelines research was intended to support Through-the-Season area estimation procedures for use in foreign areas, particularly Argentina. However at the time of this study, no Argentina spectral data were available. For this reason the labeling guidelines research was conducted using the spectral data from segments located within the U.S. Corn Belt and Corn Belt Periphery. Segments selected for inclusion in the study were chosen based on the following: (1) how well they represented the geographical diversity within the Corn Belt and Corn Belt Periphery, and (2) the adequacy of their Landsat acquisition histories. A good acquisition history was one that included at least one acquisition prior to the earliest planting date for corn, at least one acquisition during or just past corn tasseling or soybean pod setting, and a sufficient number of acquisitions in between these two bounding crop biostages. The dates of corn planting, corn tasseling, and soybean pod setting, as well as other crop calendar information was determined from the statewide year-specific crop calendars published by the U.S.D.A. - Statistical Reporting Service within their Weekly Crop and Weather Bulletins. Before final inclusion of a segment within the study data base, all segment acquisitions were visually screened for cloud cover, haze, and bad data lines. Eighteen segments were selected to comprise the data set. The list of selected segments and acquisitions is given in Table 2, and the segment locations are shown in Figure 3.

4.1.2 Segment Preprocessing

Sun angle and haze correction was performed on all acquisitions selected for inclusion in the data set. The sun angle and haze correction algorithm used to normalize the spectral data was the global XSTAR algorithm[2] developed by the Environmental Research Institute of Michigan (ERIM). This algorithm had been used quite successfully on numerous previously analyzed data sets of Landsat spectral data. Following the application of XSTAR, the spectral features of interest for the analysis were extracted. The spectral features extracted for analysis were as follows:

(a) Tassel-cap component 1 (TC-1, Brightness)
(b) Tassel-cap component 2 (TC-2, Greenness)--Green vegetation indicator
(c) GRABS[3] (Greenness Above Bare Soil)--Green vegetation indicator

Tassel-cap Brightness (TC-1) and GRABS were given the most emphasis in the analysis due to the successful results achieved in labeling crop type from prior studies.

Tassel-cap transformation is an afine transformation of the Landsat four-channel MSS data into four new channels or components of data which correspond more directly with physical processes and relationships, (particularly for vegetational ground features) than the Landsat MSS bands do directly. GRABS is a green vegetation indicator (measure of infraredness) derived from tassel-cap greenness and the threshold of detection for green vegetation established for the 7/5VI:[3]

$$GRABS = (TC\text{-}2) - 0.09178\ (TC\text{-}1) + 5.58959.$$

4.1.3 Sampling of Fields by Crop Type

Digitized ground data supplied by Johnson Space Center (JSC) was used to identify specific fields within a given crop type or vegetation cover class. A maximum of 10 fields for each summer crop type present within a segment was sampled. Sufficiently large non-summer crop fields were also sampled if they were present within a given segment. To minimize the effects of misregistration between acquisitions, and to insure some level of spectral purity within the crop type samples, only field center pixels were included within the sample. A pixel was included in the sample of a field if it had a margin around it that was at least two pixels wide, or if the surrounding pixels were of the same cover class. This sampling strategy had the effect of excluding small fields from the study. In total 574 fields were sampled from the 18 segments in the data set. The number of fields sampled by segments and cover class is shown in Table 3.

4.1.4 Analysis Approach

For each of the sampled fields, a field mean was calculated in each of the spectral features to be analyzed for each acquisition. All of the analyses were then carried out on the field means data. Temporal plots of the field means were generated for Brightness (TC-1) and GRABS spectral features for each sampled field. In addition, segment level (segment average) temporal plots were generated for each segment by using a weighted (by pixel number) average of the field means within each crop type within each segment. Appendix A contains the segment mean temporal plots for Brightness and GRABS for each cover type sampled.

In order to determine whether there were any detectable differences between the crop groups, and the summer crop types at various points earlier in the growing season prior to end-of-season, the above described temporal plots were examined and evaluated with particular emphasis on observing differences as early in the growing season as possible. In addition the data were evaluated to try to determine at what points in the growing season significant increases in identification accuracies would likely occur as a function of the additional spectral and crop calendar data which become available as the season progressed.

5.0 DETERMINATION OF t_2: SUMMER CROP SPECTRAL EMERGENCE DATE

5.1 DEFINITION, RATIONALE AND ASSUMPTIONS

In the Corn Belt, soybean is frequently the last summer crop planted. This is so partly because corn yield is more favorably affected by early planting than is soybeans. Thus corn planting has priority over soybeans; also soybeans can be double cropped after small grains so that double cropped soybean planting is delayed until after small grain harvest. Observations from past research of the temporal patterns of corn, soybean, and other summer crops in the Corn Belt have shown this later planting pattern for soybeans to be reasonably consistent within the region, though local variations do occur. The date of t_2 is defined as the date when all summer crops are detectable. Within the Corn Belt t_2 can be approximately defined as the date when all soybeans are detectable. The word "all" in these definitions should be read $\geq$"95%". This is similar to the manner in which the spectral biowindows were defined for C/S-1.

Since by definition from the model, the "early season" labeling guidelines would be based on the spectral-temporal characteristics of detectable vegetation, it was necessary to know or to be able to estimate when "all" summer crops were detectable in order to correctly operate the appropriate labeling procedures.* That is, the actual date of occurrence of t_2 needed to be determined. A method for estimating the occurrence of t_2 prior to its occurrence was also expected to be needed in the eventual Through-the-Season Estimation Procedure to be developed.

Since t_2 was expected to vary between years, a long-term average crop calendar would not be adequate for estimating t_2 as closely as was felt necessary. Therefore, a real-time method for estimating the occurrence of t_2 in any given inventory year was needed. The assumption was made that, at the least, some real-time crop calendar model data would be available. However, since no crop calendar model data was available for evaluation, and only limited progress on a Corn Crop Calendar Model was perceived at the time by these investigators, reliance upon such crop calendar model data was minimized as much as possible. The only year-specific crop calendar data available for this study, however, was the U.S.D.A.-S.R.S.'s Statewide Crop Calendars. Therefore the statewide year-specific crop calendar information was used to develop the method for estimating the occurrence of t_2. It was hoped that crop calendar models under development could supply the needed information in foreign areas at some time in the not-too-distant future.

Since t_2 was expected to vary each year within each region, a reference point or start date t_0 was required that could be determined for each region each year. From the statewide year-specific U.S.D.A.-S.R.S. Crop Calendars t_0 was defined as the day on which 50% of the first planted summer crop was reported to have been planted. Thus in the Corn Belt, t_0 was defined as the date on which 50% of corn was reported to have been planted. From past research in crop calendar analysis for summer crops and small grains, it was determined that the 50% planted date for any crop tended to be less variable year-to-year than other percent planted points e.g. 5%, 75%, 95%, etc. Based on this perceived tendency toward higher stability, the 50% planted date was chosen as t_0. In addition, this definition of t_0 allowed t_0 to be determined from data that would be available reasonably early in any growing season so that true Through-the-Season procedures could be developed that would start with the season and not at some later point in the season. (Past definitions of early and mid-season

*Labeling guidelines for a period $\leq t_2$ are called Very-Early Season guidelines by definition and may not rely on detectable vegetation for all potential summer crop fields.

have been stated in terms of days preceding harvest. One, therefore, needed an estimate of when harvest was to occur before one could classify acquisitions as to early or mid-season.)

The time between t_0 and t_2 (time interval t_2-t_0) needed to be determined and its year-to-year variation evaluated.

5.2 ESTIMATION OF (t_2-t_0)

Figure 4 graphically represents one preliminary method used to estimate (t_2-t_0). 1978 data from segment 127, Montgomery County, Indiana, was used to make a "first-look" sample calculation of the interval from 50% corn planted (t_0) to 95% soybean detectability (t_2). Segment 127 was selected from the 18 sampled segments because it had a good acquisition history, good crop calendar information, and was one of the first segments to pass through pre-processing (sun angle and haze correction, etc.). GRABS values were used to calculate the detectability date because GRABS=0 (green vegetation threshold value) is standard for all segments and acquisitions processed through the LACIE Program. Mean GRABS values of ten soybean fields were plotted for the first five acquisitions; June 1, June 10, July 16, July 26 and August 4. All ten fields passed the GRABS threshold of detectability between the fourth and fifth acquisitions, Figure 5. A variable x (Julian date) = the t intercept, of the line drawn between GRABS values on acquisitions 4 and 5 with the threshold of detectability (GRABS = 0), was determined for each sampled field. Using the value of this variable for each sample field, a weighted mean and variance was calculated. The 95% confidence interval was determined and added to the weighted mean giving a Julian day by which 95% of sampled soybean fields were detectable. In 1978 50% statewide planted day for soybean was obtained from the Indiana annual crop and livestock report for the year and subtracted from the 95% mean detectability day + the 95% confidence interval. The difference, 15 days, was the interval x_2 in Figure 4.

The interval from the 50%-planted day for corn and the 50%-planted day for soybean was ascertained as shown in Table 4. Six years of crop calendar data was available from which to calculate a mean number of days from the statewide 50% corn planted day to the 50% soybean-planted day. The 95% confidence interval was determined and added to the mean to give an interval, x_1 in Figure 4, of 26 days. The 26-day interval was added to the 15-day interval from soybean planting to first detectability to estimate x_1 in Figure 4--the number of days from the 50%-planted day for corn to first detectability of all soybean fields in segment 127. The final value, 41 days, was rounded off to 40 days for convenience.

Although the 40-day interval from corn planting to soybean detectability was calculated from a single segment year, the time interval t_0+40 was used as the initial estimate of (t_2-t_0) for all 18 segments. The actual value for t_2-t_0 varied from state to state because of state-to-state variation in the 50% corn-planted day, but almost all corn and soybean fields were detectable on the first acquisition after t_0+40.

99.1% of summer crop fields had mean GRABS values above 0 on the first acquisition after t_0. 97.3% of the fields had mean values above GRABS = 5.0. The number of days from t_0+40 to the first acquisition varied between 5 and 40 with an average, weighted by the number of fields in each segment, of 18.5 days. In contrast, 41.8% of summer crop fields had GRABS values above 0 on the last acquisition prior to the t_0+40 date. The number of days between the acquisition prior to t_0+40 and the (t_0+40) date varied between 5 and 31 with a weighted average of 15.0. The data is summarized in Table 5.

The estimate of a 40-day interval from planting to detectability was further evaluated using field measurements data obtained from LARS. Corn fields had at least 20% ground cover* approximately 40 days after planting, especially with the more dense, and more common, plantings. Soybean fields passed the 20% ground cover point well before 40 days after 50% planted date of the soybeans. The spectral emergence of the soybean fields could not be evaluated with respect to a 50% corn planted date since this was somewhat of an artificial situation.

Additional analysis was performed to estimate t_2 using all corn and soybean pixels in seven Indiana and seven Iowa segments. Digitized and registered ground data was used to sample all identified corn and soybean pixels within the 14 segments. The percentage of corn and soybean pixels above GRABS = 5.0 decision threshold** on each acquisition for each segment was determined and plotted against Julian date. The segment plots were then combined by state and a statewide (as represented by the sample of seven segments/state) cumulative spectral emergence curve (S curve) was generated for each state. The S curve was fit to the data points using a two piece curve fitting method whereby all data before the obvious upper break in slope plus the 1st group of data points at or after the obvious break in slope were fitted by regression to the exponential function $y = ae^{bx}$. The second group of points which included all data points at or after the obvious upper break in slope were fit by regression to the linear function $y = ax+b$. The two curves were then pieced together visually (i.e. the upper shoulder was estimated by eye). Two analyses were done, a) one using t_0 = 50% planted date for corn statewide, and b) one using t_0 = 50% planted date for corn at the CRD to which a given segment belonged. Thus the second analysis was done on data normalized for t_0 at the CRD level. The non-normalized S curves of data points for each set of segments by state are shown in Figure 6. The normalized S curves and data points are shown in Figure 7.

The results of this analysis are shown in Table 6. The earlier estimate of $t_0+40 = t_2$ = 95% summer crops spectral emerged based on analysis of segment 127 sampled corn and soybean fields does not appear to have been very good. From the above described analysis $t_2 = t_0+70$ and t_0+51 for Iowa and Indiana non-normalized data respectively. For the normalized

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* From work at ERIM it has been estimated that approximately 20% ground cover is necessary in order to reach the threshold of spectral detectability.

** Two GRABS detectability thresholds were used, 0 and 5, because temporal plots of summer crop field mean values indicated that GRABS values sometimes fluctuated between 0 and 5 prior to t_0+40. GRABS values did not exceed 5 on any consecutive acquisitions prior to t_0+40.

data, $t_2 = T_0+58$ and T_0+56 days for Iowa and Indiana respectively. There was also better correspondence between estimates of other % emergence points between the two states in the normalized data. The r^2 values for the regression curve fit were fairly good for Indiana - .86 and .84 for non-normalized and normalized data respectively. However the r^2 values for the regression curve fit for Iowa were not very good - .57 and .40 non-normalized and normalized data respectively.

This new estimate for $t_2 = t_0+57$ days actually corresponds very well with the definition for the end of Summer Crop biowindow SC2 from C/S-1 baseline procedure if one adjusts for the difference between 5% corn planted (from C/S-1) and 50% corn planted from the Through-the-Season Model. This was to be expected since the SC2/SC3 biowindow boundary point and t_2 are theoretically the same from their conceptual definitions.

It is clear from inspection of Figures 6 and 7 that there is much more variation in Iowa spectral crop calendars. To what this variation is due cannot be determined in any certainty in this study, however it would seem reasonable to suspect that most of the crop calendar variation in Iowa is due to greater variation in planting dates throughout the state than occurs in Indiana. The observation that the two normalized fitted spectral emergence curves for Iowa and Indiana were similar leads one to suspect that normalization for planting date variation can be valuable for any agricultural multitemporal spectral data processing. This of course was the idea behind UCB's dynamic stratification work. However the large variation in the Iowa data even after normalization seems to suggest that crop calendar "strata" in Iowa are smaller than CRD size. In Indiana on the other hand CRD size strata seem to be reasonable.

The above observations are relevant to the Through-the-Season effort in that it suggests that any Through-the-Season Labeling Procedure or Area Estimation Procedure based on certain kinds of models (i.e. models that have some variable based on crop calendar) would be more effective if normalization for planting date can first be performed. Another method for controlling the variation would be through crop calendar stratification.

Which method would be more desirable would be totally dependent upon the over-all area estimation procedure design and the operational environment of the procedure.

6.0 EARLY SEASON TEMPORAL-SPECTRAL CHARACTERISTICS: SUMMER CROPS VS OTHER

Edwin J. Sheffner

6.1 GREEN VEGETATION INDICATOR-GRABS

Differences between summer crops and non-summer crop temporal profiles become more apparent when examined within the context of the Through-the Season Labeling Accuracy Model where t_2 is defined as a reference point. Note: The following analysis was performed prior to the latest estimation of $t_2 = t_0+57$ days, and so the analysis was performed relative to the original estimate of $t_2 = t_0+40$ days.

6.1.1 Summer Crops vs. Other

Spectral Emergence

Mean GRABS values for corn, soybean and sorghum fields rarely exceeded the decision threshold GRABS = 5.0 on acquisitions prior to the t_0+40 date. 1572 was the only segment with summer crop mean GRABS values above 5.0 on any acquisition prior to t_0+40 (sorghum), and no segments had two consecutive acquisitions prior to t_0+40 with summer crop values above 5.0. Sixteen of the 18 sampled segments had alfalfa/pasture fields. Mean GRABS values of alfalfa/pasture exceeded 5.0 on at least one acquisition prior to t_0+40 in all 16 segments. Fourteen of the 16 segments with alfalfa/pasture fields had more than two acquisitions prior to t_0+40; in 12 of the segments alfalfa/pasture field mean GRABS values exceeded 5.0 on at least three acquisitions prior to t_0+40.

Idle cover and fallow fields also tended to have higher GRABS values than summer crops early in the season. Eight segments had sampled idle cover fields and six segments had sampled fallow fields. Idle cover field mean GRABS values exceeded 5.0 on more than one acquisition prior to t_0+40 in five of the eight segments and exceeded 5.0 on more than two acquisitions prior to t_0+40 in four of the eight segments. Fallow field mean GRABS values exceeded 5.0 on more than two acquisitions prior to t_0+40 in three of six segments.

The sampled summer crop confusers tended to reach maximum GRABS values earlier in the season than summer crops. All summer crop fields reached maximum GRABS values after the t_0+40 date, but alfalfa/pasture fields reached peak GRABS values prior to t_0+40 in 12 of 16 segments, idle cover fields reached peak GRABS values prior to t_0+40 in two of six segments.

A dip in summer crop mean GRABS values prior to the t_0+40 date occurred in several segments. The GRABS temporal plots of corn and soybean in segment 127, (Figure 5), illustrate the dip in GRABS values which occurred between the third and fifth acquisitions. The CRABS value dip was a more common occurrence in soybean and sorghum fields than in corn fields. The dip occurred in soybean fields in 14 of 17 segments and in three of four segments with sorghum, but only in half the segments (9 of 18) with corn. Similar dip phenomenon was noted in non-summer crops. Nine of 16 segments with alfalfa/pasture, two of eight segments with idle cover fields and two of six segments with fallow fields had similar dips prior to t_0+40. The cause of the dip is uncertain. It may be a response to cultivation practices or weather or variation in sensor calibration. In either case, its appearance in the spectral data is acquisition dependent.

6.1.2 Differences Between Summer Crops

The GRABS temporal plots showed differences among the summer crops in timing and range of peak GRABS values. Corn fields generally peaked earlier than soybean fields and sorghum fields were mixed. Mean corn field values reached a peak between t_0+40 and t_0+85 in 11 of 17 segments, whereas soybean fields reached peak GRABS values after date t_0+85 in 10 of 15 segments. Three segments lacked adequate acquisitions to use in this analysis. Segments with sorghum fields were evenly split--two of the four segments had sorghum fields which peaked in the period t_0+40 and t_0+85 and two segments had sorghum fields which peaked in the period after t_0+85. During specified periods of the growing season, mean summer crop GRABS differed. In the period between t_0+40 and t_0+57, corn mean GRABS values varied between 14.42 and 31.12. Mean soybean field values were lower, varying between 1.03 and 27.62. Later in the season, the situation reversed. For acquisitions obtained between t_0+85 and t_0+102, mean corn values were between 17.62 and 22.63. Soybean mean field values were between 31.52 and 45.65 during the same period. Sorghum field GRABS values varied between 7.17 and 12.18 in the earlier period and between 15.67 and 31.12 later in the season.

GRABS emerged as a significant feature for early season separation of summer and non-summer crops. Vegetation within fields of major summer crop confusers tend to be detectable on Landsat in the GRABS feature earlier than summer crops, reach peak values before summer crops, and generally described different spectral development patterns. The descriptions of the development of the various cover types given above and the conclusions drawn from them are based on mean values of all field means of a given cover type. Individual fields varied significantly from the mean as can be seen in Appendix A by the plots of standard deviation. Some non-summer crop fields, particularly idle cover and fallow fields, mimic summer crops in GRABS development pattern, and, occasionally, a field identified as summer crop on ground data was observed to follow a typical alfalfa/pasture pattern. The possibility that anomalies are present must be kept in mind during the labeling process.

6.2 BRIGHTNESS VALUES

The dip noted in the GRABS feature for summer crops is also observed in the tassel-cap brightness feature. Mean TC1 values for corn fields in 12 of 17 segments dipped and then increased in value prior to t_0+40. The same behavior occurred for soybean fields in 14 of 16 segments and 3 of 4 segments with sorghum. The TC1 dip also occurred in some non-summer crop fields. Mean values for idle cover fields in five of eight segments and for fallow fields in 4 of 6 segments had a TC1 dip, but the dip was evident in only 5 of 15 segments with alfalfa/pasture.

The time of maximum TC1 values varied among the summer crops and between the summer crops and non-summer crops. Maximum TC1 values occurred prior to t_0+40 in corn fields in 13 of 17 segments and in 3 of 4 segments with sorghum fields, but only in 4 of 16 segments with soybean. Maximum soybean TC1 values were attained between t_0+40 and t_0+85 in 6 segments and after t_0+85 in 6 additional segments.

Maximum TCl values were reached in half the segments with alfalfa/pasture fields prior to t_0+40 and between t_0+40 and t_0+85 in the majority of the remaining alfalfa/pasture segments.

TCl values for soybeans remained consistently higher than corn or sorghum values after the t_0+40 date. Soybean field mean values of TCl varied between 56.38 and 81.68 on acquisitions between t_0+40 and t_0+57 and between 75.10 and 90.74 for acquisitions between t_0+85 and t_0+102. Corn field values for the same periods varied between 61.73 and 74.98, and 61.79 and 83.76 respectively. Sorghum TCl values were similar to corn in both time frames.

7.0 SUMMARY

Landsat data has proven to be effective in large scale agricultural inventories. However, prior to AgRISTARS, the usefulness of Landsat data was limited by the lack of labeling logic for identification of crops other than small grains and earlier than at-harvest.

To improve the timeliness of Landsat area estimates, UCB under took the experiment described in this report. The results of the experiment included a framework for understanding how Landsat data can be used in conjunction with ancillary data to identify crop groups (in the Corn Belt) at any time during the growing season (labeling accuracy plateaus) and the demonstration that first detectability of green vegetation on Landsat was a critical event in the spectral development of summer crops in the Corn Belt which could be used to separate summer crops from non-summer crops as early as 40 days after the 50%-planted date statewide for corn (t_0+40). Maximum green development was identified as the earliest time in the growing season when corn and soybeans are separable.

While the results of this experiment indicate that procedures for summer crop labeling prior to harvest are feasible, there are a number of significant problems that remain to be examined. The method described in this report for determining the boundaries of the labeling accuracy plateaus assume that a season-specific starting date (from crop calendar information or a planting model) will be available. The assumption may not be realistic.

Although t_0+40 may have no meaning outside the Corn Belt, the labeling accuracy plateau appraoch may be appropriate in other regions. The nature of summer crop cultivation in non-Corn Belt regions needs to be studied before Through-the-Season labeling procedures can be written.

Within the Corn Belt, additional research is required to quantitatively establish the remaining boundaries of the labeling accuracy plateaus. A multiyear approach which incorporates information on crop rotation and planting patterns may yield a reliable date prior to t_0+40 for summer crop/non-summer crop discrimination.

TABLE 1. List of "Important Questions" for Crop Type Identification

Question #	Question Statement	Determinant Characteristic
1	When (during what time period) is a green vegetation canopy detectable or present within the given feature?	Temporal
OR THREE MORE SIMPLE, ALTERNATIVE QUESTIONS:		
1a	Is there a bare soil stage observable? When?	
1b	When is a green vegetation canopy first detectable within the spectral data for a given feature?	Temporal
1c	When is a green vegetation canopy last detectable within the spectral data for a given feature?	Temporal
2	When do the maximum (or minimum) values for specific spectral variables occur?	Temporal
2a	When does the maximum value for the measure of "infraredness," the green vegetation indicator, occur?	Temporal
2b	When does the maximum or minimum value for the brightness measure (Brightness) occur?	Temporal
2c	When does the maximum or minimum value for the visual yellow-green measure occur? (Can not be adequately measured with Landsat at this time)	Temporal
3	What is the value of the maximum for the Green Vegetation Indicator?	Spectral
4	Is there a senescent biostage observable for the feature?	Spectral
5	If there is a senescent biostage observable for the feature, when does it occur?	Temporal
6	What is the shape of the temporal profile (Temporal plot) of the green vegetation indicator vs. time? (Does the profile have a plateau, is it broad-peaked, narrow-peaked, tall, squat, etc.?)	Temporal-Spectral

TABLE 2. Location and Acquisition Dates - Data Set Segments

Segment	Location	Acquisition Dates
123	Hamilton Co. Indiana	89 107 152 161 197 233 269
127	Montgomery Co. Indiana	89 107 152 161 197 207 216 243 252 269
141	Madison Co. Iowa	86 103 130 166 167 212 220
144	Wapello Co. Iowa	130 165 183 219 220 238 246 264 274
205	Clark Co. Missouri	93 101 137 155 164 209 218 246 272 282 290
809	Ogle Co. Illinois	101 163 164 209 218 244 254
832	Adams Co. Indiana	88 97 151 160 178 232 268
843	Henry Co. Indiana	88 97 151 152 160 178 197 251
852	Randolf Co. Indiana	88 97 151 160 178 232 250 268
853	Randolf Co. Indiana	88 97 151 160 178 232 250 268
860	Wells Co. Indiana	88 97 107 116 151 152 160 161 178 197 232 251
864	Crawford Co. Iowa	87 96 141 150 159 186 222 231 248 258
865	Crawford Co. Iowa	87 96 141 153 159 168 186 231 249 267
880	Monona Co. Iowa	87 96 141 150 186 204 222
881	Monona Co. Iowa	87 96 141 159 186 213 222 231 249 267
882	Palo Alto Co. Iowa	86 96 131 141 150 159 186 213 221 231 258 267 293
1572	Custer Co. Nebraska	134 153 170 189 206 224 243
1591	Webster Co. Nebraska	134 152 169 188 205 223 241 259

TABLE 3: Number of Fields Sampled From Data Set

	CROP TYPE					CROP TYPE					
SEGMENT	C	SY	SR	SB	SU	A	P	H	IC	F	T
123	7	5				3			3	3	1
127	10	10			2	4		2	3	1	3
141	7	6				4	5	4			
144	10	10				3	5	5			5
205	10	9		2			1	1	1	6	4
809	10	10				5	3	3			
832	10	10				5	2	3		2	
843	9	10				3	5	2	2		
852	10	10				2	5	4		2	
653	10	10				2	3	3			
860	8	8				1		2		2	
864	6	10				4	6	2	3		
865	10	10	5				7		2		
880	10	10	4			2	2		15	3	
881	10	10				7	5		9	1	5
882	10	10				2	8		3	2	
1572	5	0	5			5	5			5	
1591	10	3	7				5		3	1	
TOTAL	162	151	21	2	2	52	67	31	34	28	17

TOTAL: Summer Crops = 338 Non-Summer Crops = 236

C = Corn
SY = Soybean
SR = Sorghum
SB = Sugar Beet
SU = Sunflower

A = Alfalfa
P = Pasture
H = Hay
IC = Idle Cover
F = Fallow
T = Trees

Table 4: Calculation of maximum number of days between 50% planted day of Corn and 50% planted day of soybean in Indiana.

Year	A Day on which 50% of Corn was Planted*	B Day on which 50% of Soy was Planted*	B-A
1973	140	161	21 days
1975	133	140	7
1976	124	140	16
1977	131	142	11
1978	152	160	8
1979	138	148	10
	136.33 $\pm$ 24.48	148.5 $\pm$ 25.07	

Mean = 12.17 days

Standard Deviation = 5.34 days

NOTE: 95% Confidence Interval = 12.17 days $\pm$ 13.74

Day Interval = 12.17 + 13.74 = 25.91 or 26 days

* From Indiana Annual Crop and Livestock Summaries

TABLE 5: Accuracy to t_0 + 40 Date in Predicting Summer Crop Detectability on Landsat

Segment	t_0 + 40 Day*	A	B	C	D
123	192	5	12	12 (100)	12 (100)
127	192	5	20	20 (100)	20 (100)
141	174	38	13	13 (100)	13 (100)
144	174	9	15	15 (100)	15 (100)
205	178	31	21	21 (100)	21 (100)
809	184	25	20	20 (100)	20 (100)
832	192	40	20	20 (100)	20 (100)
843	192	5	20	20 (100)	19 (95.0)
852	192	40	20	20 (100)	20 (100)
853	192	40	20	20 (100)	20 (100)
860	192	5	16	16 (100)	15 (93.8)
864	174	12	16	16 (100)	16 (100)
865	174	12	24	24 (100)	24 (100)
880	174	12	23	23 (100)	23 (100)
881	174	12	20	19 (95.0)	18 (90.0)
882	174	12	20	20 (100)	20 (100)
1572	175	14	10	8 (80.0)	8 (80.0)
1591	175	13	20	20 (100)	20 (100)

A = Number of days from t_0 + 40 date to first acquisition after t_0 + 40.

B = Number of sampled summer crop fields.

c = Number of sampled summer crop fields with mean GRABS values above GRABS=0 on first acquisition after t_0 + 40 (%).

D = Number of sampled summer crop fields with mean GRABS values above GRABS=5 on first acquisition after t_0 + 40 (%).

* = t_0 + 40 Day = 40 days after 50% corn planted day, statewide.

Summary of Above Data

Number of Segments

4	5	68	68 (100)	66 (97.1)
1	9	15	15 (100)	13 (86.7)
5	12	103	102 (99.0)	101 (98.1)
2	13/14	30	28 (93.3)	27 (90.0)
6	20+	114	114 (100)	114 (100)

TABLE 6: Evaluation of $(t_2 - t_o)$ using accumulated 's-curve' approach.

% Corn + Soybean Spectrally Emerged	$t_{\%}$ emerged - t_o(days) Non-Normalized t_o = statewide 50% planted date of corn		$t_{\%}$ emerged - t_o(days) Normalized t_o = CRD 50% planted date of corn	
	IOWA	INDIANA	IOWA	INDIANA
95%	70 days	51 days	58 days	56 days
90%	57 days	45 days	52 days	52 days
75%	49 days	41 days	47 days	48 days
50%	42 days	33 days	39 days	40 days
25%	29 days	17 days	25 days	25 days

Coefficients from $y = ae^{bx}$ curve fit

a	6.95	10.38	7.22	7.91
b	.05	.05	.05	.05
r^2	.57	.86	.46	.84

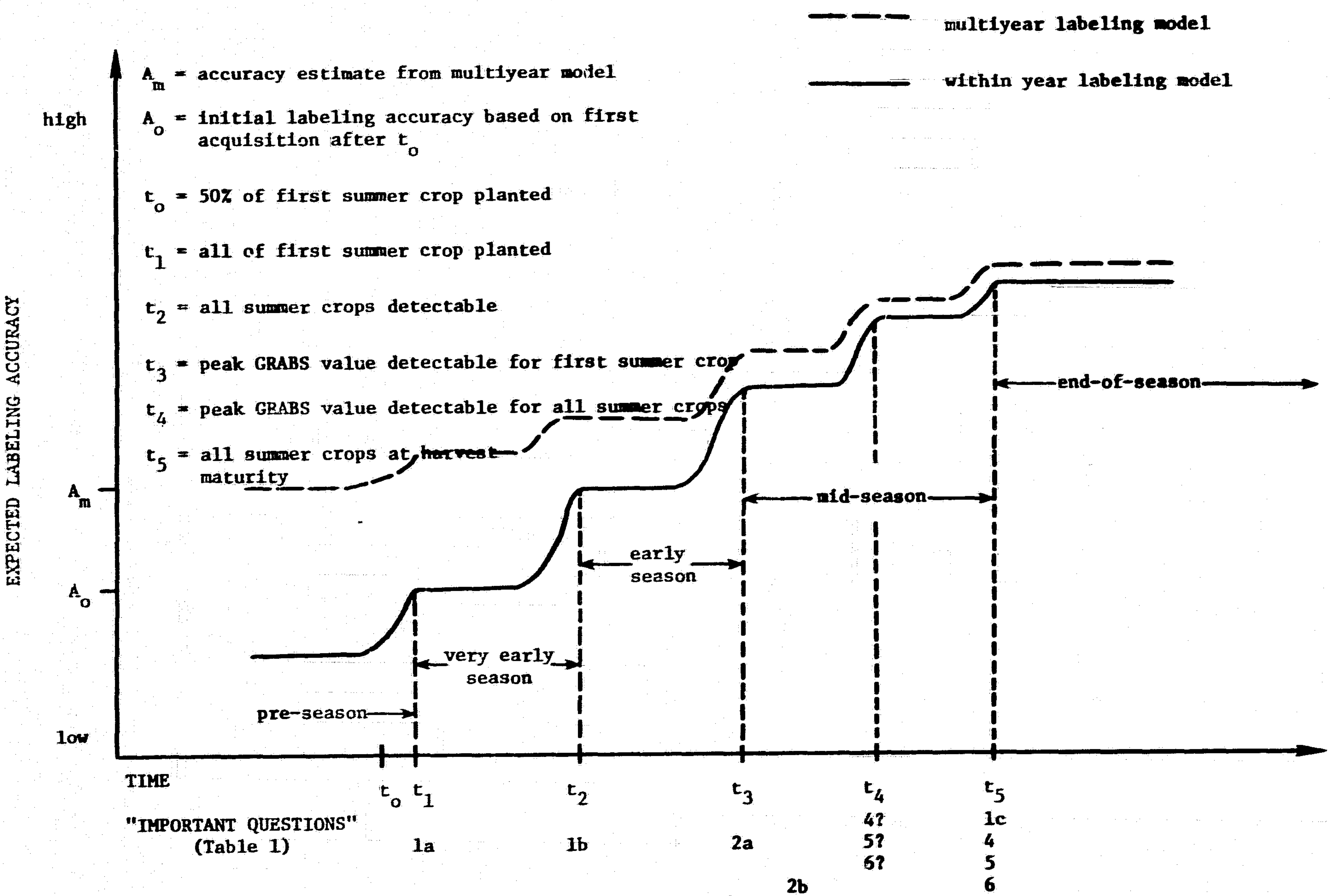


FIGURE 1. General, through-the-season, labeling accuracy model.

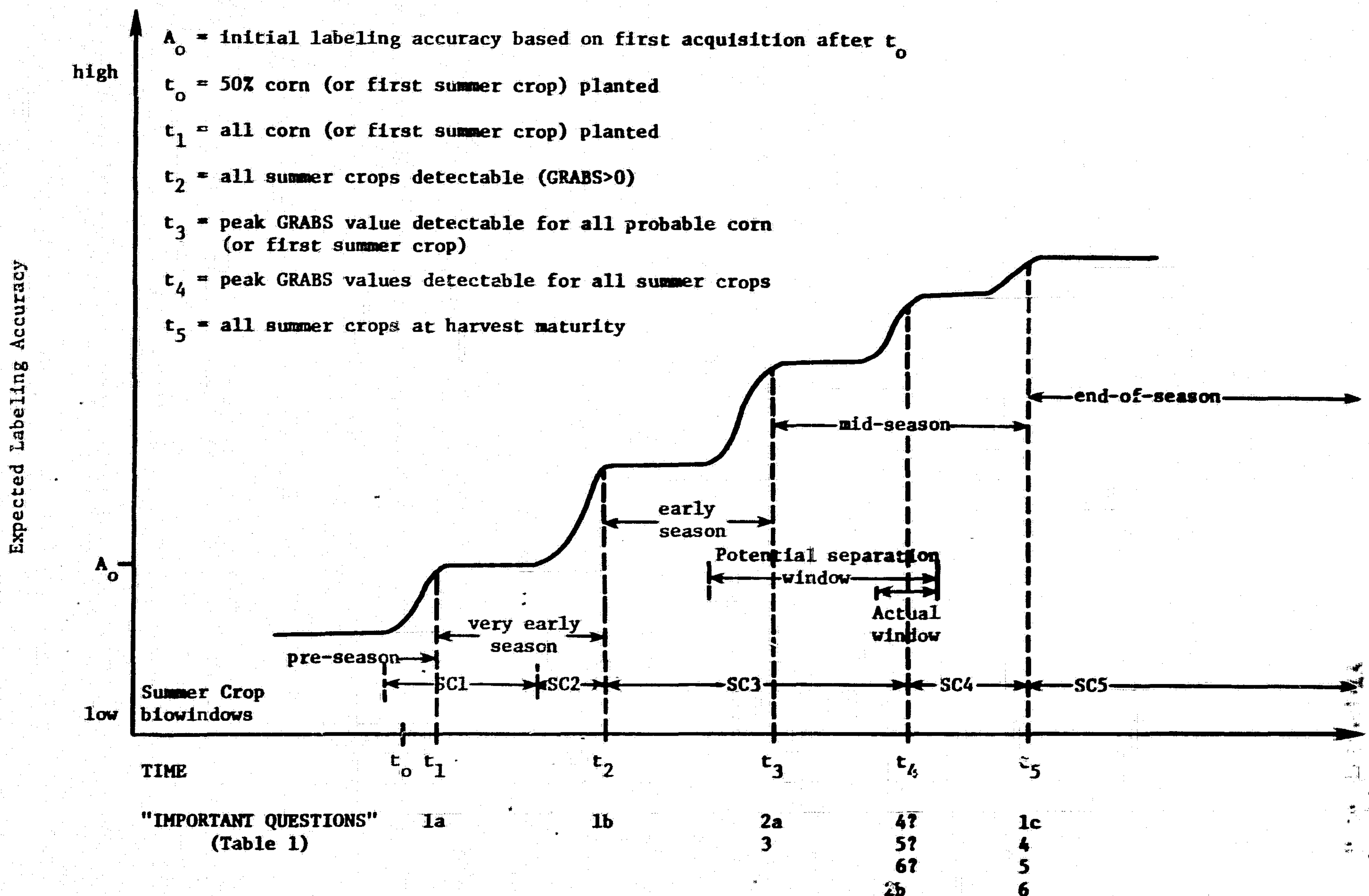


FIGURE 2. Specific, through-the-season, labeling accuracy model for corn and soybeans in the U.S. Corn Belt and peripheries.

FIGURE 3

LOCATION OF SAMPLE SEGMENTS

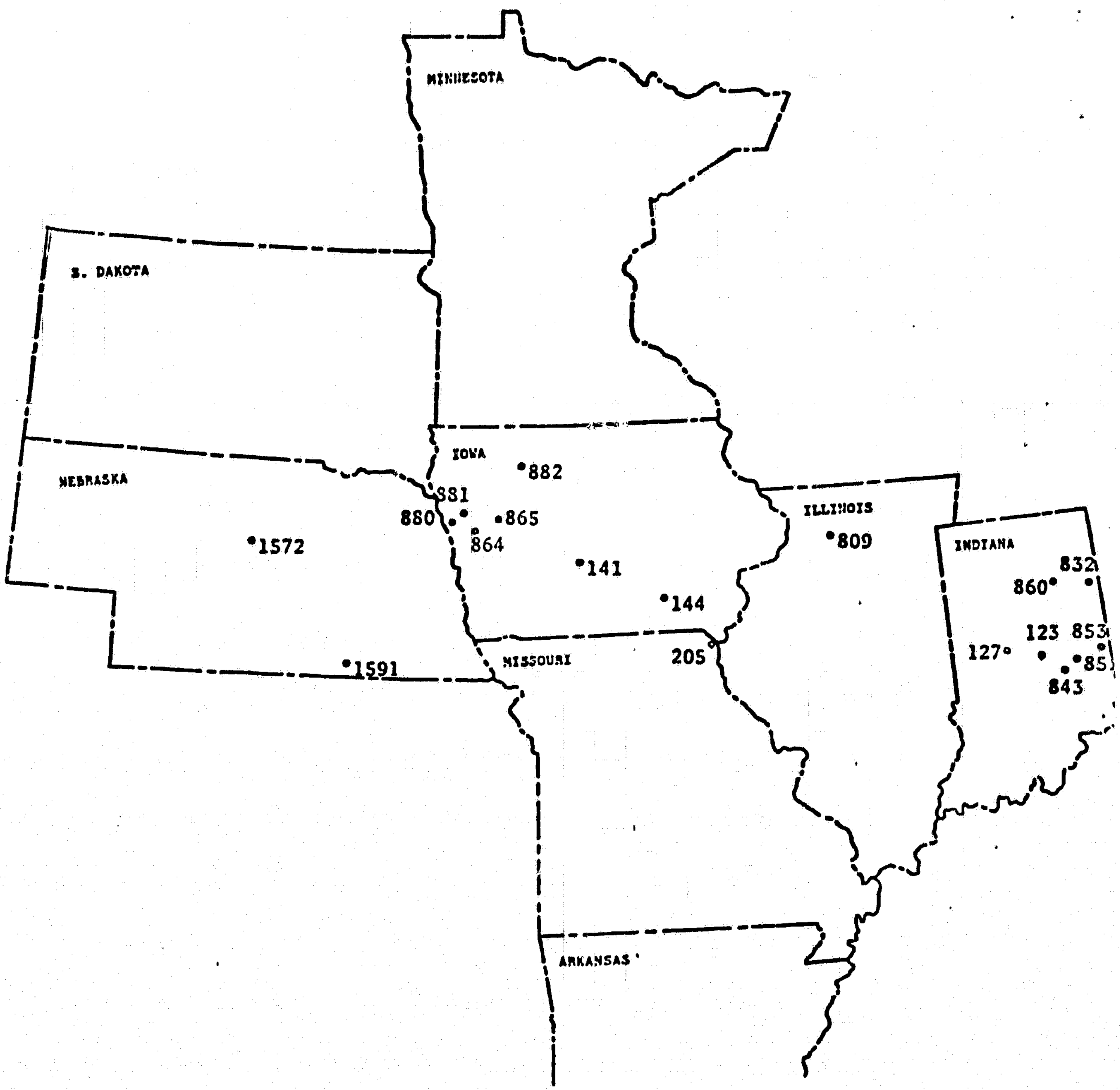
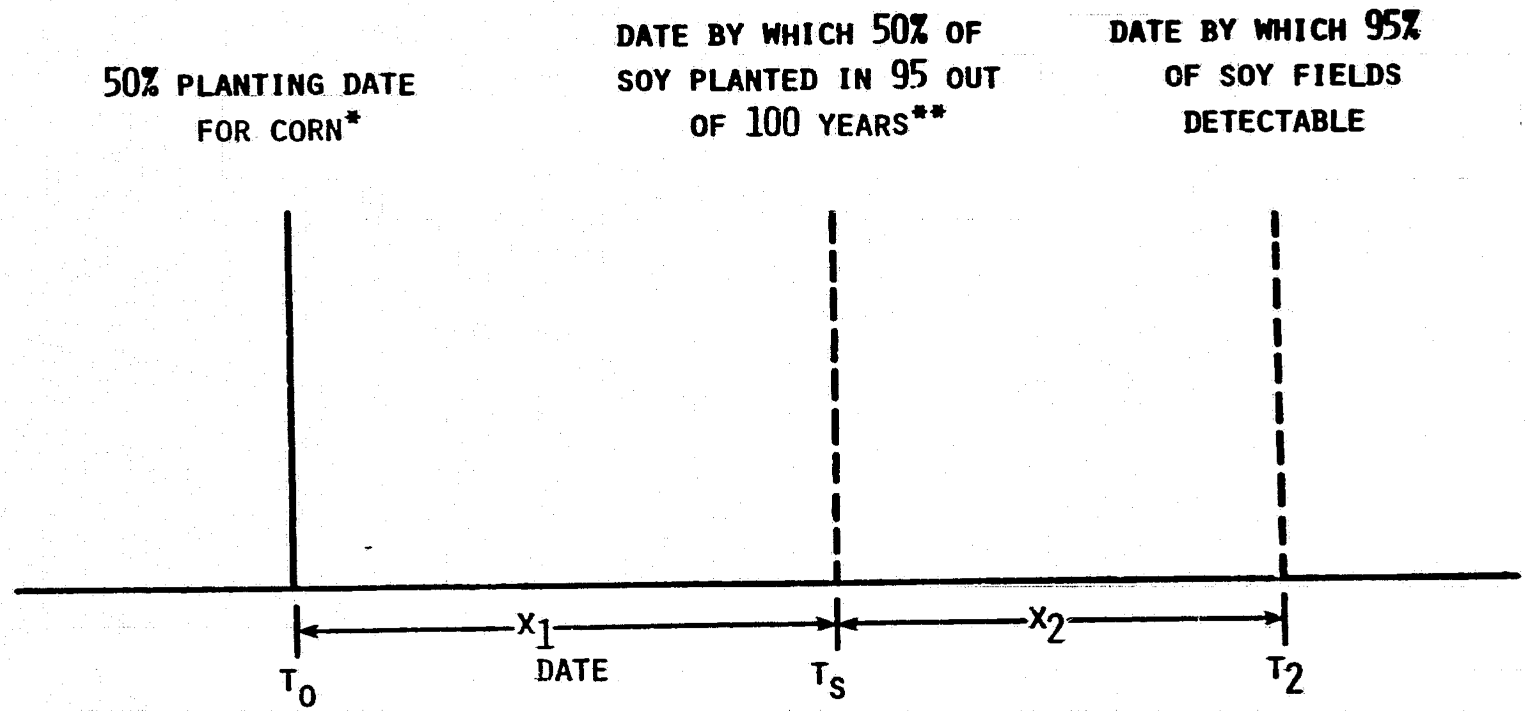


Figure 4

Method for Determining when Summer Crops Have Passed Landsat Threshold of Green Vegetation Detectability

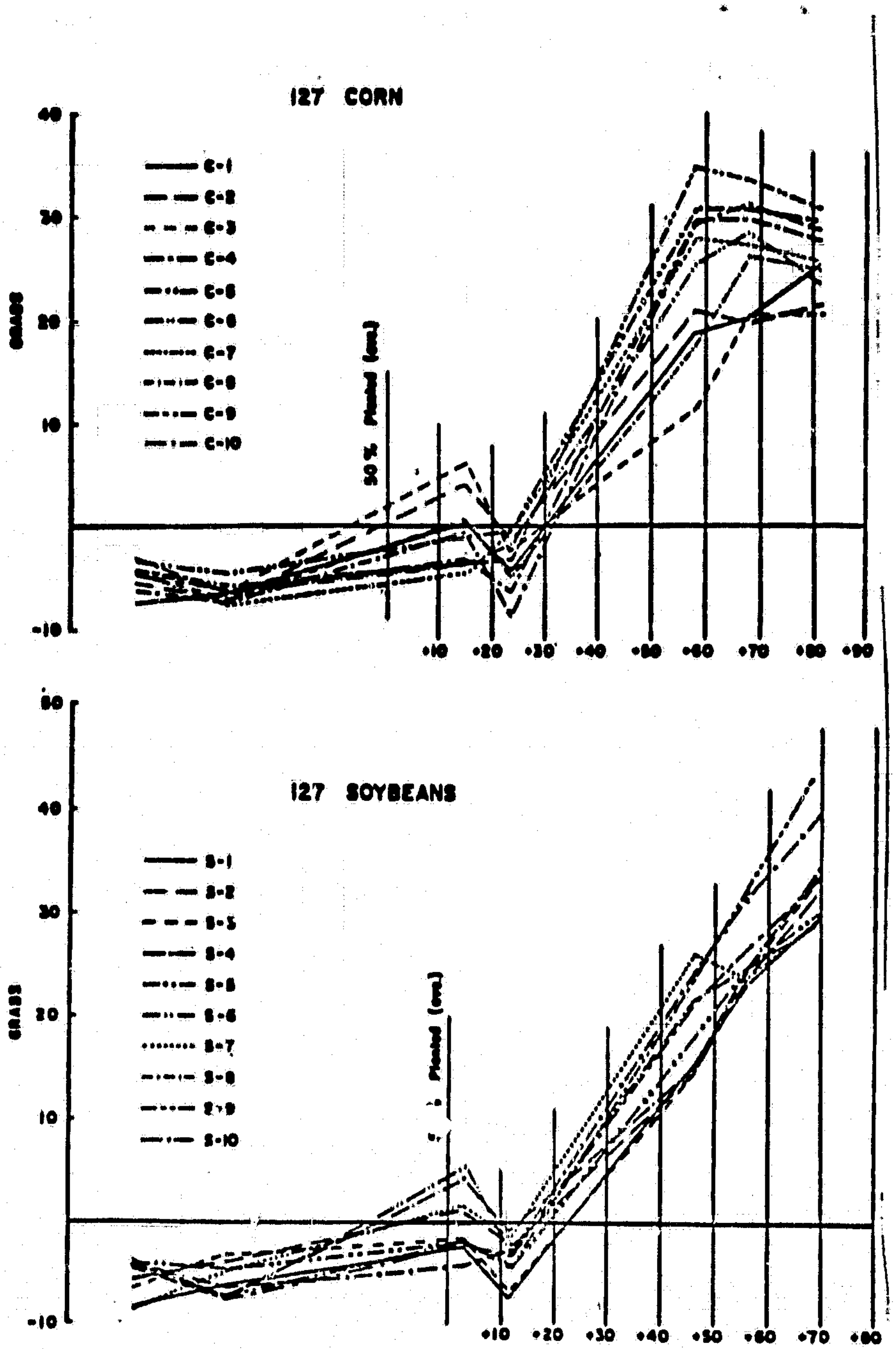


ΔT = NUMBER OF DAYS AFTER 50% PLANTING DATE FOR CORN WHEN WINDOW FOR EARLY SEASON ESTIMATE CLOSES

$\Delta T = X_1 + X_2$

*FROM CROP CALENDAR OR PLANTING MODEL

**FROM CROP CALENDAR DATA



Acquisitions

MR30 (89)
AP17 (107)
JN01 (152)
JN10 (161)
JY16 (197)
JY26 (207)
AG04 (216)

Figure 5

GRABS/Temporal Plots of
Corn and Soybean Field Means, Segment 127

X-axis scales are equal. All fields are detectable
40 days after 50% planted day for corn.

FIGURE 6. Percentage of Corn and Soybean Pixels above GRABS = 5.0 as a Function of Time from Statewide Corn 50% Planted Date.

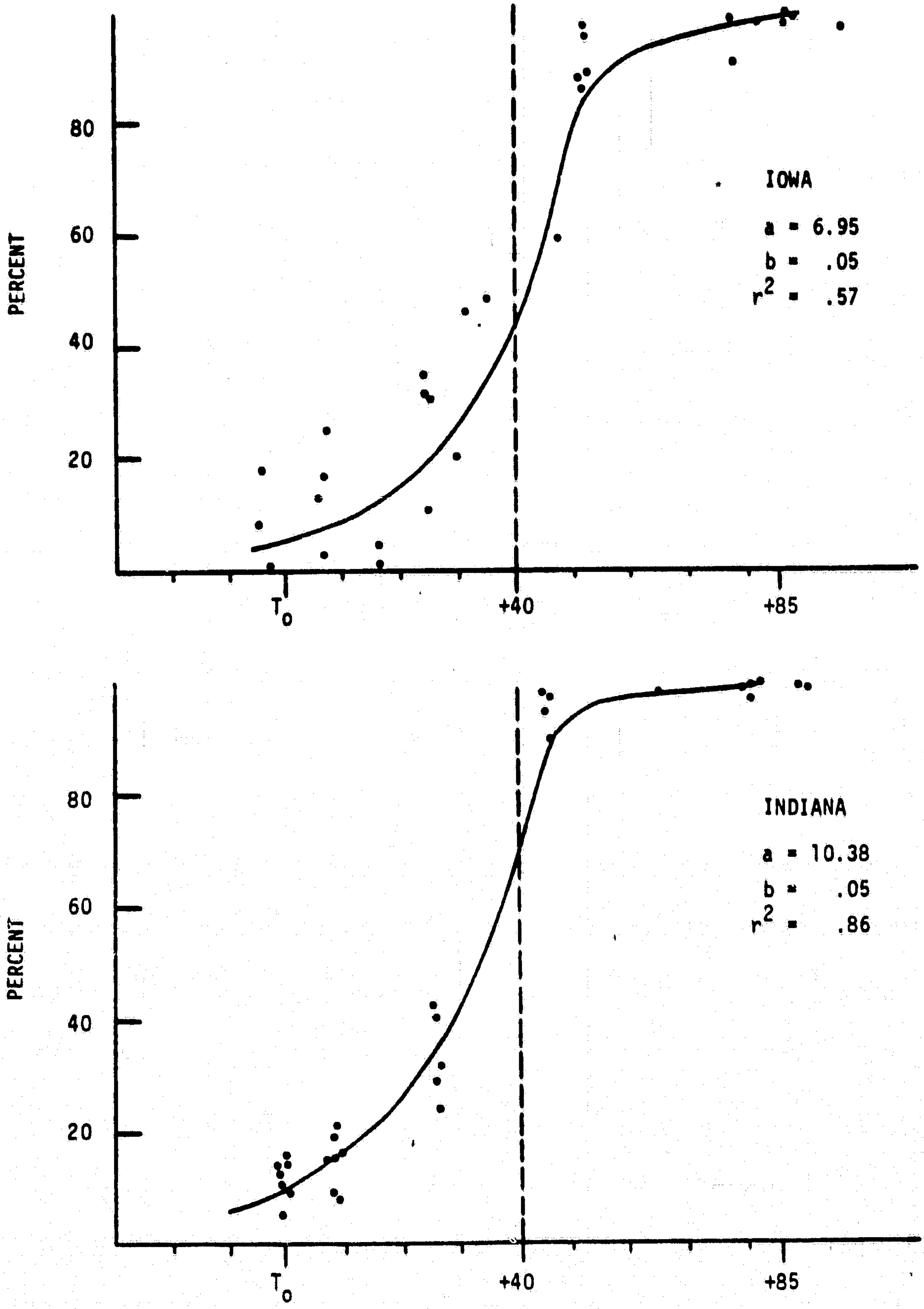
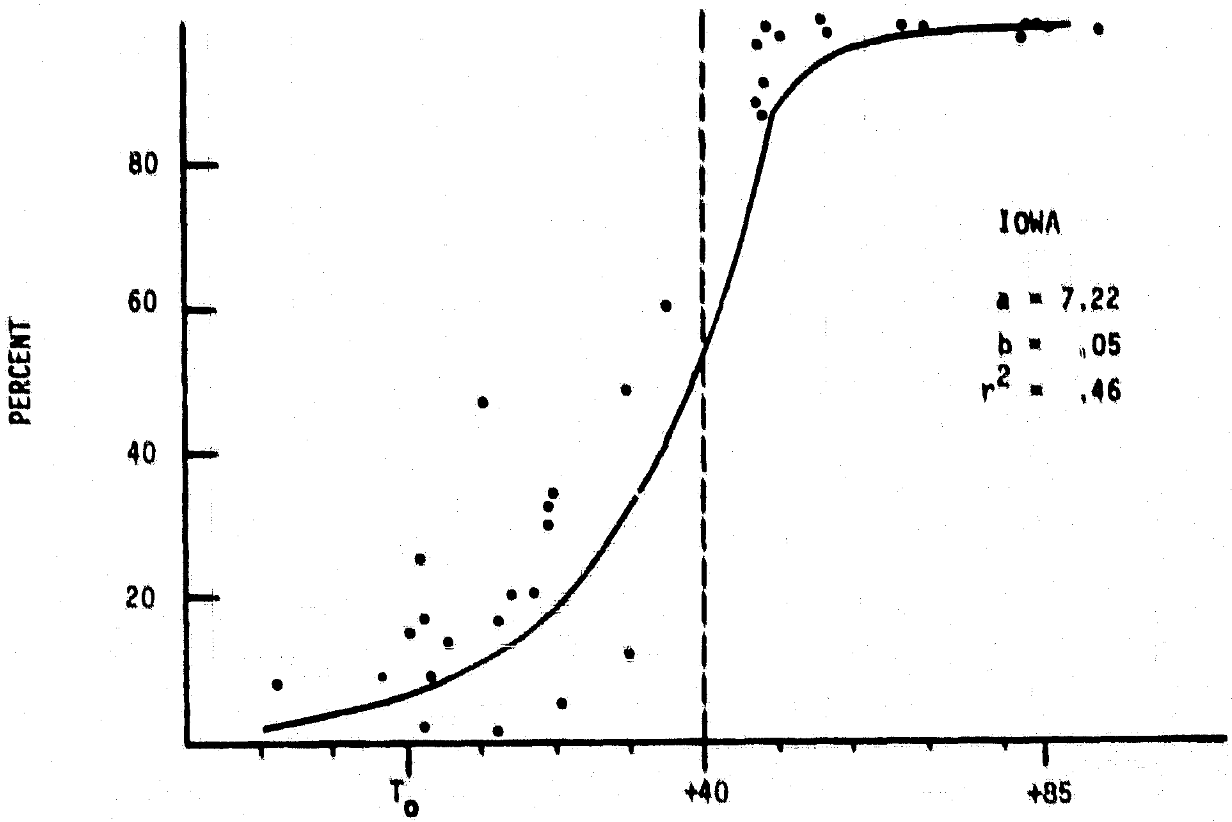
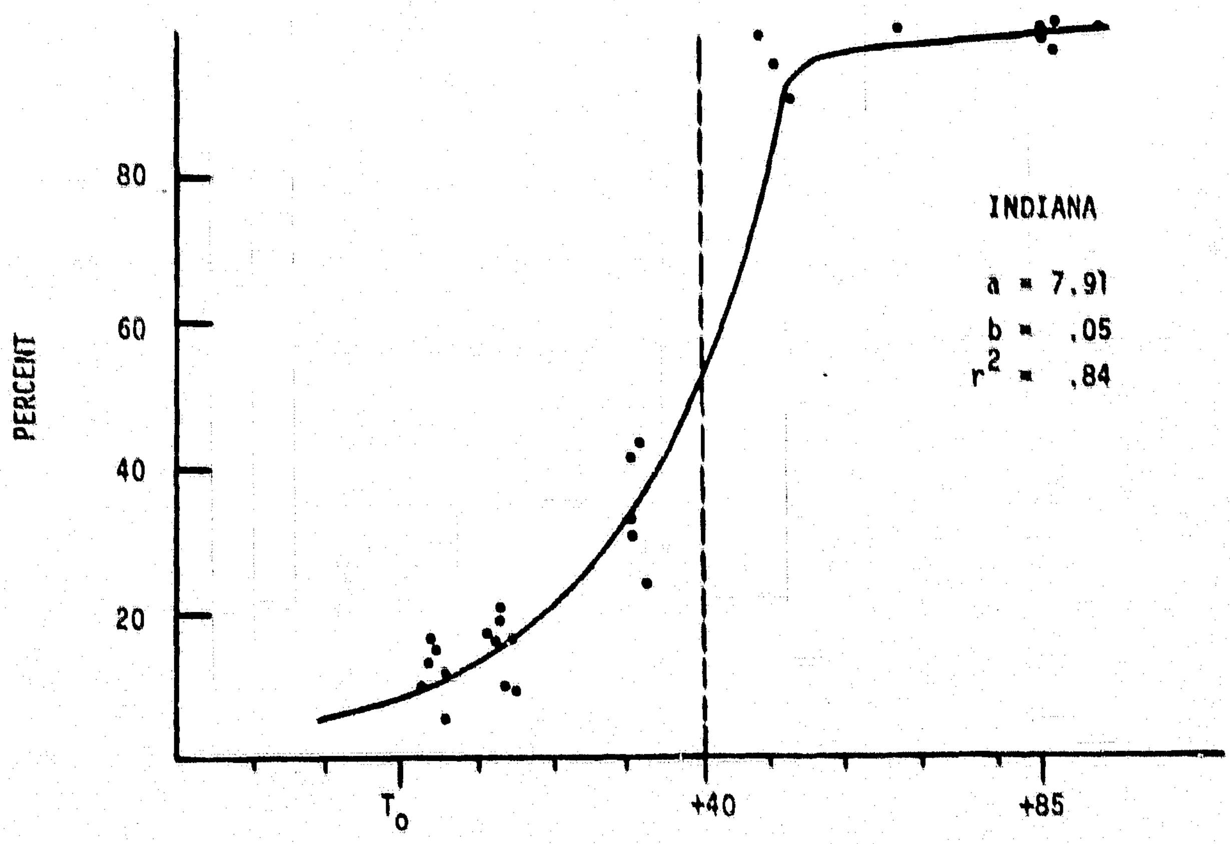


FIGURE 7. Percentage of Corn and Soybean Pixels above GRABS = 5.0 as a Function of Time from Statewide Corn 50% Planted Dated Adjusted to CRD Level.





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3. Hay, C., C. Kuretz, J. Odenweller, E. Sheffner, and B. Wood, 1979. Development of AI Procedures for Dealing with the Effects of Episodal Events on Crop Temporal Spectral Response and Development of AI Guidelines for Corn and Soybean Labeling. Final Report for NASA Contract NAS9-14565, SSL Series 20, Issue 44, Berkeley, California.

APPENDIX A

GRABS and Brightness versus Time Plots

Plots of GRABS (A-1 to A-36) and Brightness (A-37 to A-72) versus time for corn, soybeans and other crops for sample segments listed in Table 2. The actual values equal the plotted value minus 10. The horizontal line indicates the detection threshold (GRABS=0). The first vertical line equals $t_o + 40$; the second vertical line equals $t_o + 85$.

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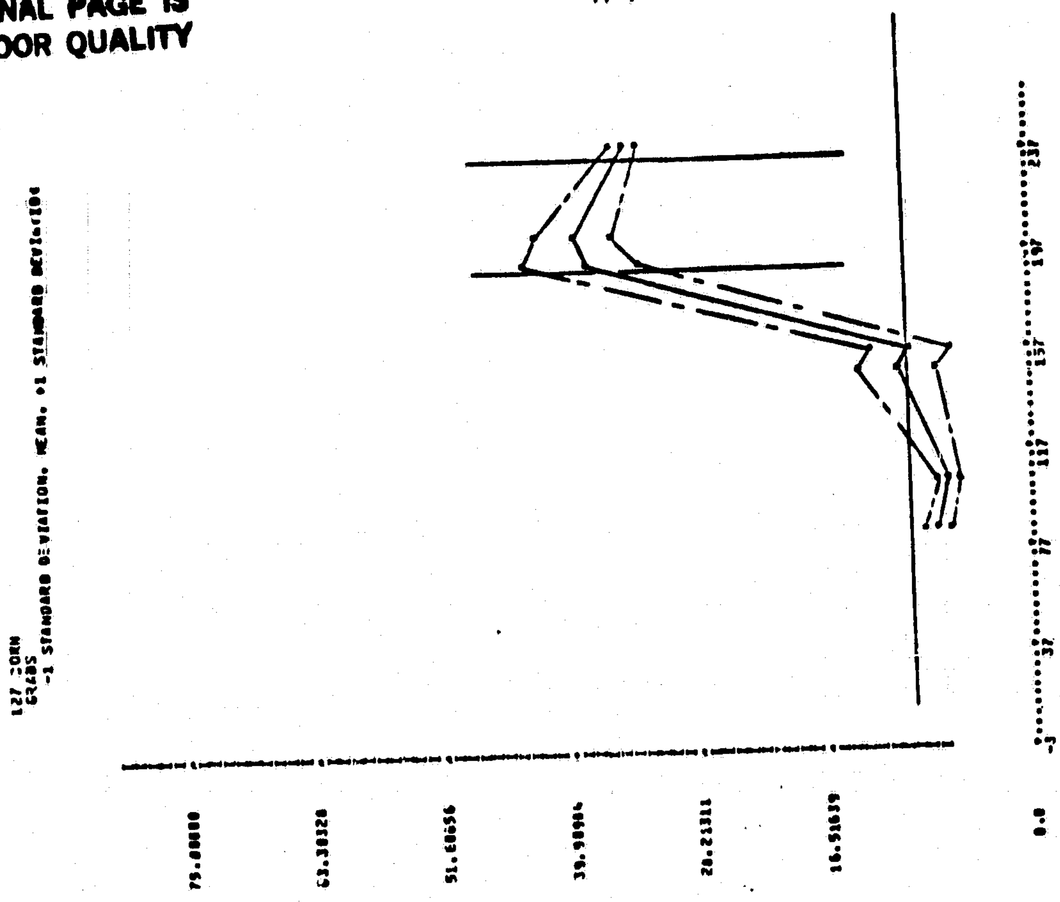

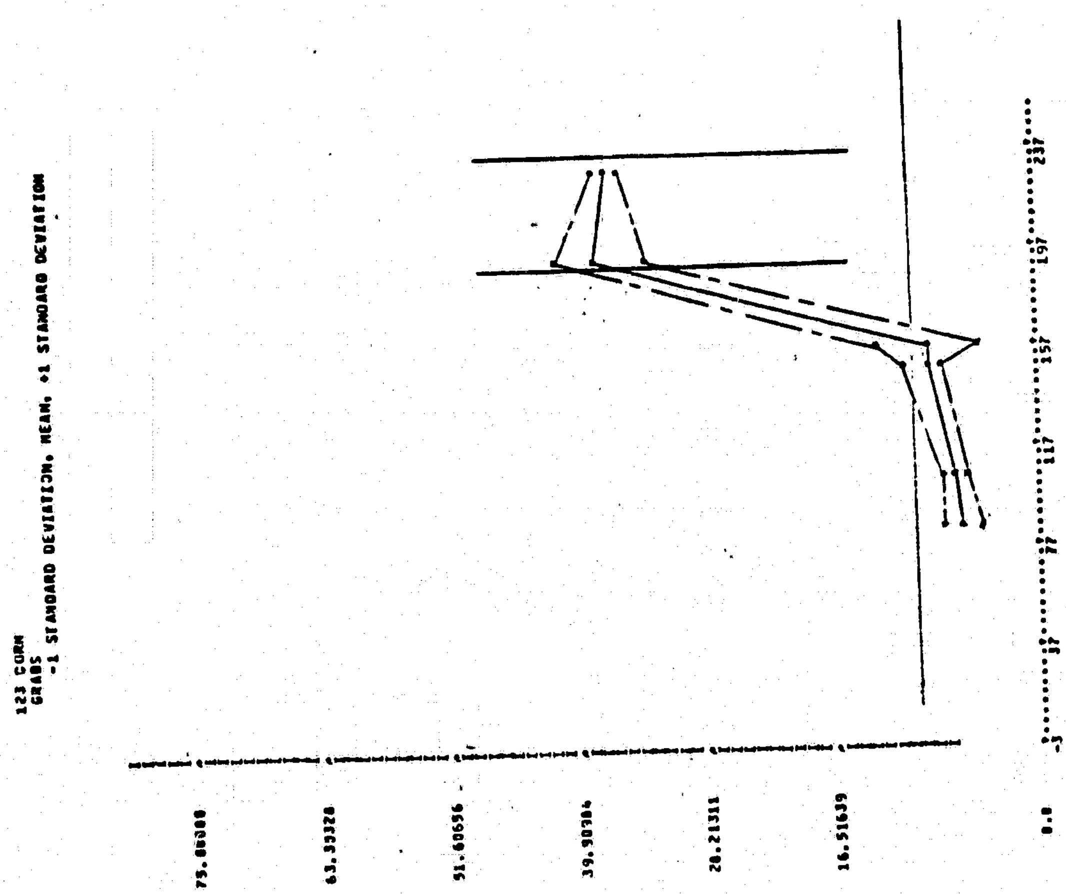

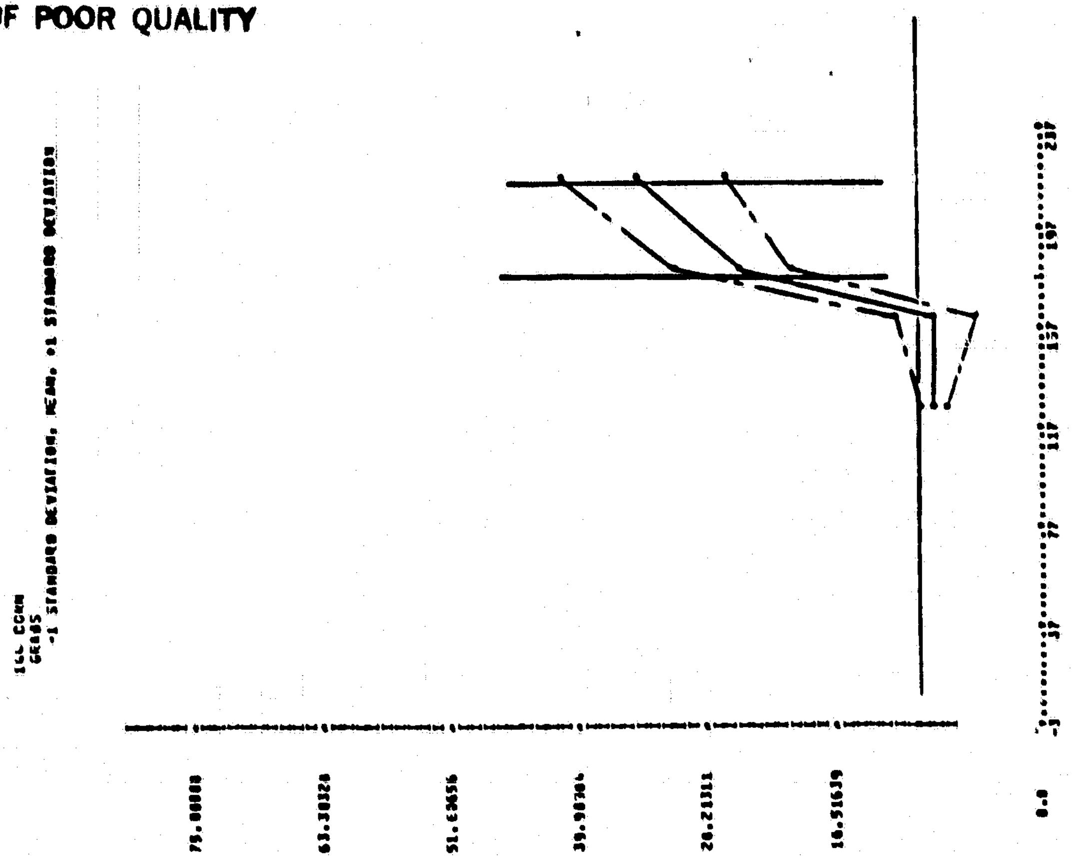
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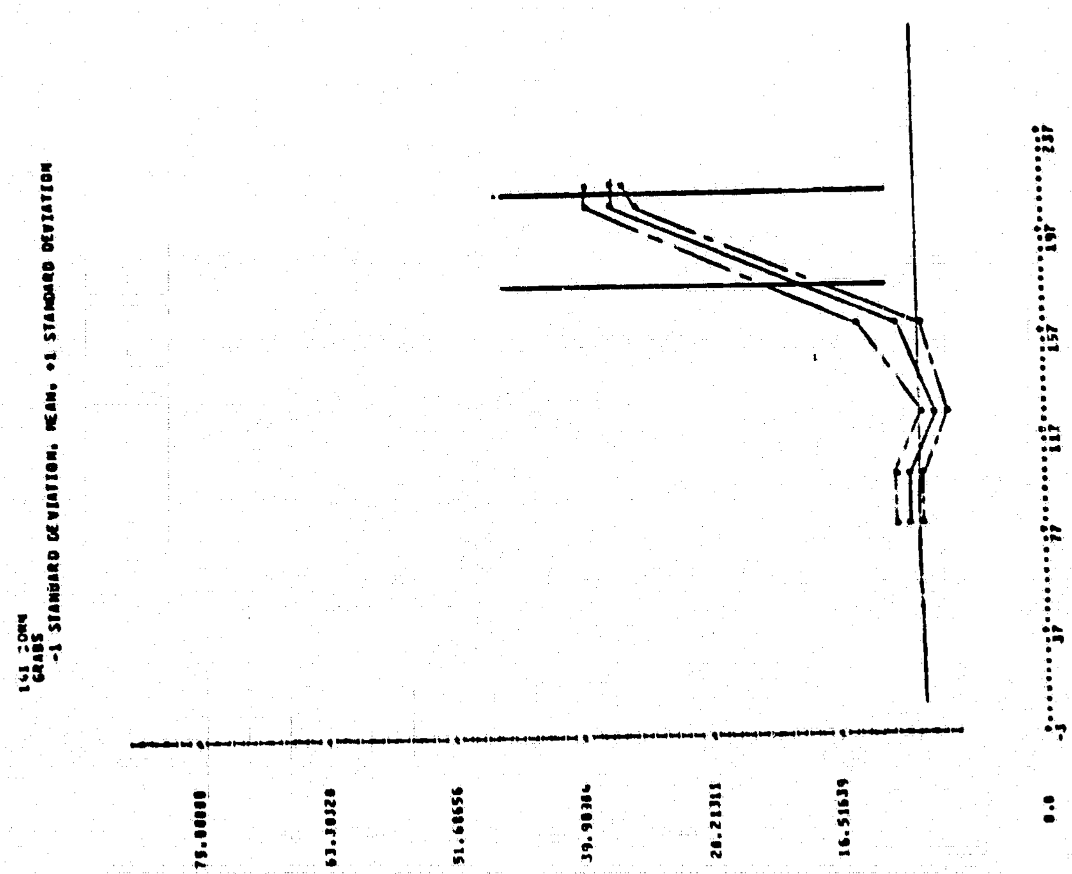
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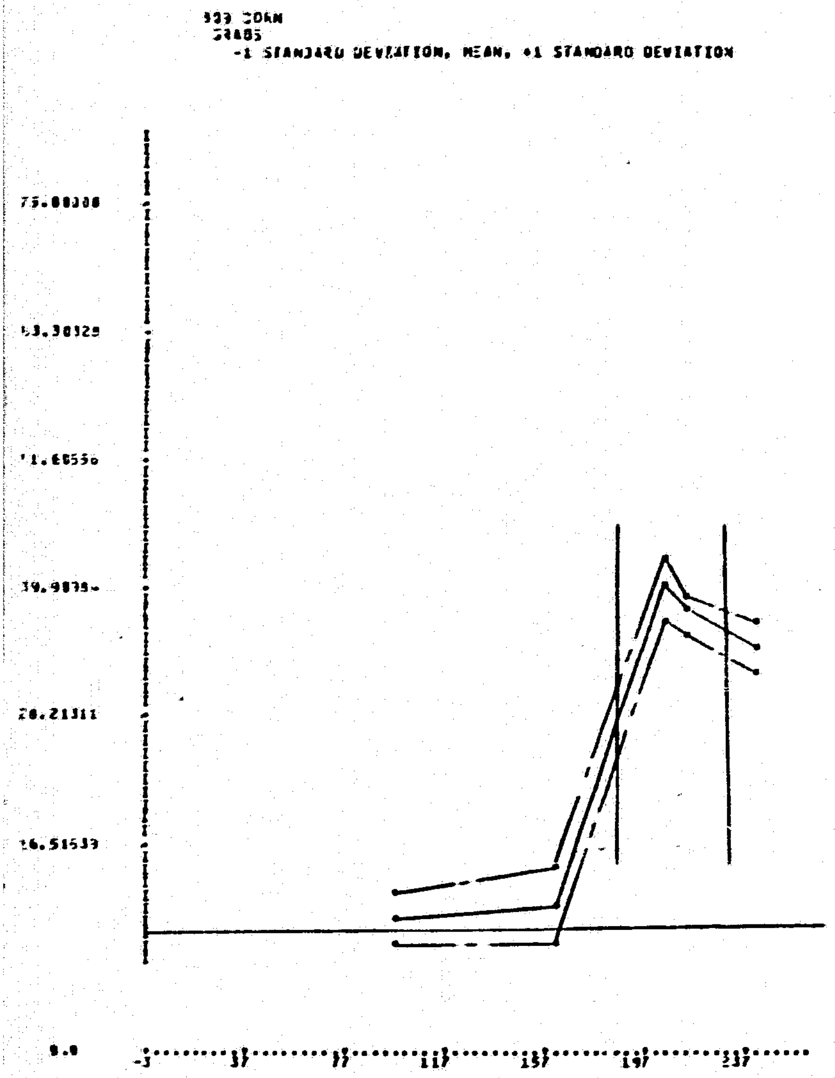
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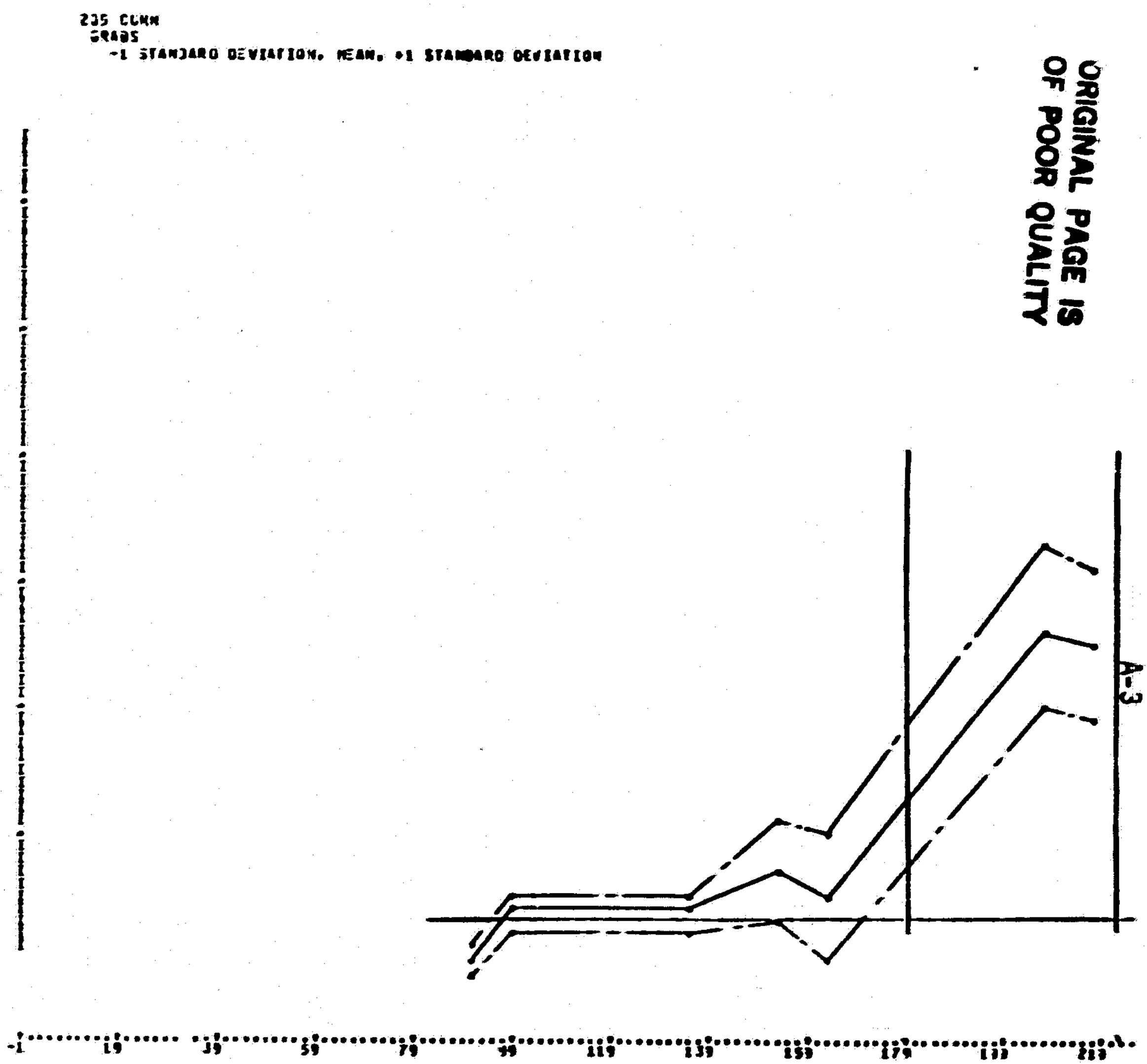
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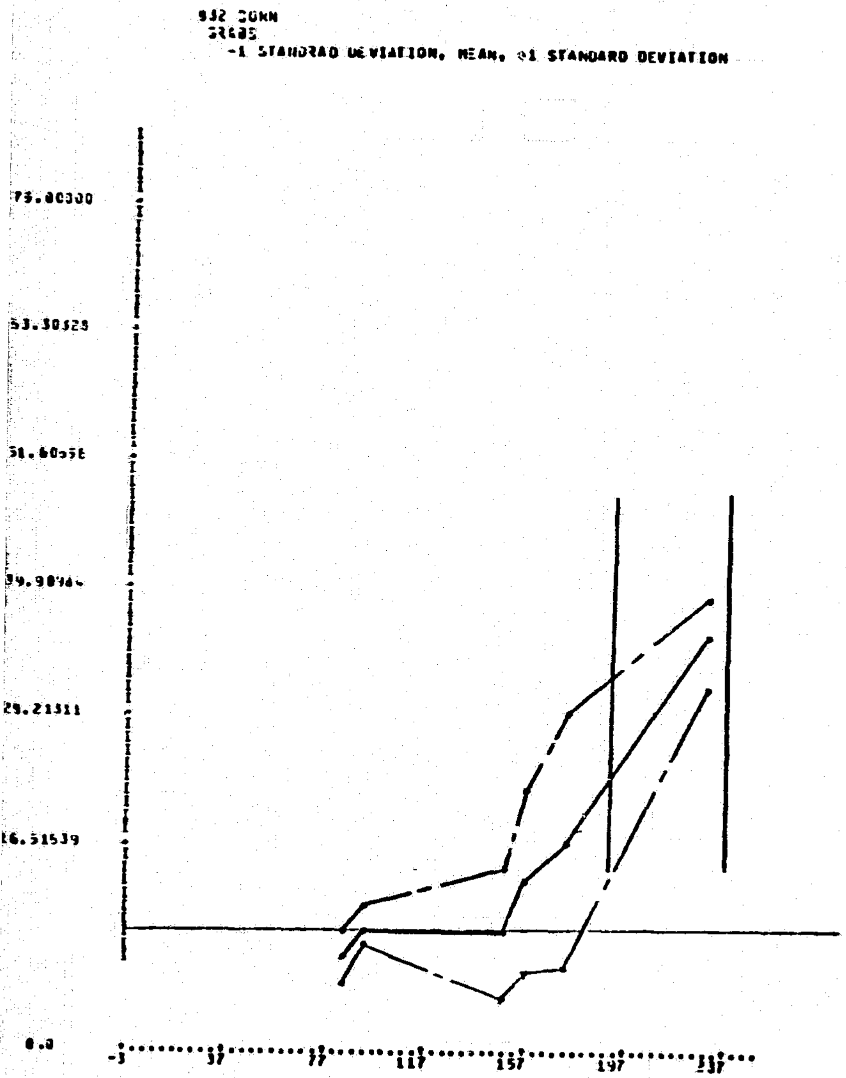

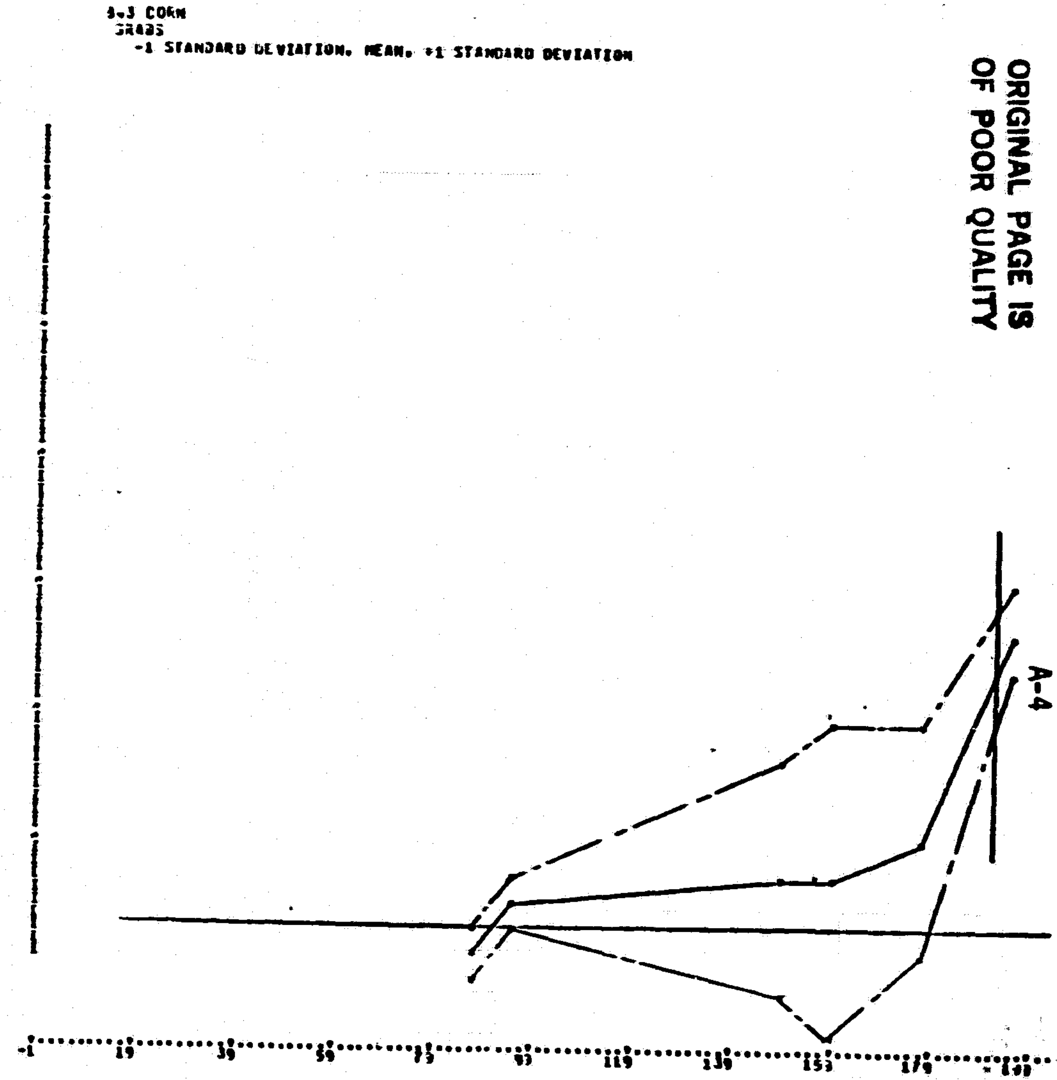

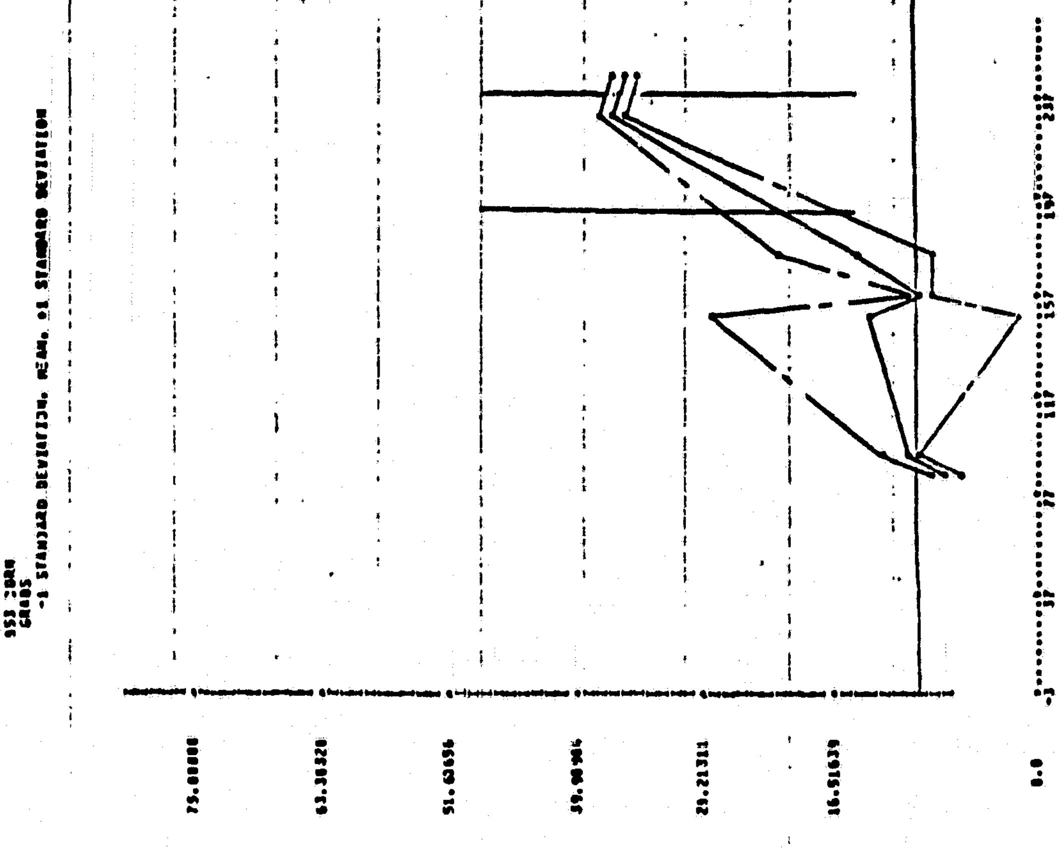
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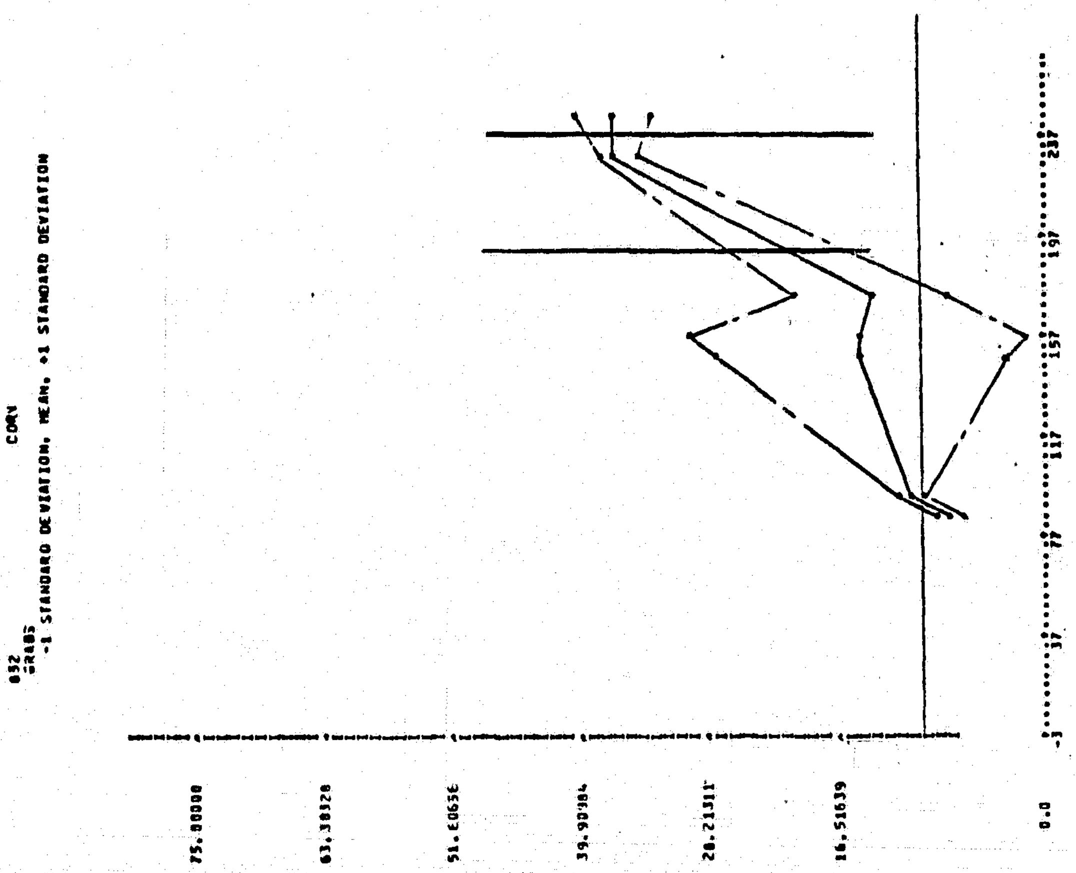
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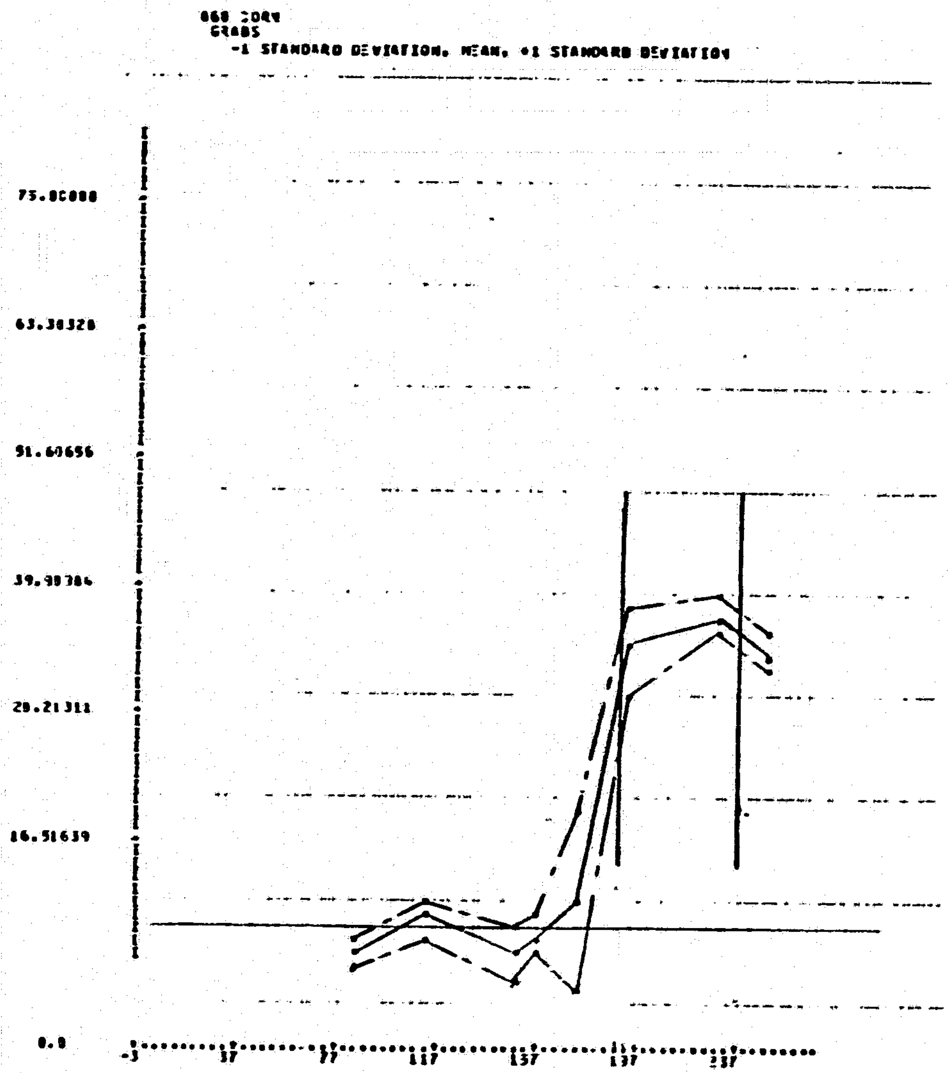
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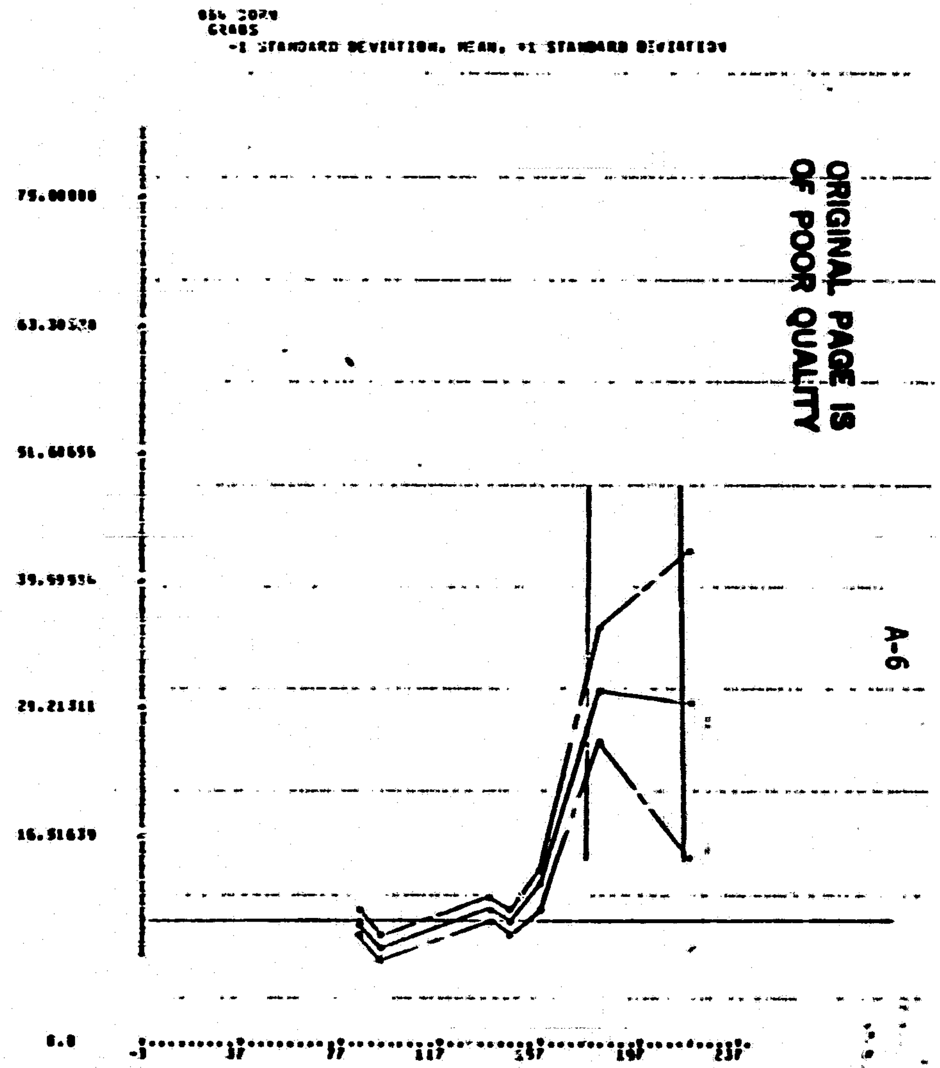
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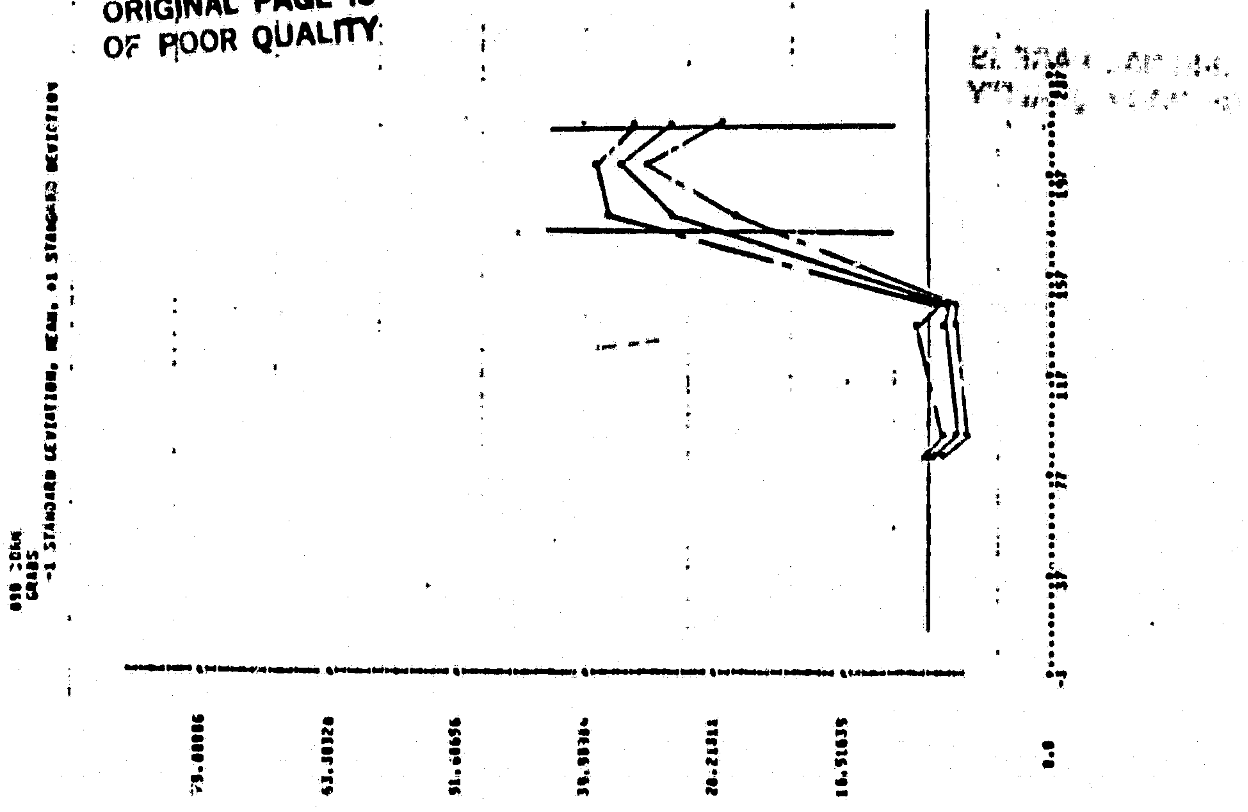
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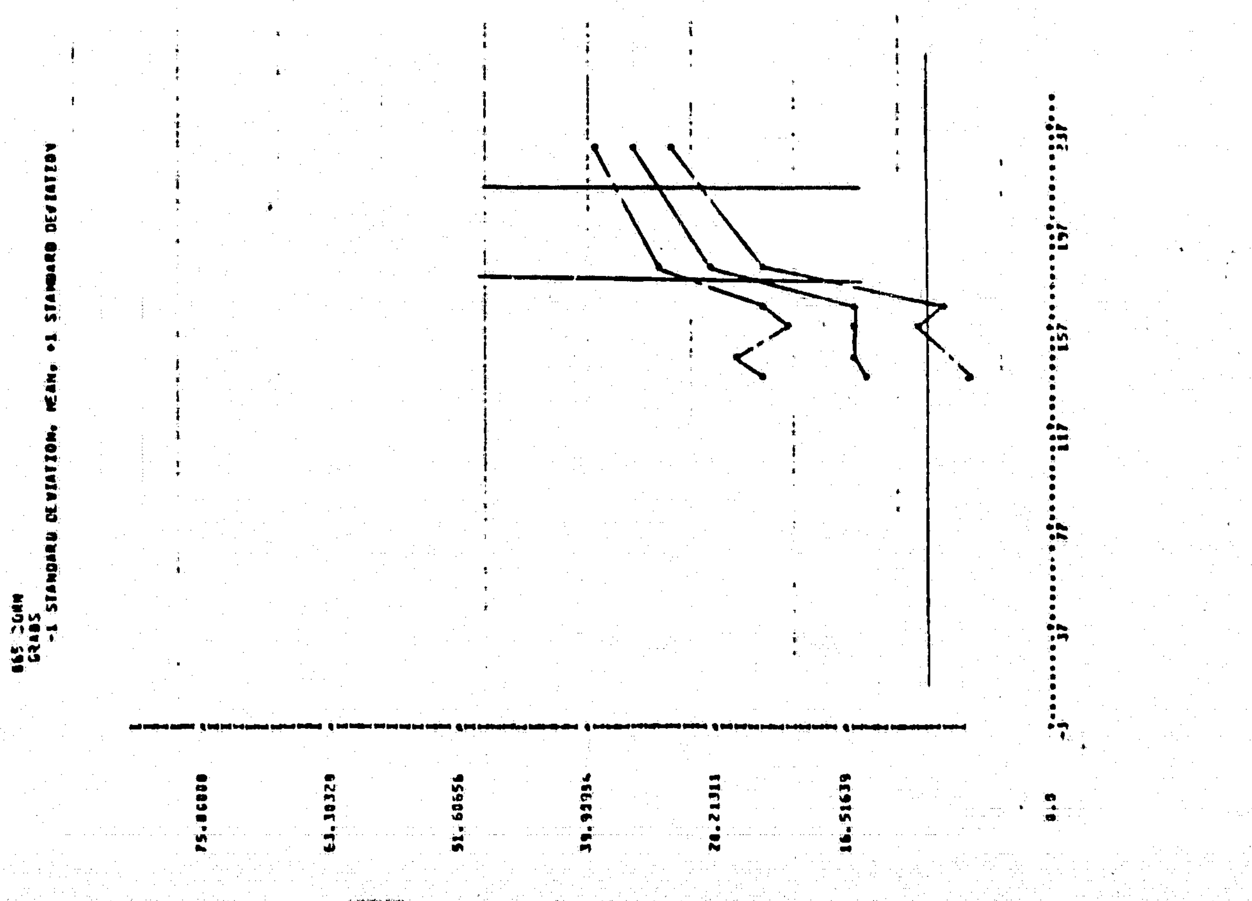
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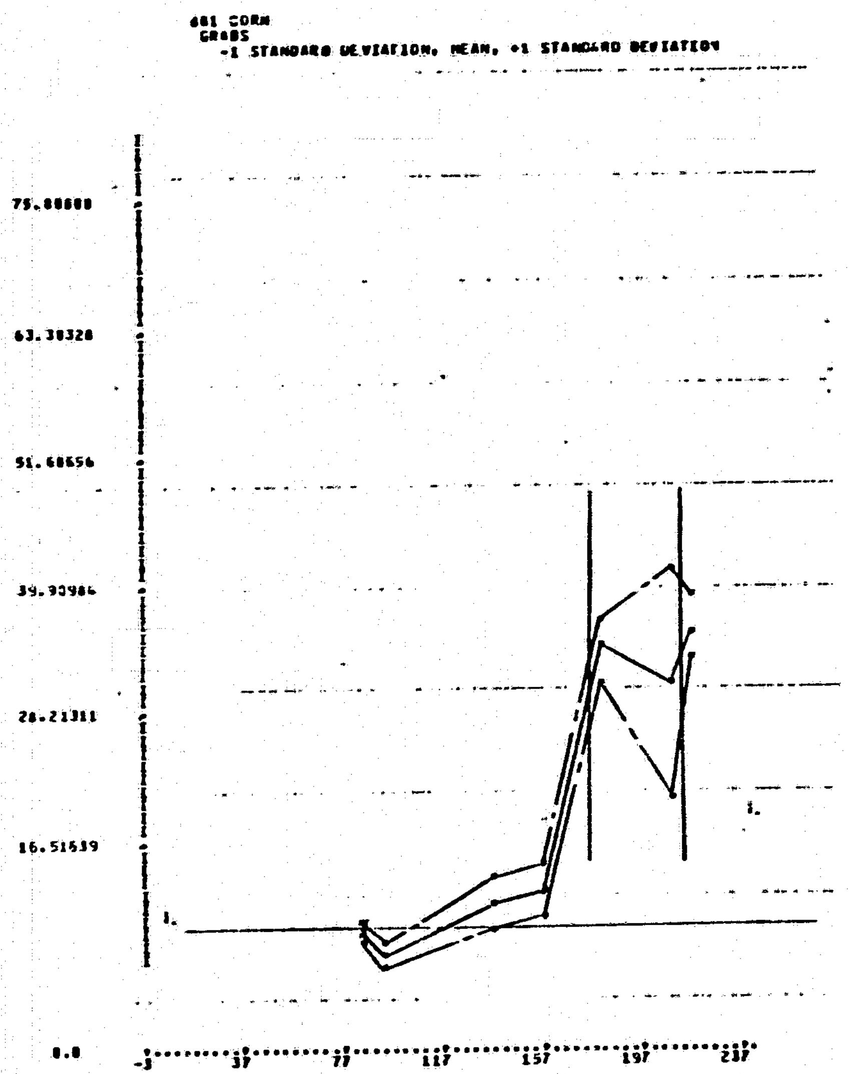
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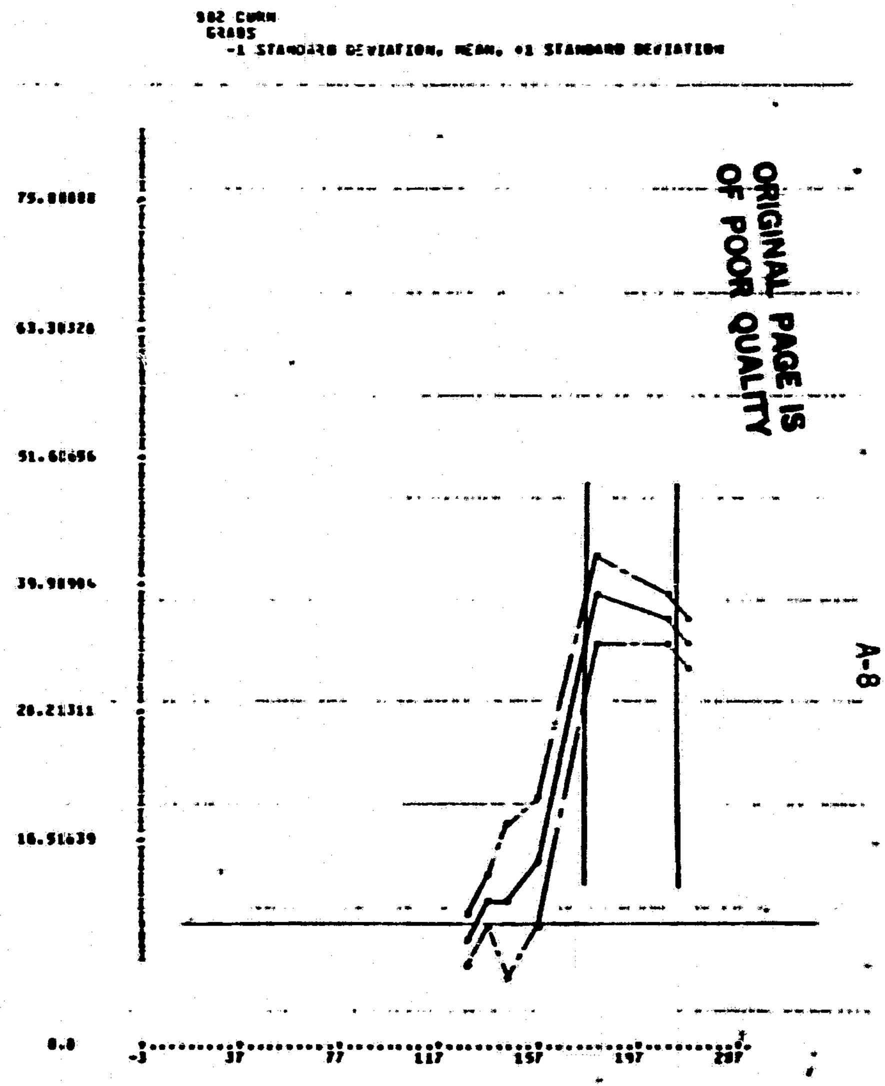
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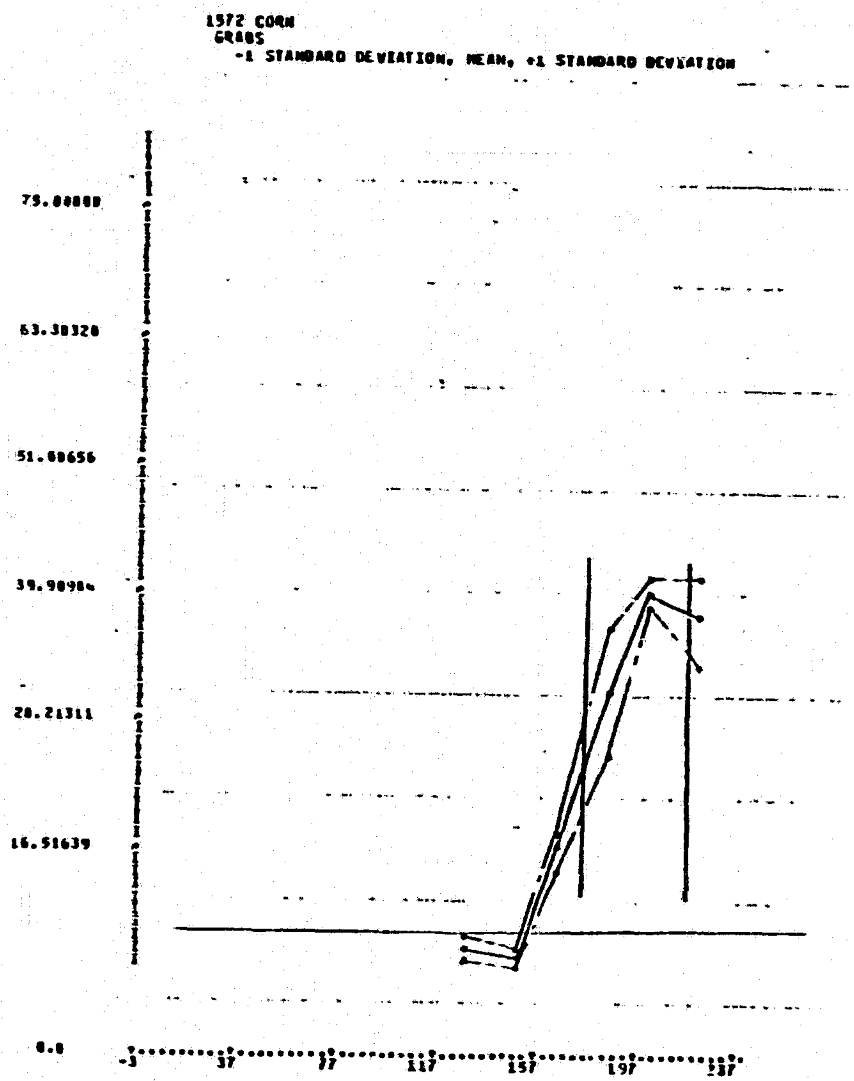
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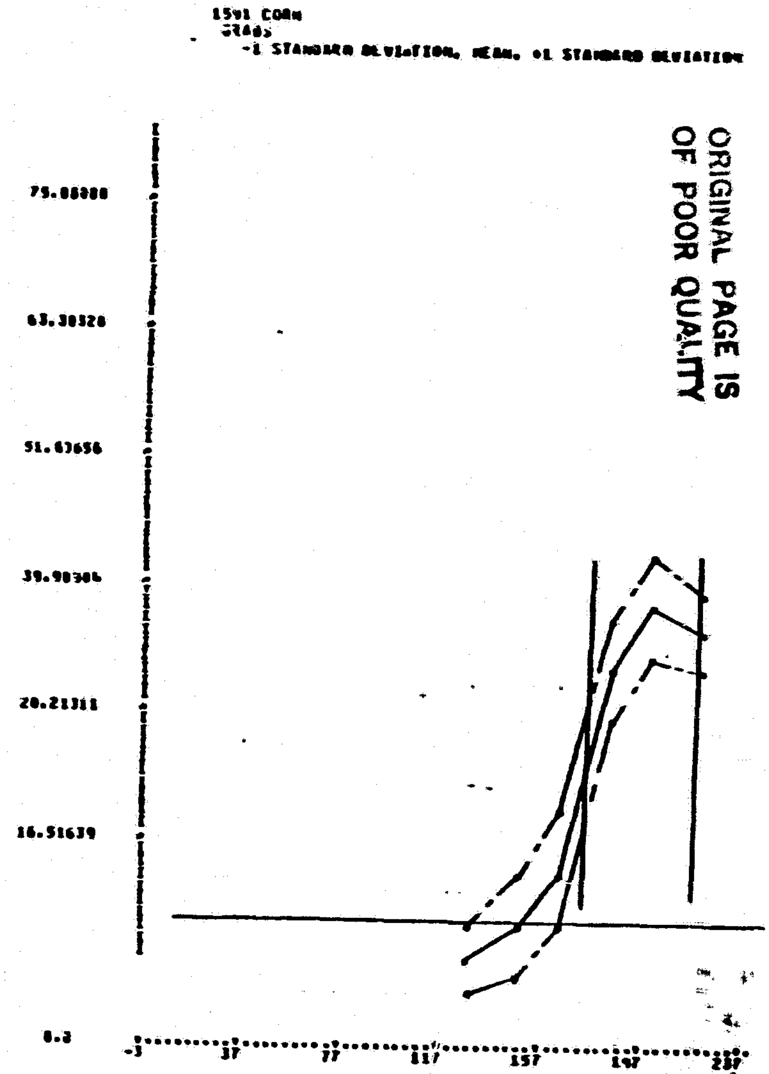
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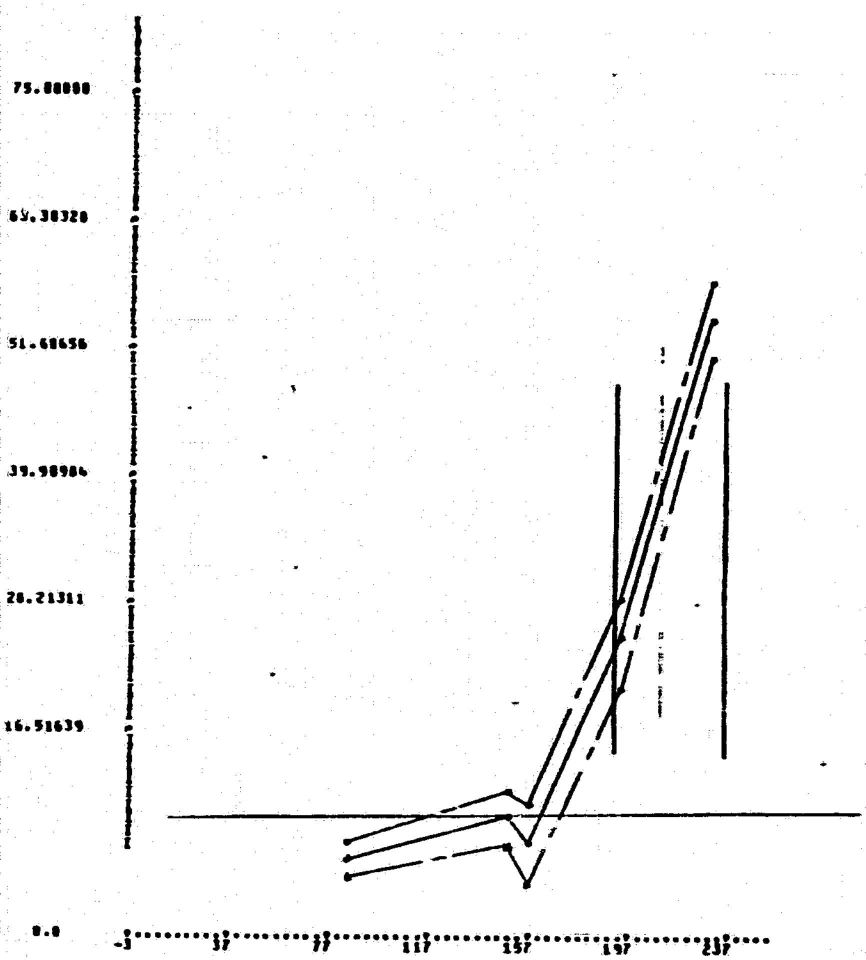
123 SOYBEANS
GRABS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



127 SOYBEANS
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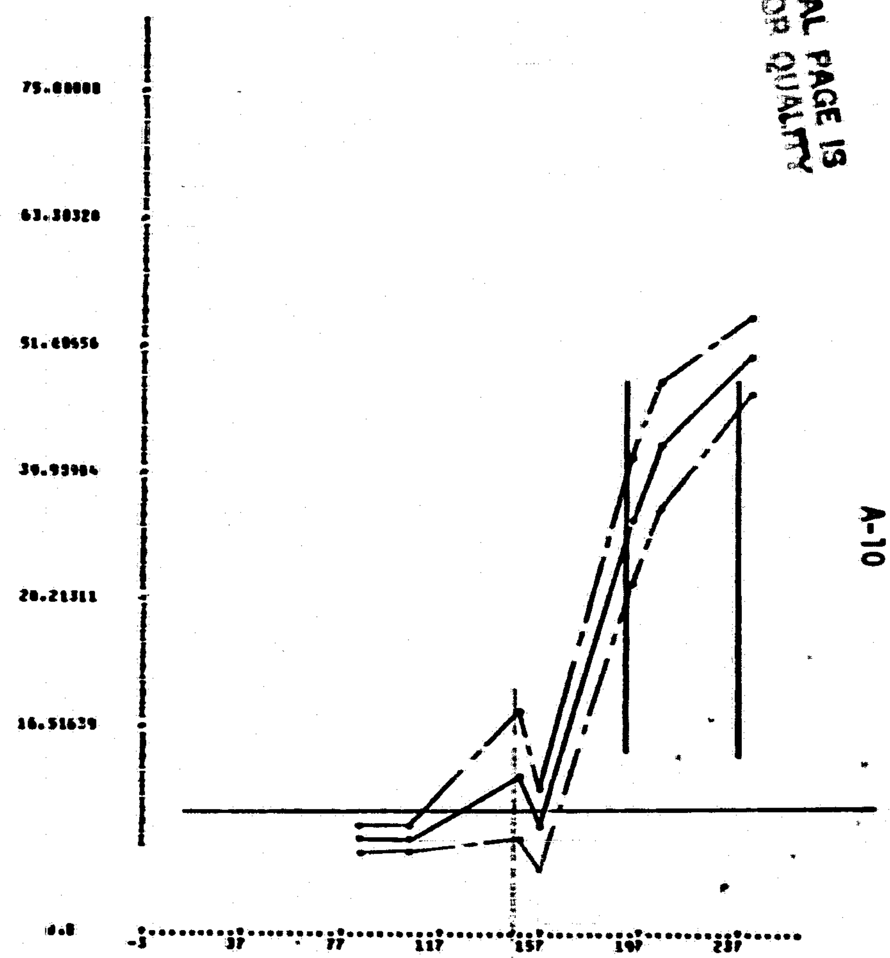

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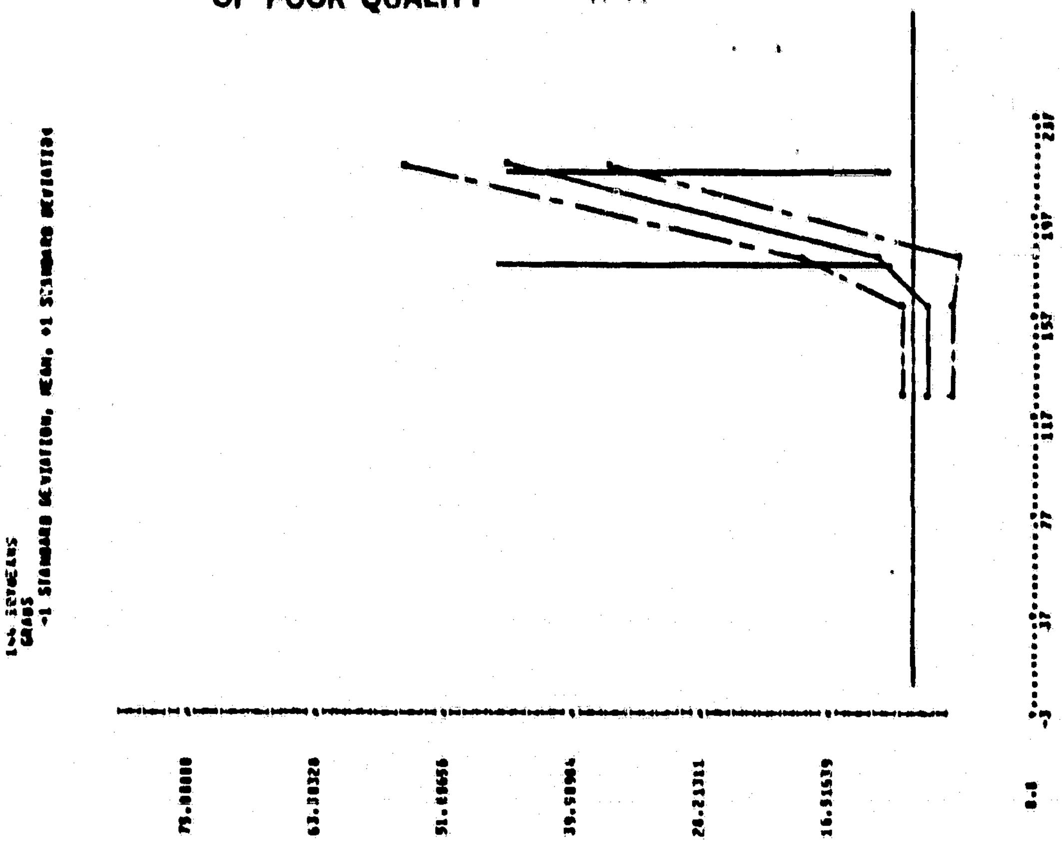

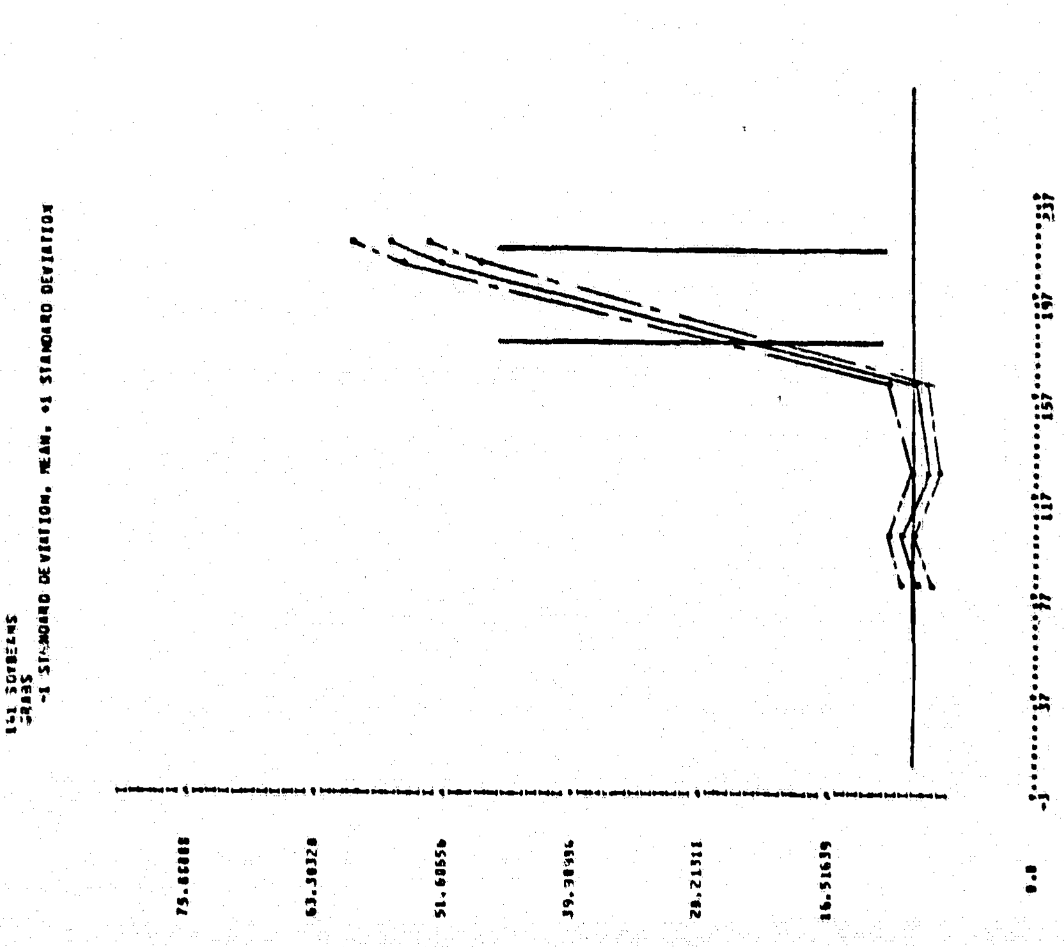

205 SOYBEANS
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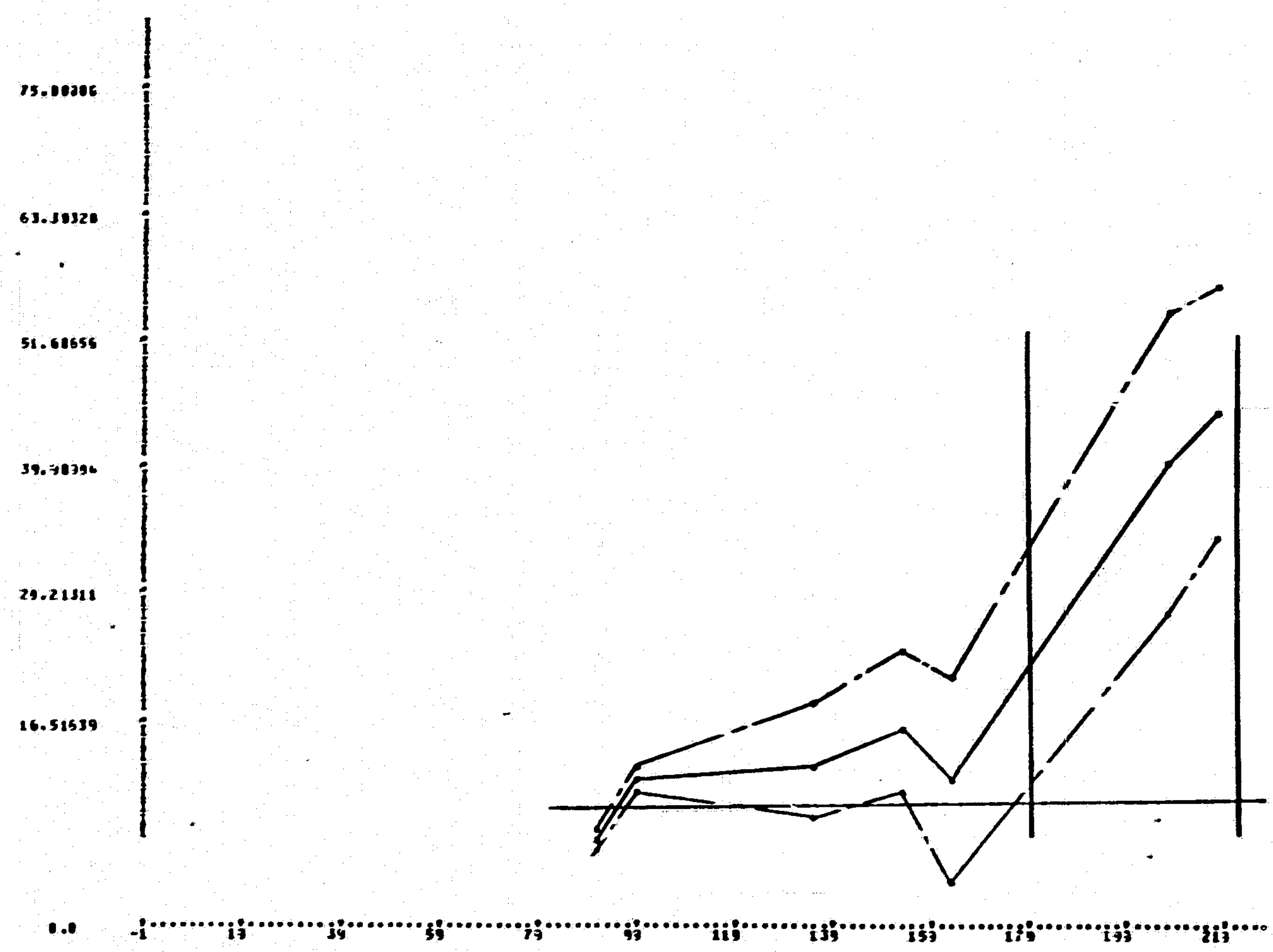

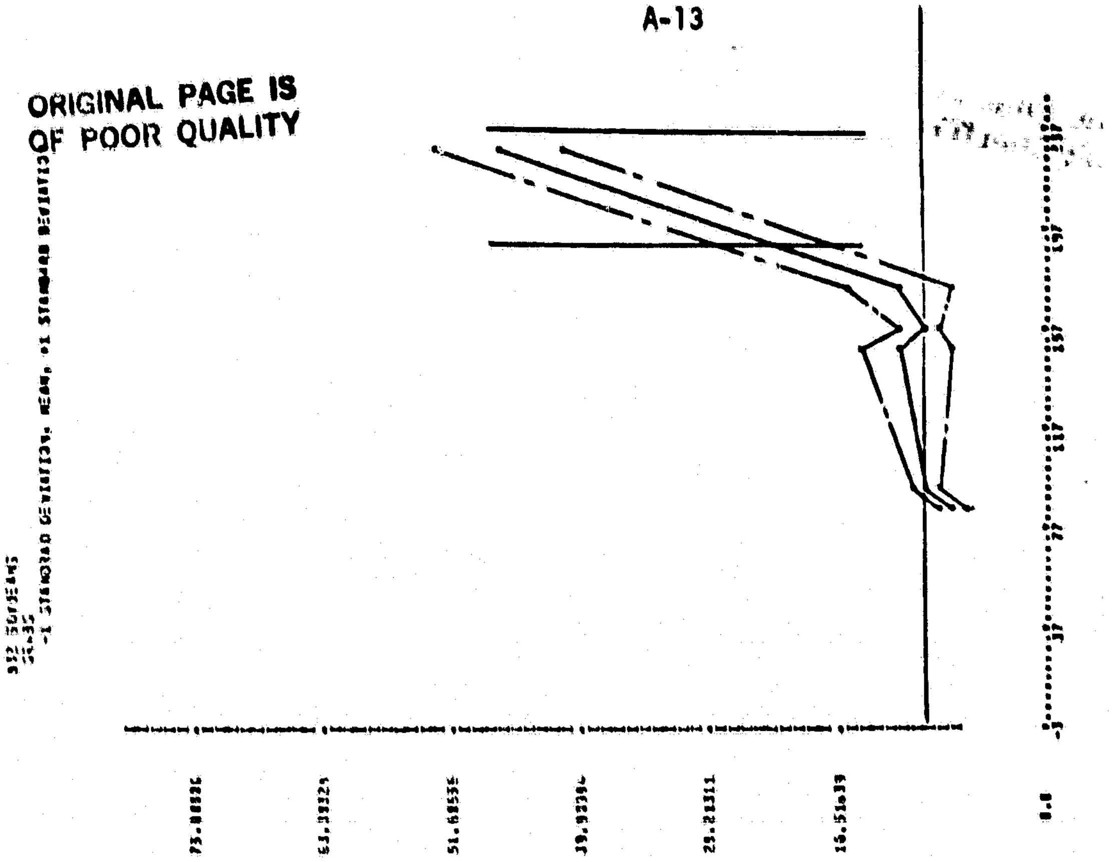
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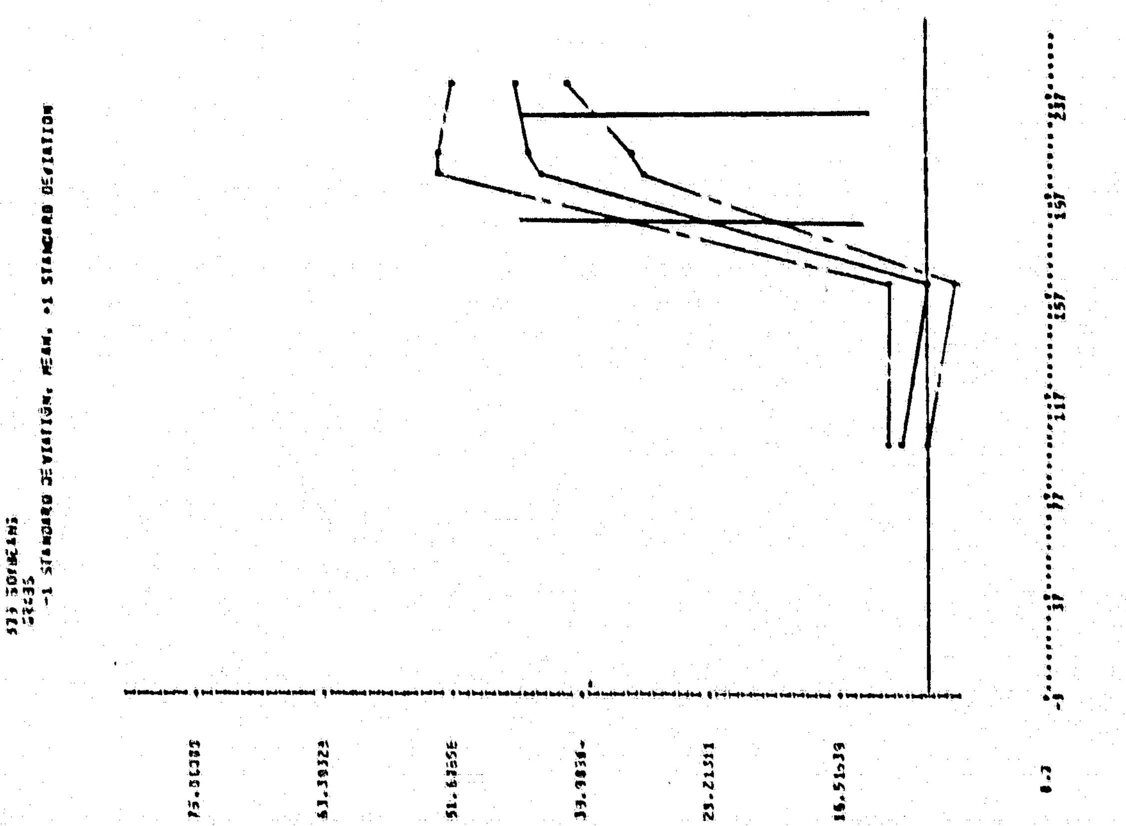
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832 SOYBEANS
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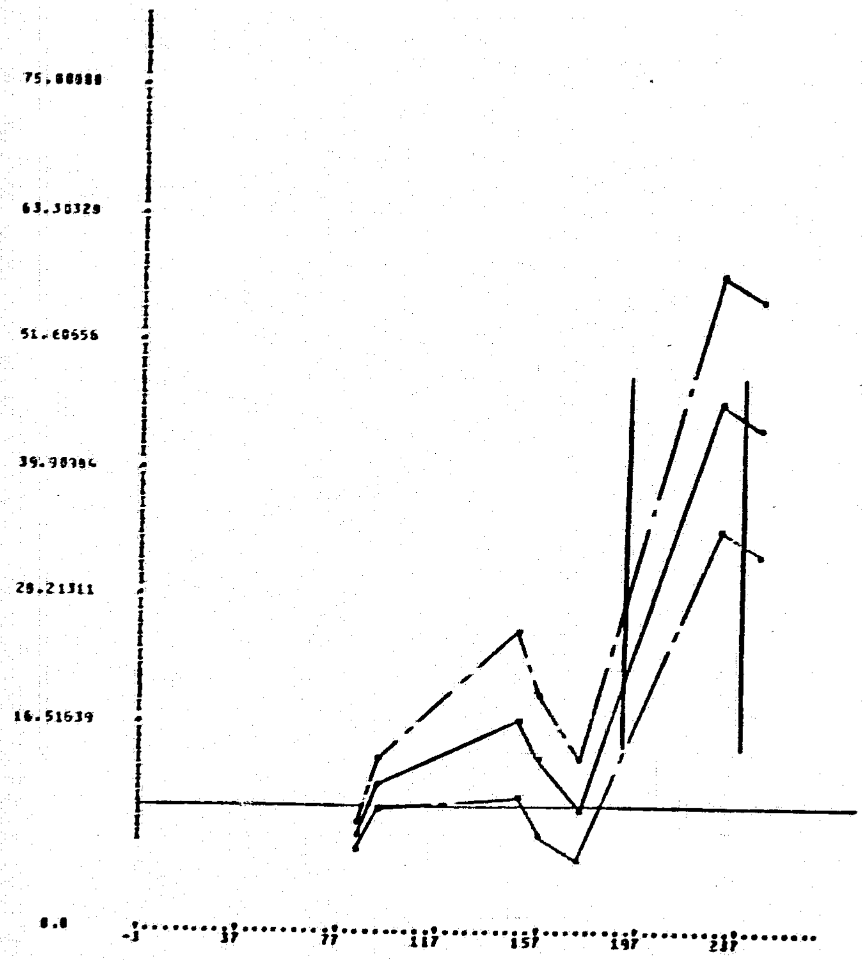

9-3 SOYBEANS
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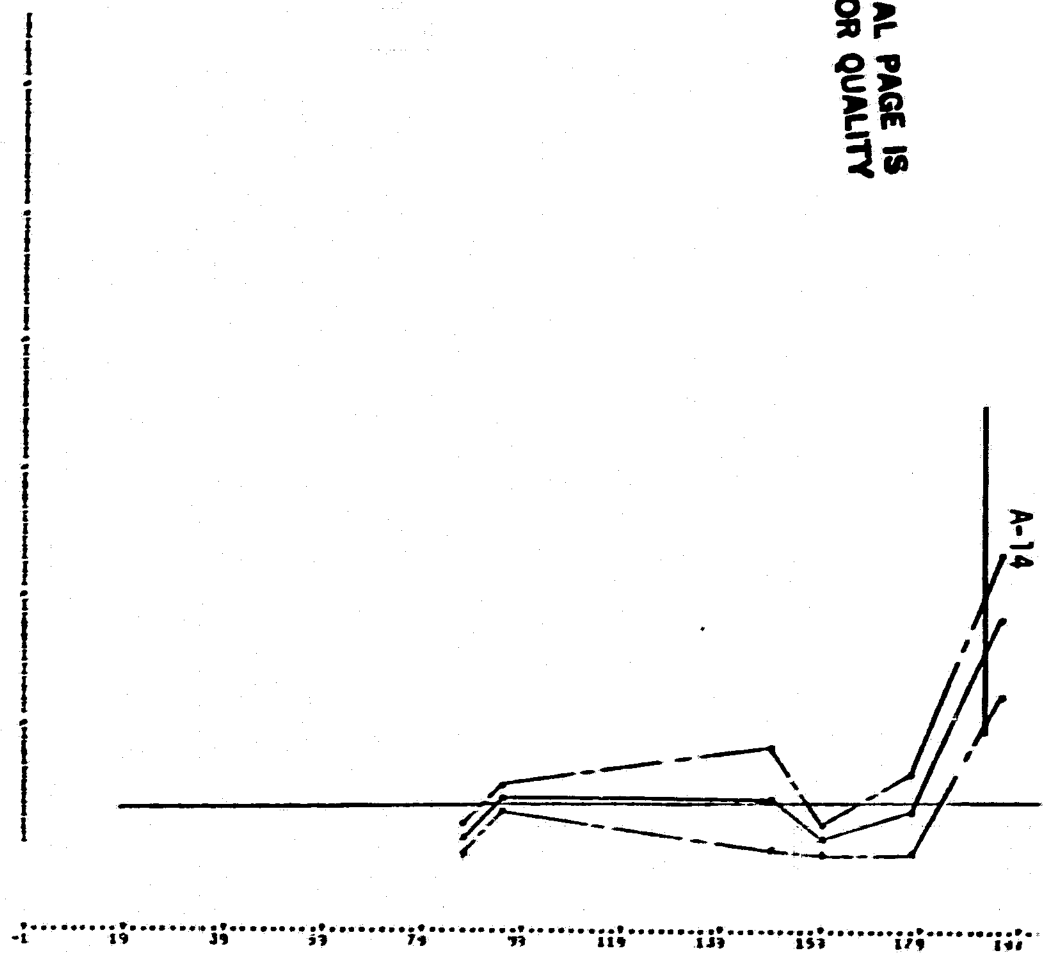

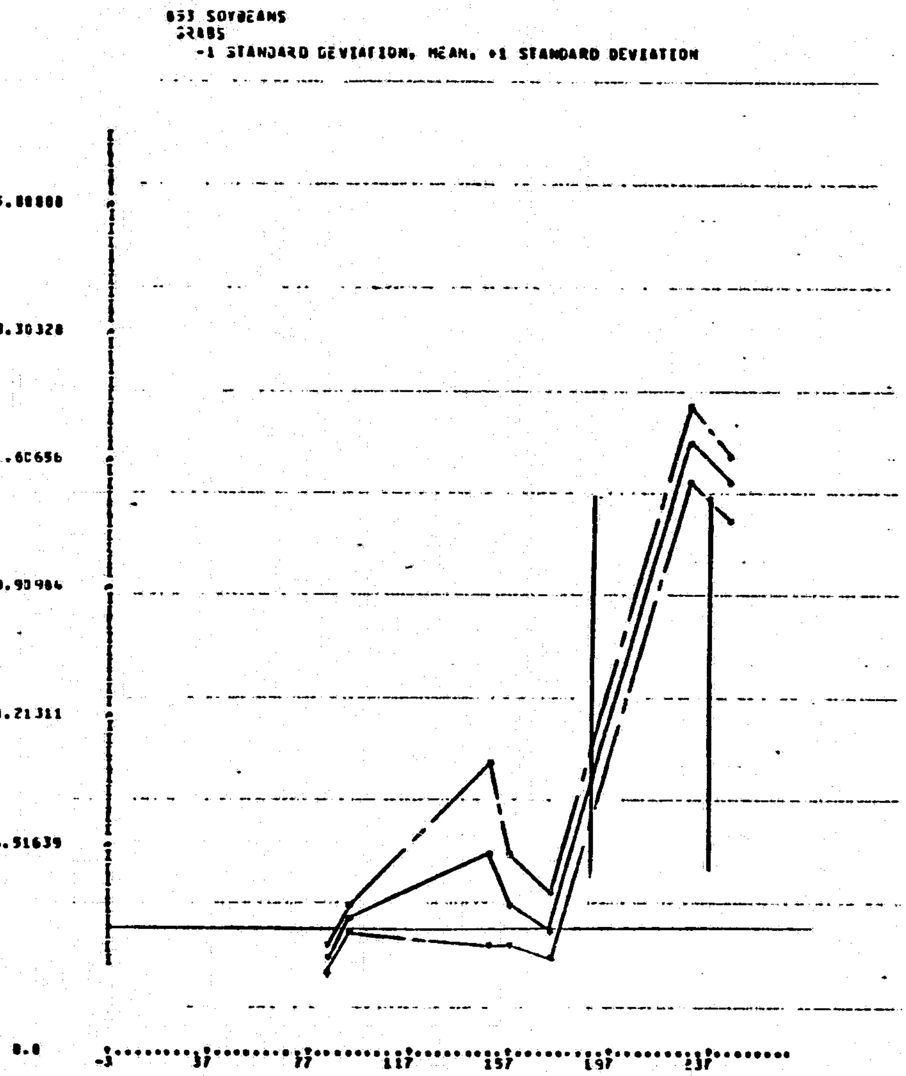
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GRABS
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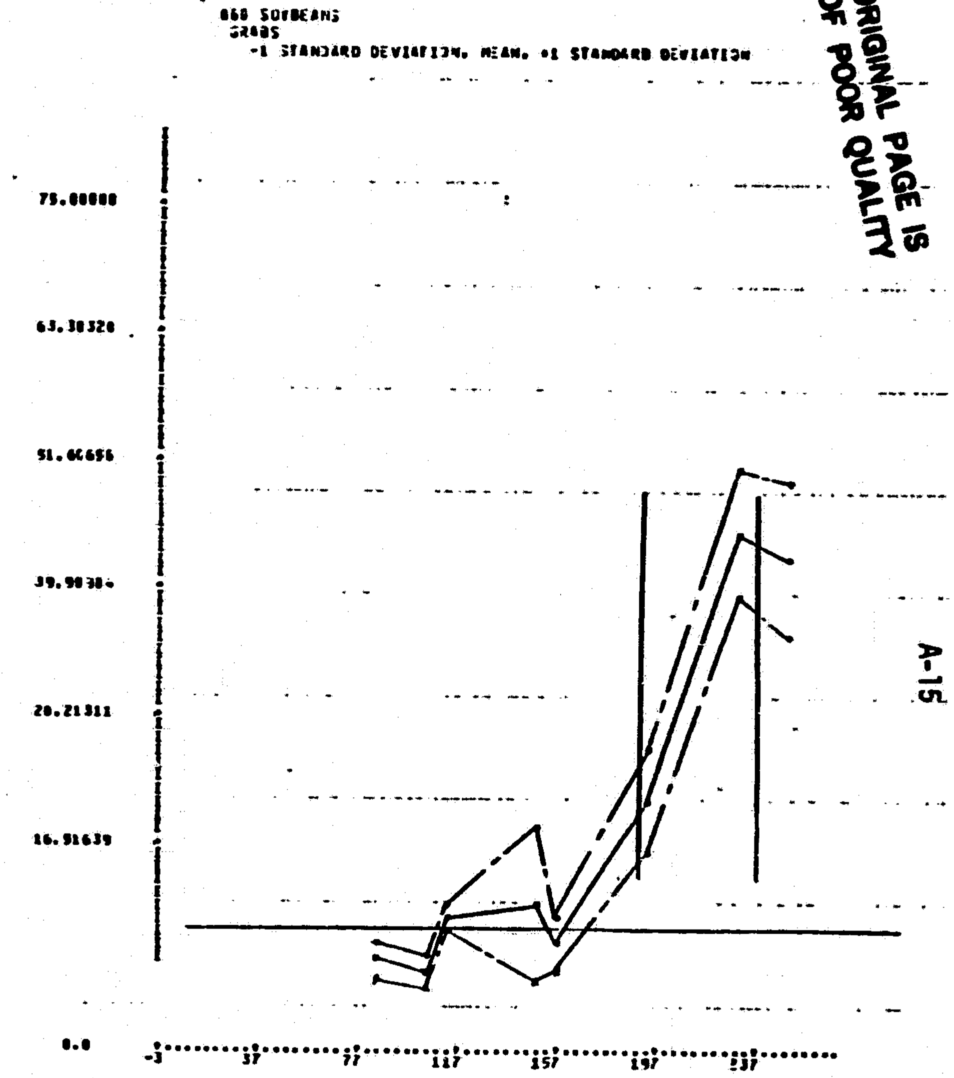
660 SOYBEANS
GRABS
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16.51639
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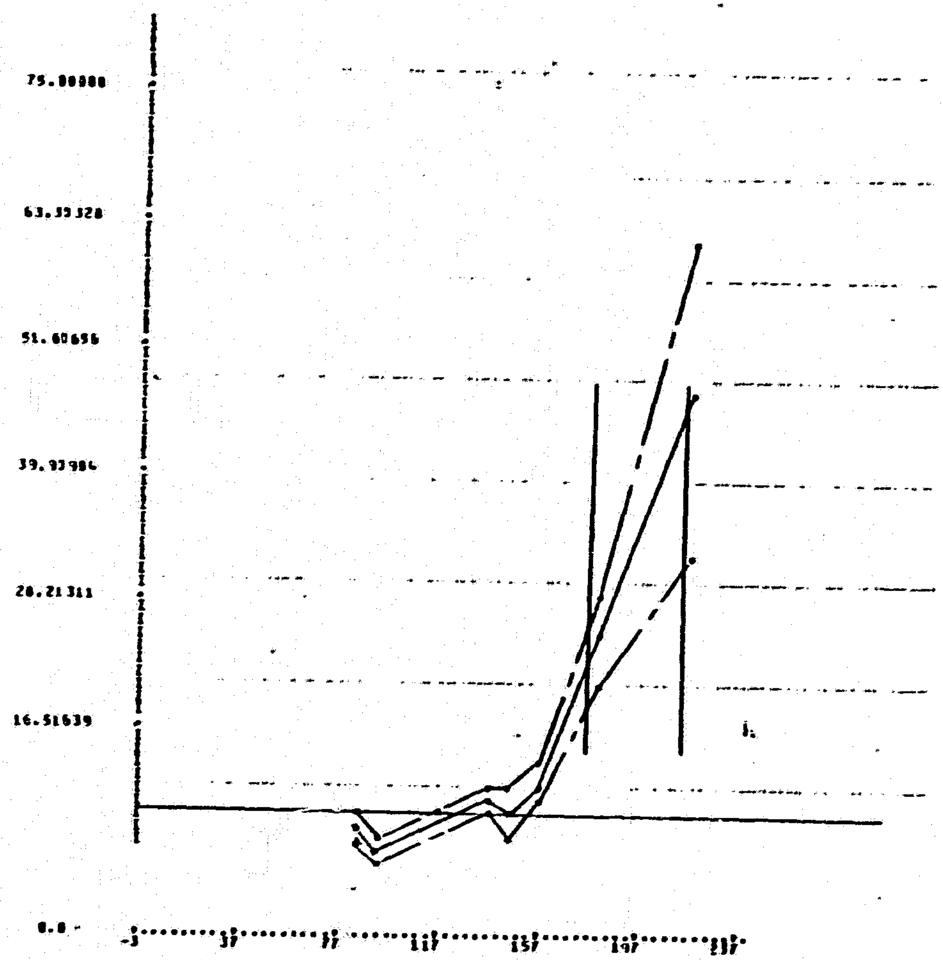
95% SOYBEANS
GRASS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



95% SOYBEANS
GRASS
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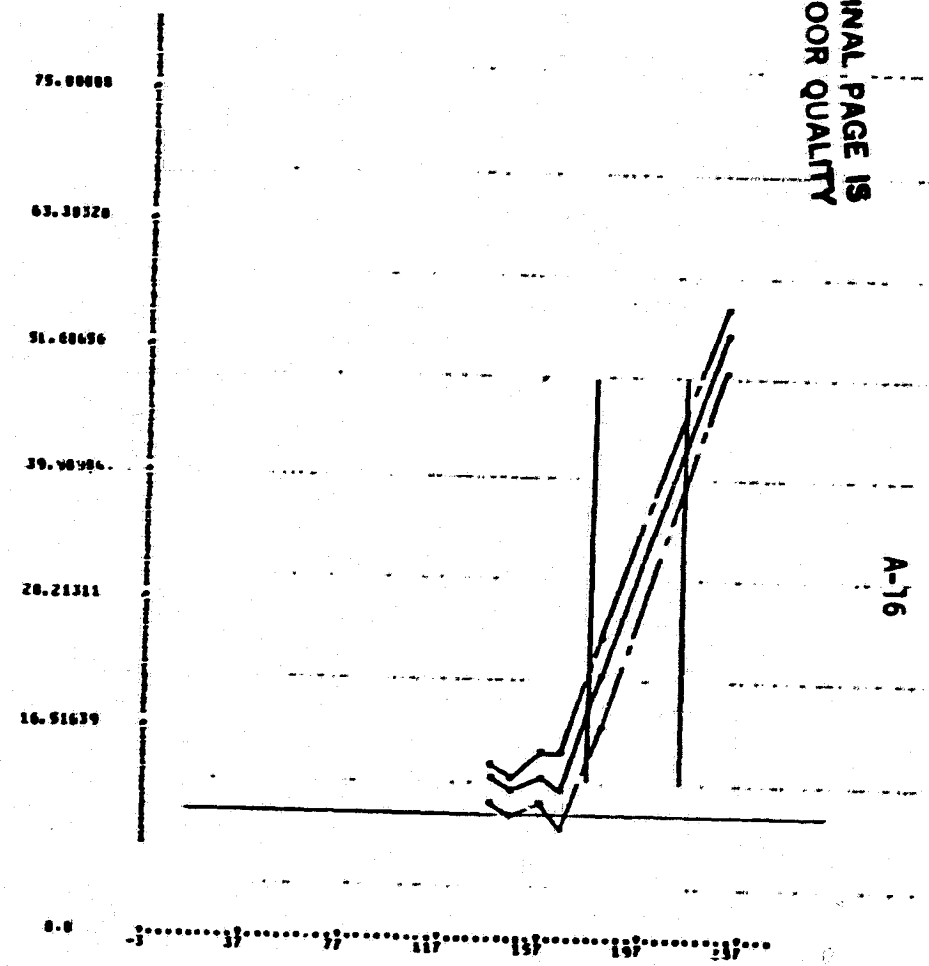

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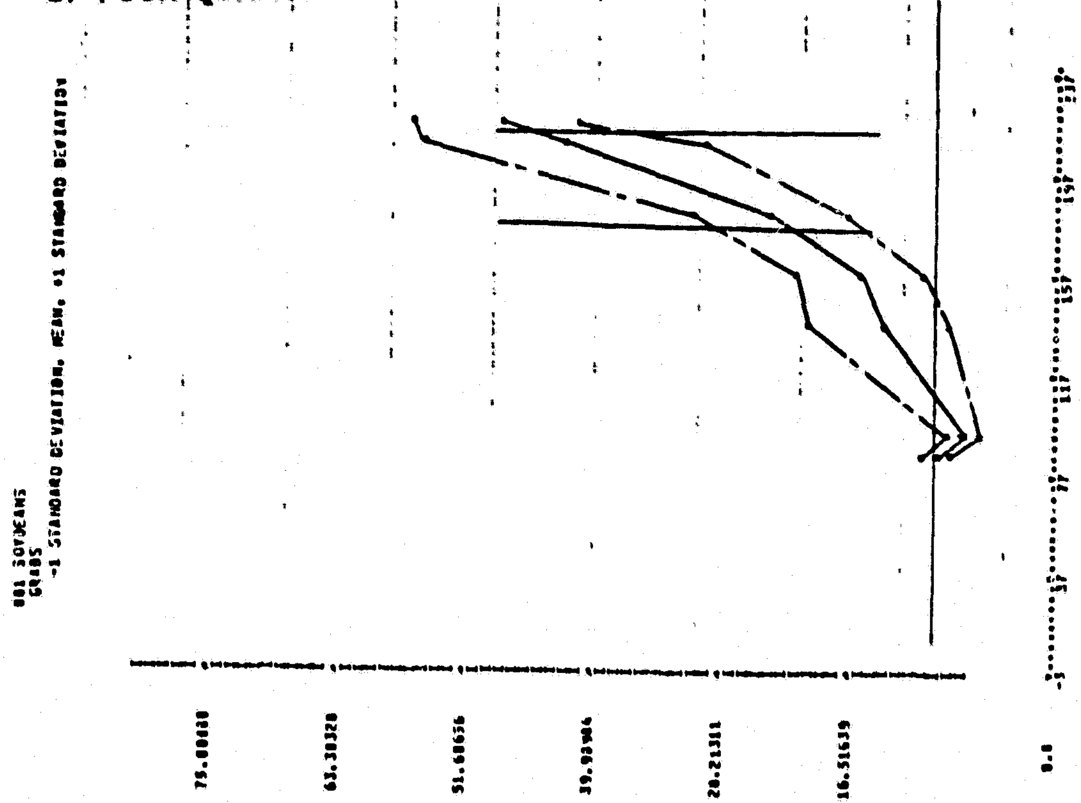

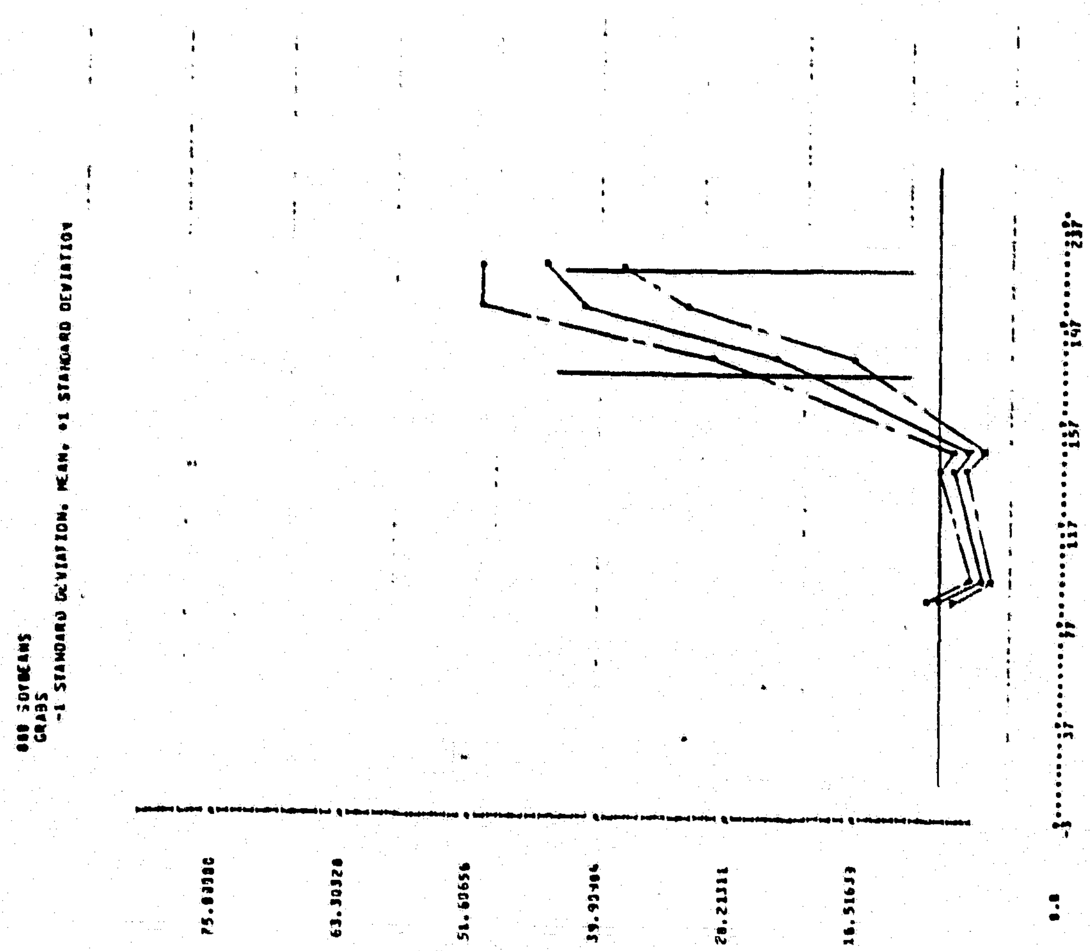

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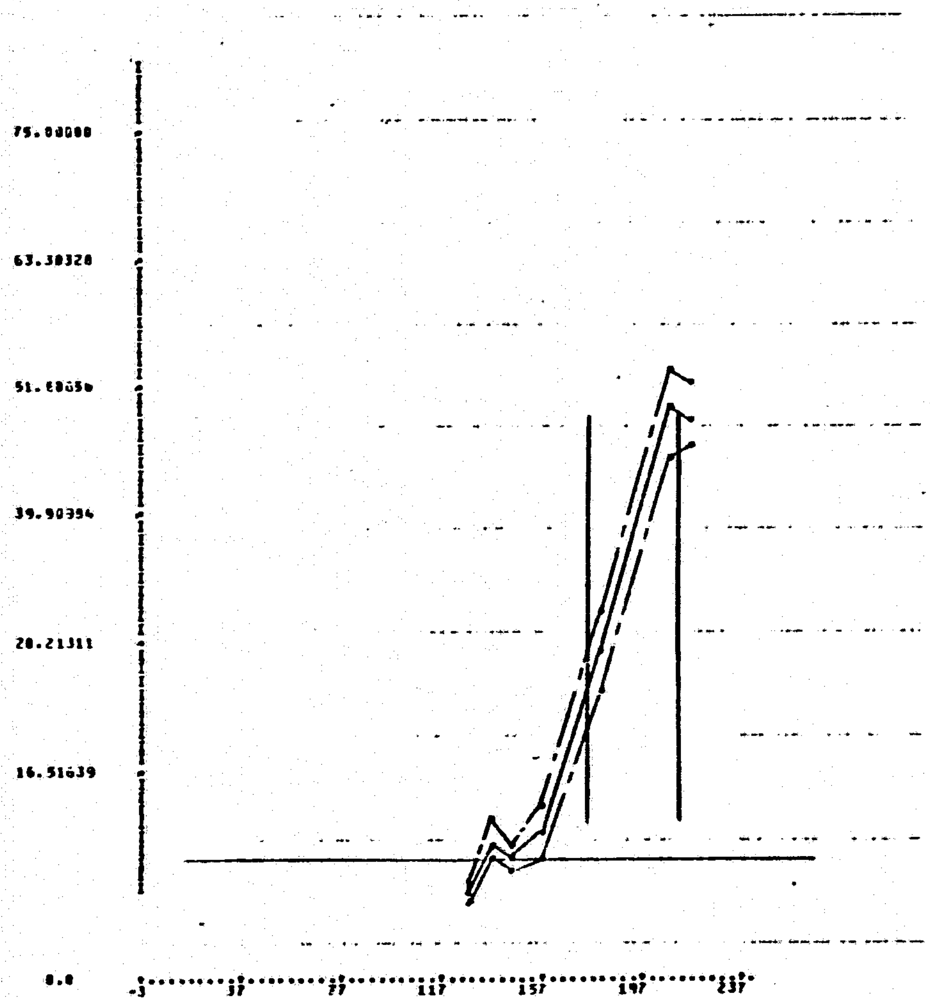

1591 SOYBEANS
GRABS
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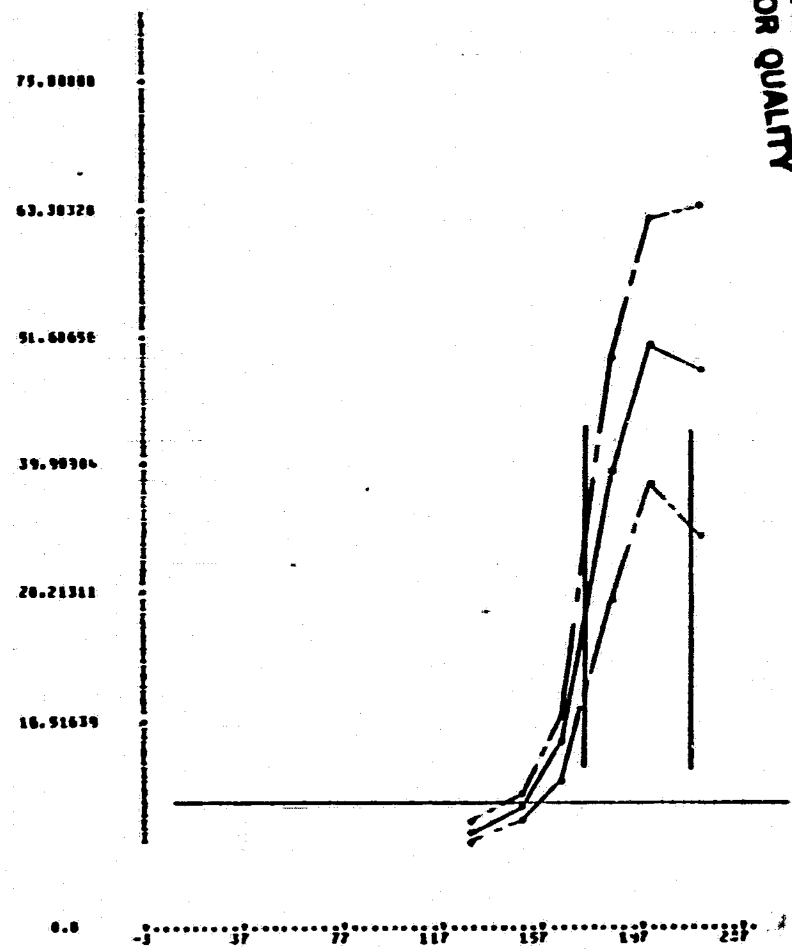
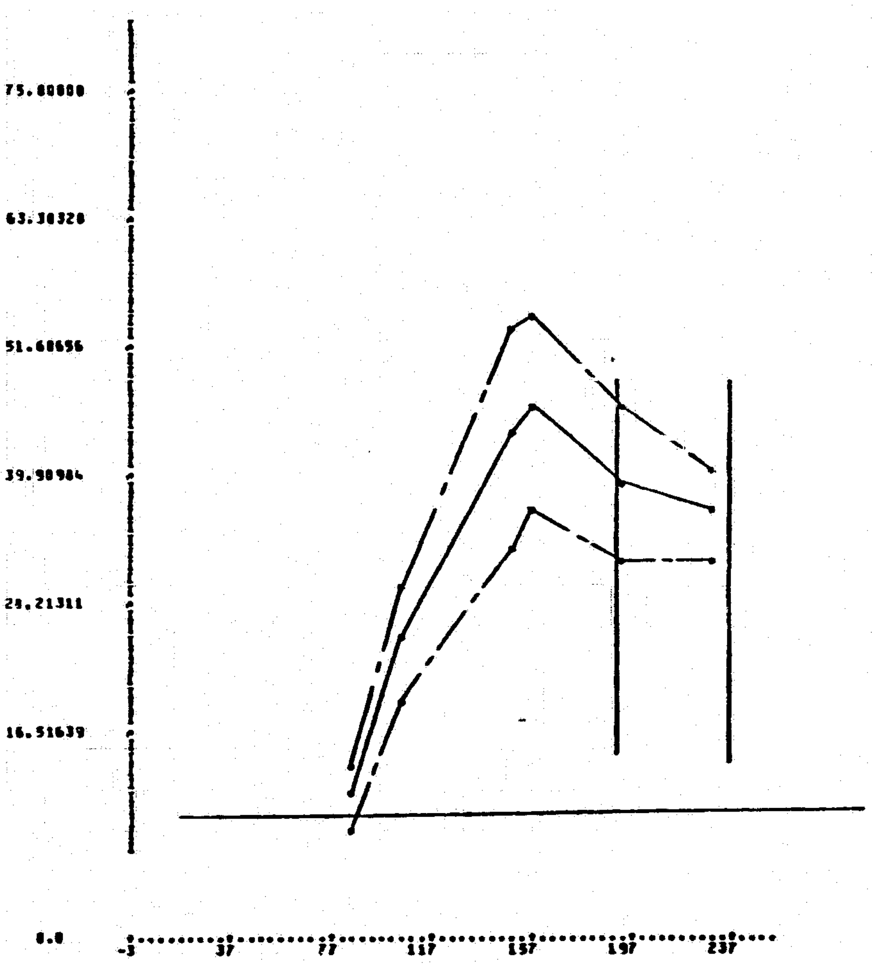


123 ALFALFA/HAY/PASTURE
GRABS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



127 HAY/PASTURE
GRABS
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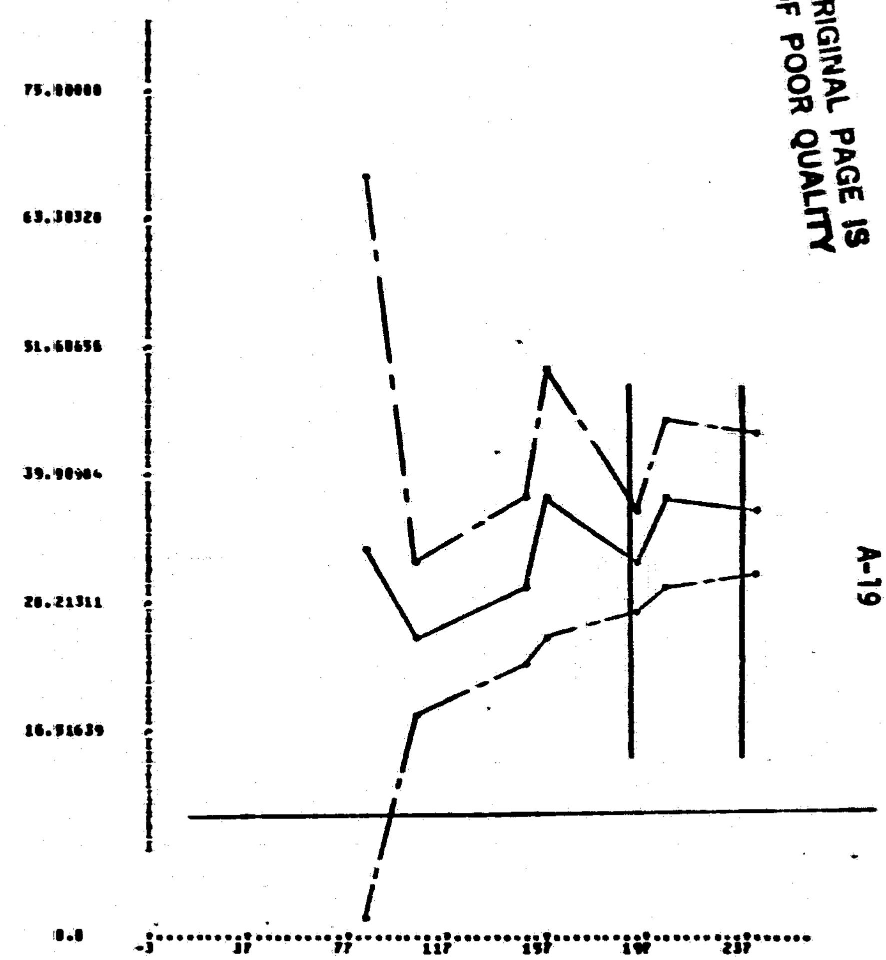

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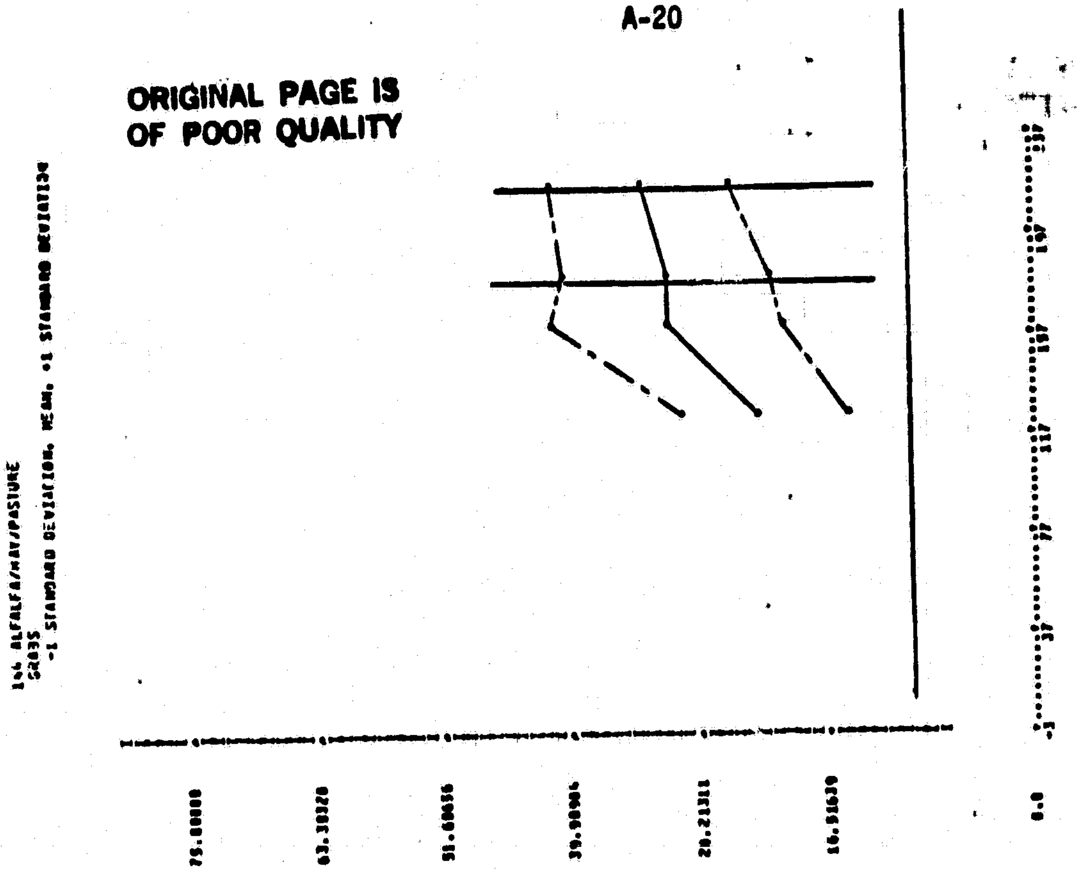

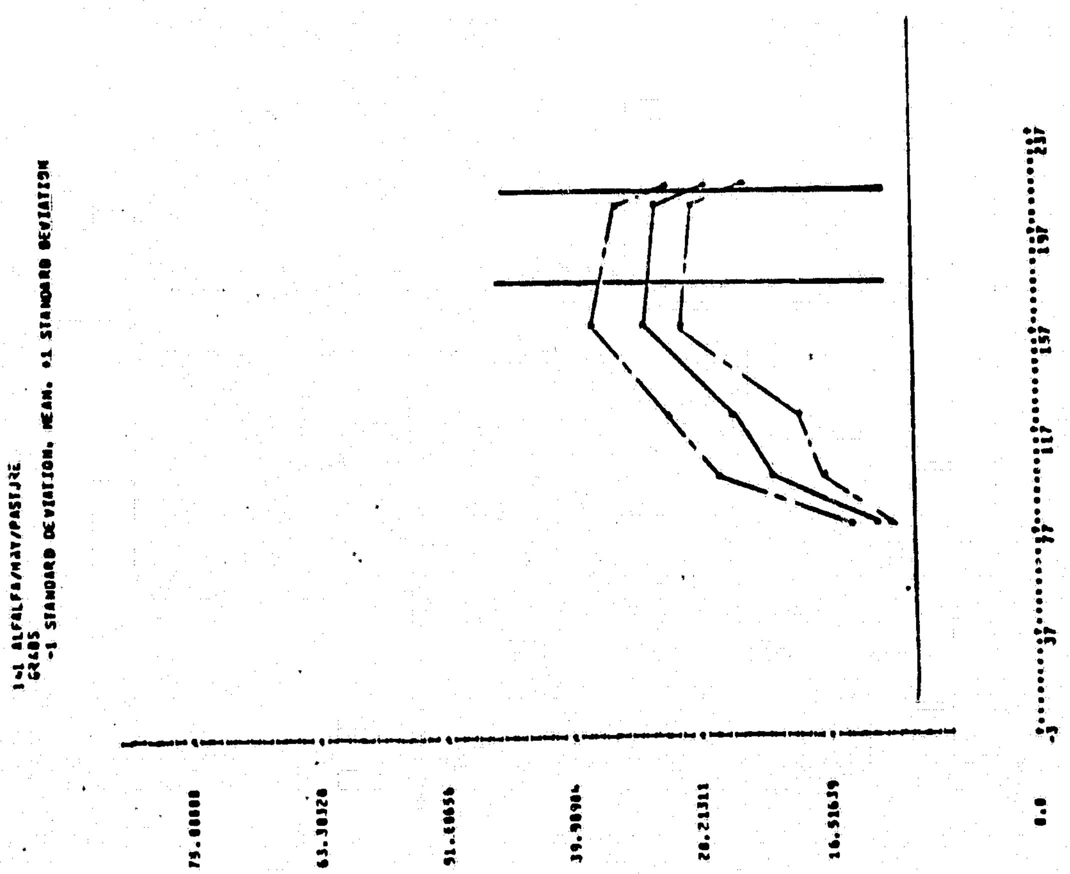

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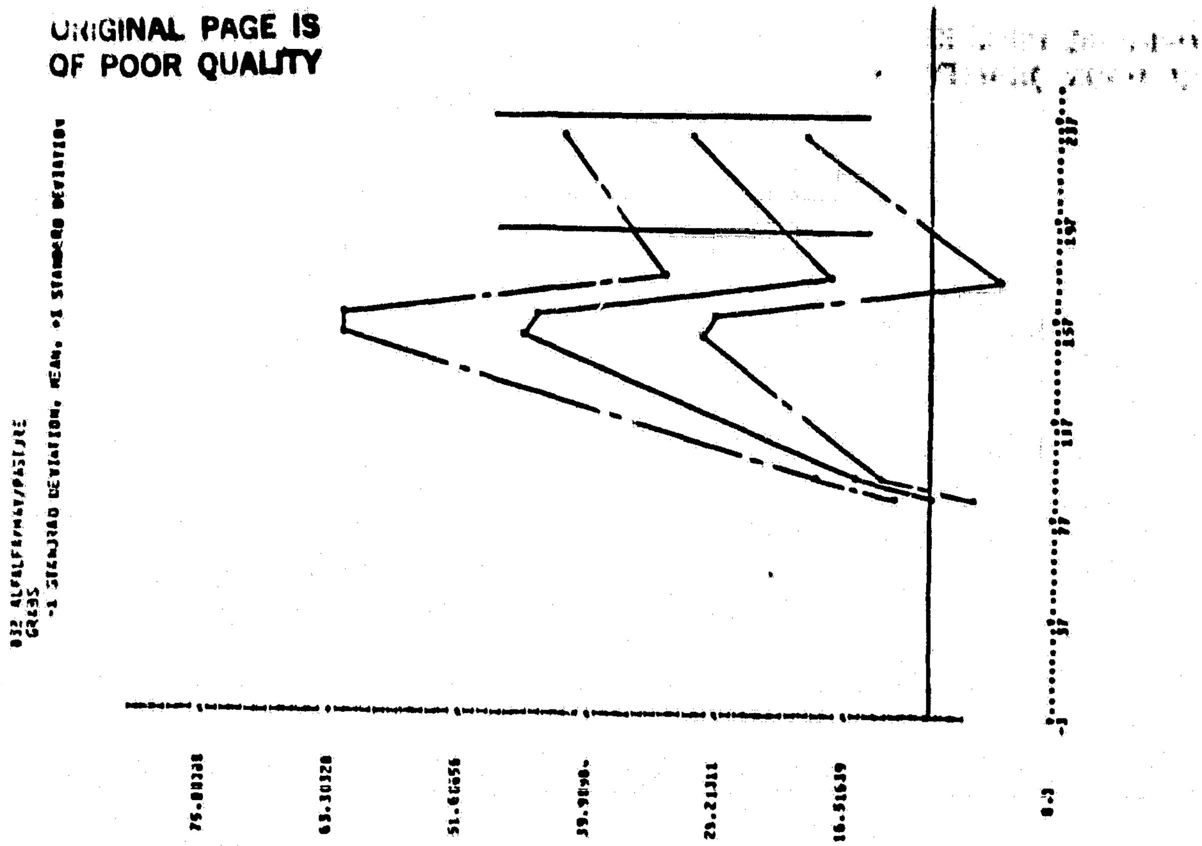

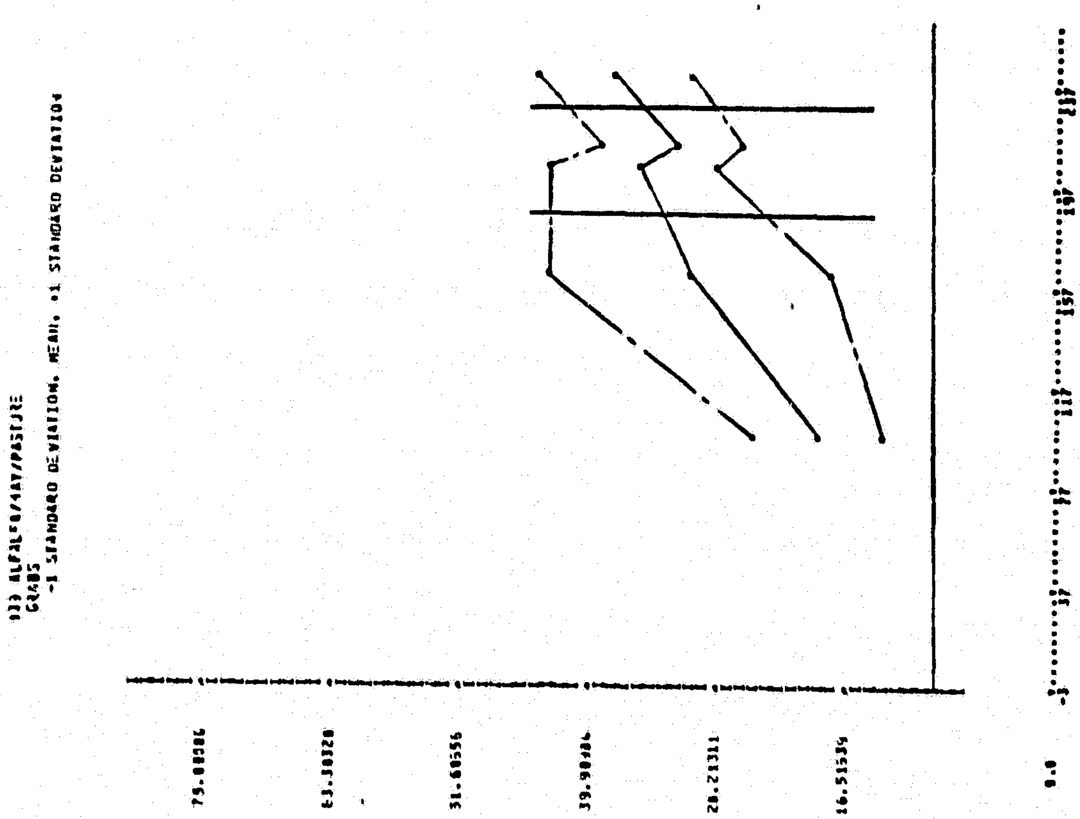

852 ALFALFA/HAY/PASTURE
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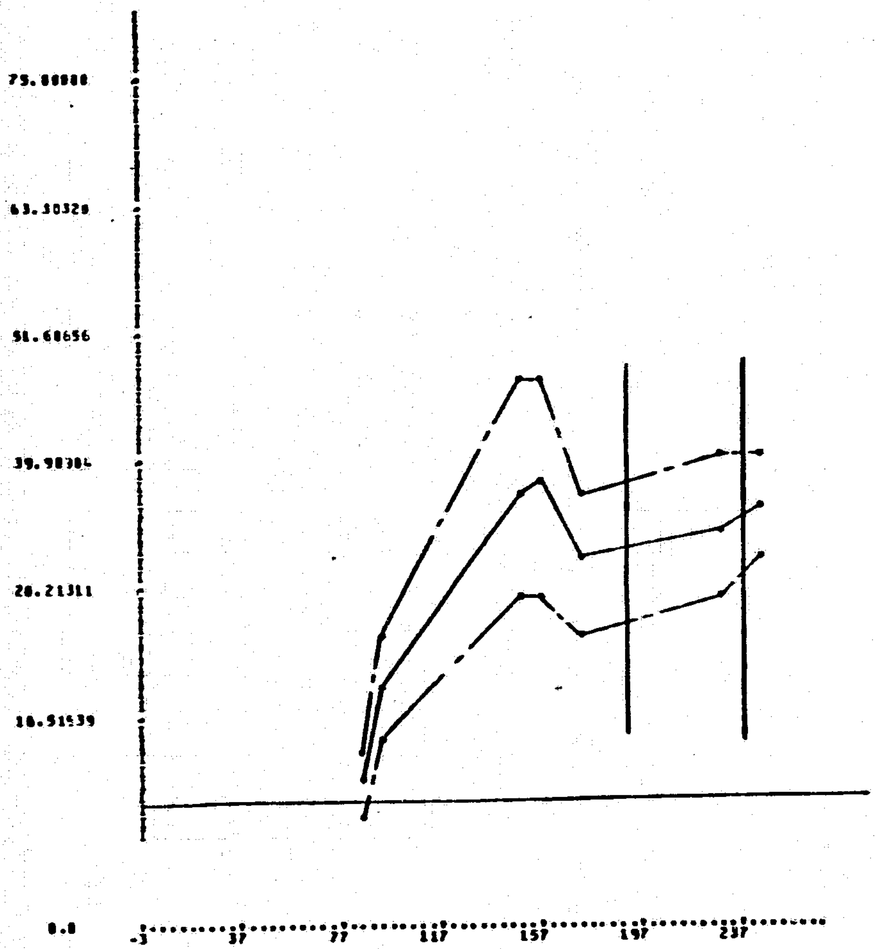

863 ALFALFA/HAY/PASTURE
GRABS
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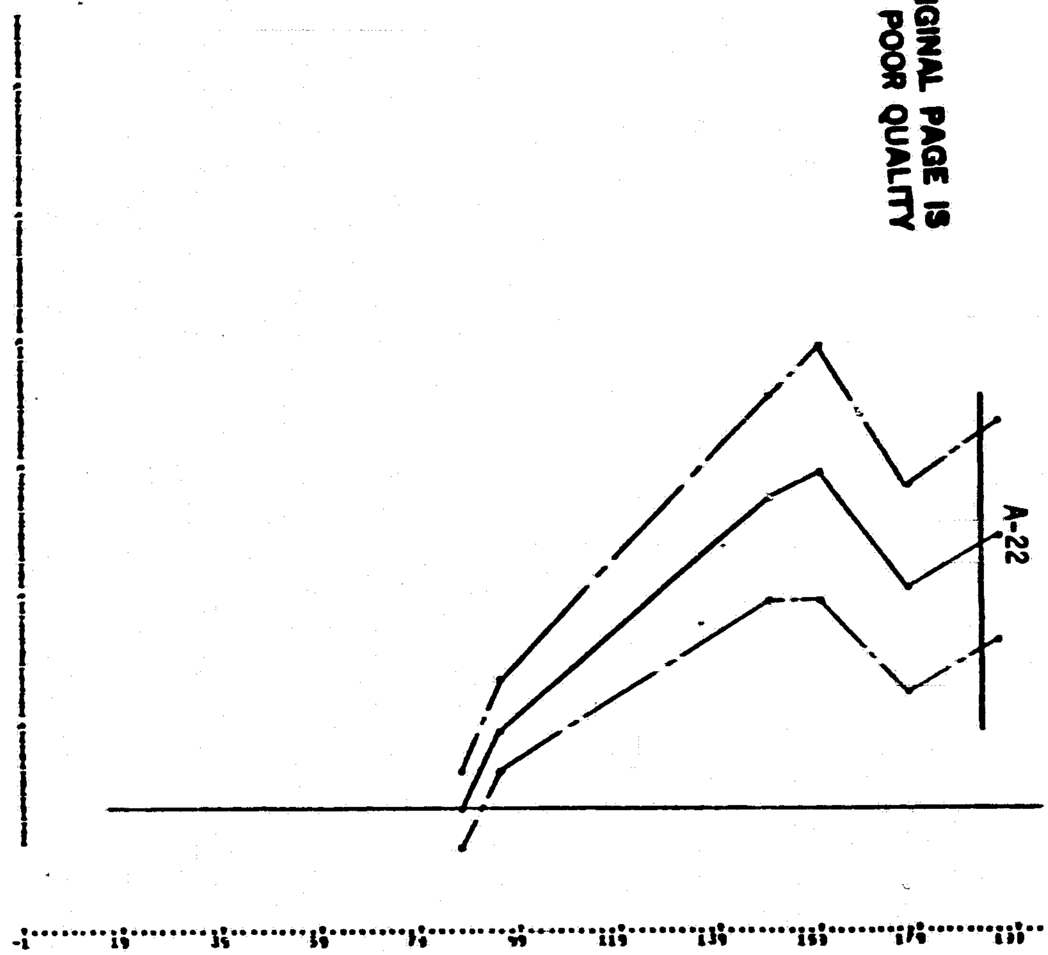

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333 ALFALFA/HAY/PASTURE/GRASS
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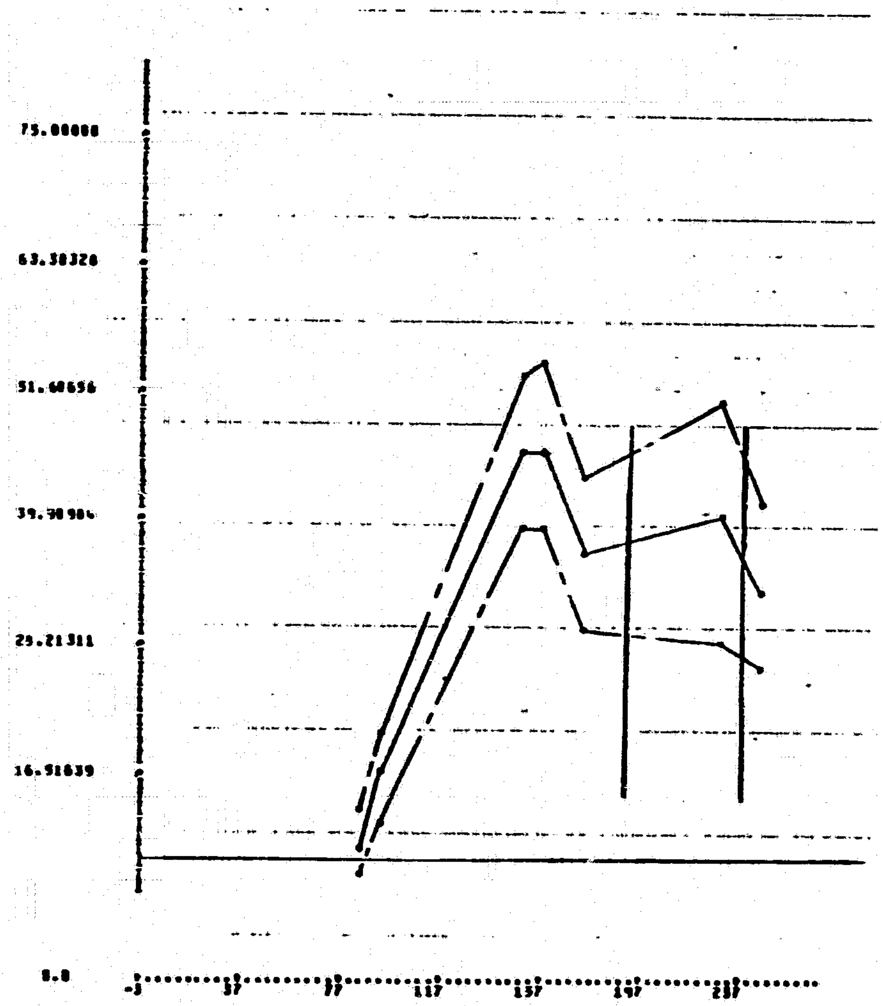

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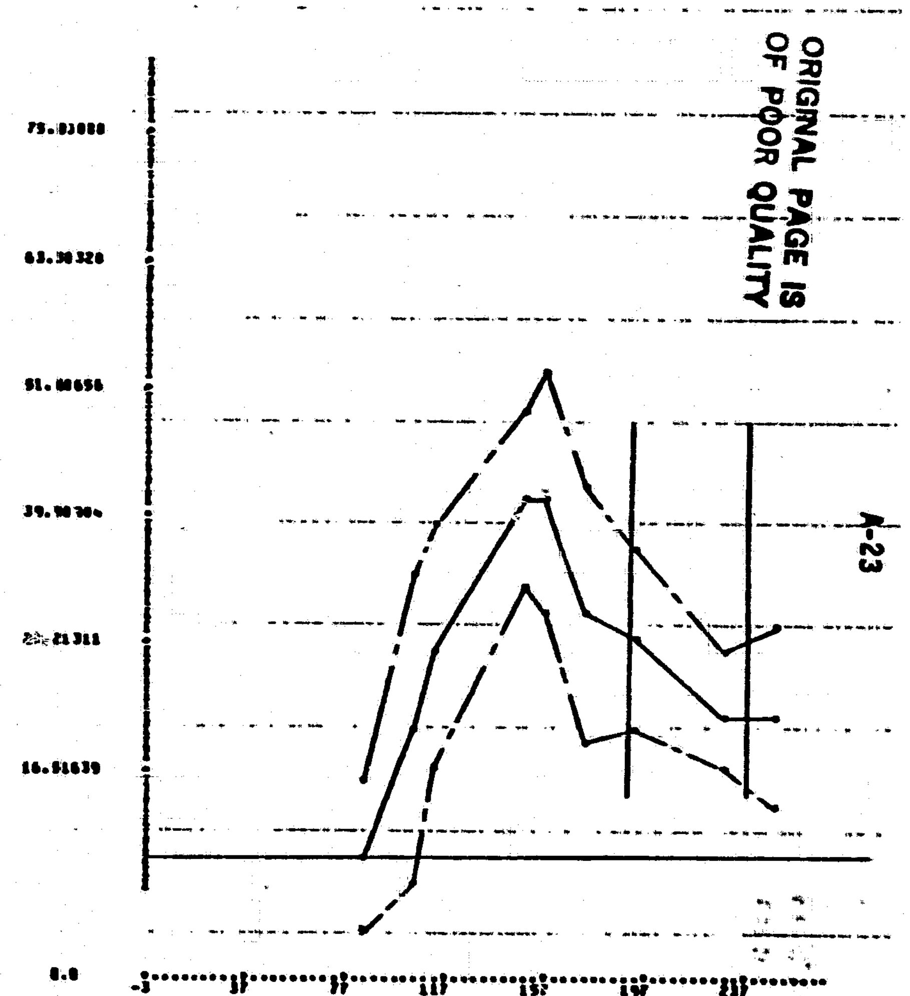

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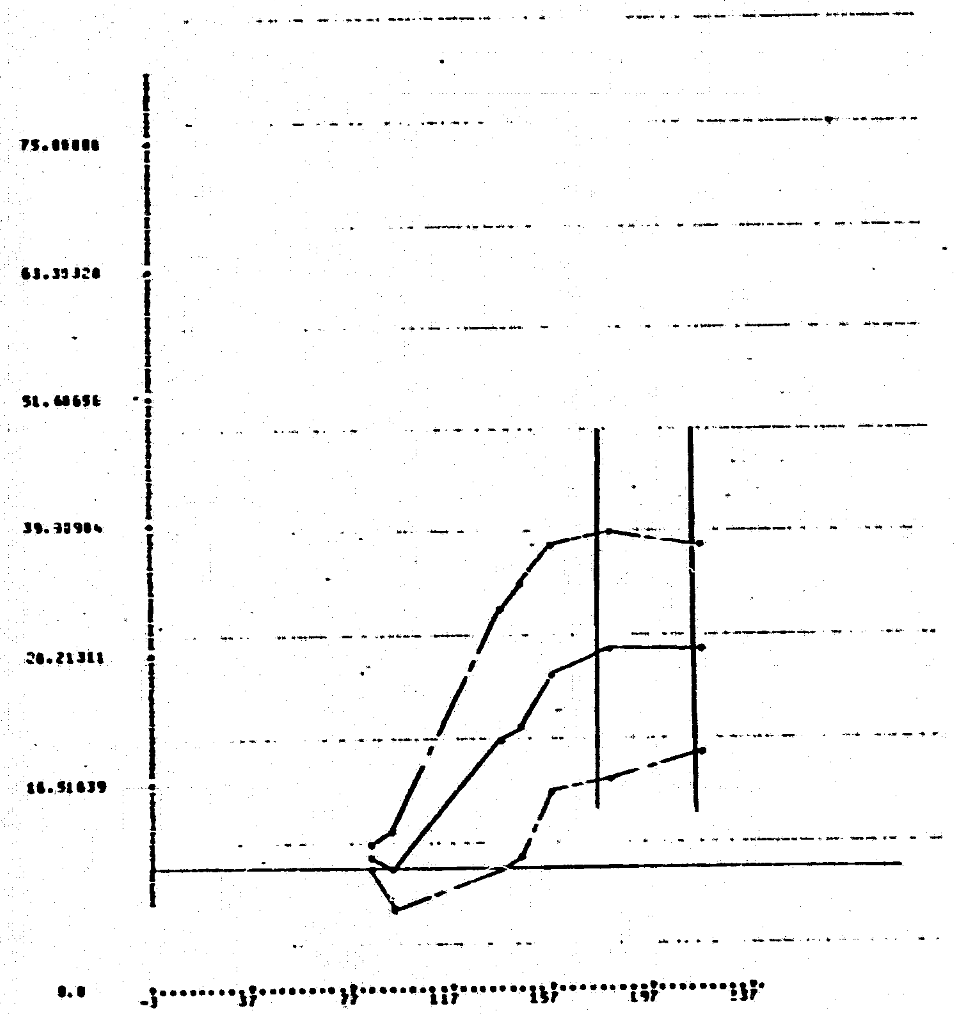

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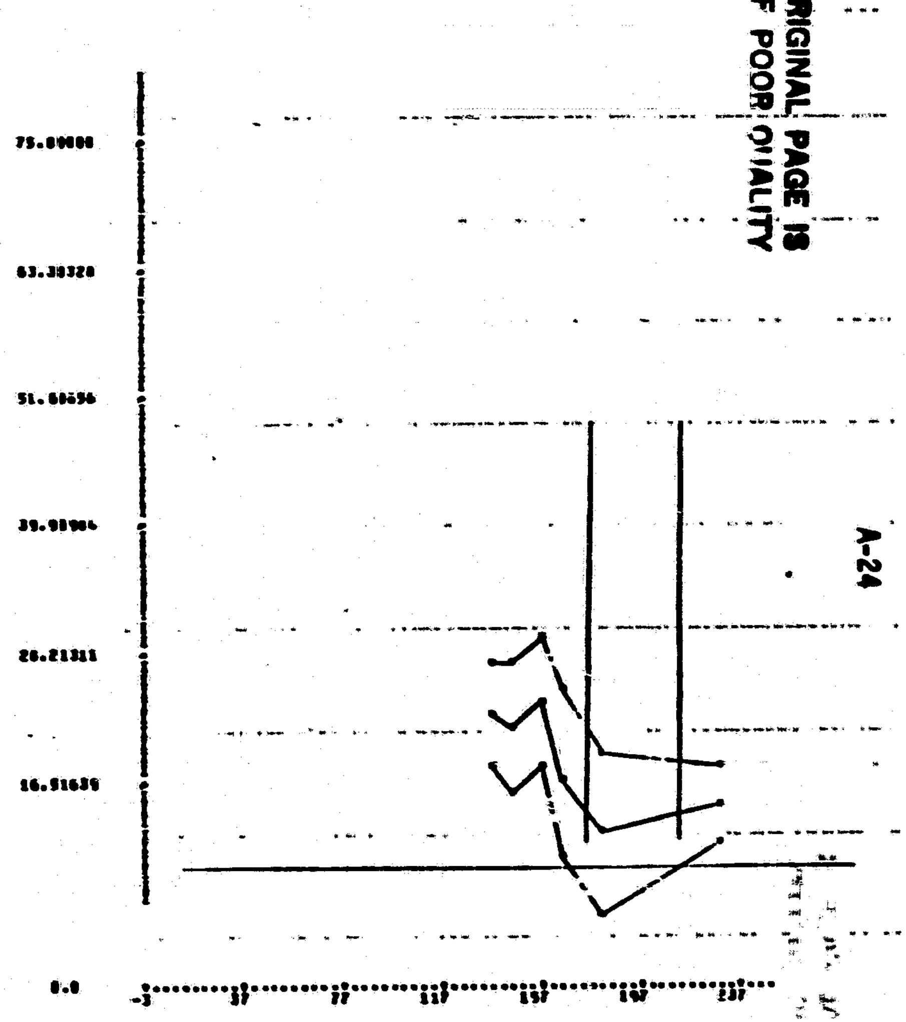

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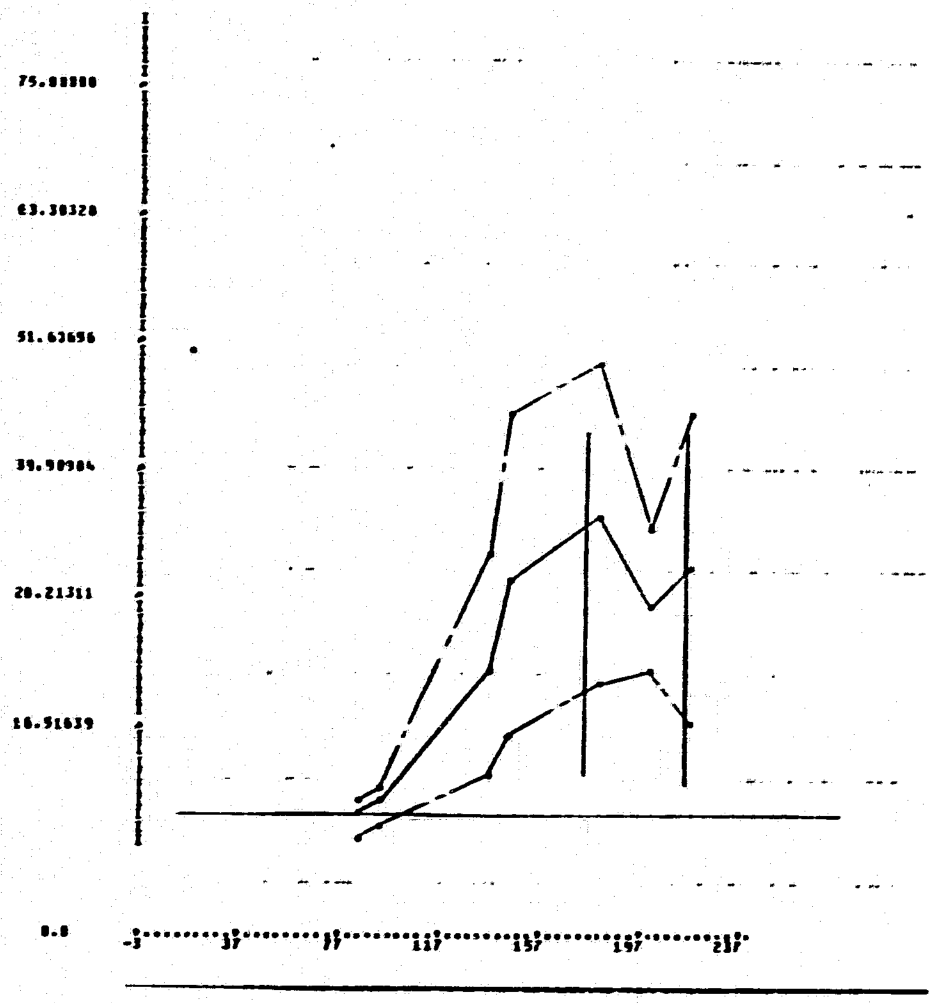

081 ALFALFA/PASTURE/GRASS
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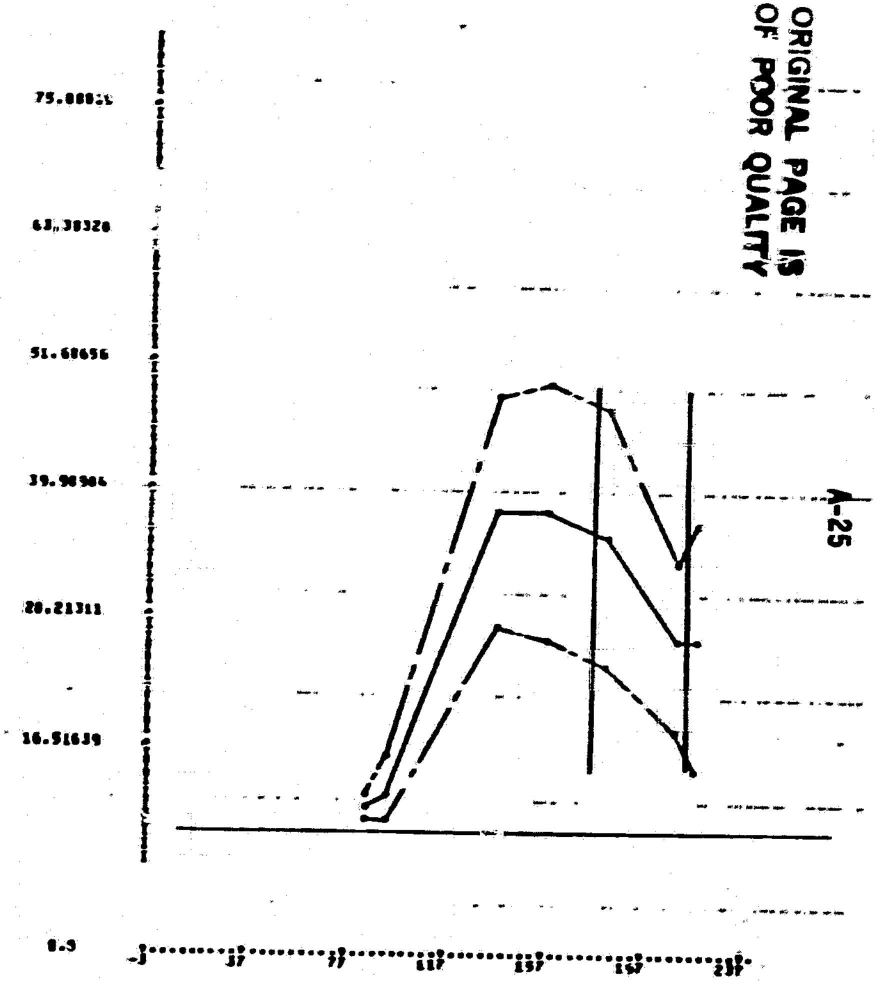

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692 GRASS/HAY/PASTURE
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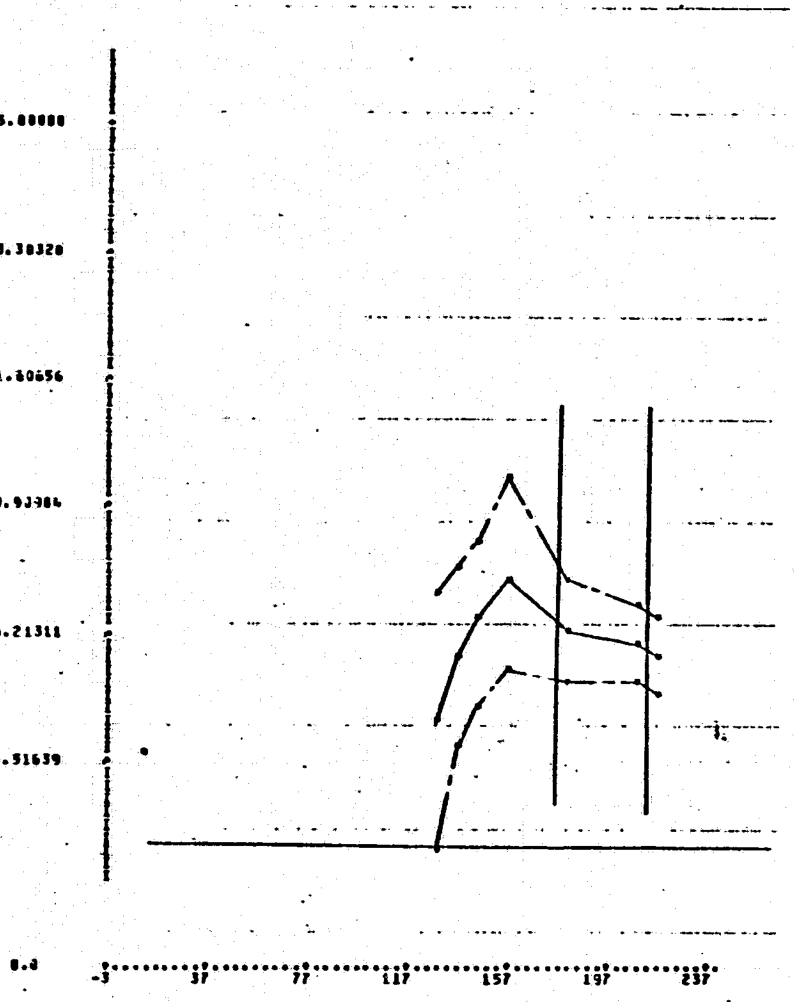

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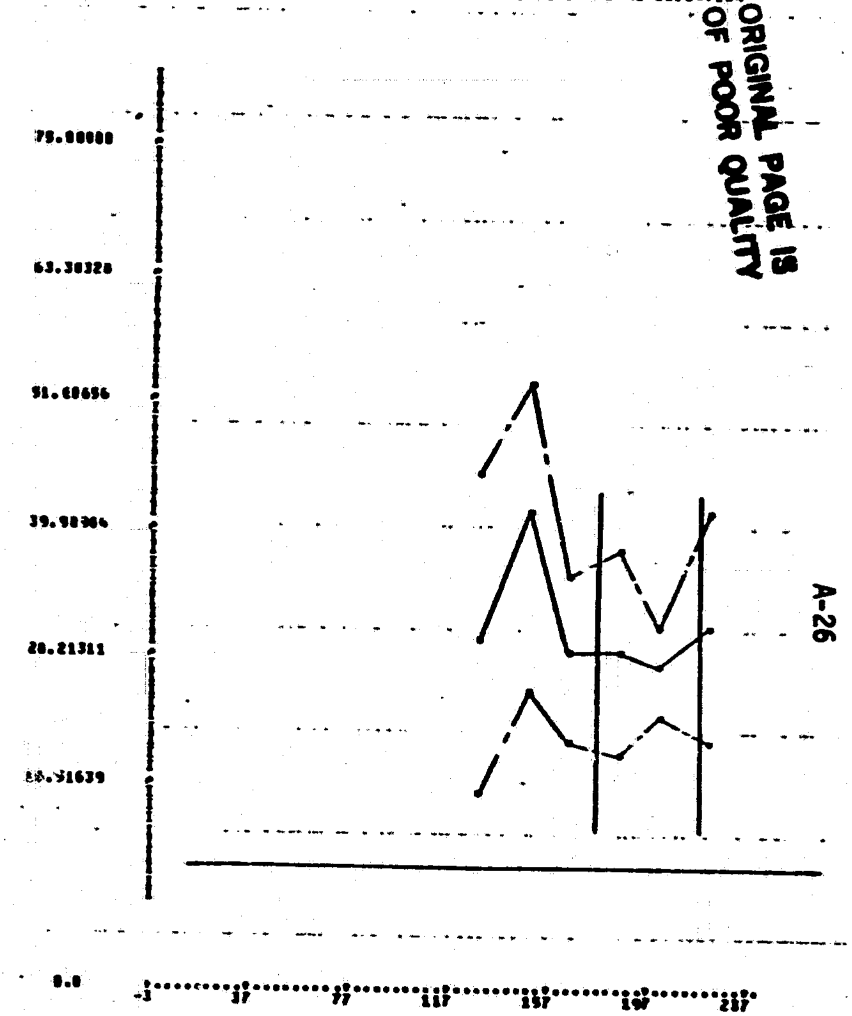

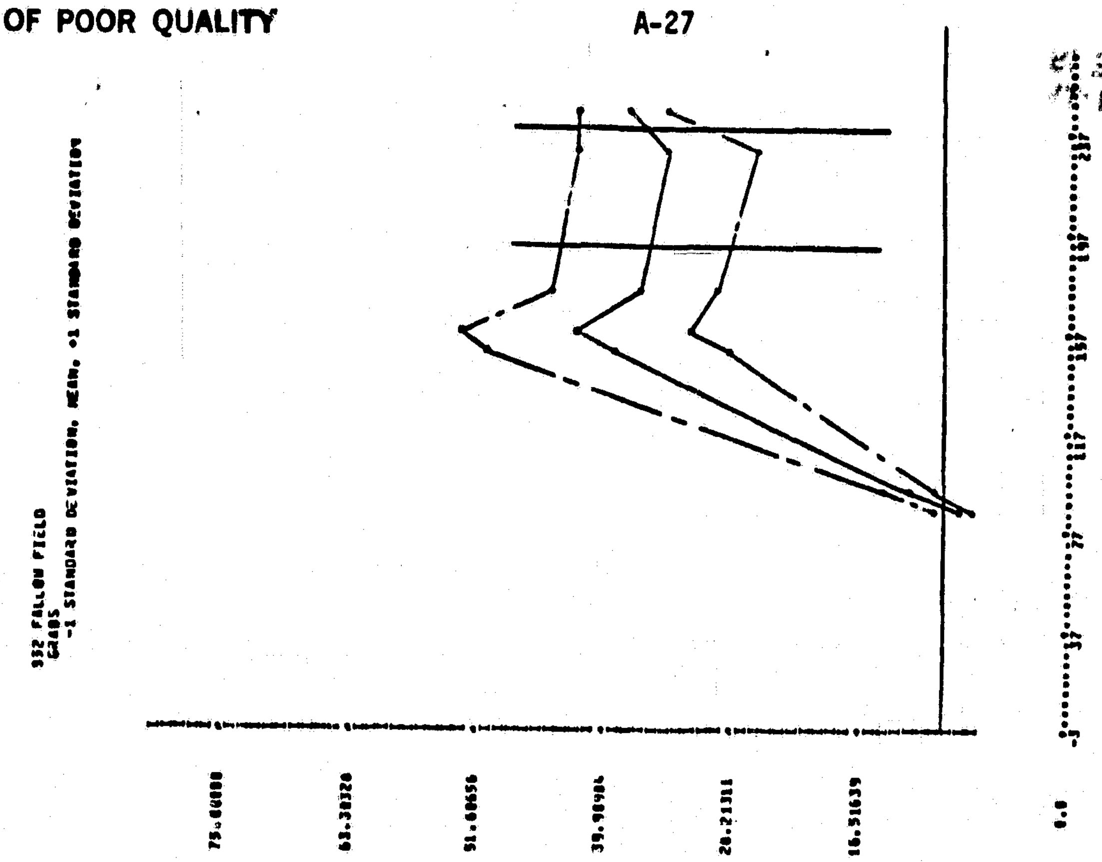
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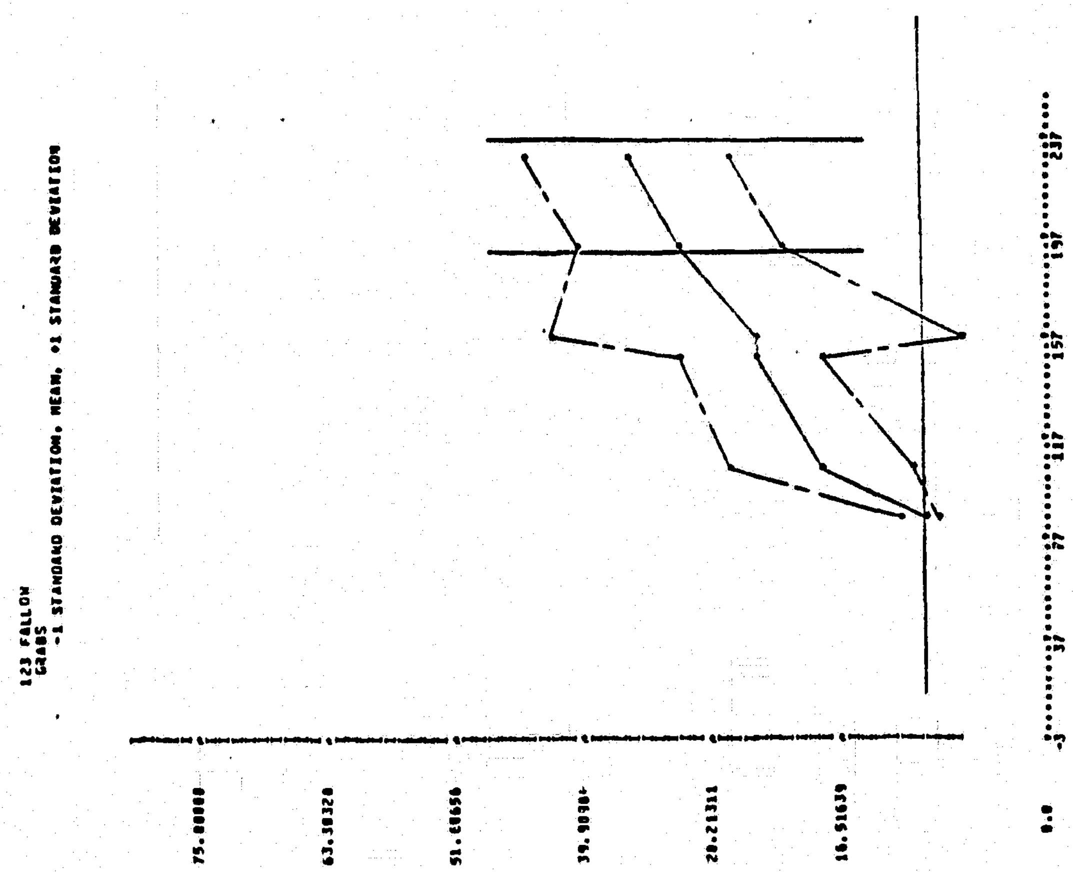
123 FALLOW
GRABS
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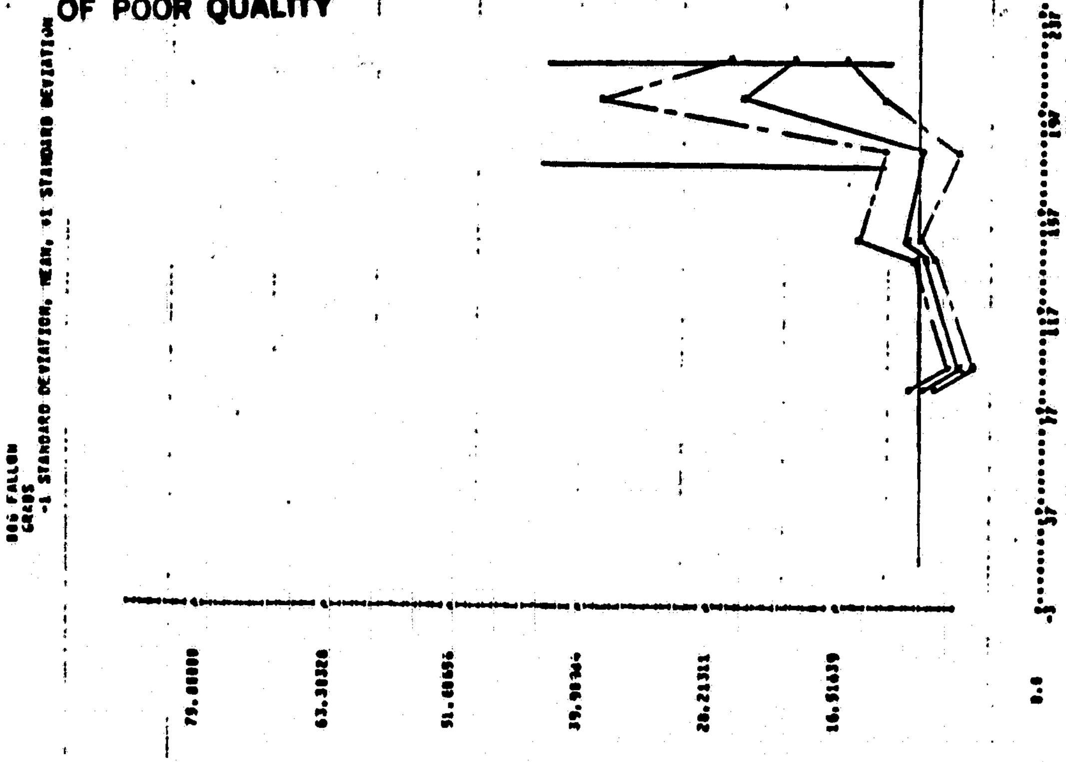

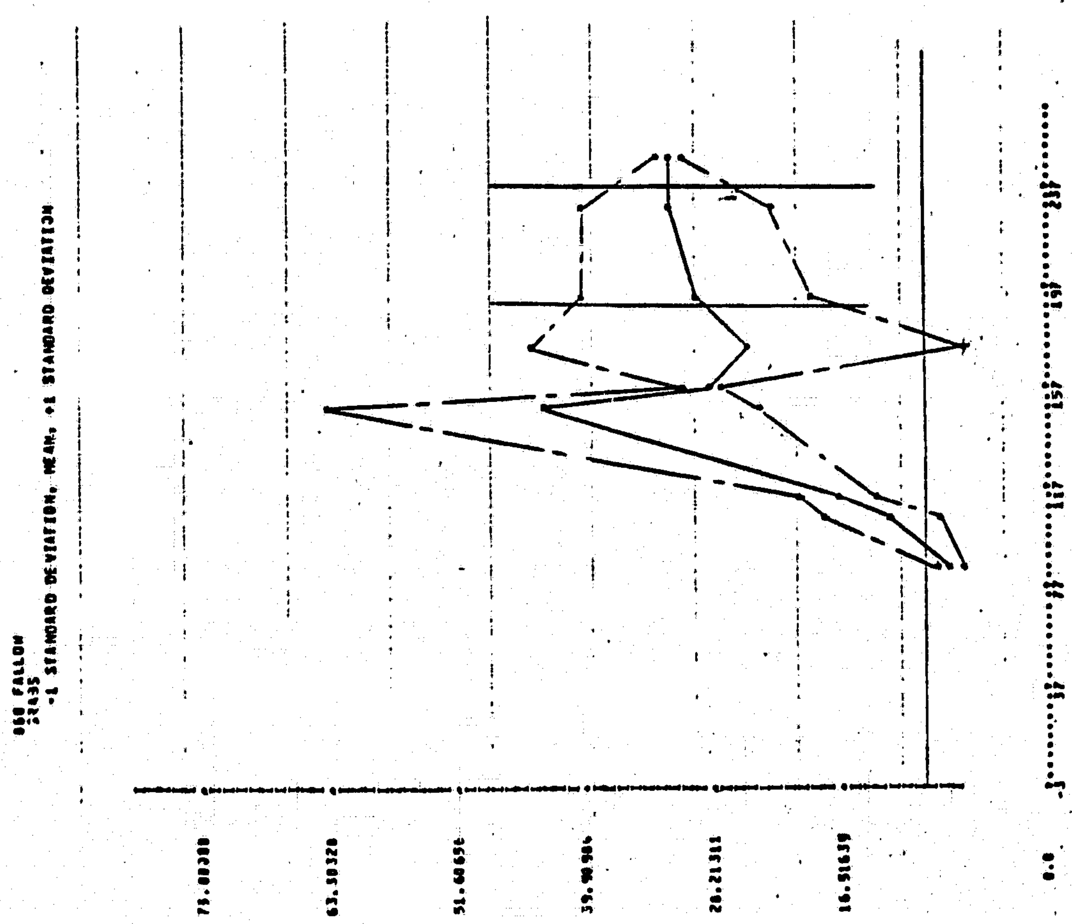

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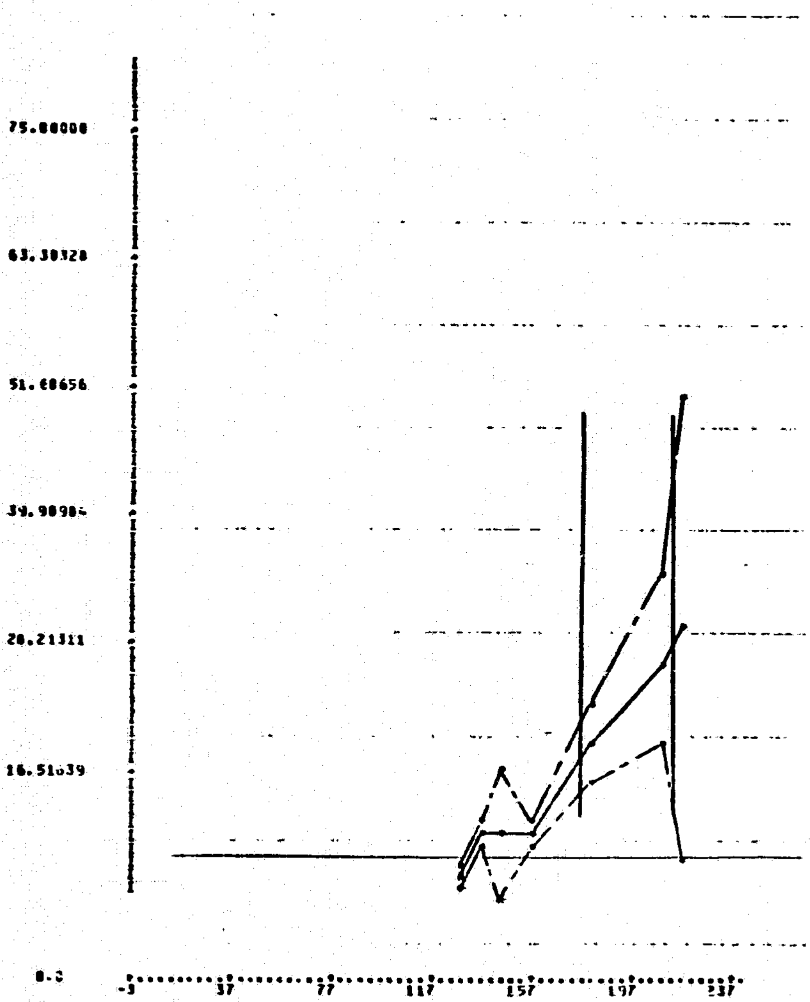

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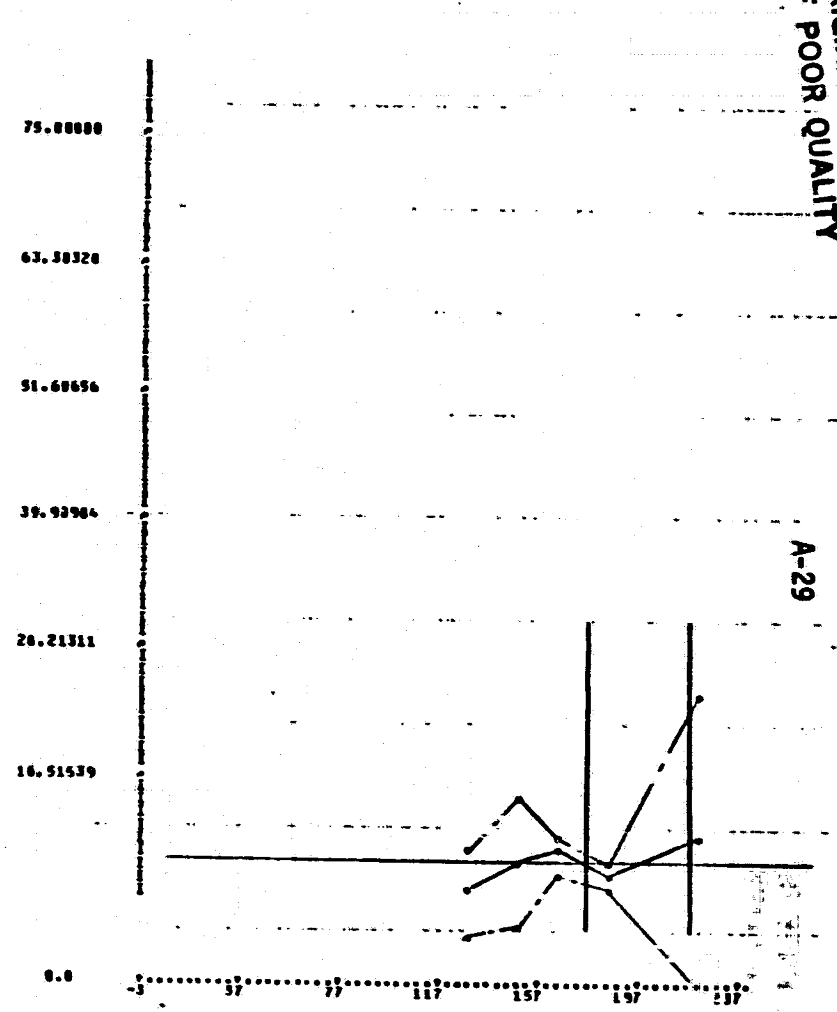

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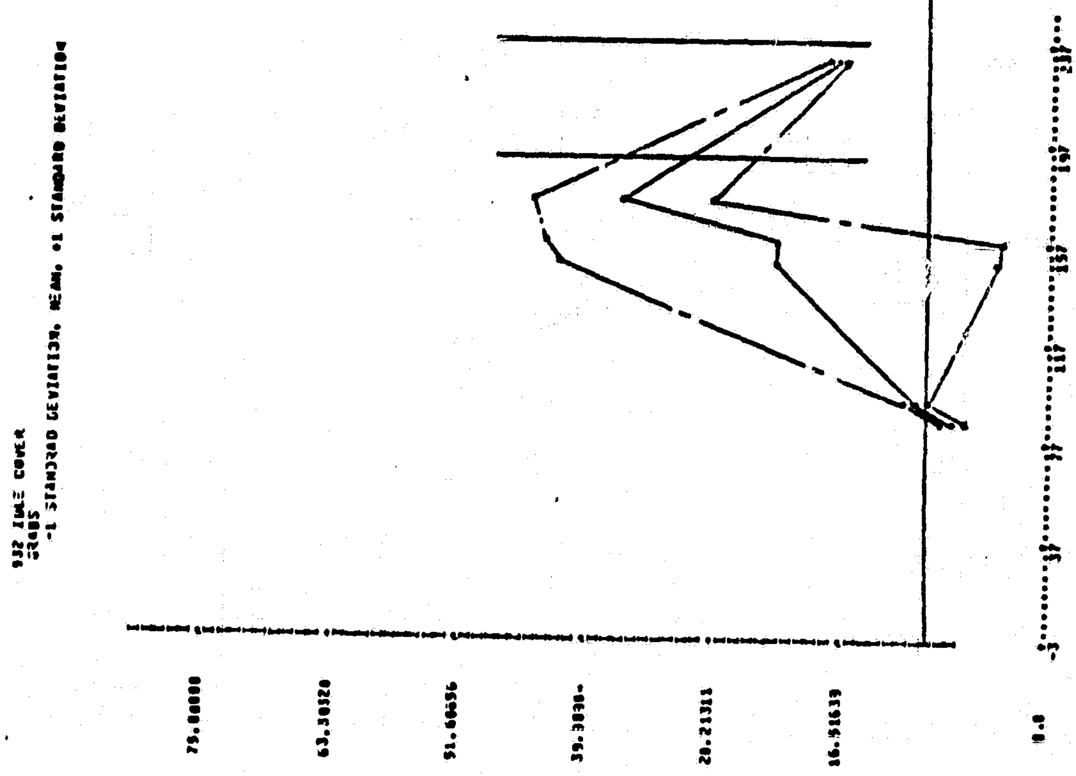

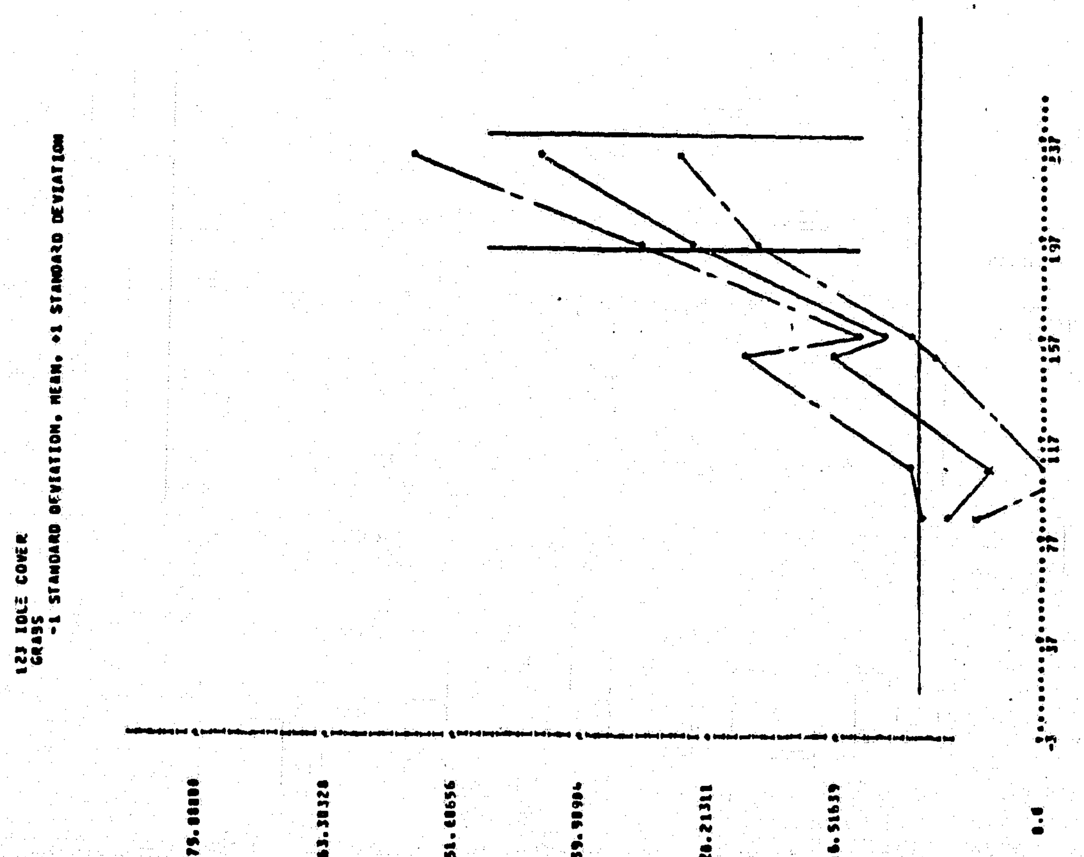

95% IDLE COVER
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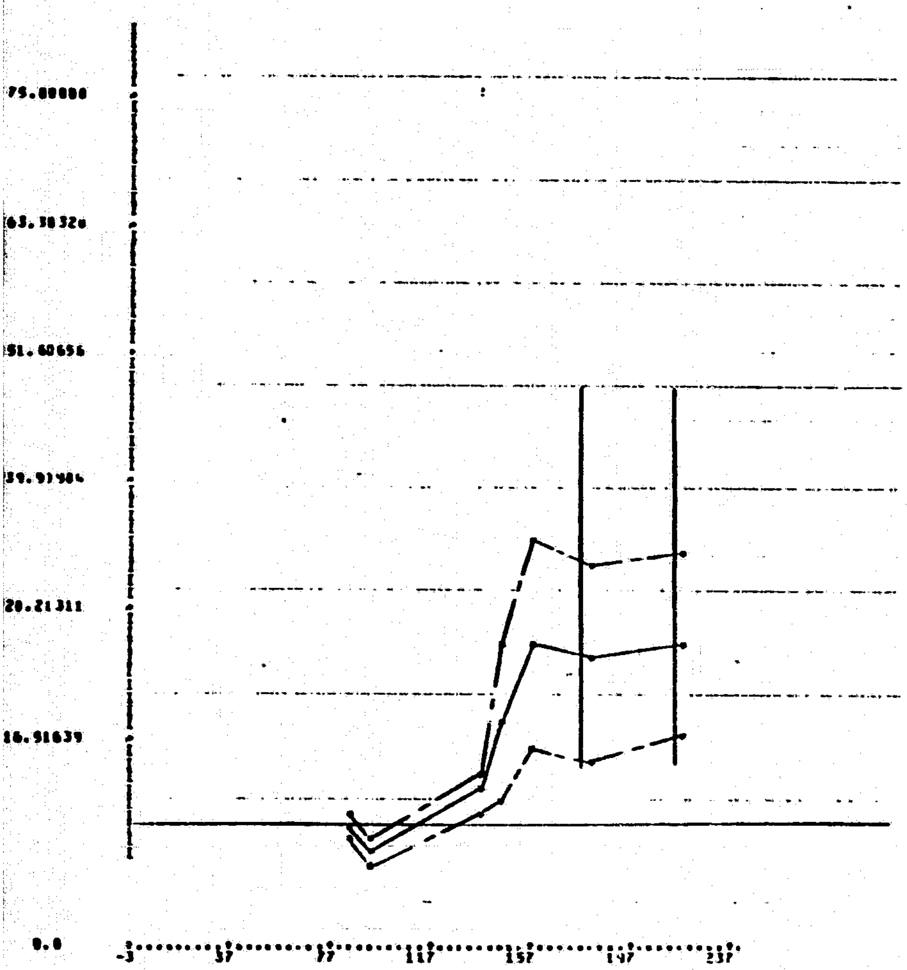

0-3 IDLE COVER CROP
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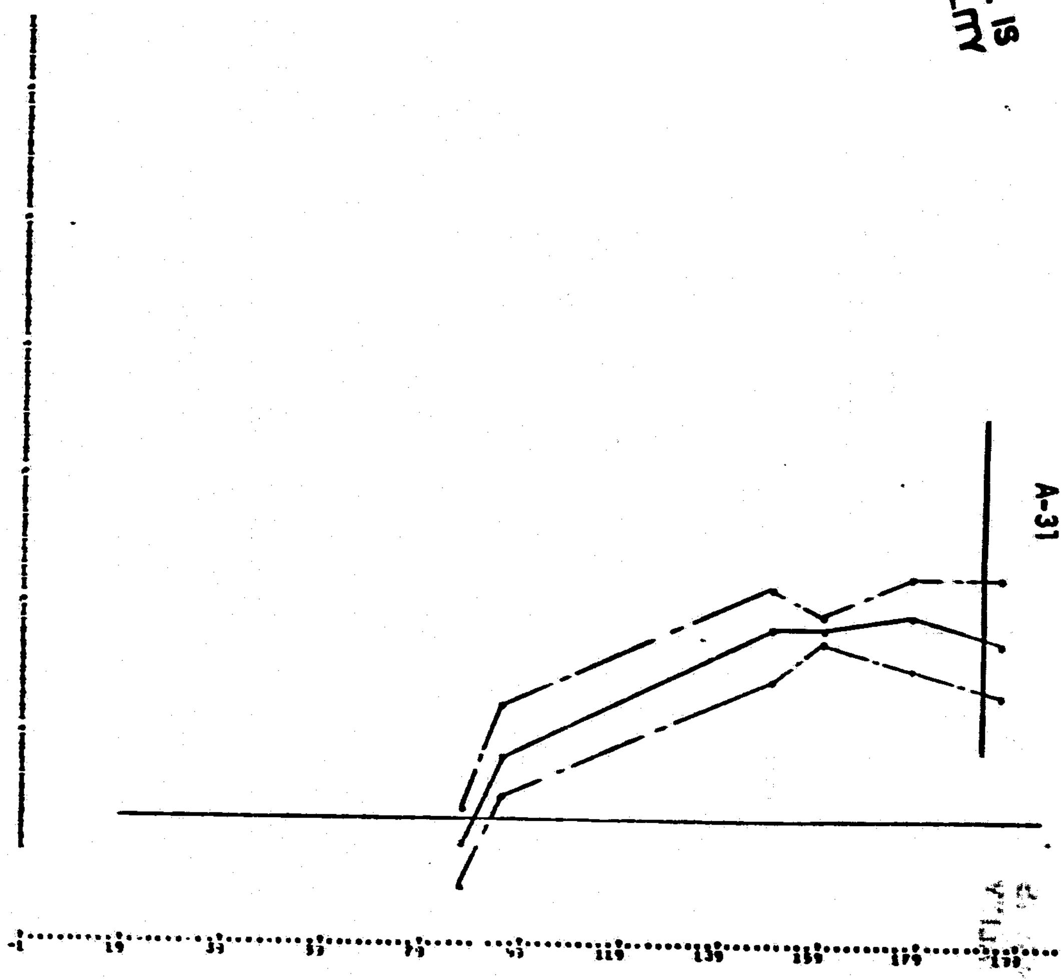

065 IDLE COVER
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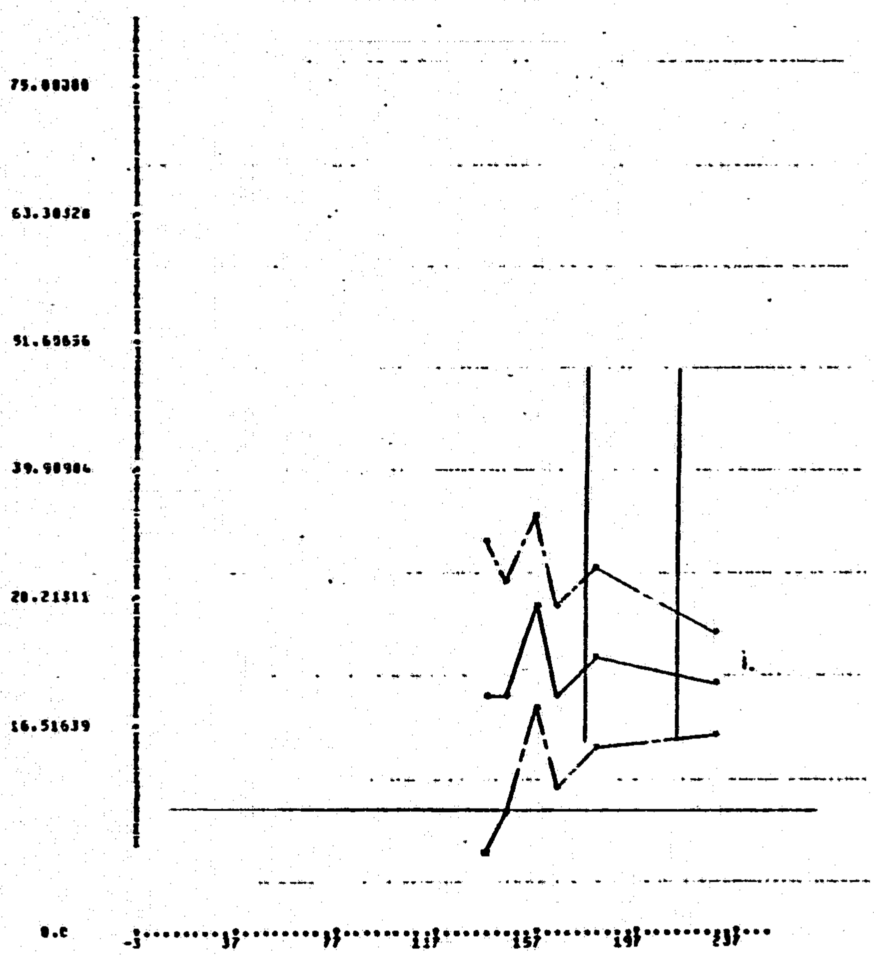

088 IDLE COVER
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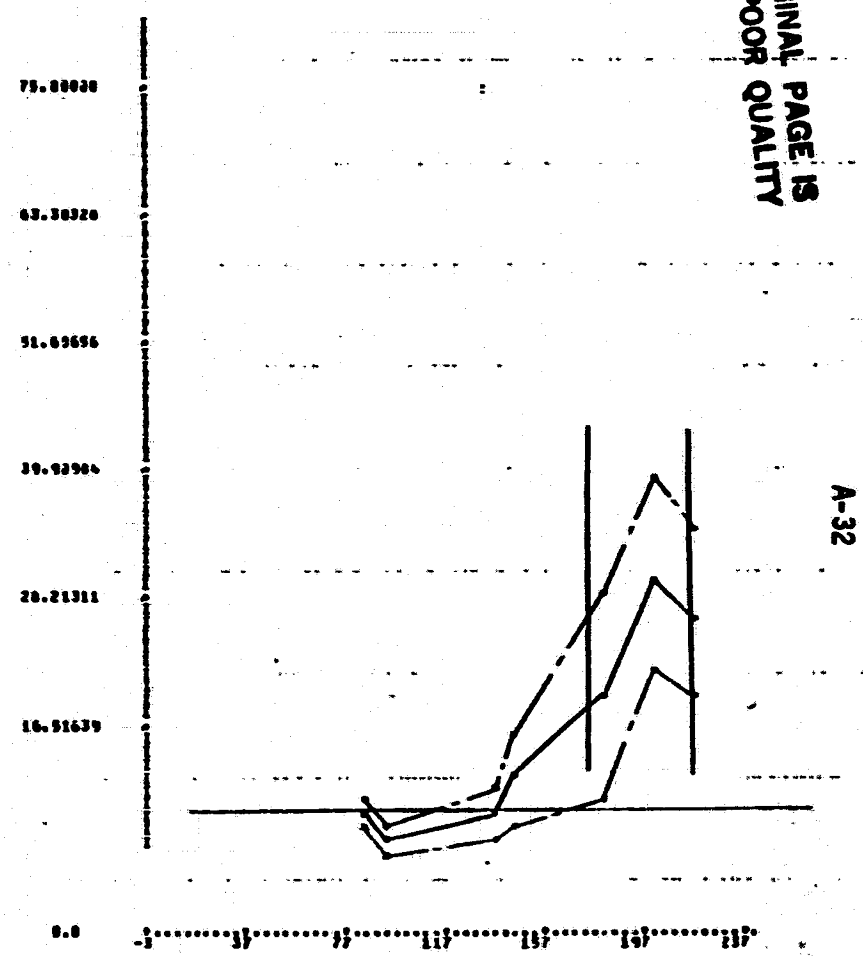

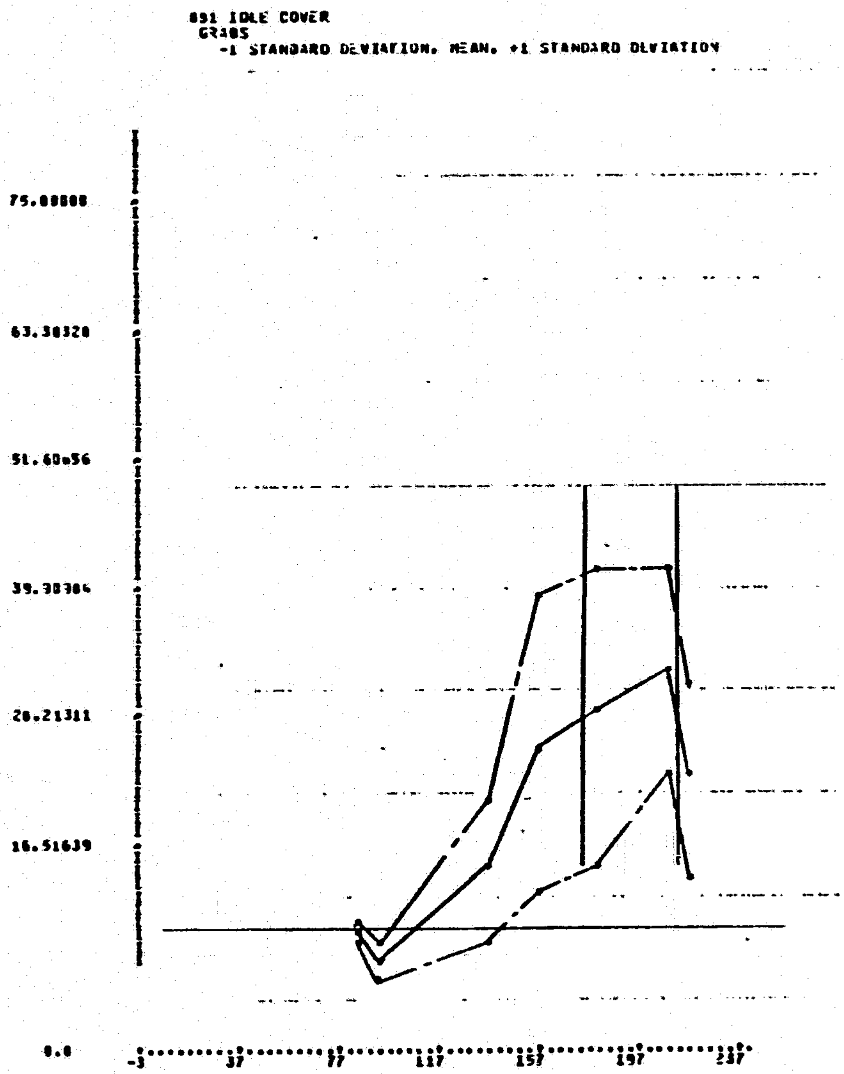

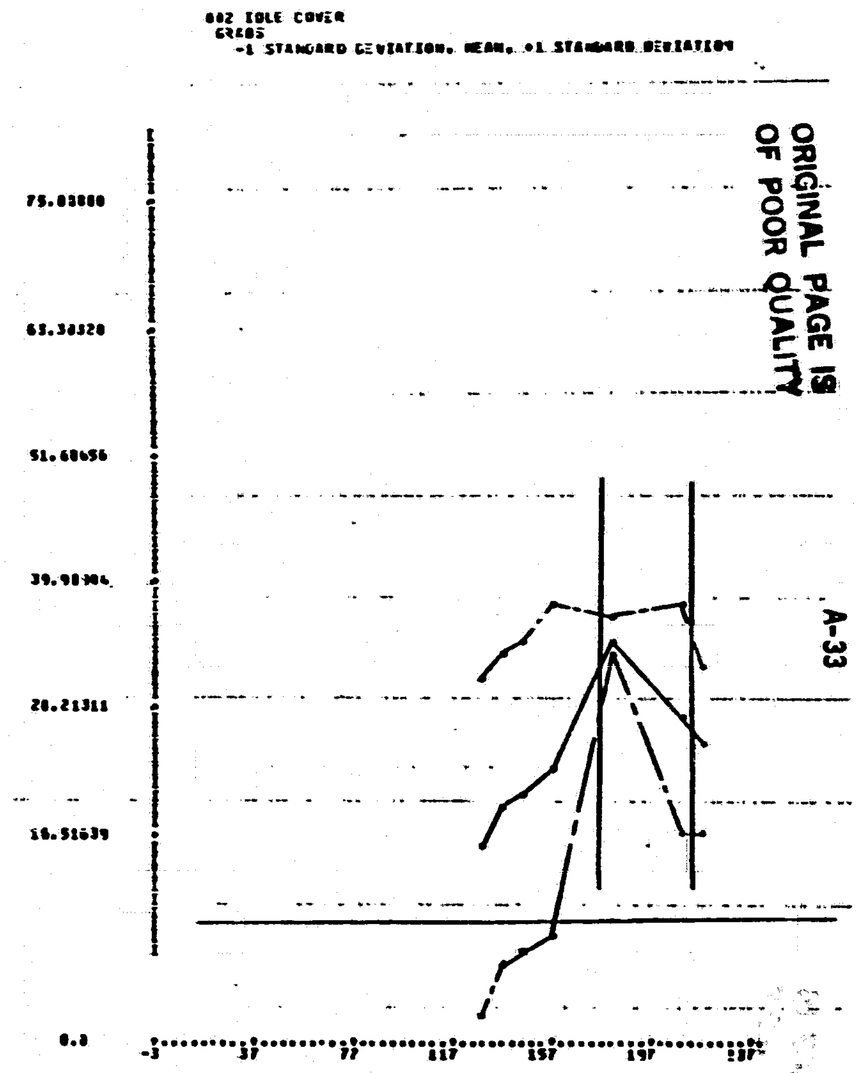

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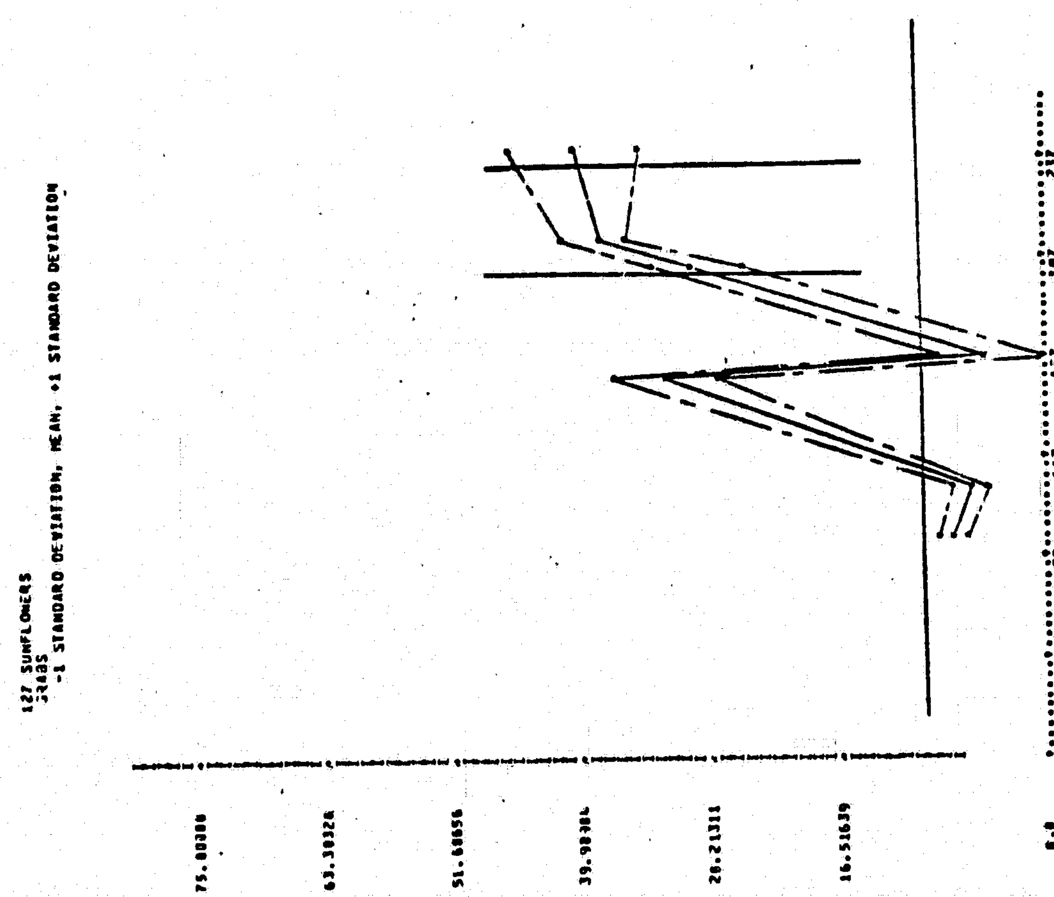

863 SORGHUM
GRABS
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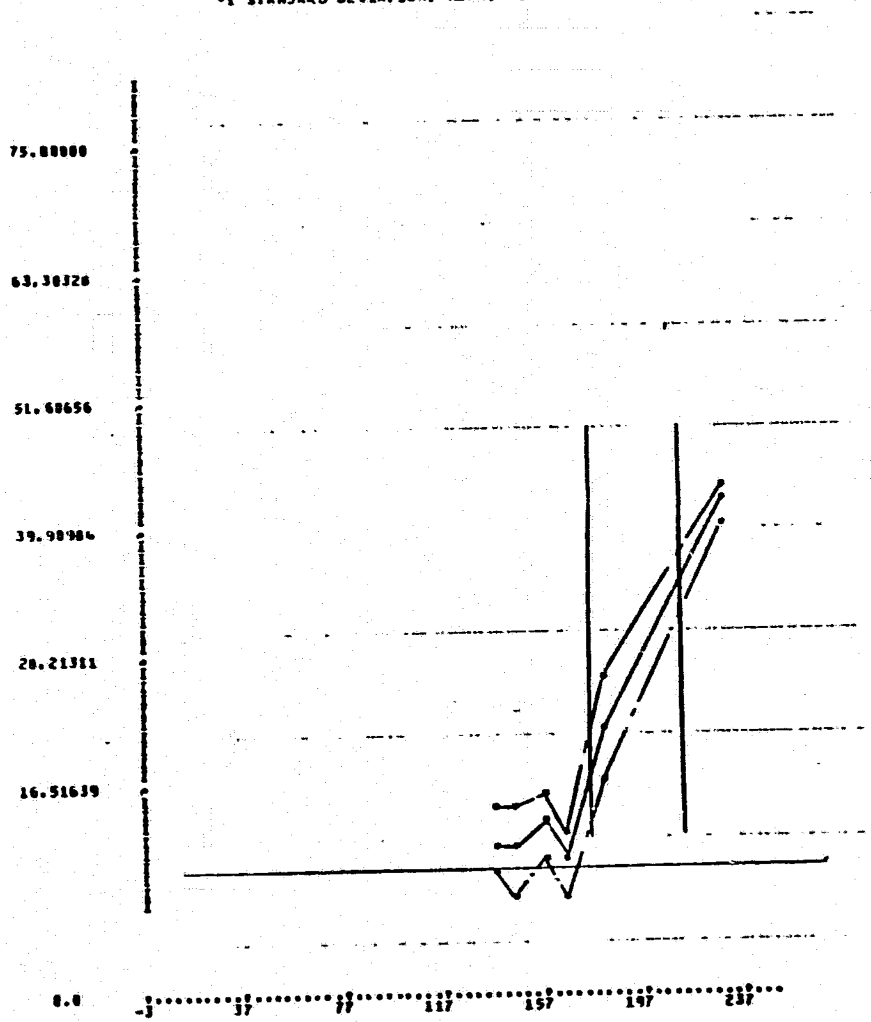

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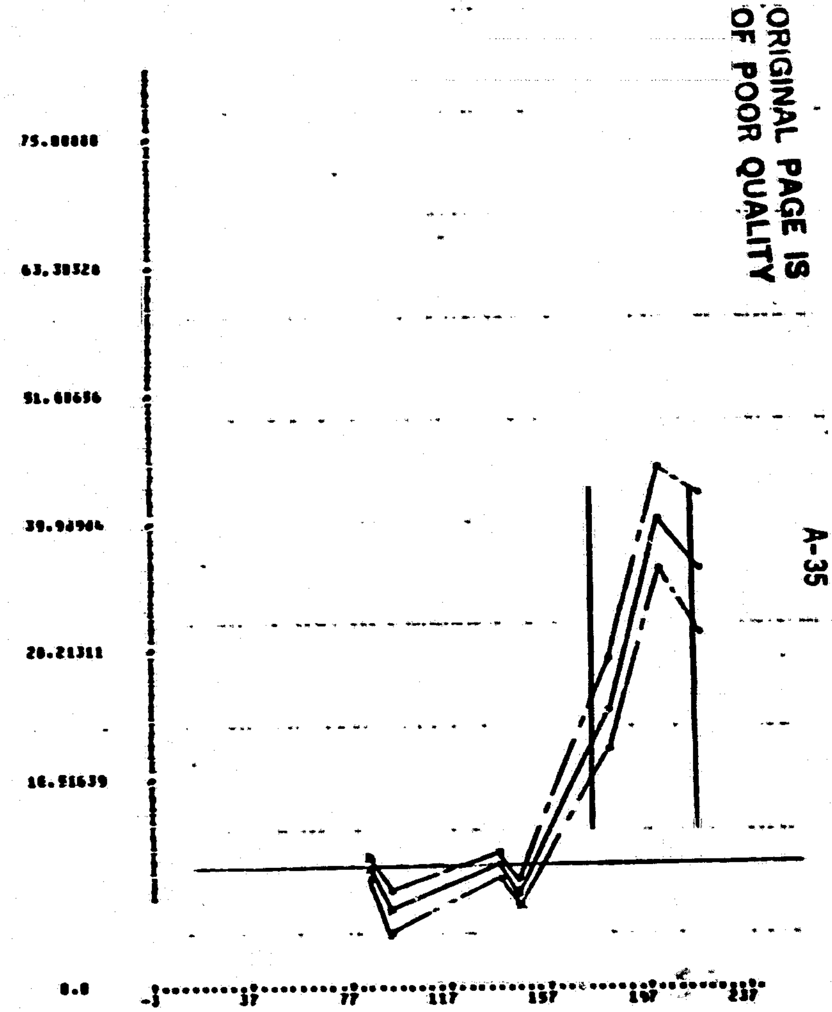

1572 SORGHUM
GRABS
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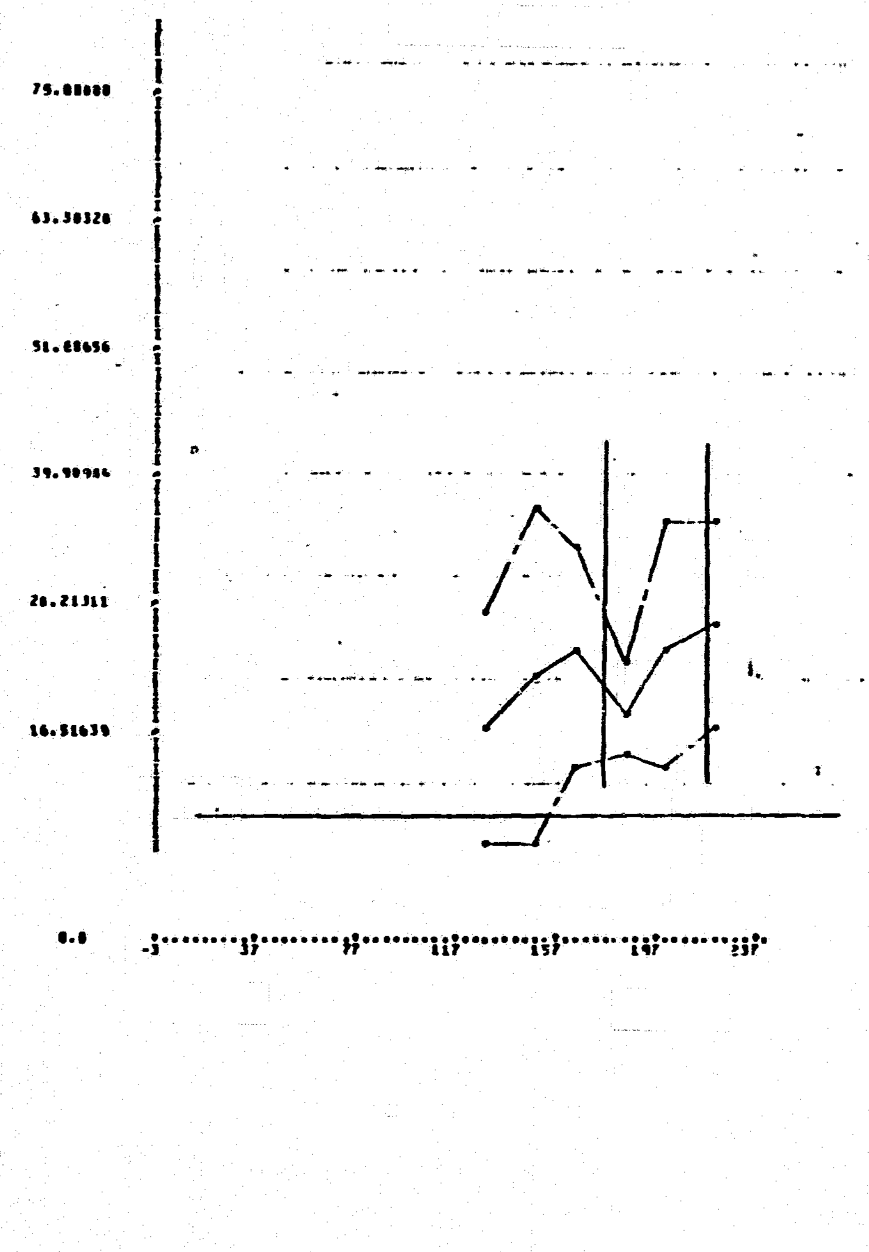

1591 SORGHUM
GRABS
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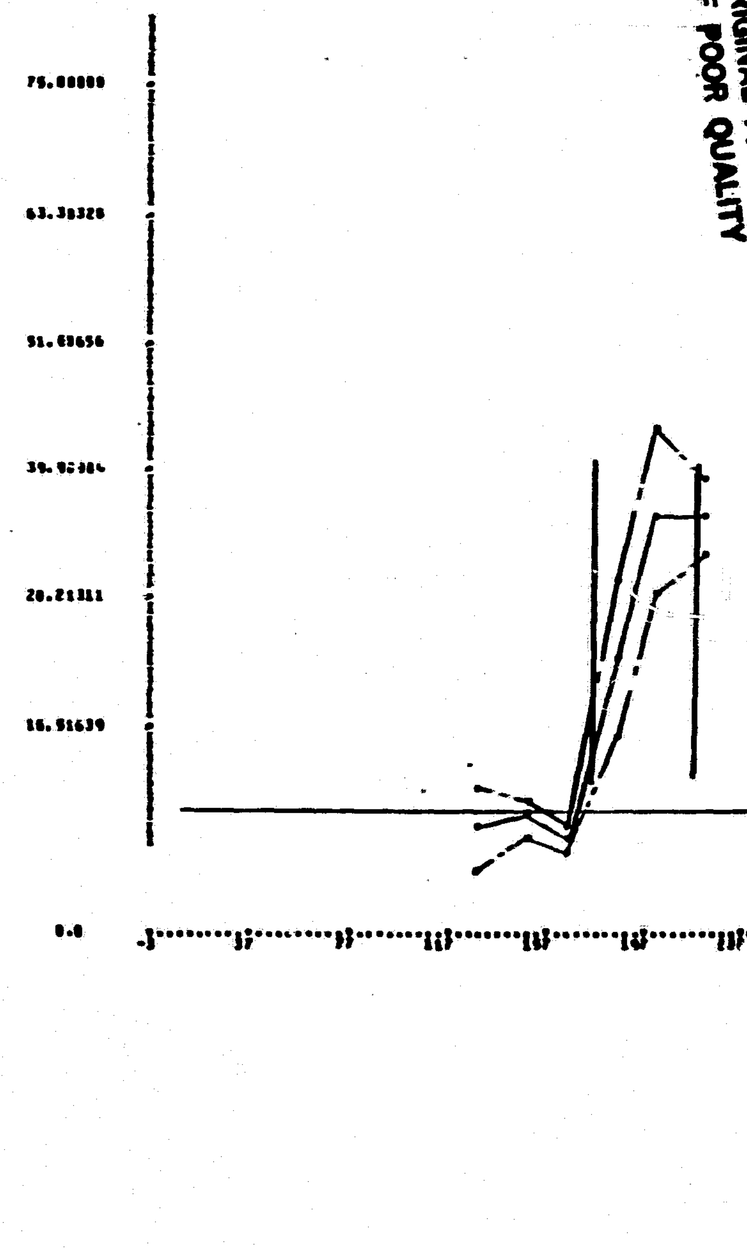

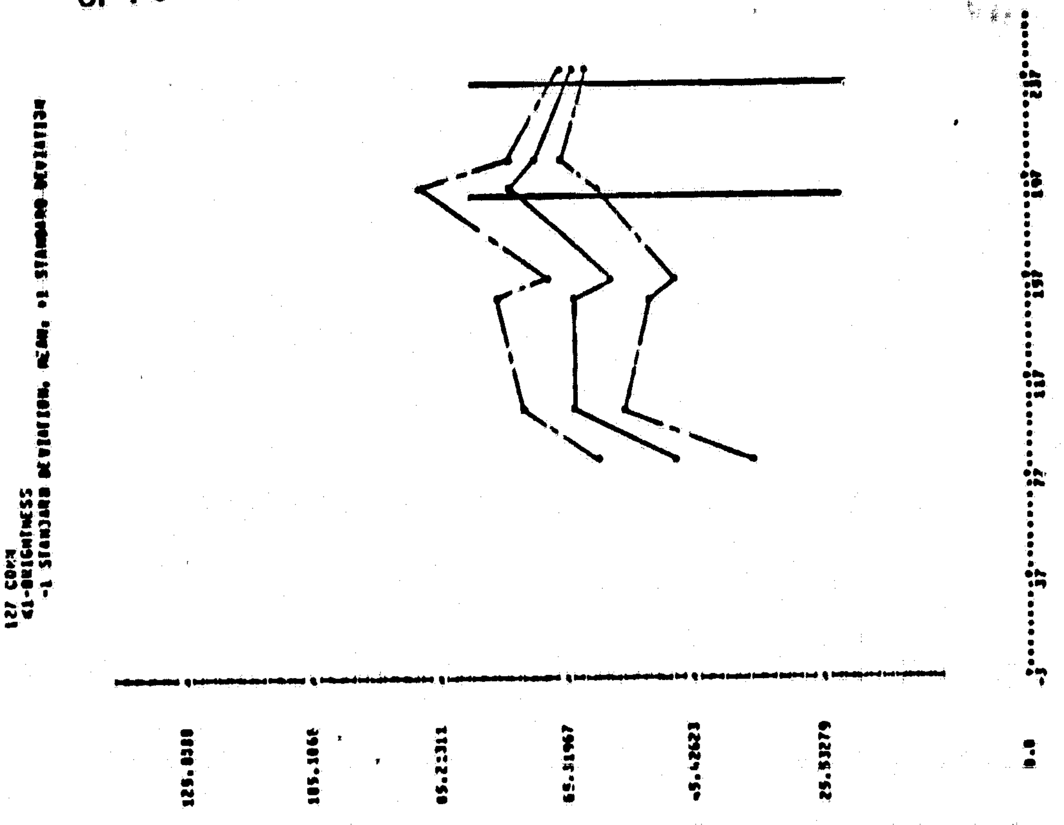
127 CORN
K1-BRIGHTNESS
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25.53279
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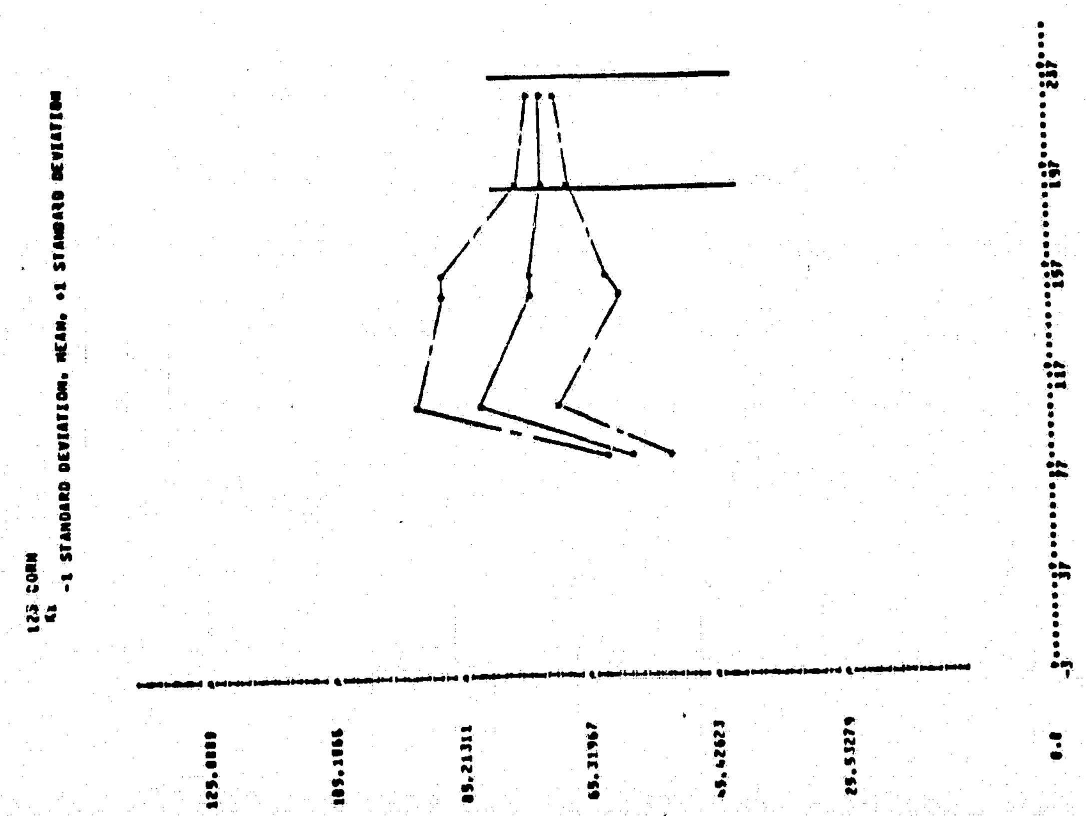
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K1
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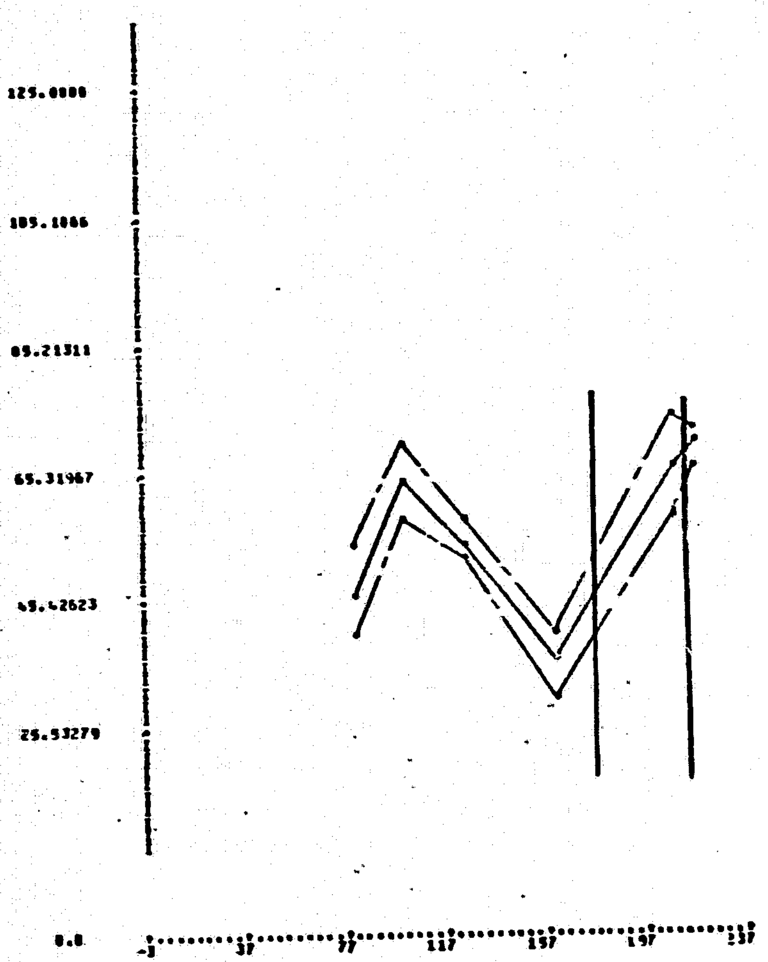
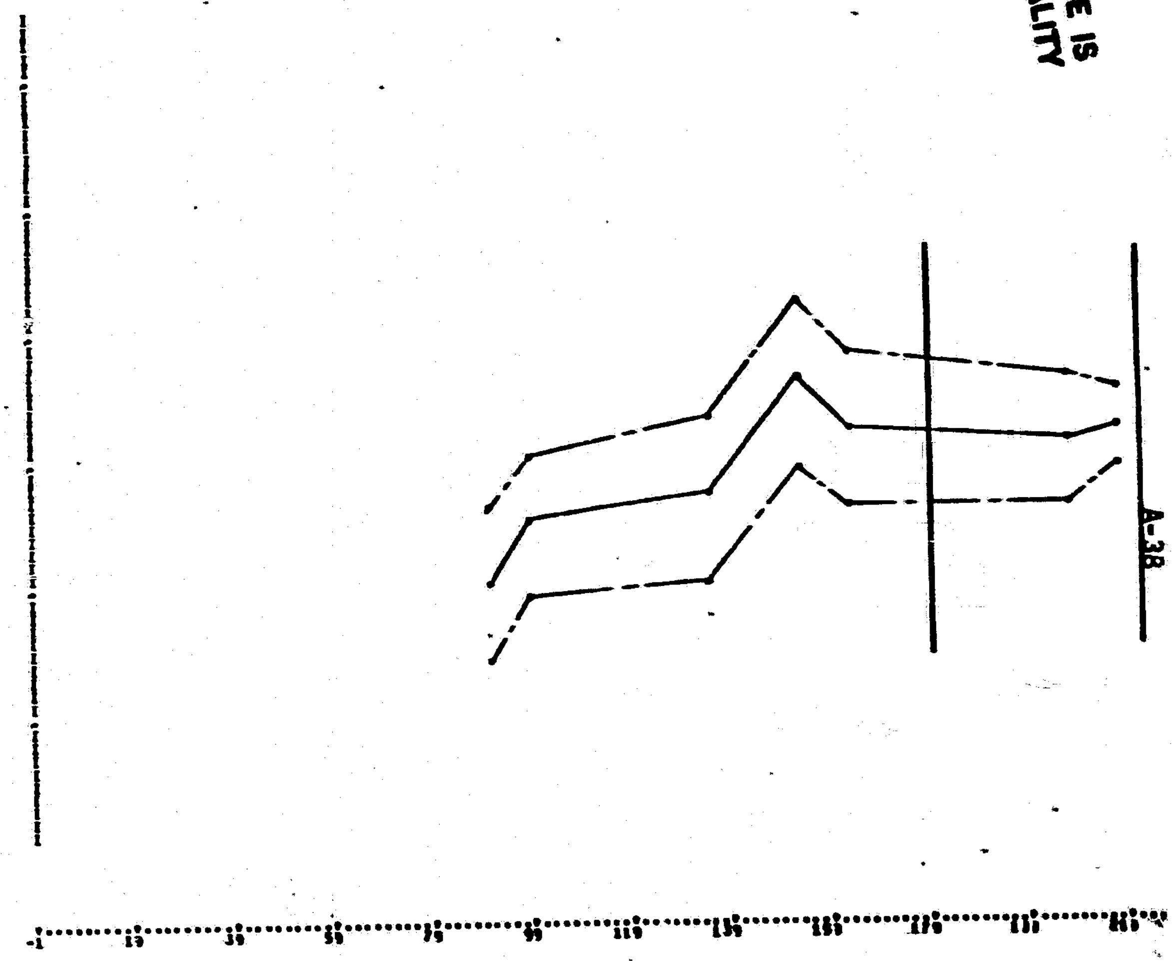
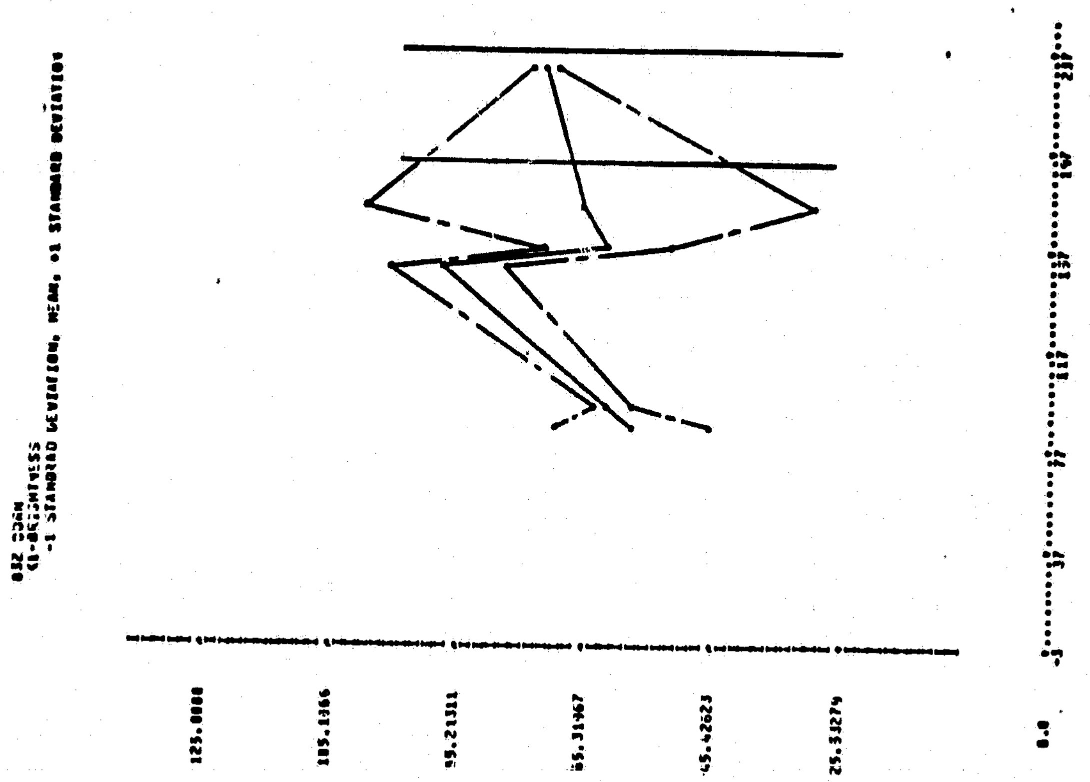
141 CORN
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



205 CORN
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION

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R1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
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197
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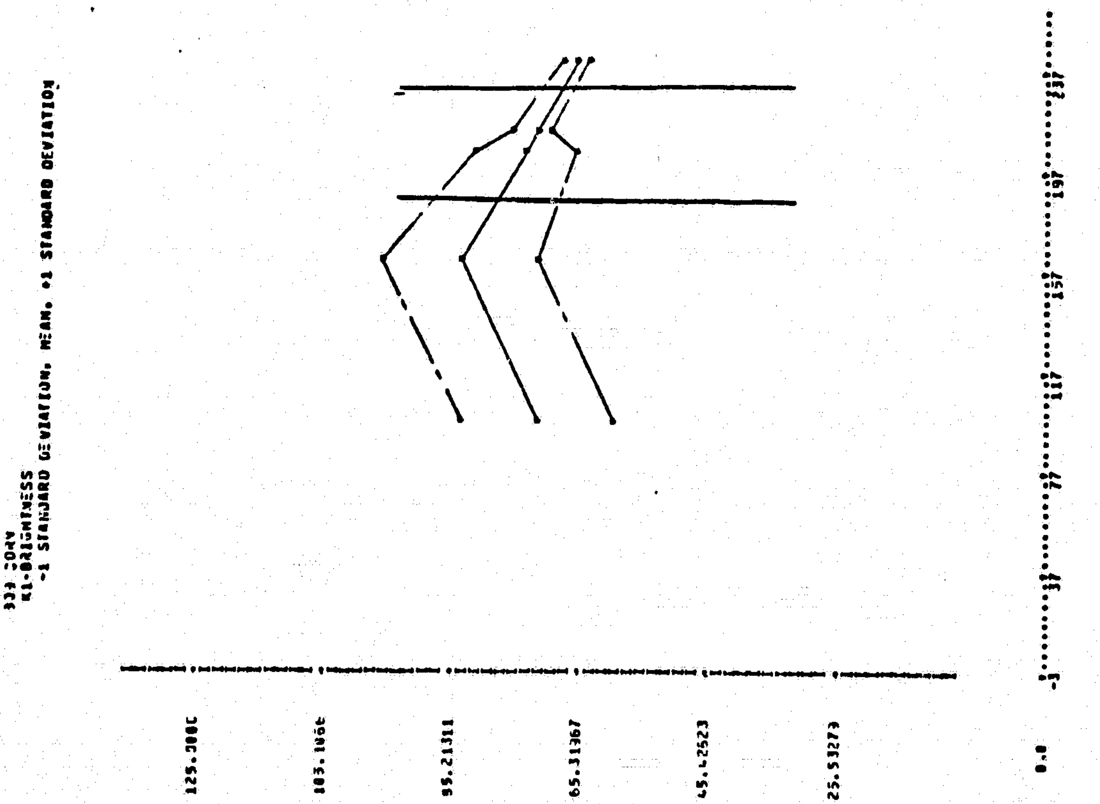
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65.31967
45.42623
25.53279
0.0
-3
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117
157
197
237

932 CORN OIL
K1-BRIGHTNESS
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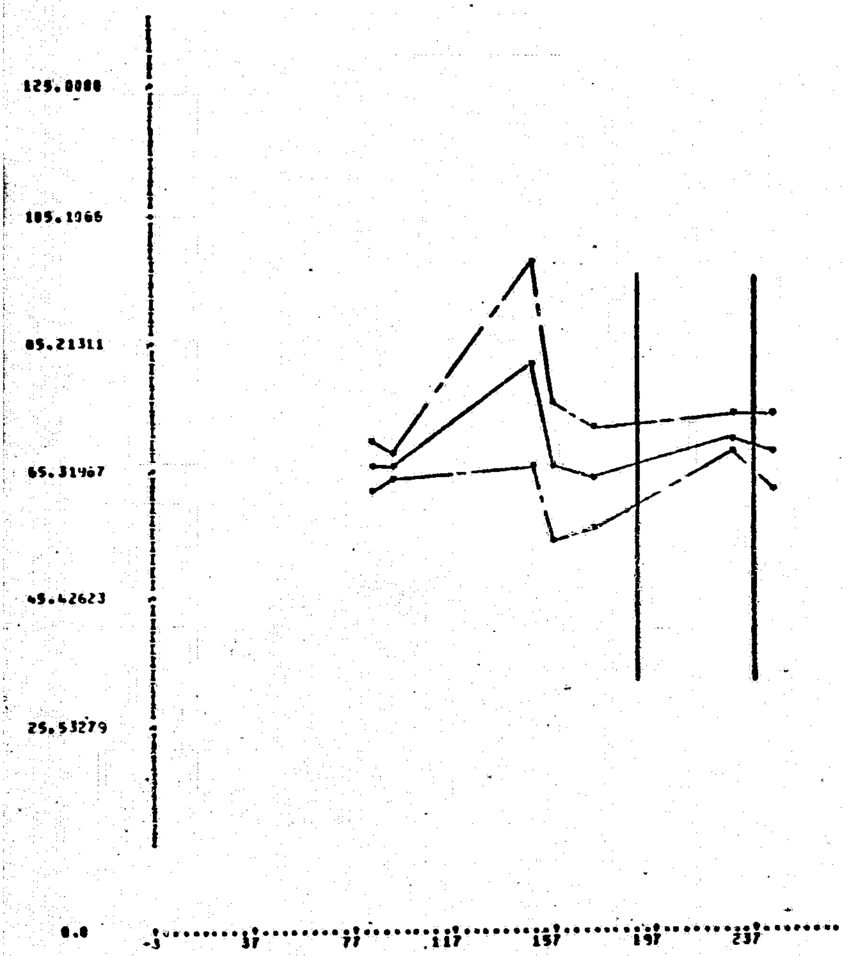

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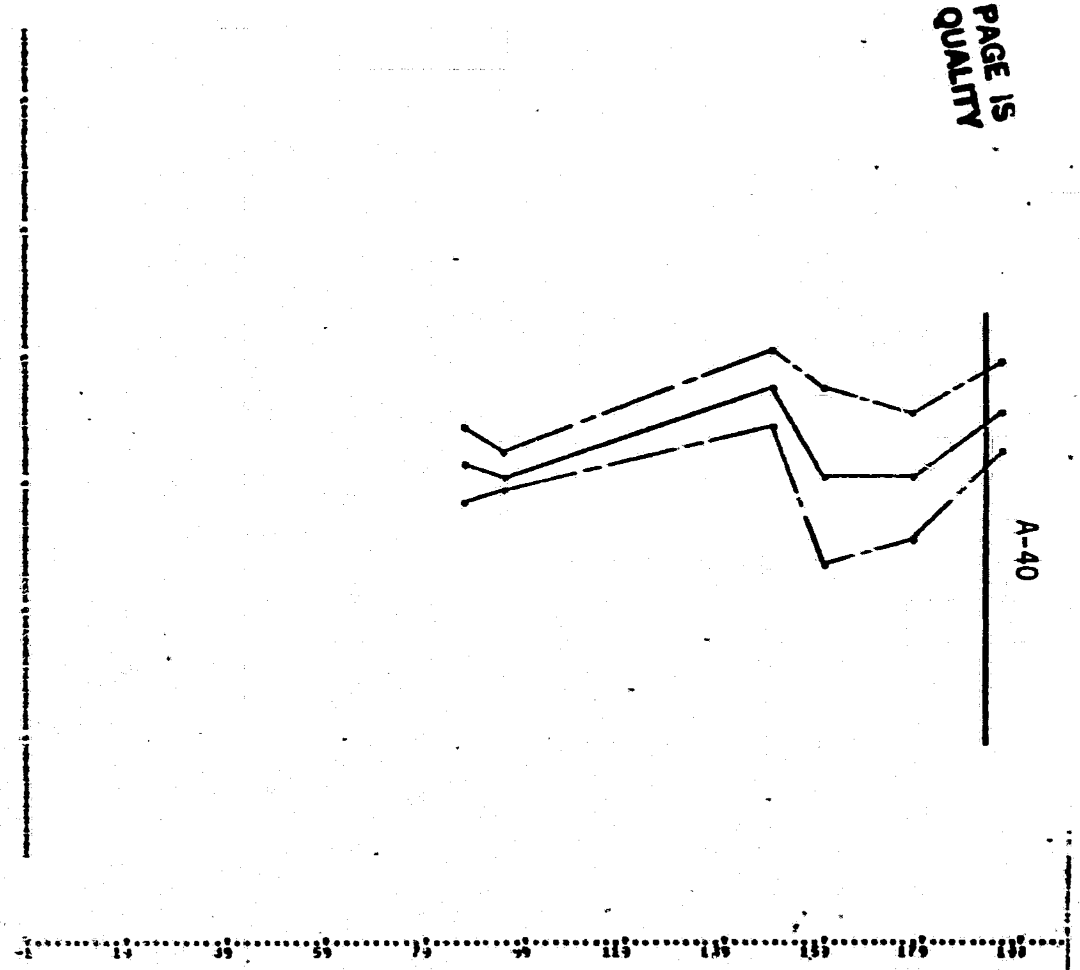

853 CORN
K1-BRIGHTNESS
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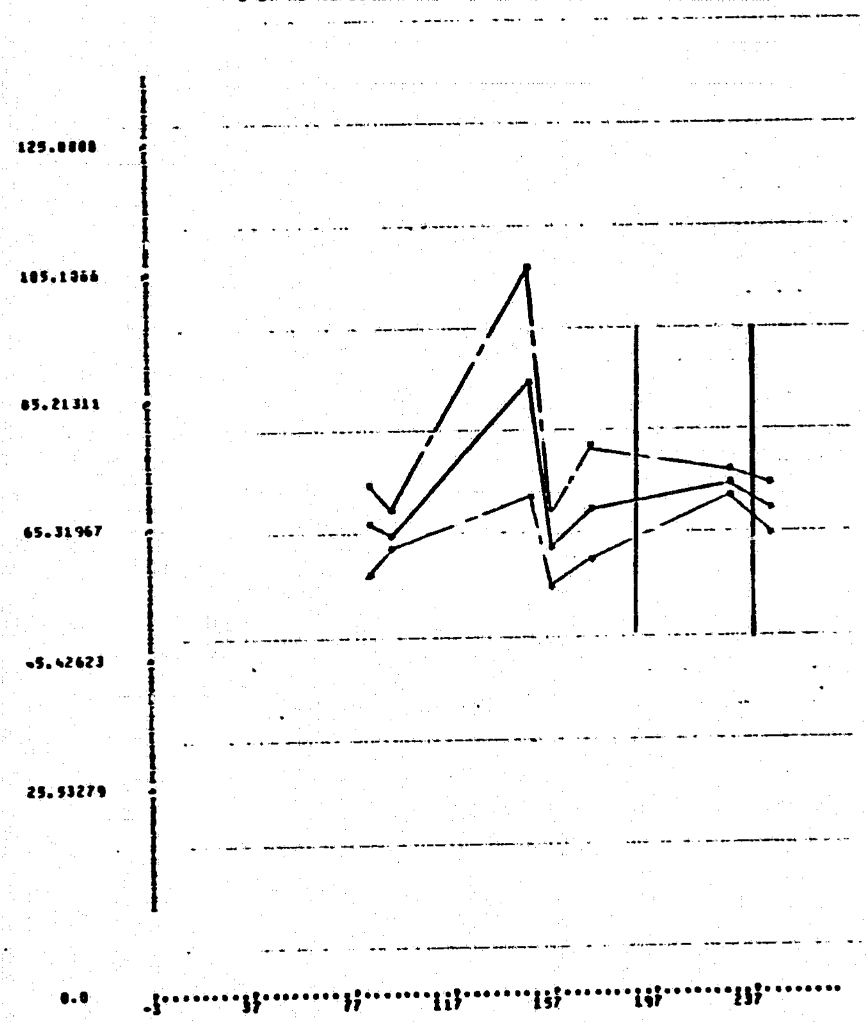

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K1-BRIGHTNESS
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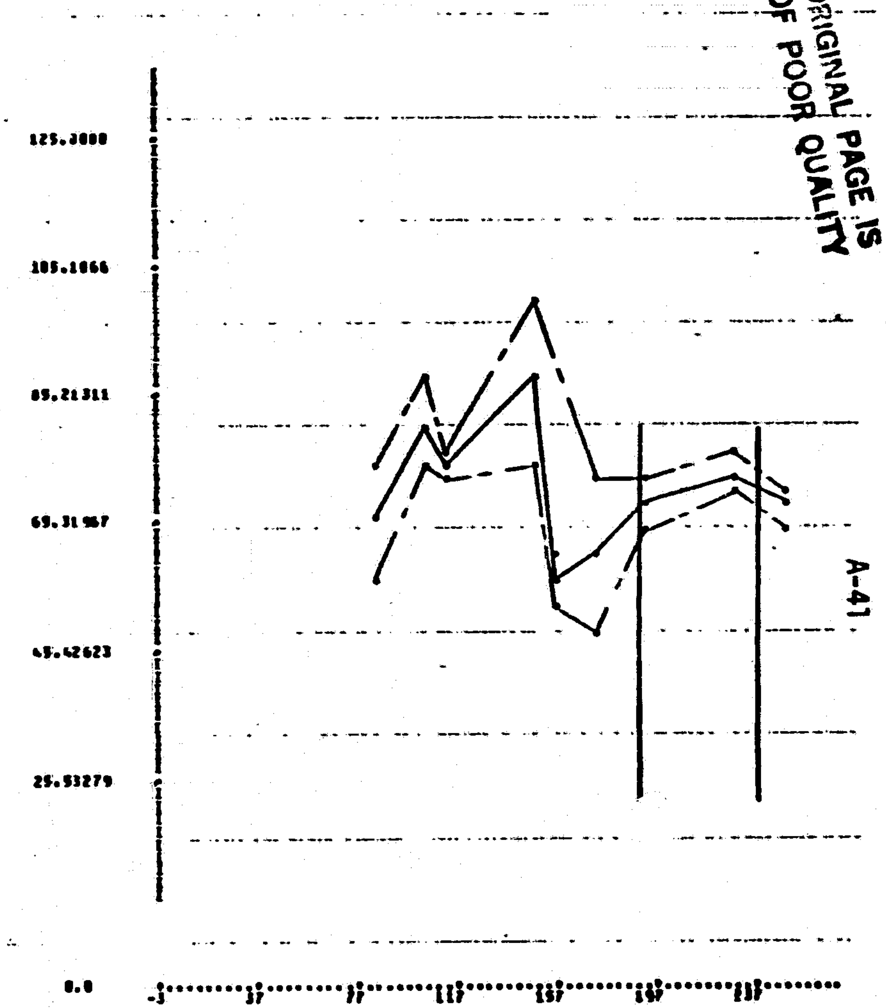

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364 CORN
K1-BRIGHTNESS
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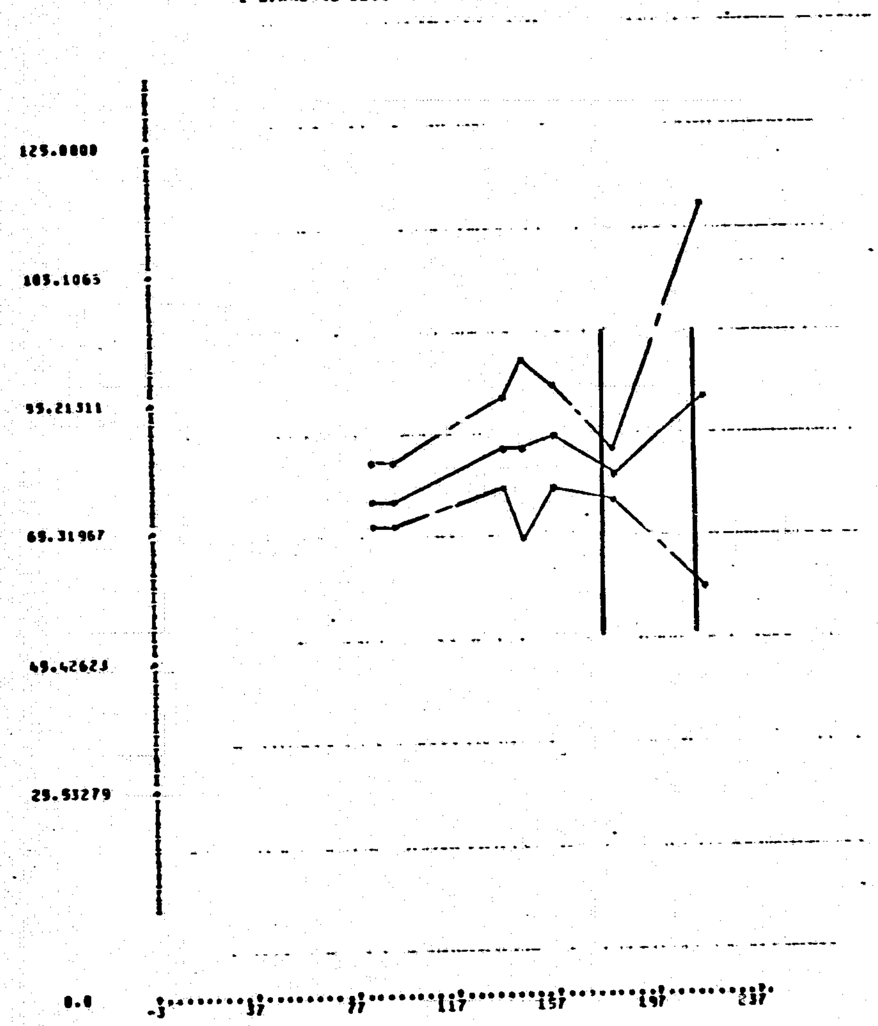

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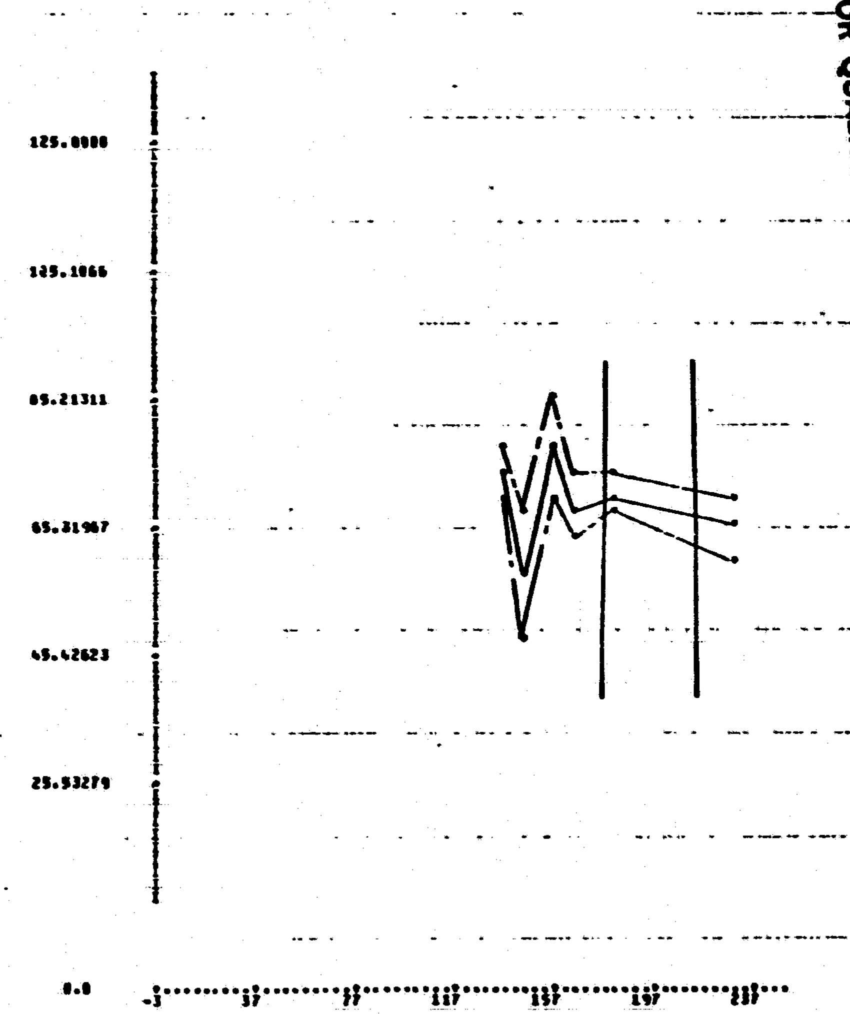

02C CORN
41-BRIGHTNESS
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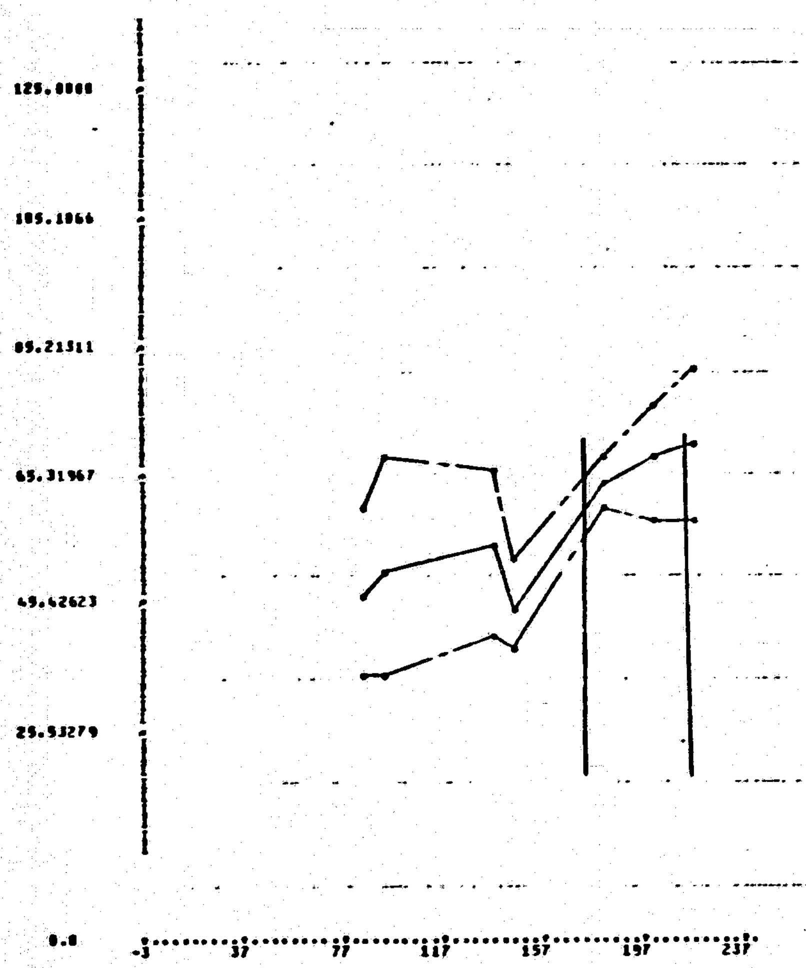

001 CORN
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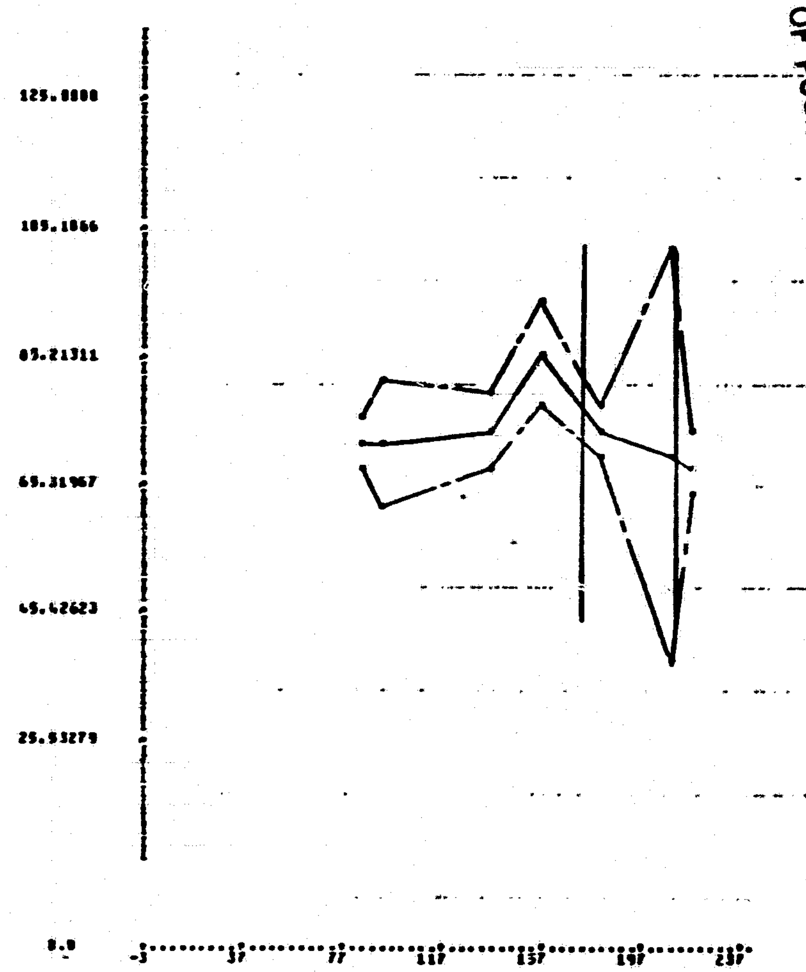

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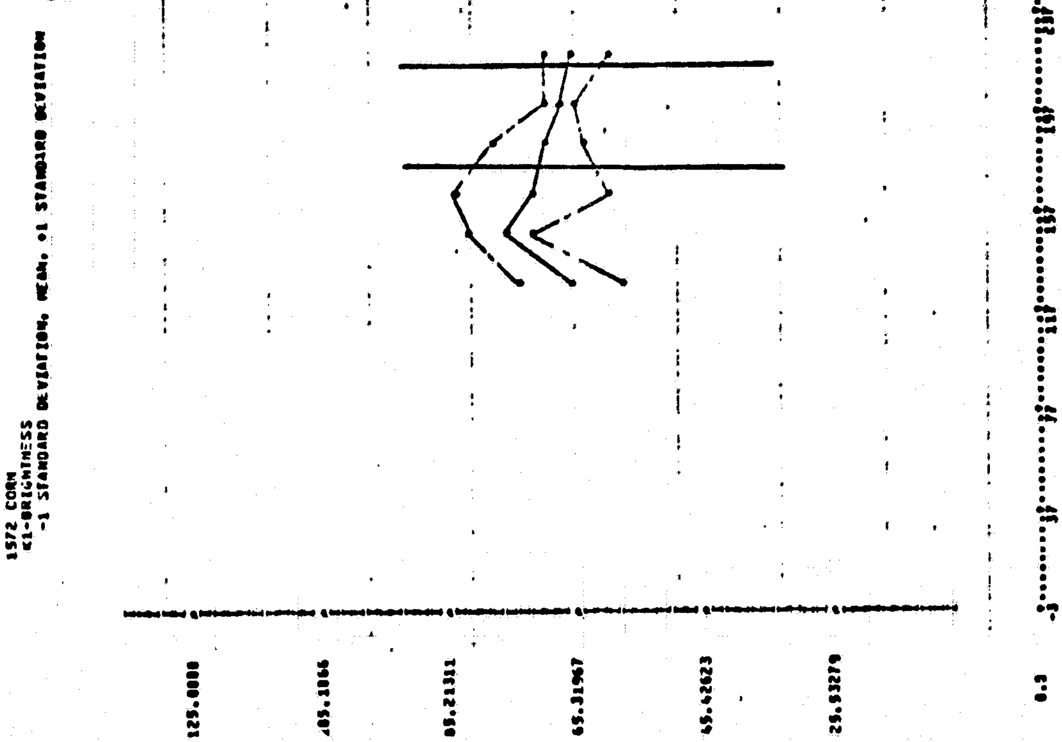

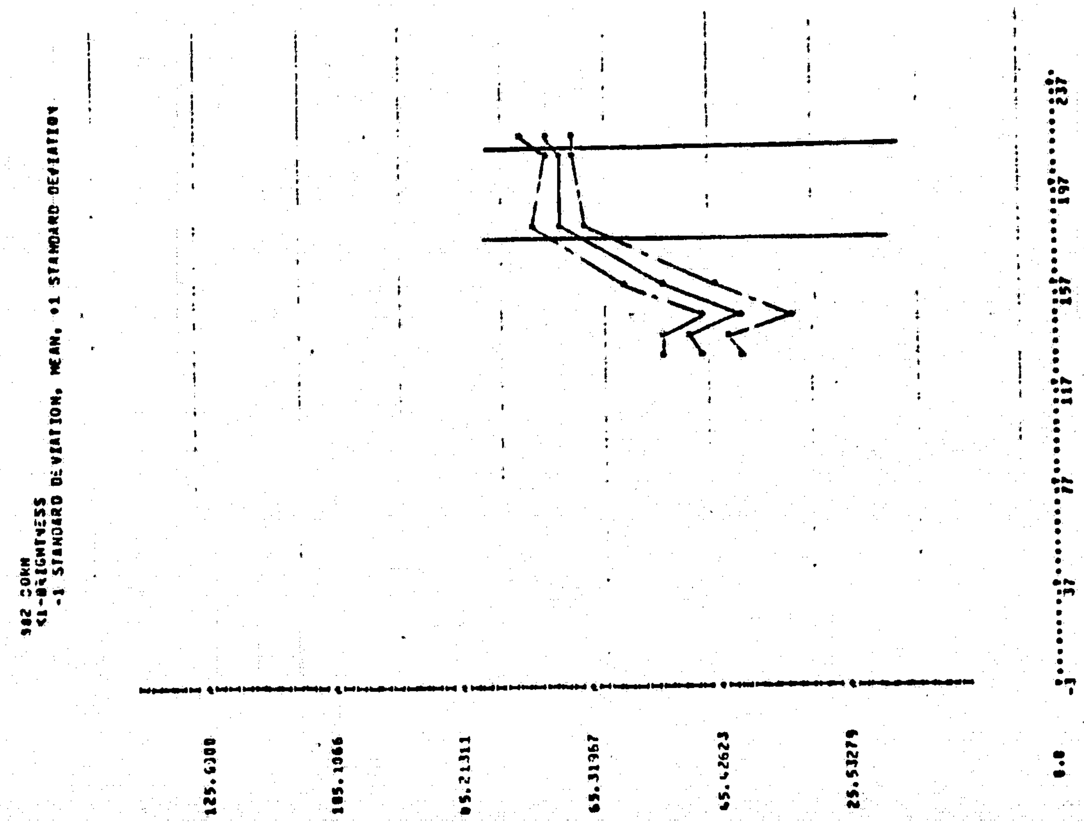

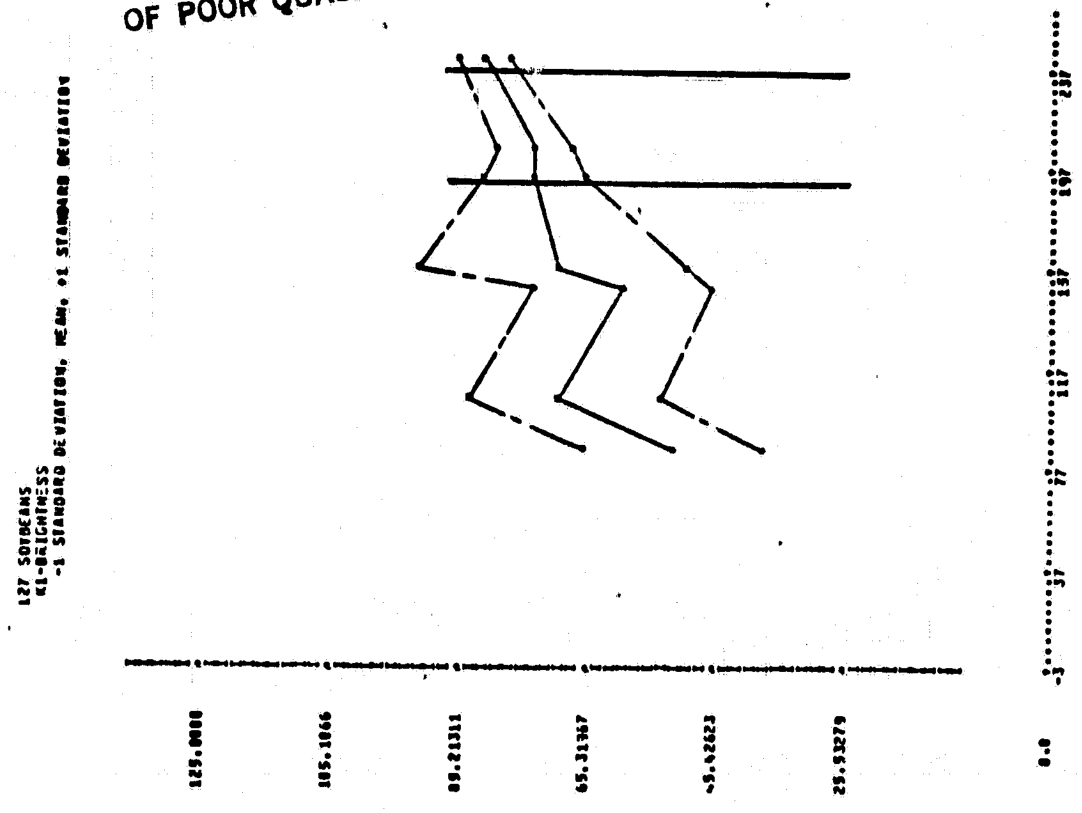
127 SOYBEANS
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65.31967
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-3
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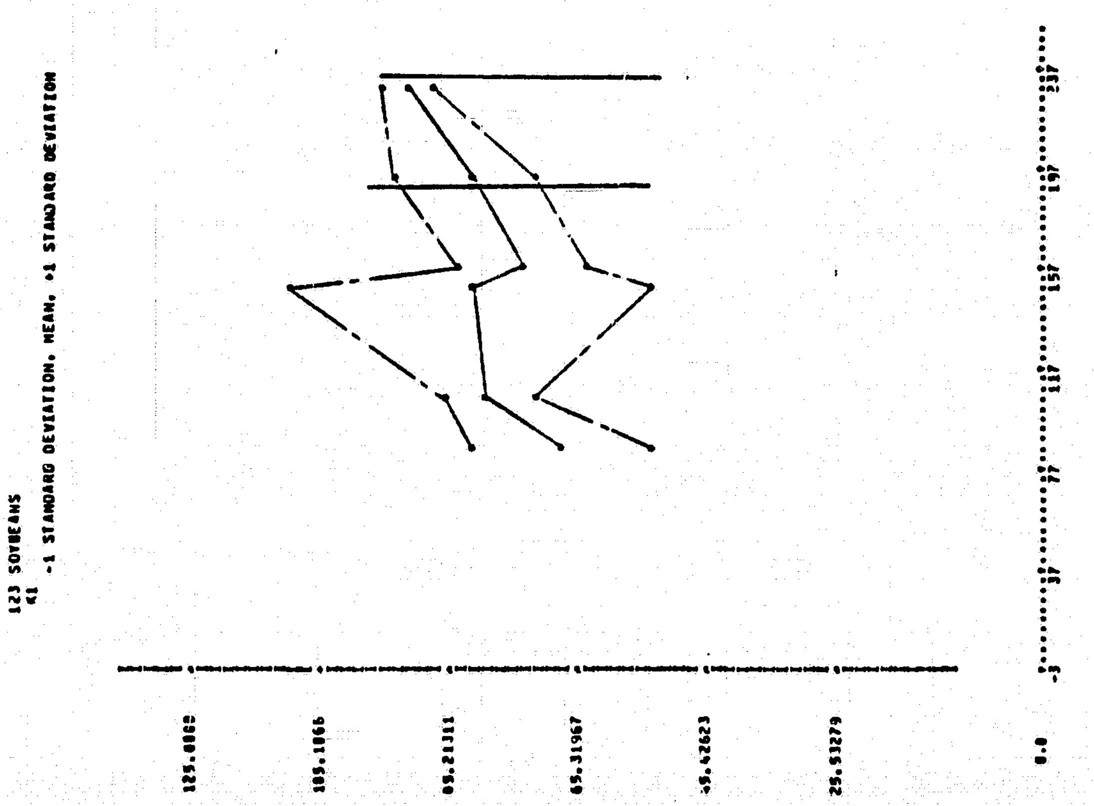
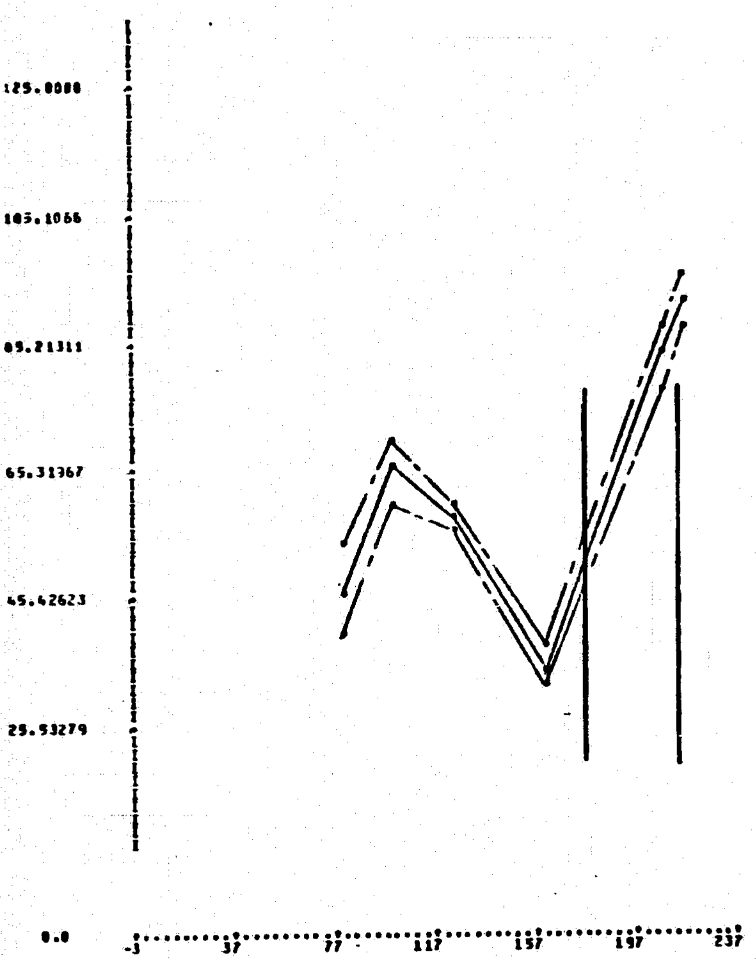
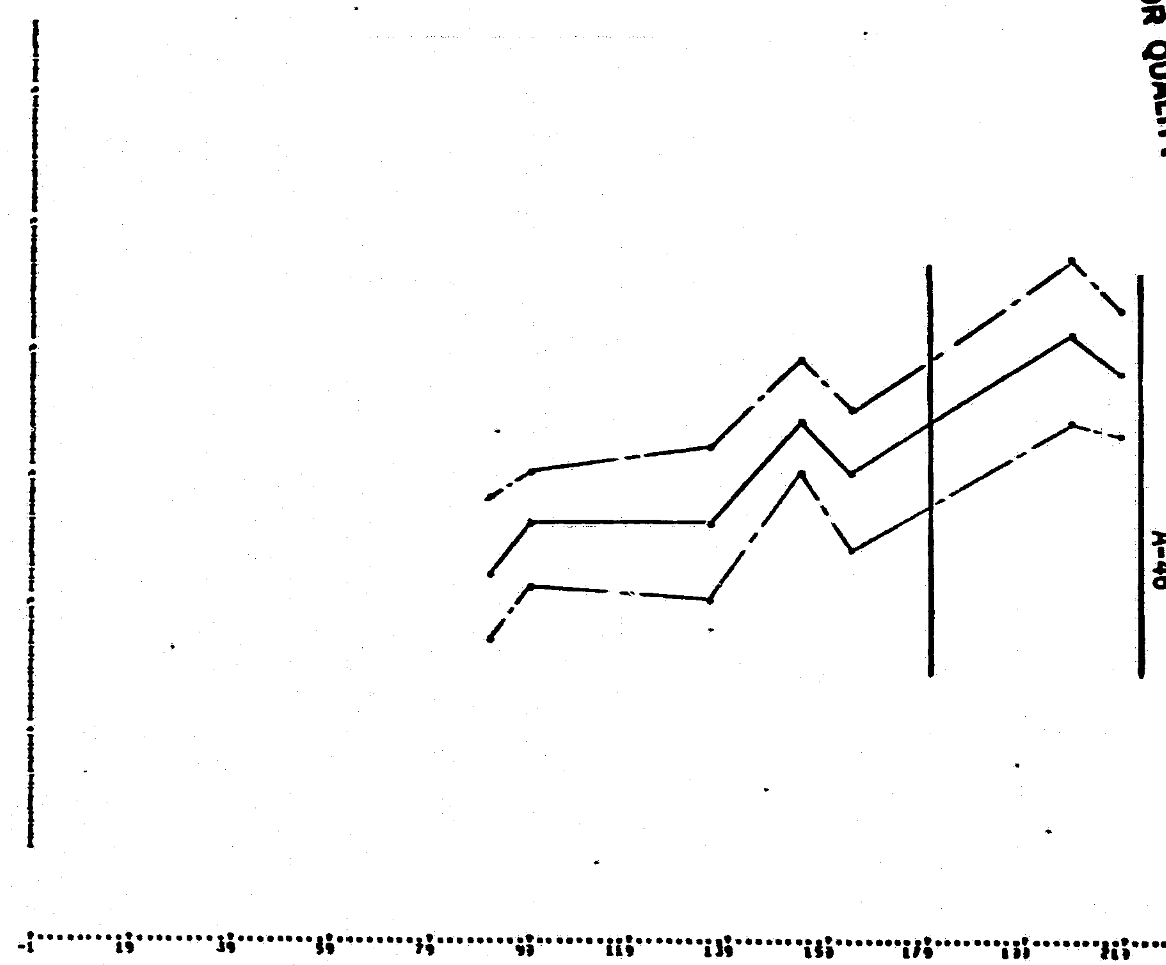

123 SOYBEANS
K1
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
125.0000
105.1066
85.21311
65.31967
45.42623
25.53279
0.0
-3
37
77
117
157
197
237

141 SOYBEANS
A1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



283 SOY BEANS
C1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



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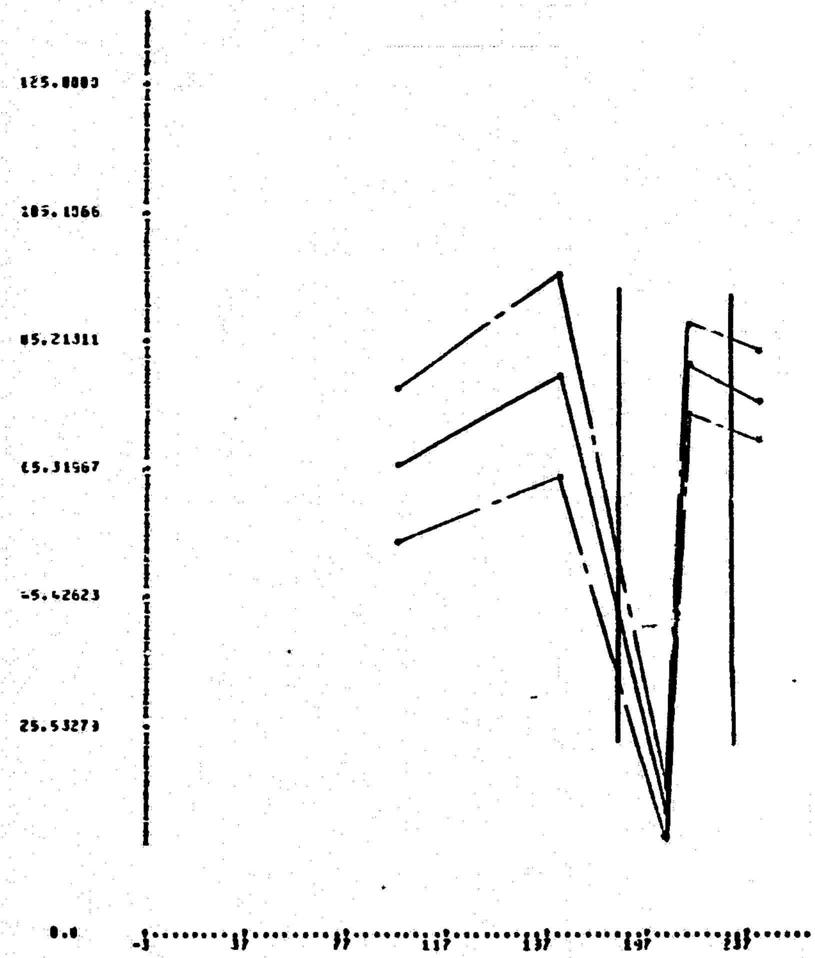

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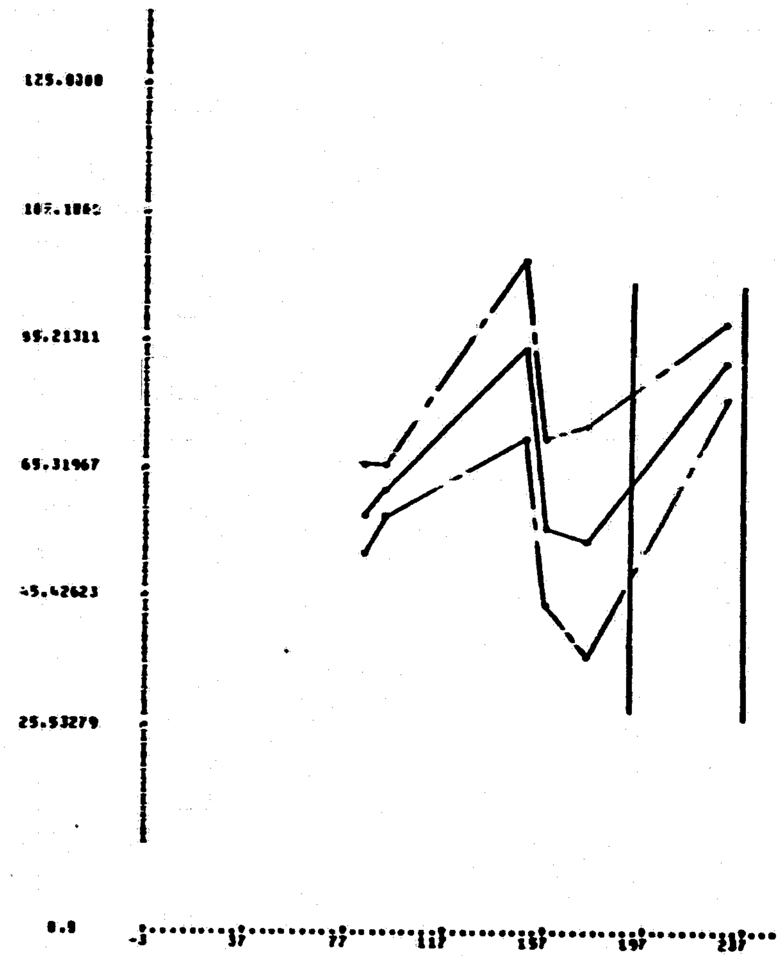

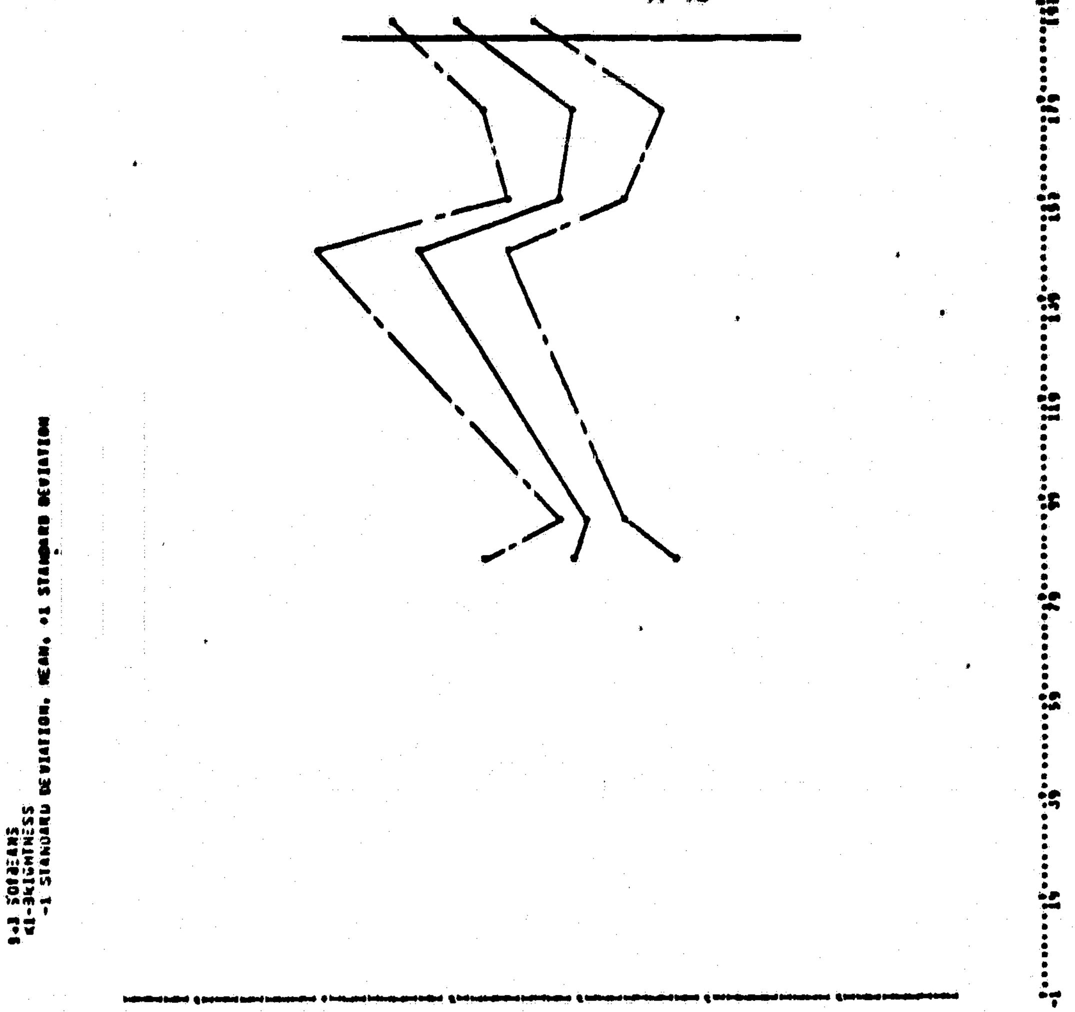

SOYBEANS
K1-BRIGHTNESS
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-1
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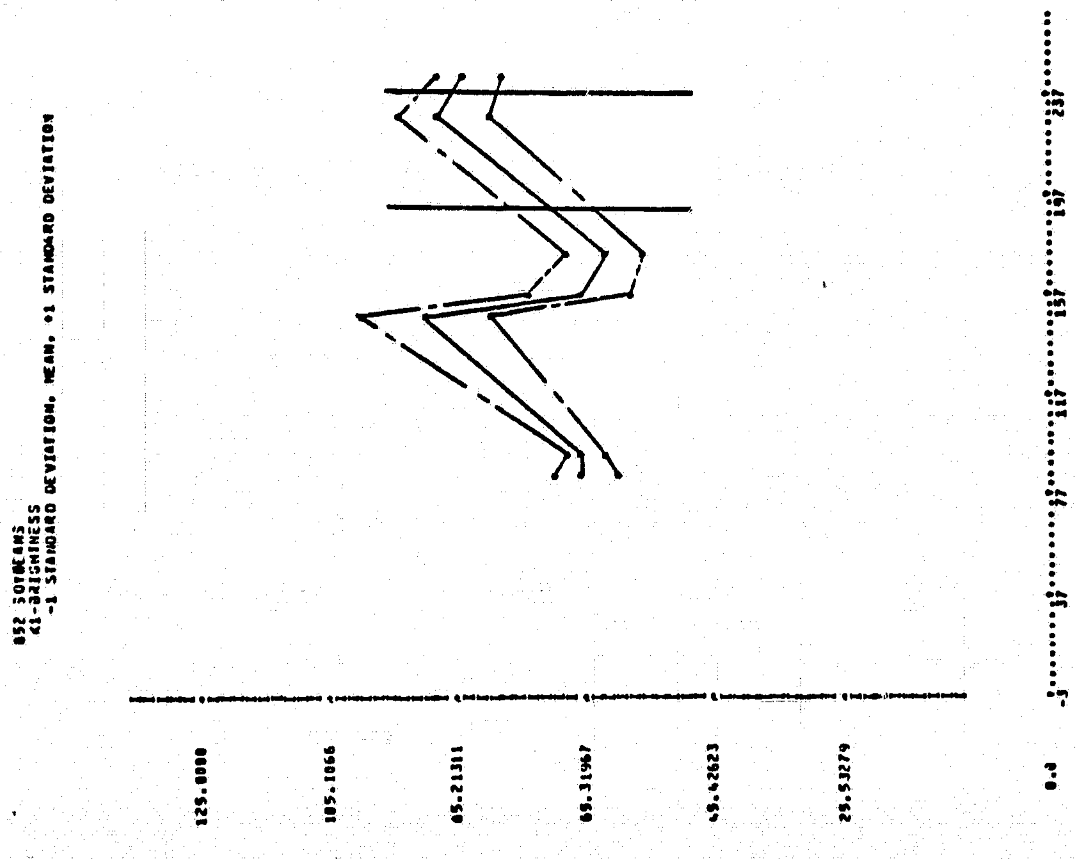
159
179



852 SOYBEANS
K1-BRIGHTNESS
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125.0000
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65.31967
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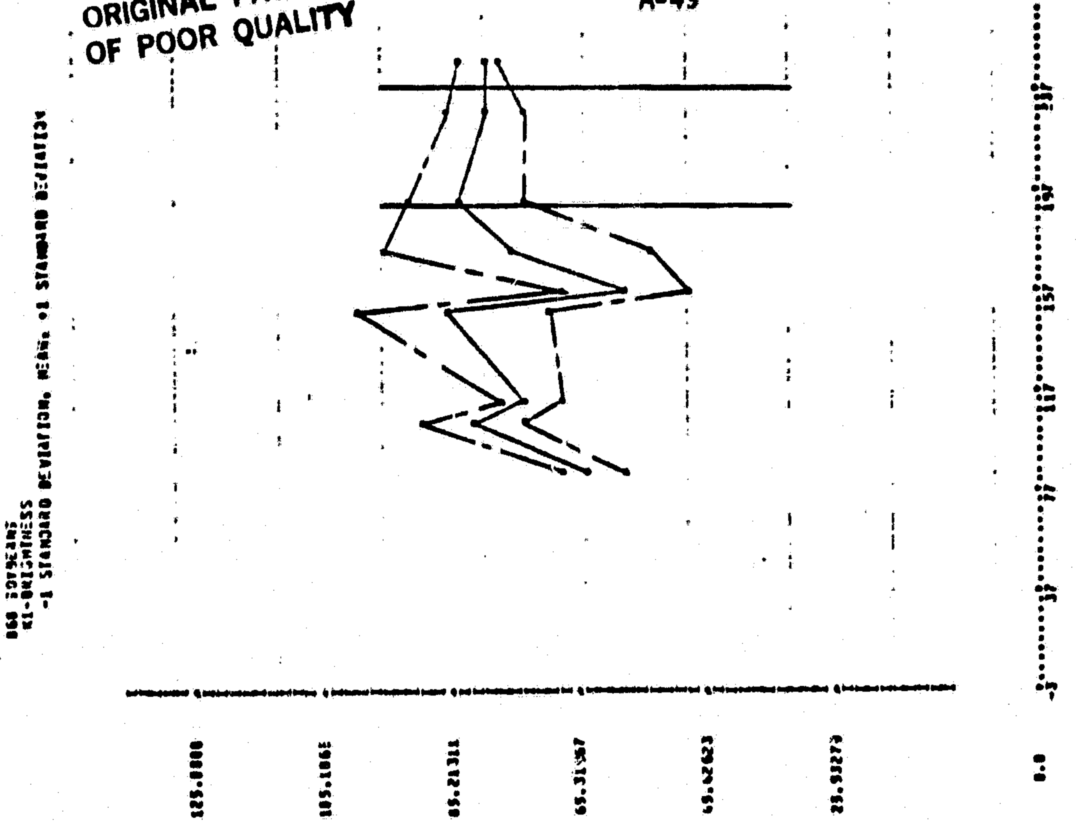
0.0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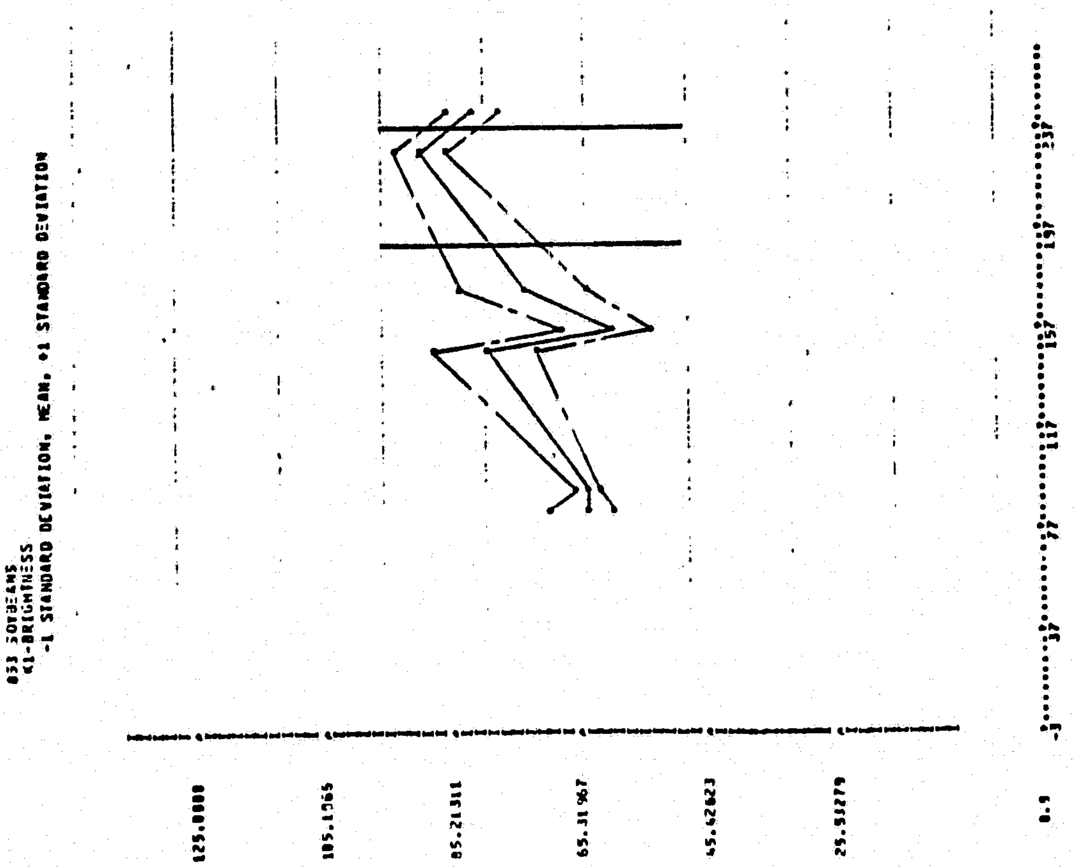
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K1-BRIGHTNESS
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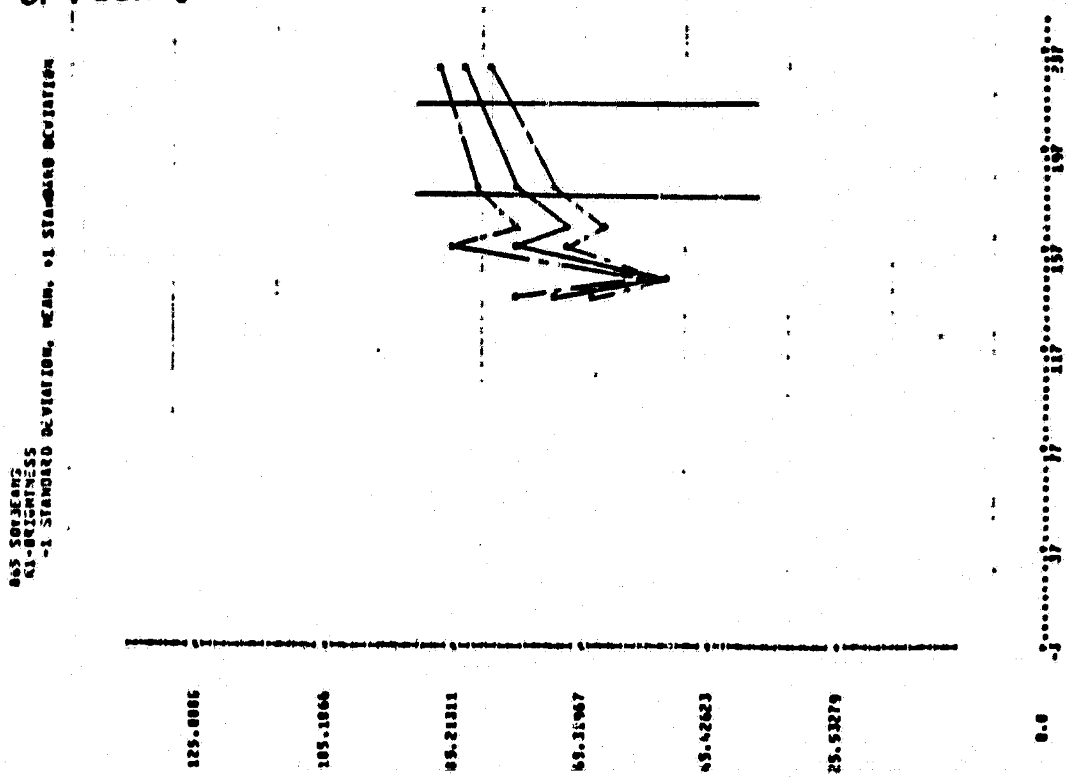

85 SOYBEANS
K1-BRIGHTNESS
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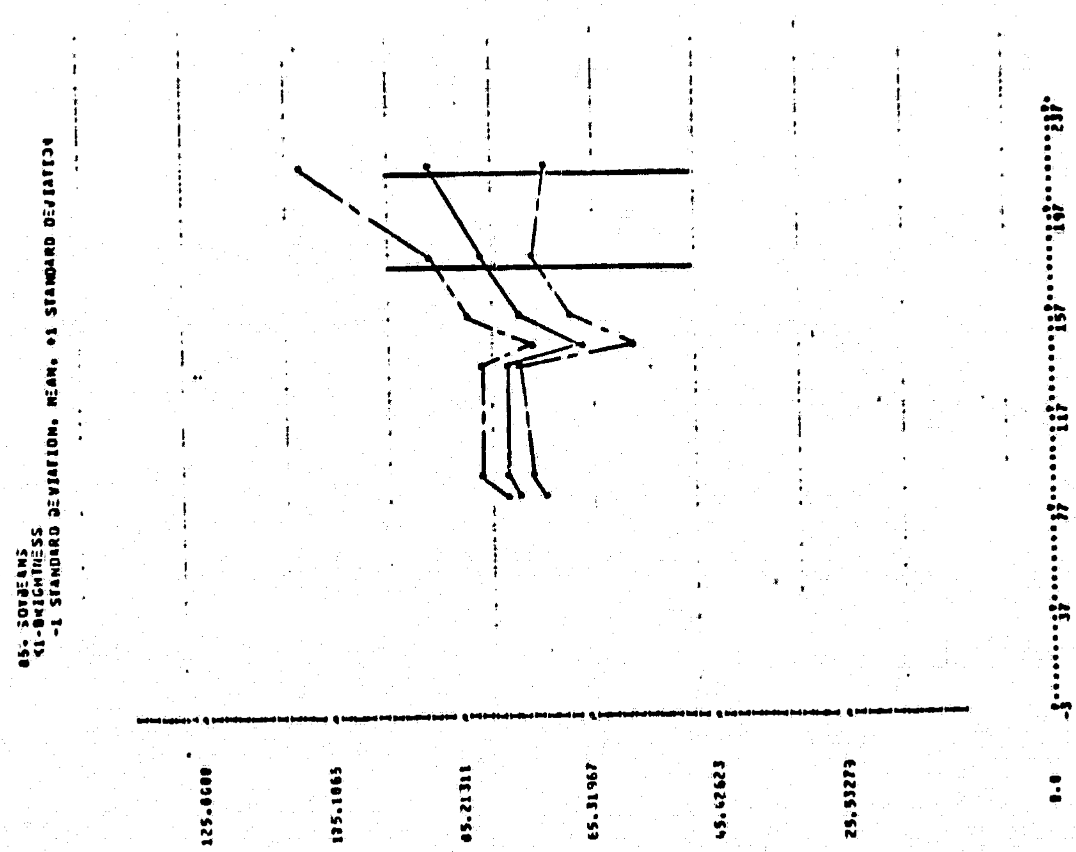

85 SOYBEANS
K1-BRIGHTNESS
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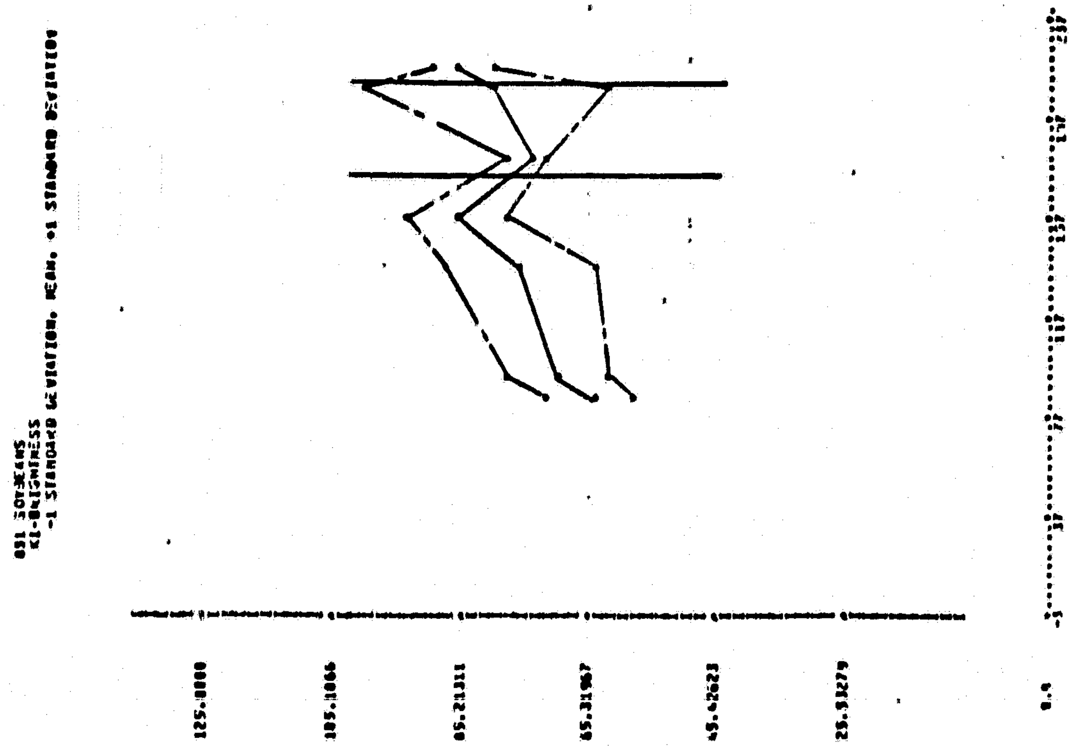
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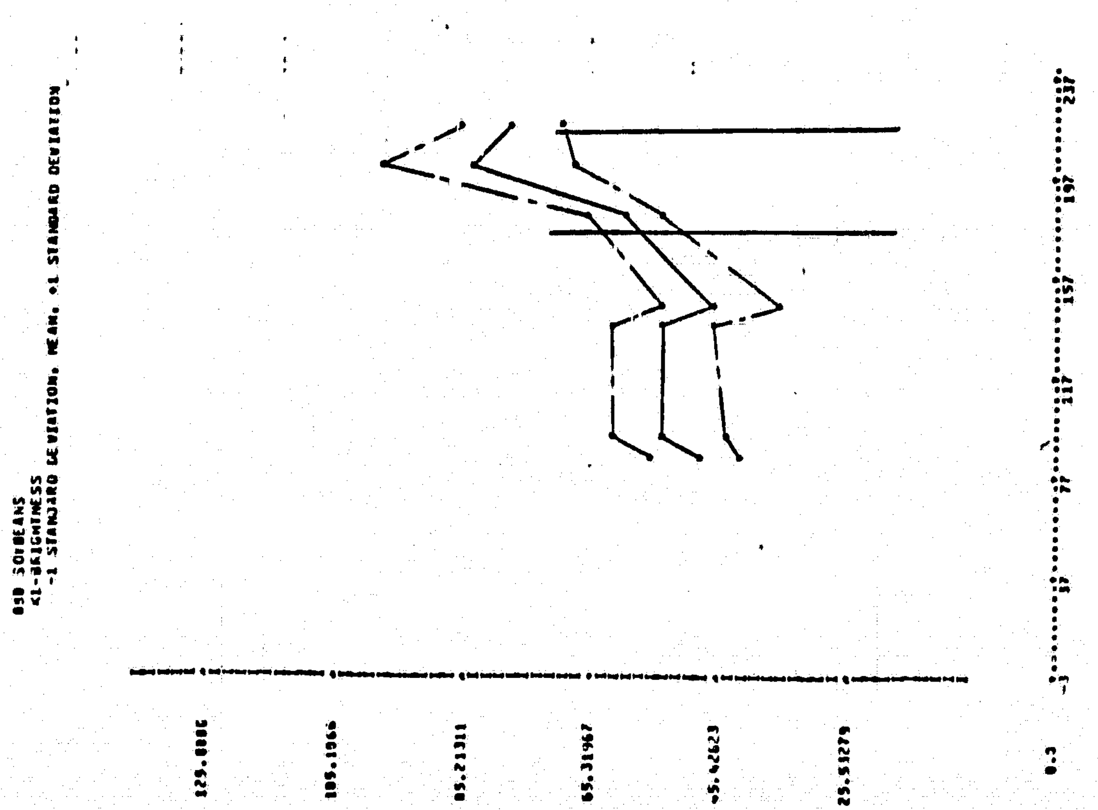
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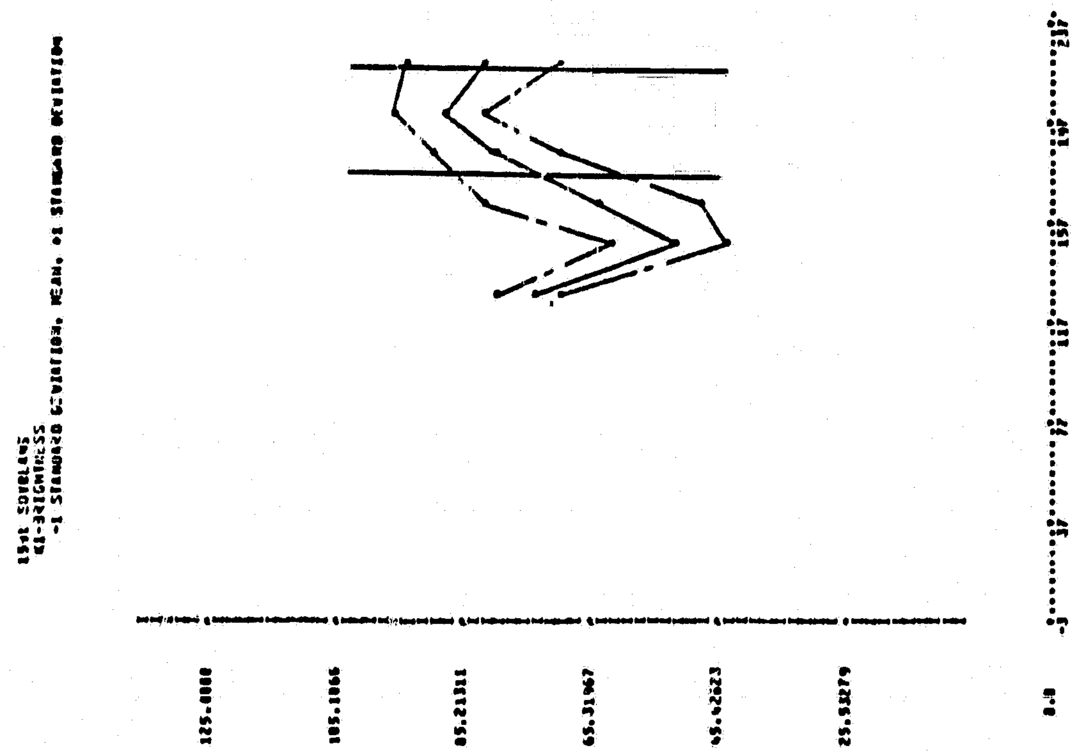
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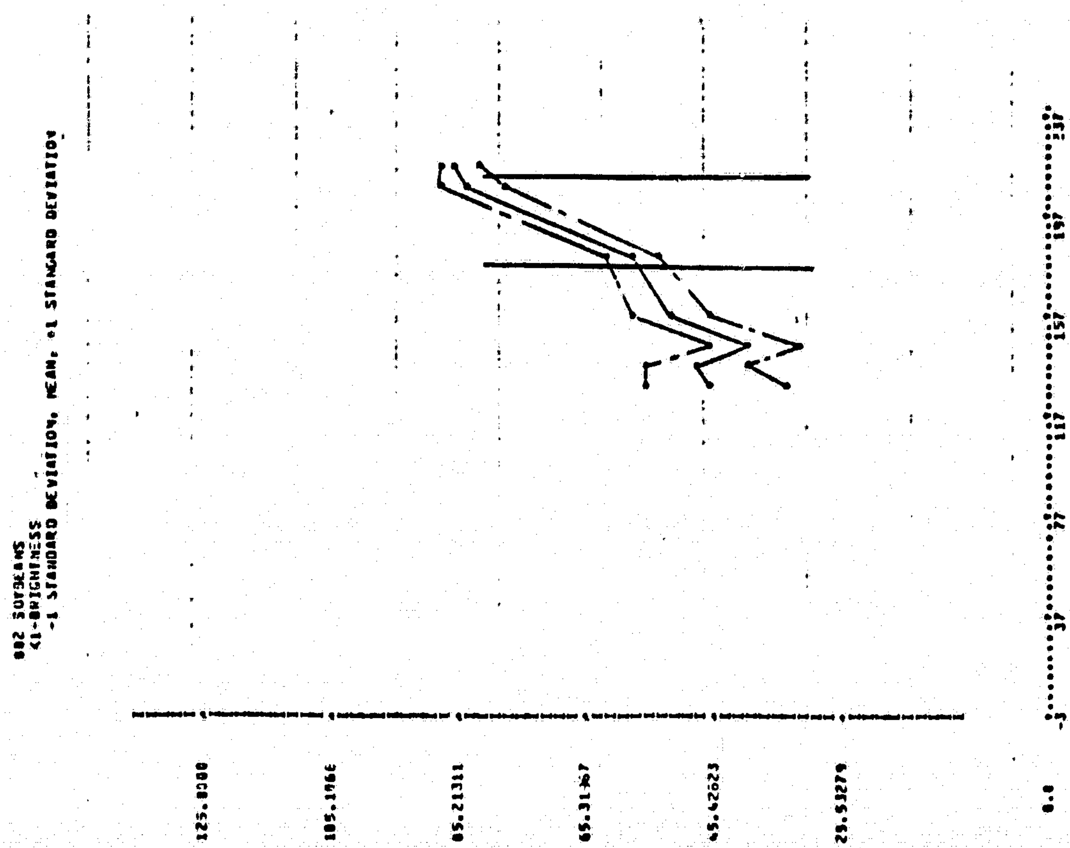
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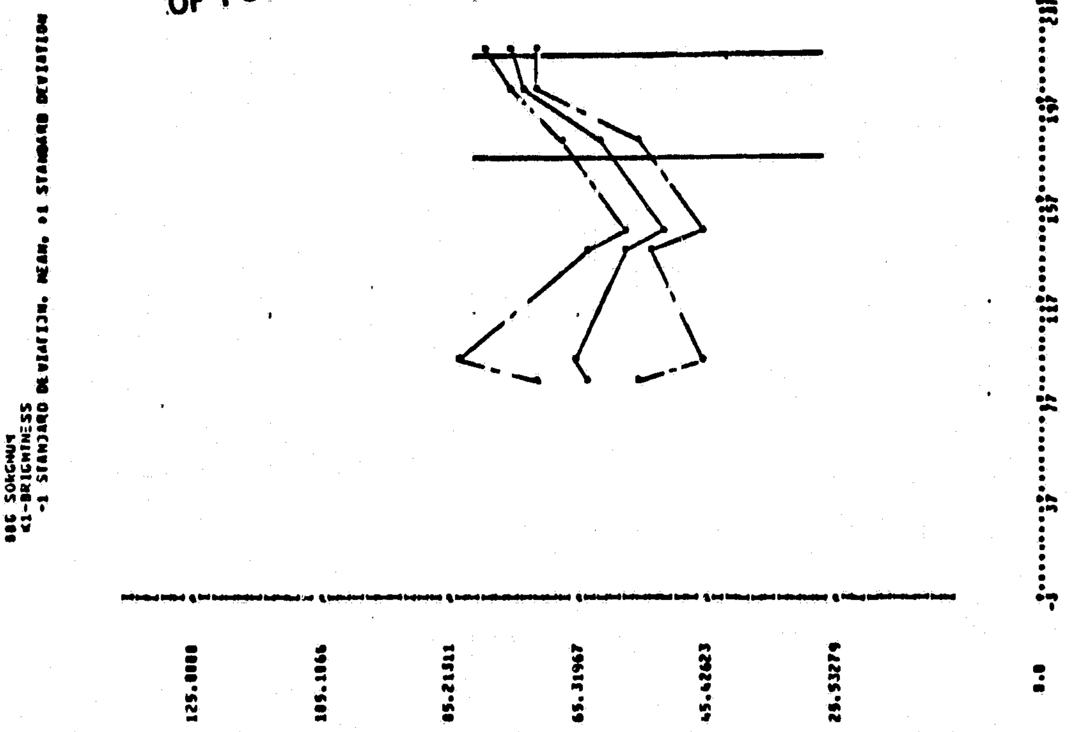
86G SORGHUM
K1-BRIGHTNESS
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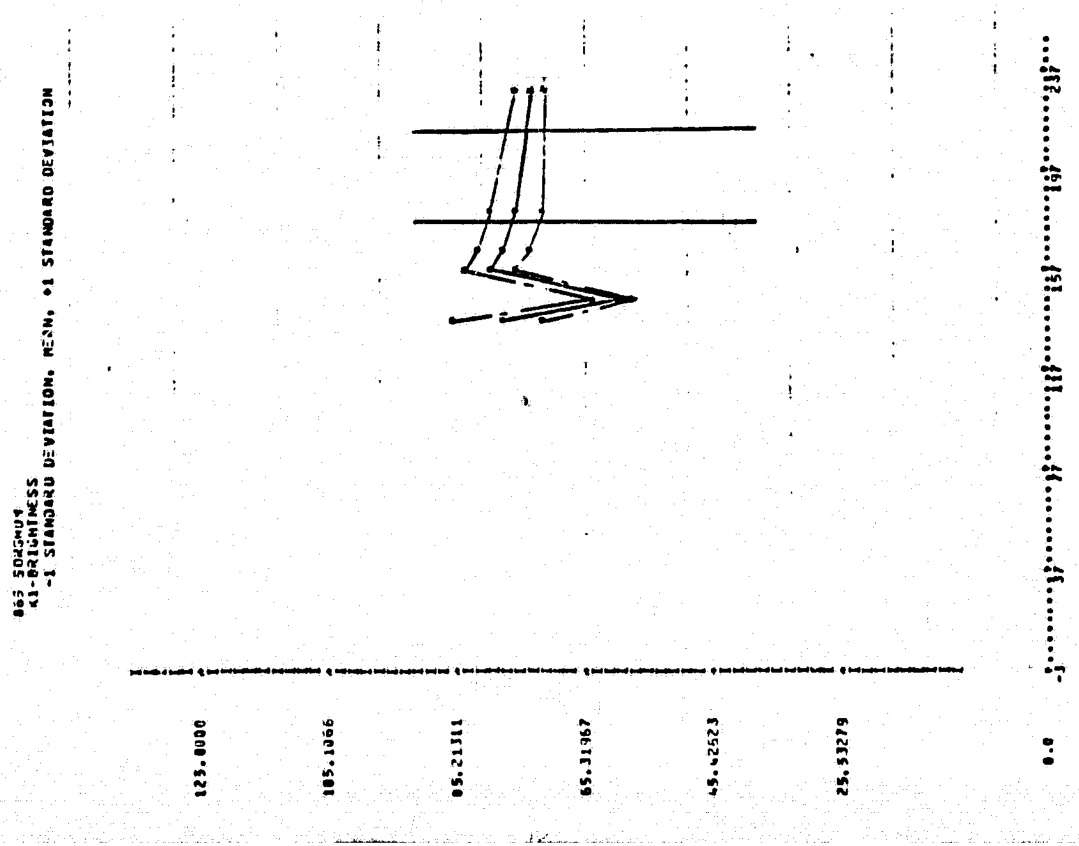
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
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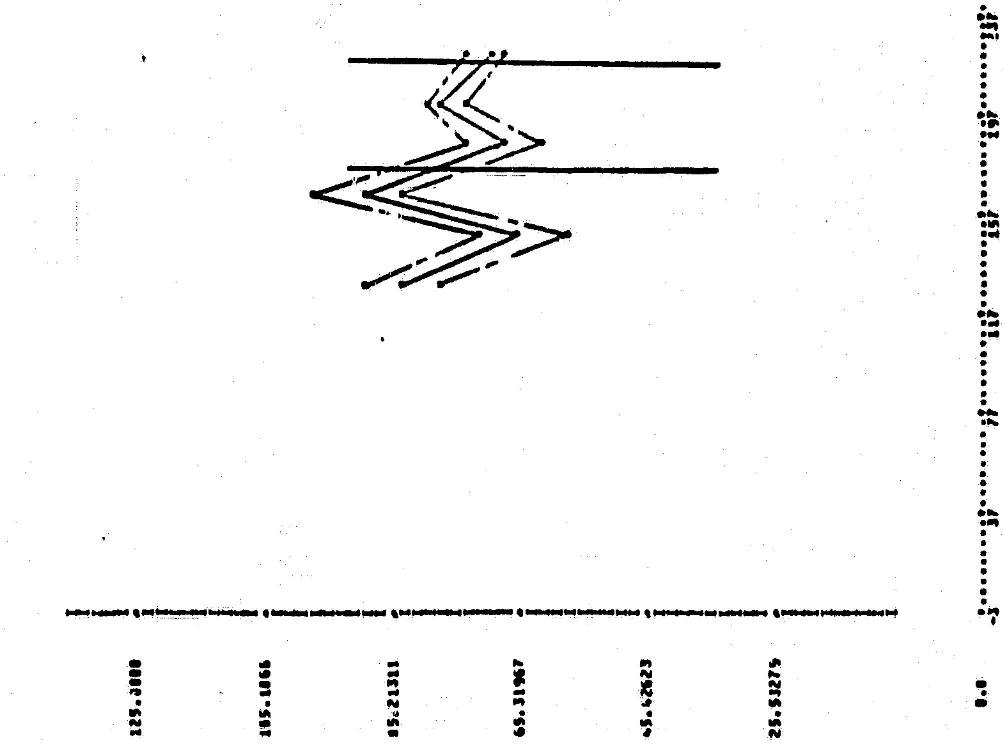

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K1-BRIGHTNESS
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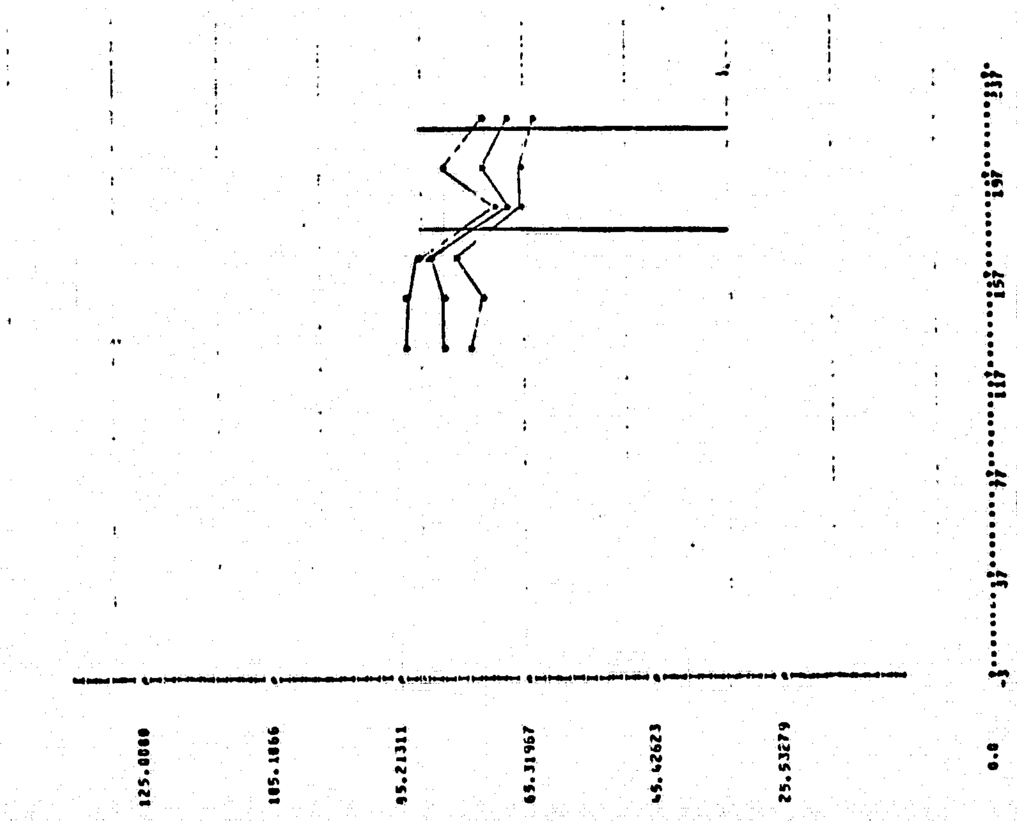

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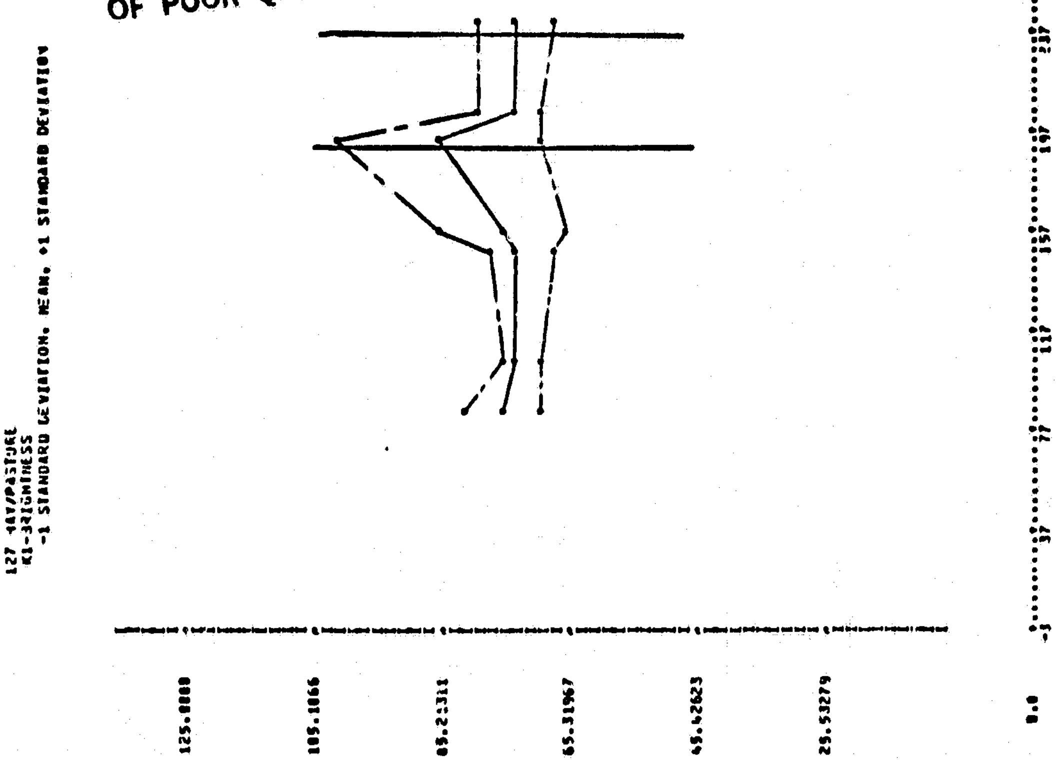
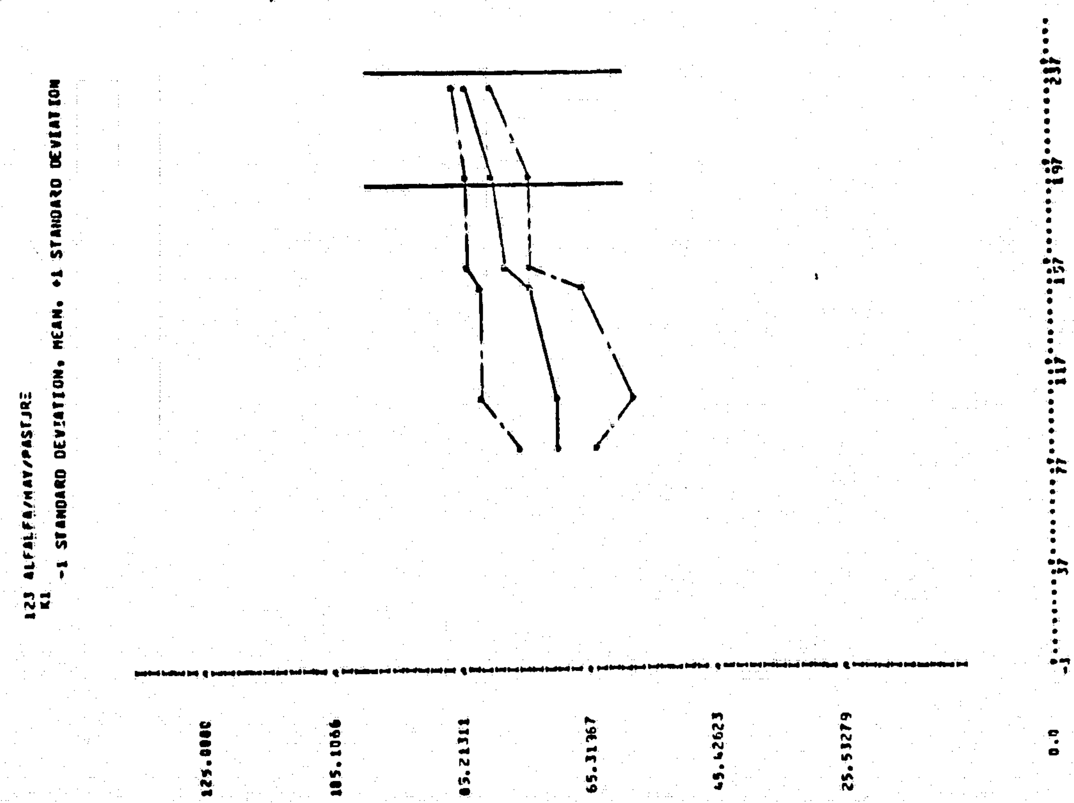
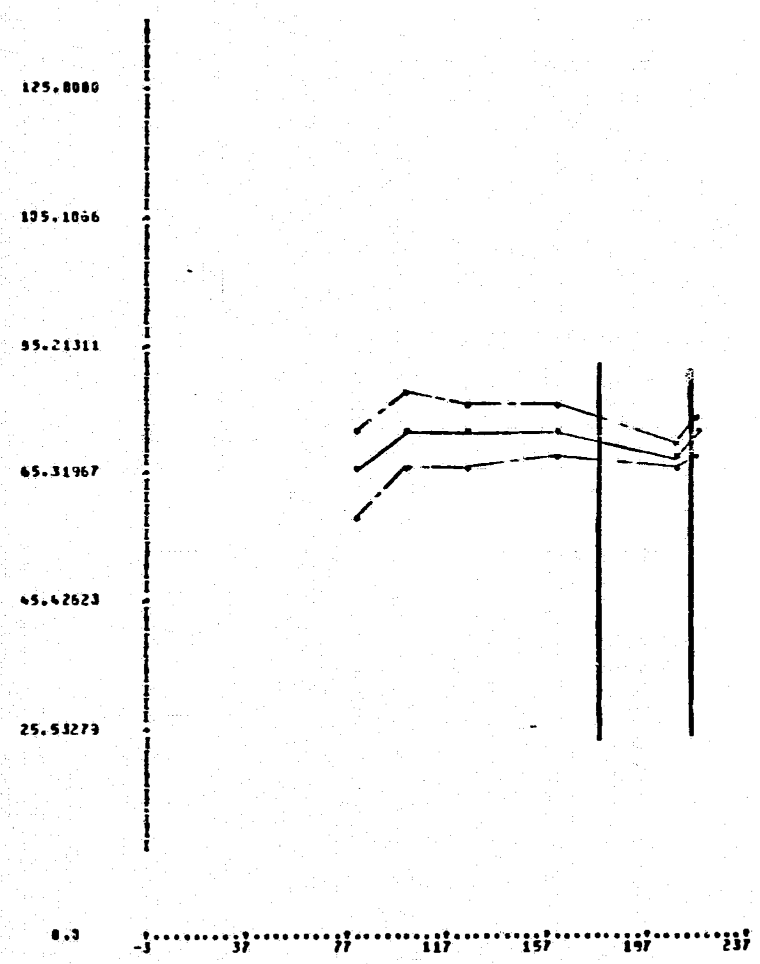




141 ALFALFA/HAY/PASTURE
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



135 ALFALFA/HAY/PASTURE
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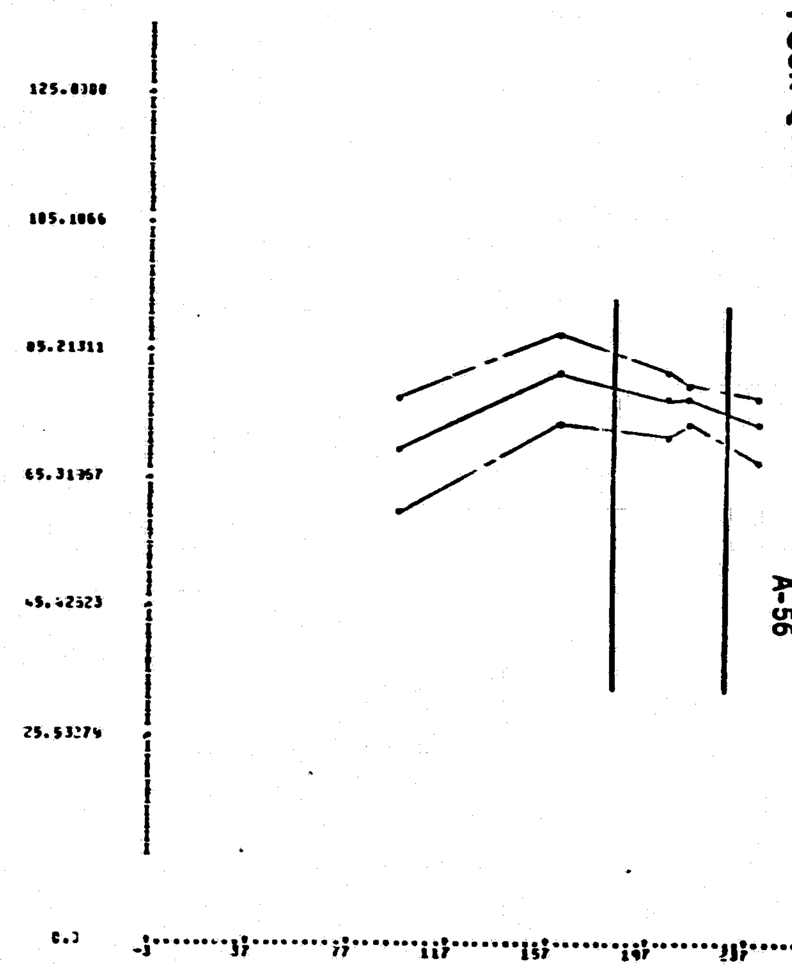
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



932 ALFALFA/HAY/PASTURE
K1-BRIGHTNESS
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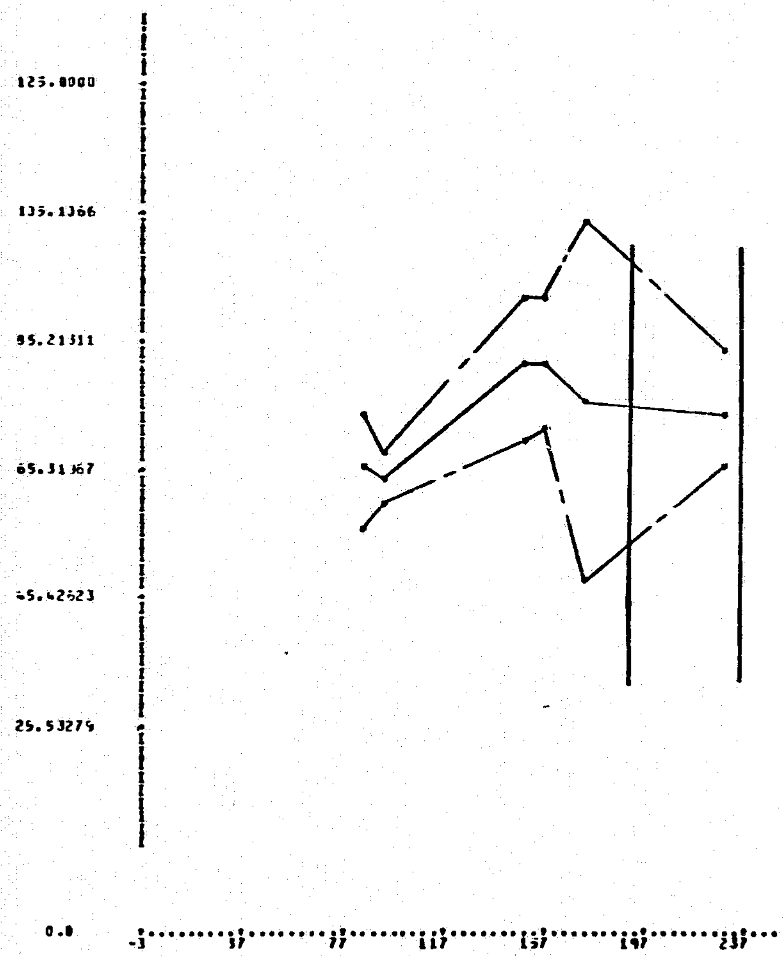

9-3 ALFALFA/HAY/PASTURE
K1-BRIGHTNESS
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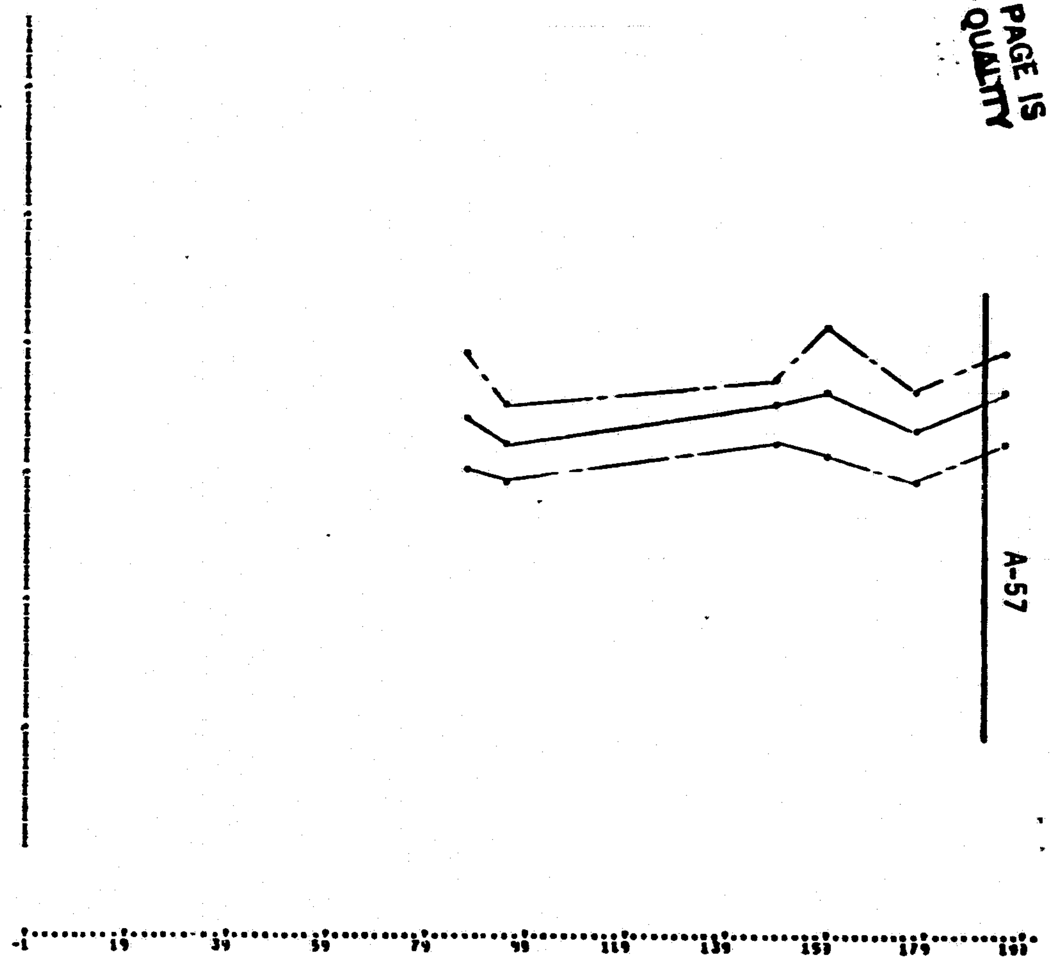

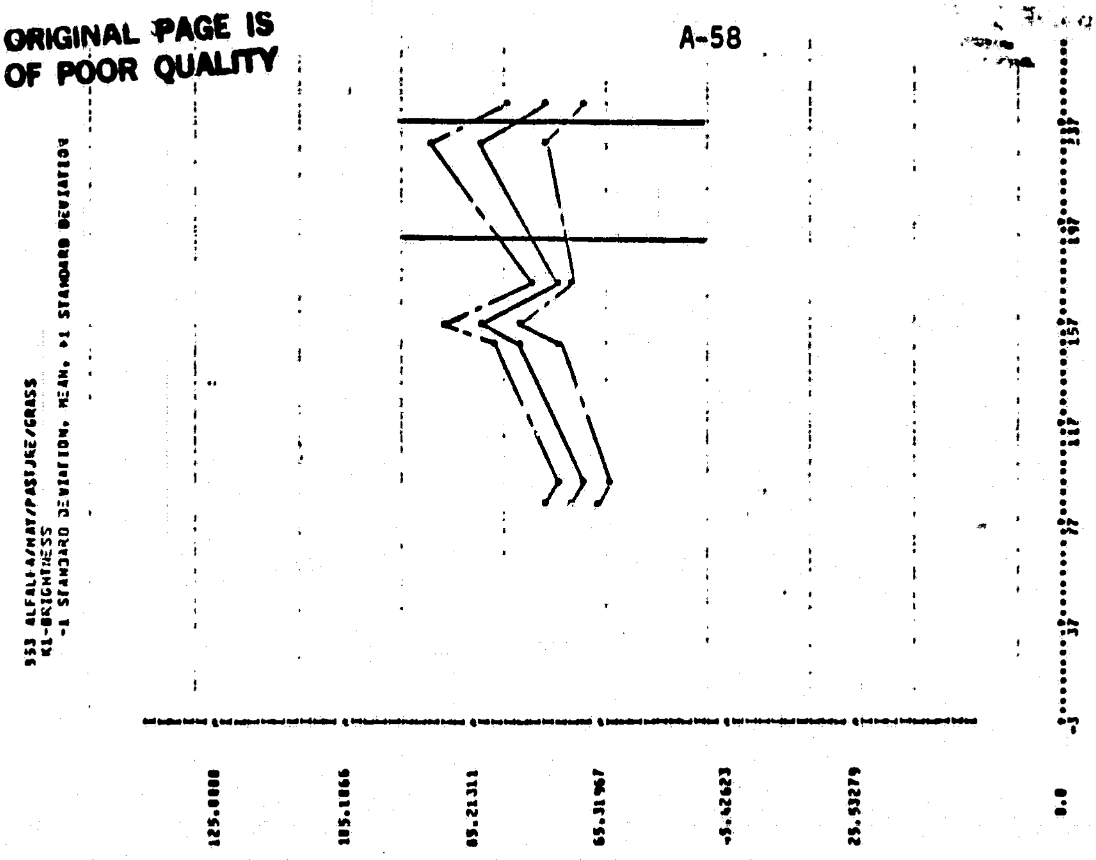
953 ALFALFA/HAY/PASTURE/GRASS
K1-BRIGHTNESS
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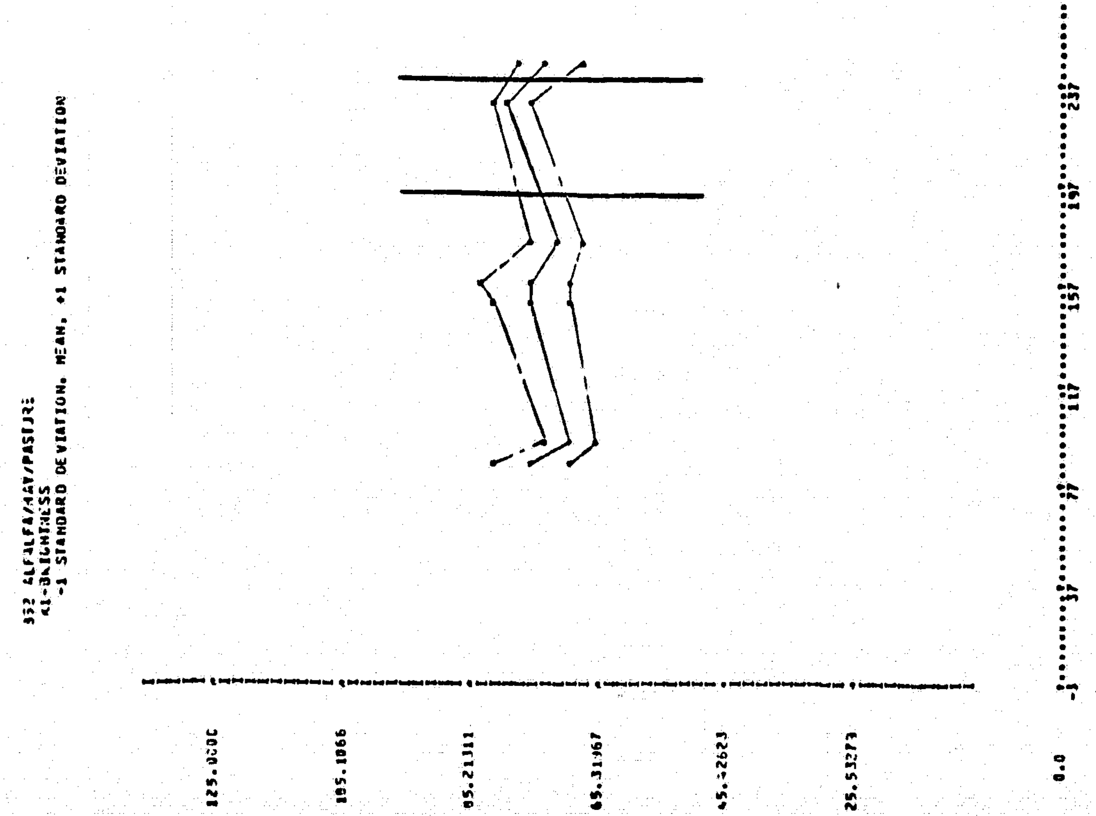
952 ALFALFA/HAY/PASTURE
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
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860 ALFALFA/HAY/GRASS
K1-BRIGHTNESS
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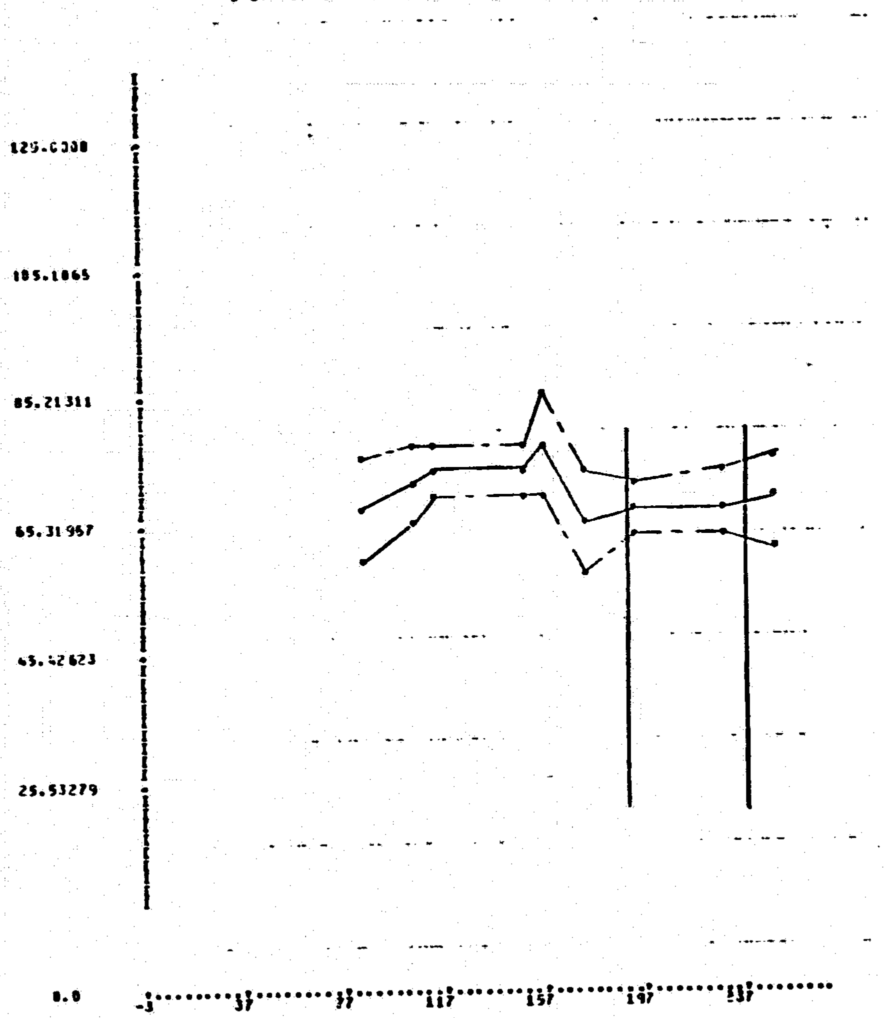

850 ALFALFA/HAY/PASTURE/GRASS
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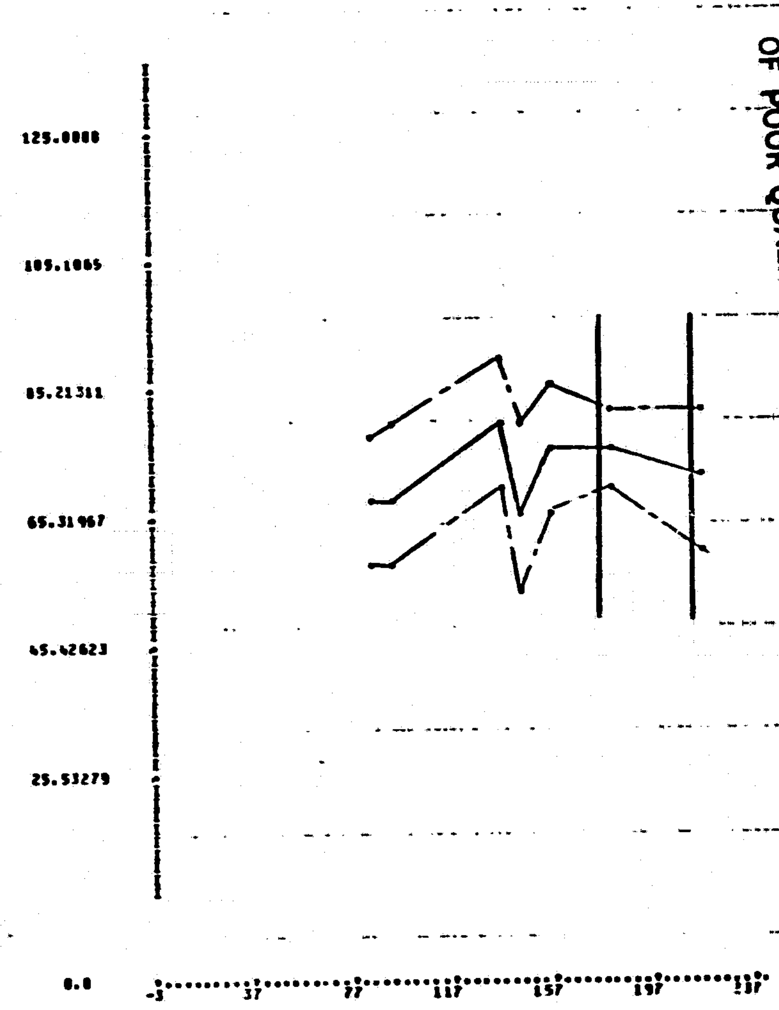

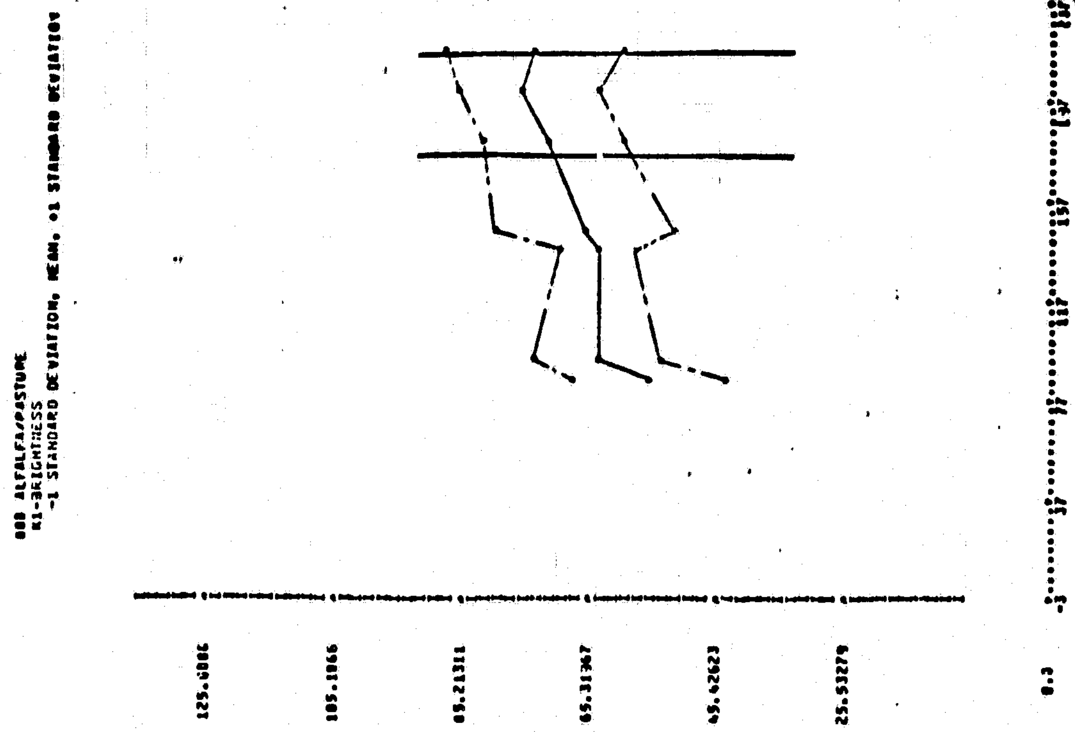
088 ALFALFA/PASTURE
K1-BRIGHTNESS
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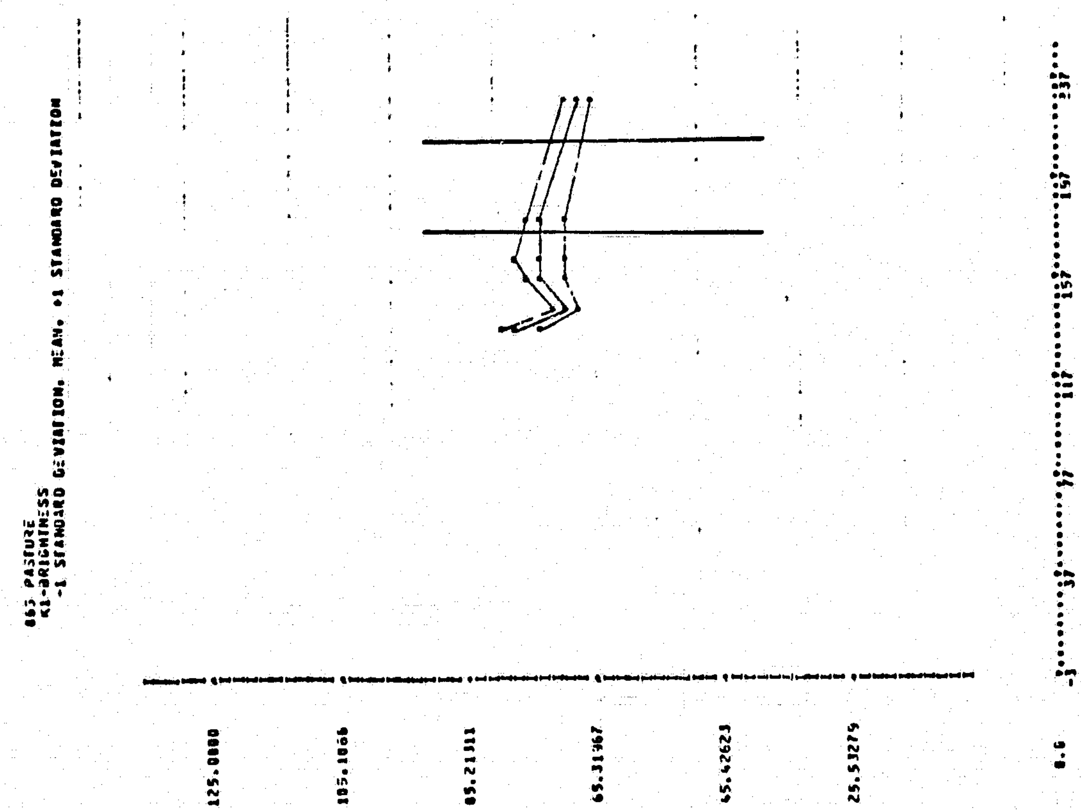
085 PASTURE
K1-BRIGHTNESS
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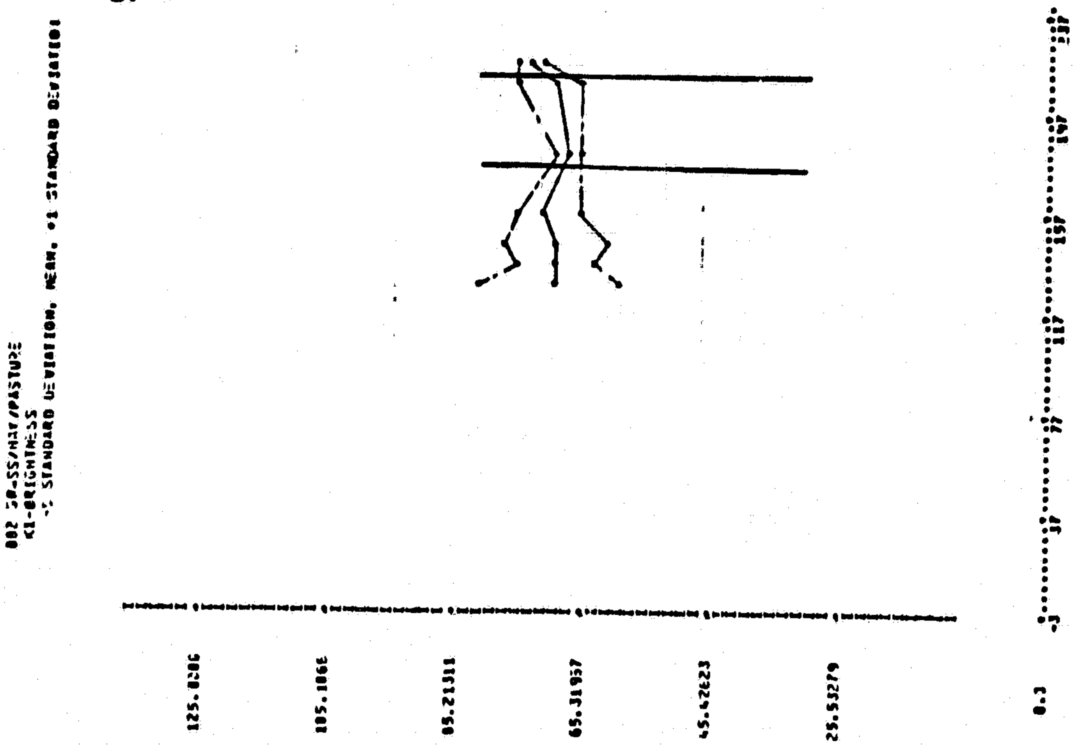

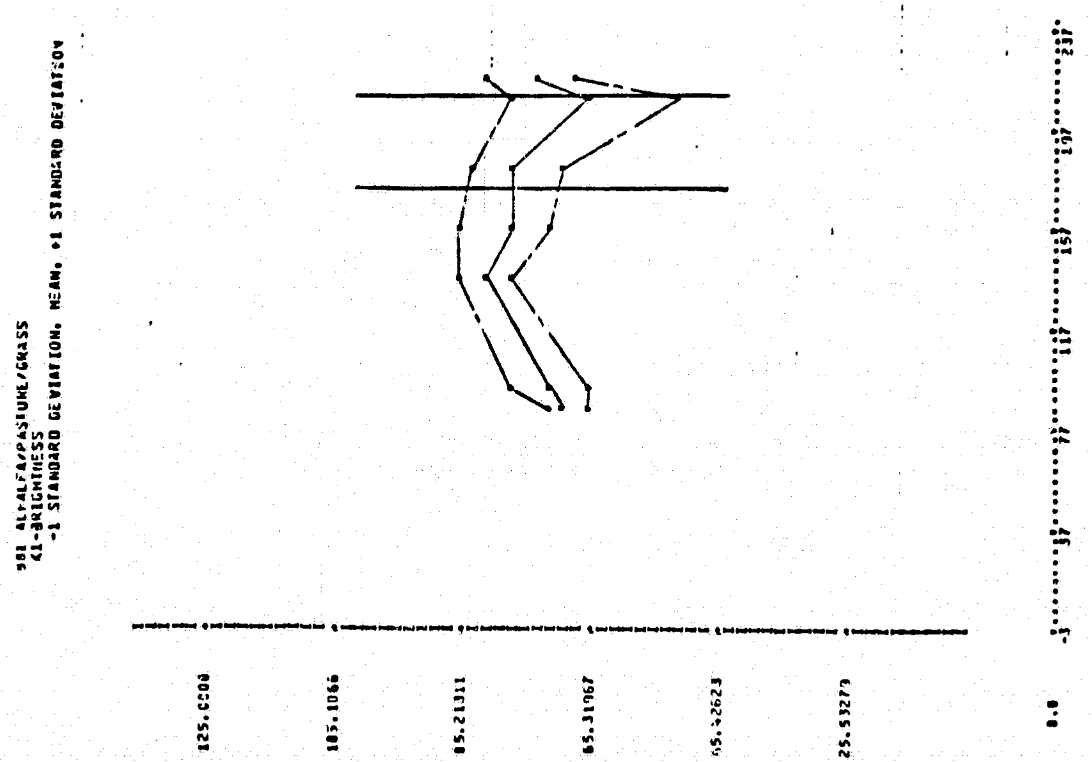

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1572 ALFALF3/PASTURE
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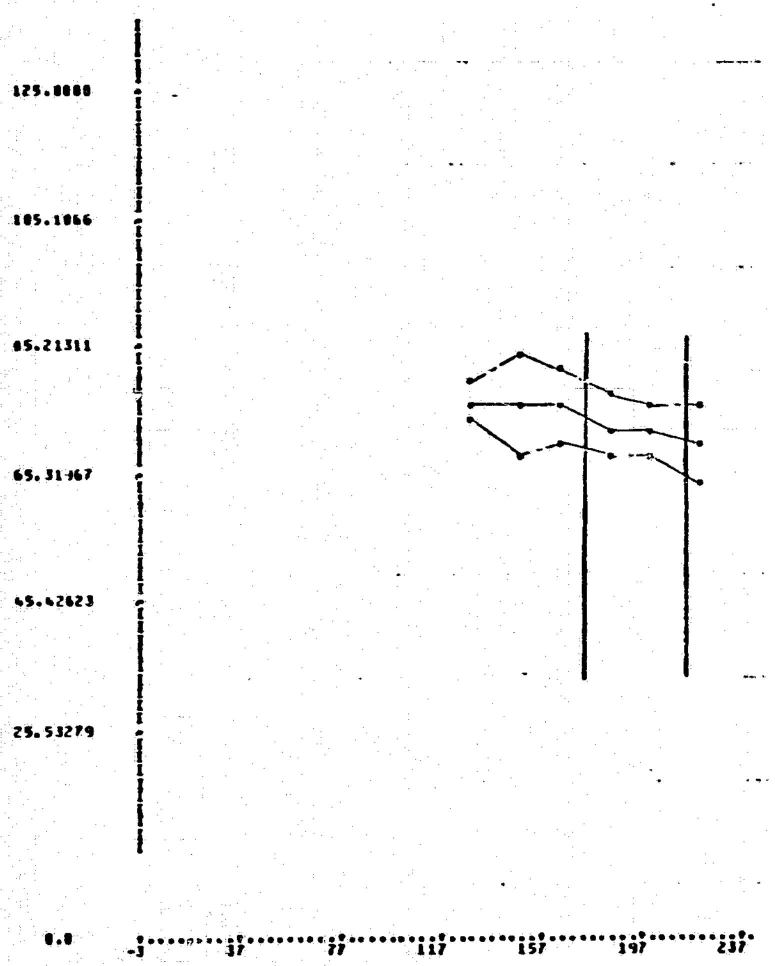
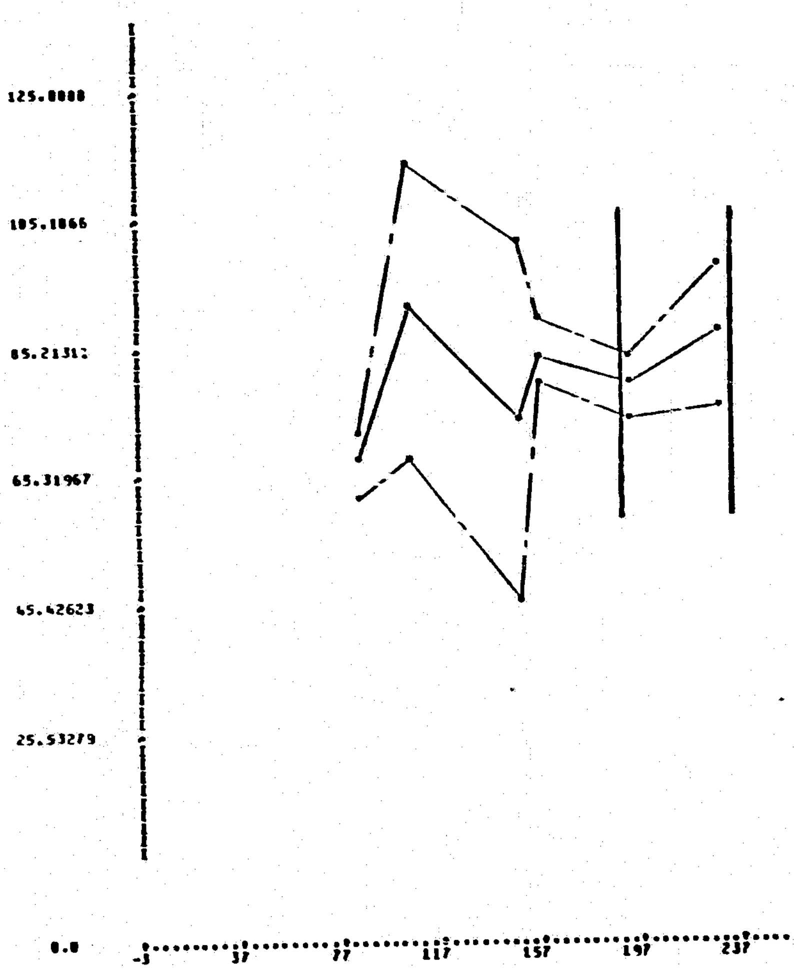


123 IDLE COVER
K1
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



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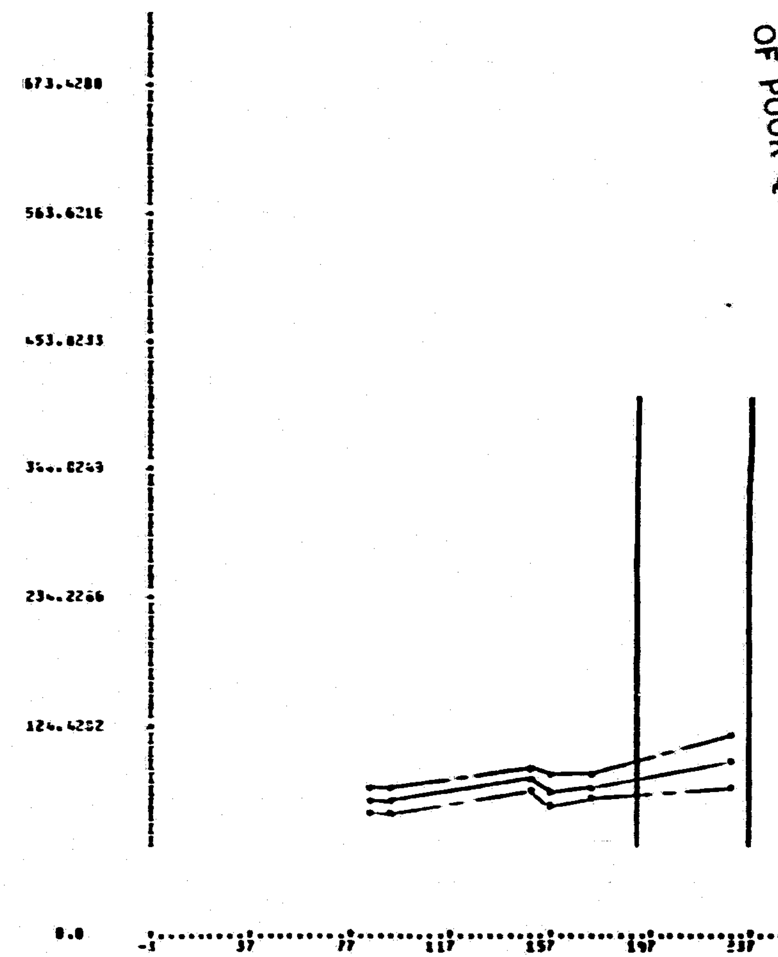

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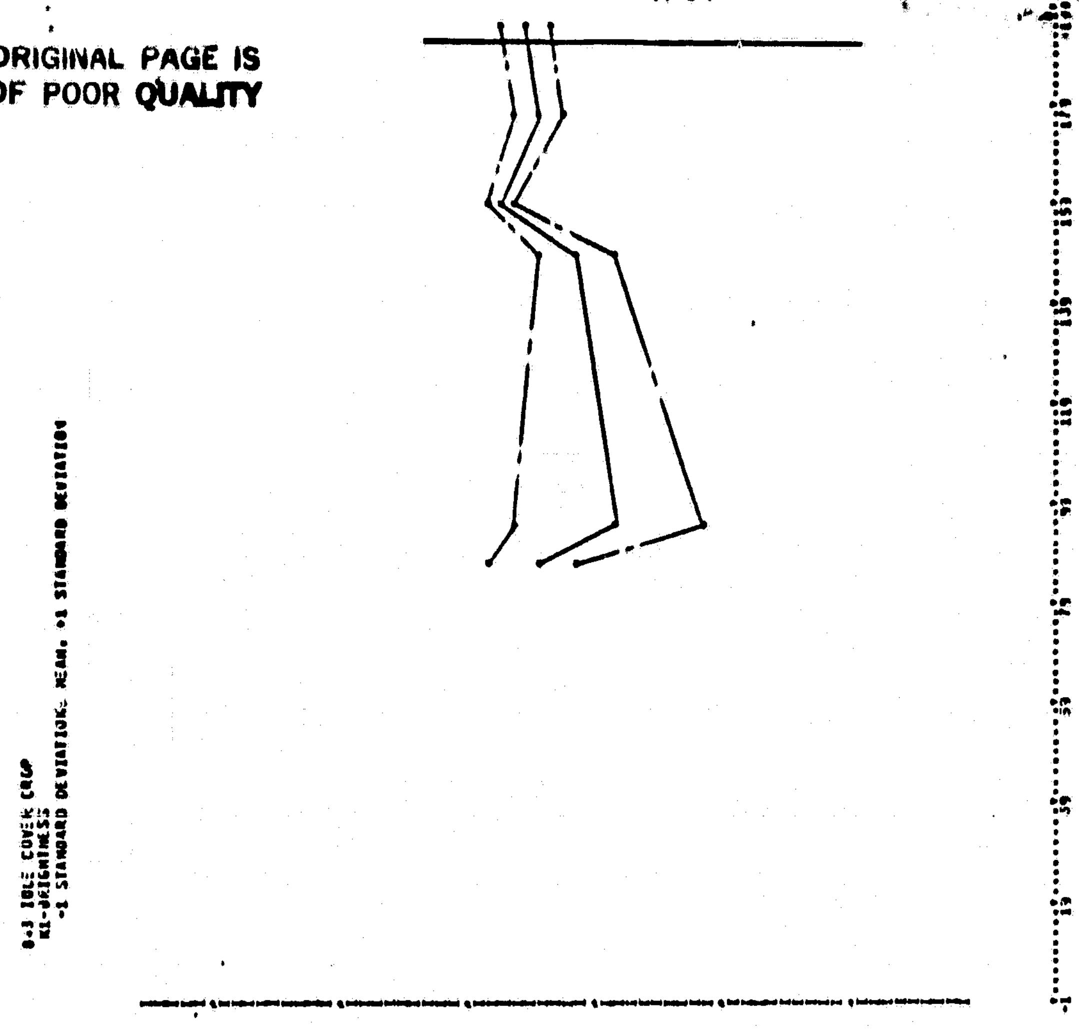

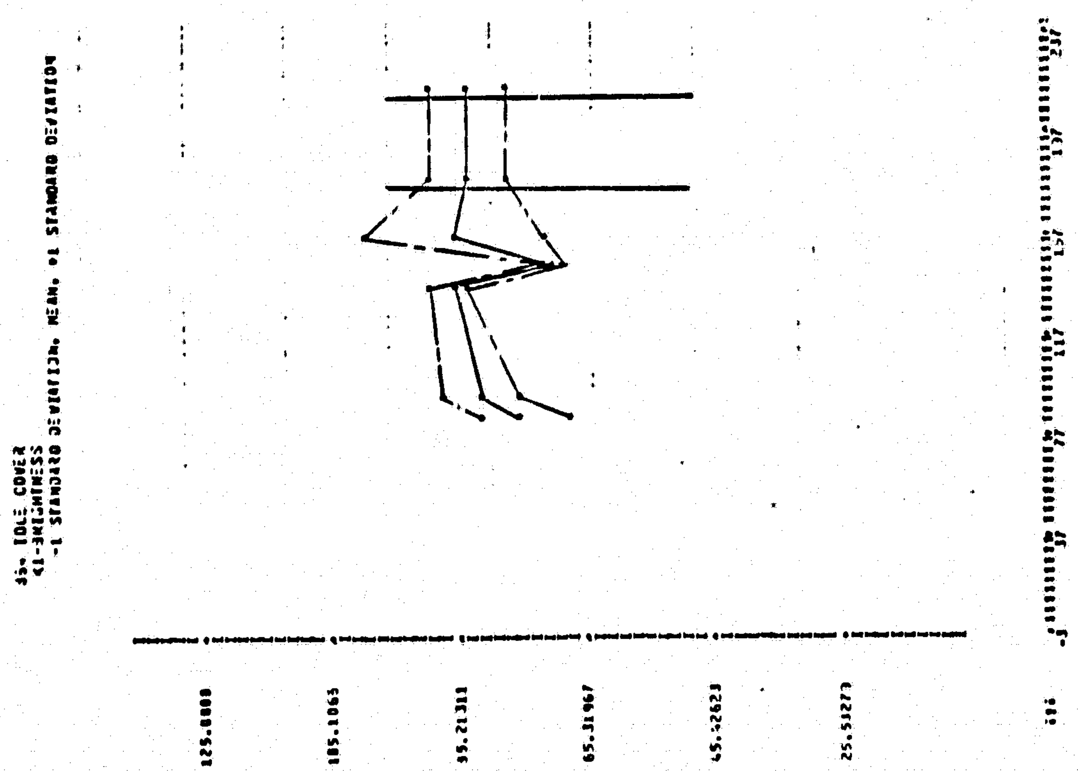

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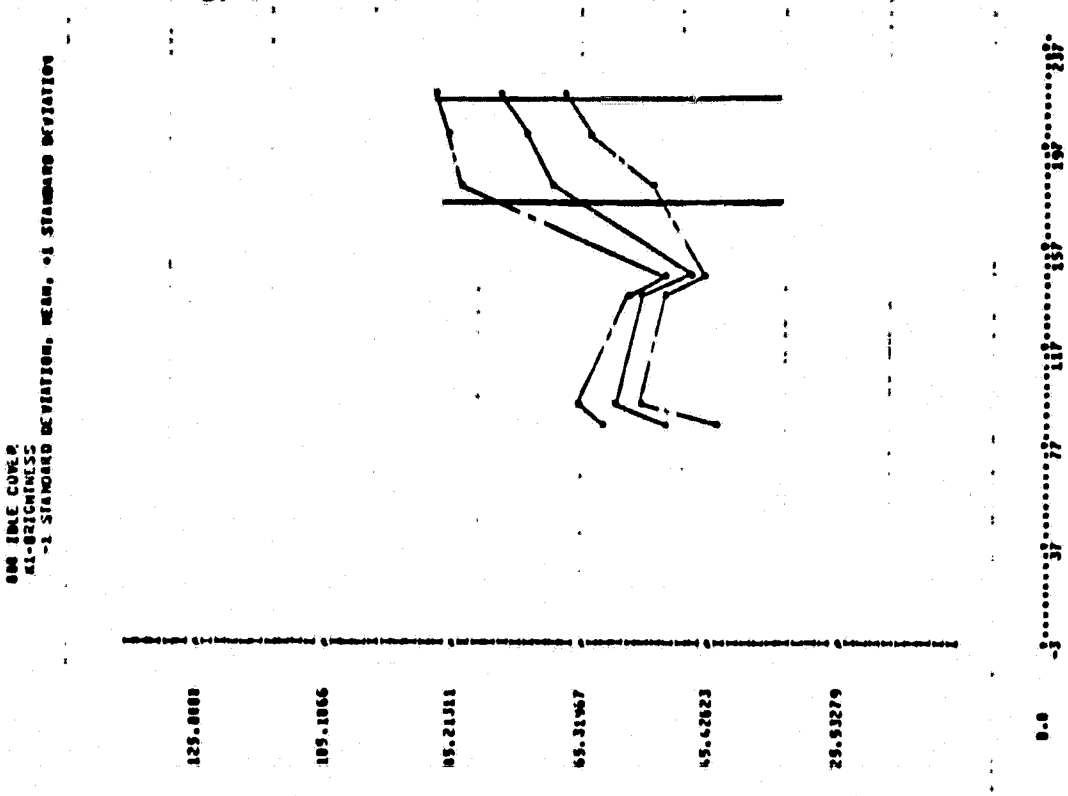

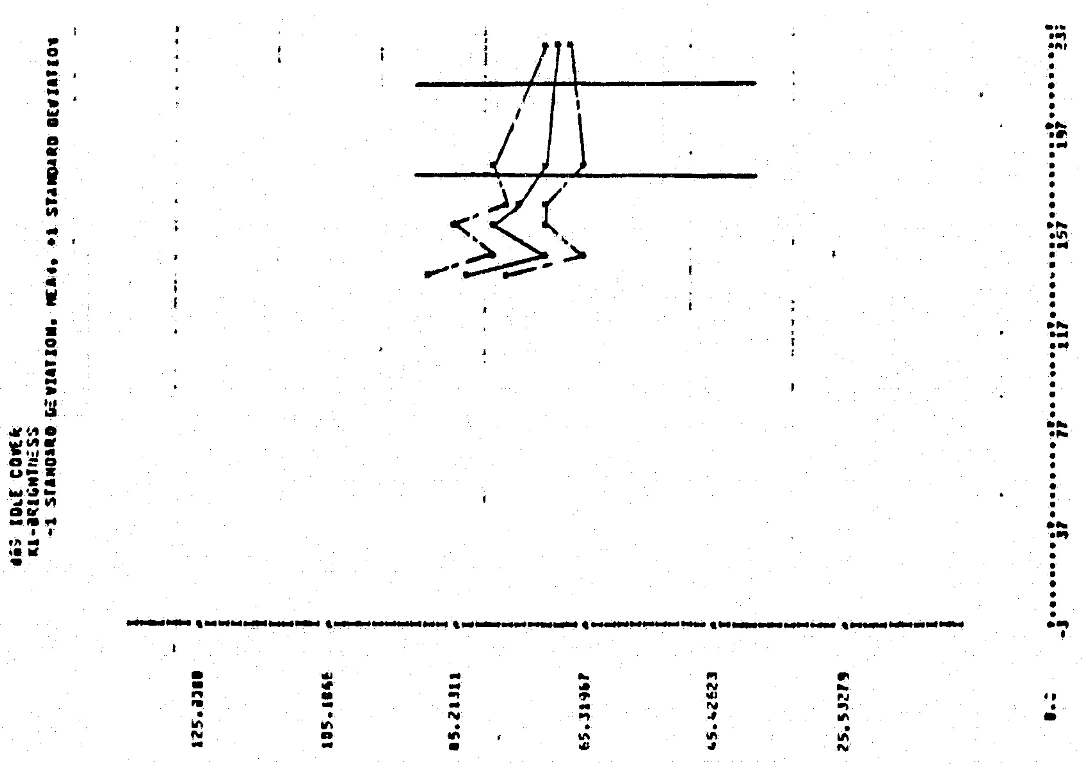

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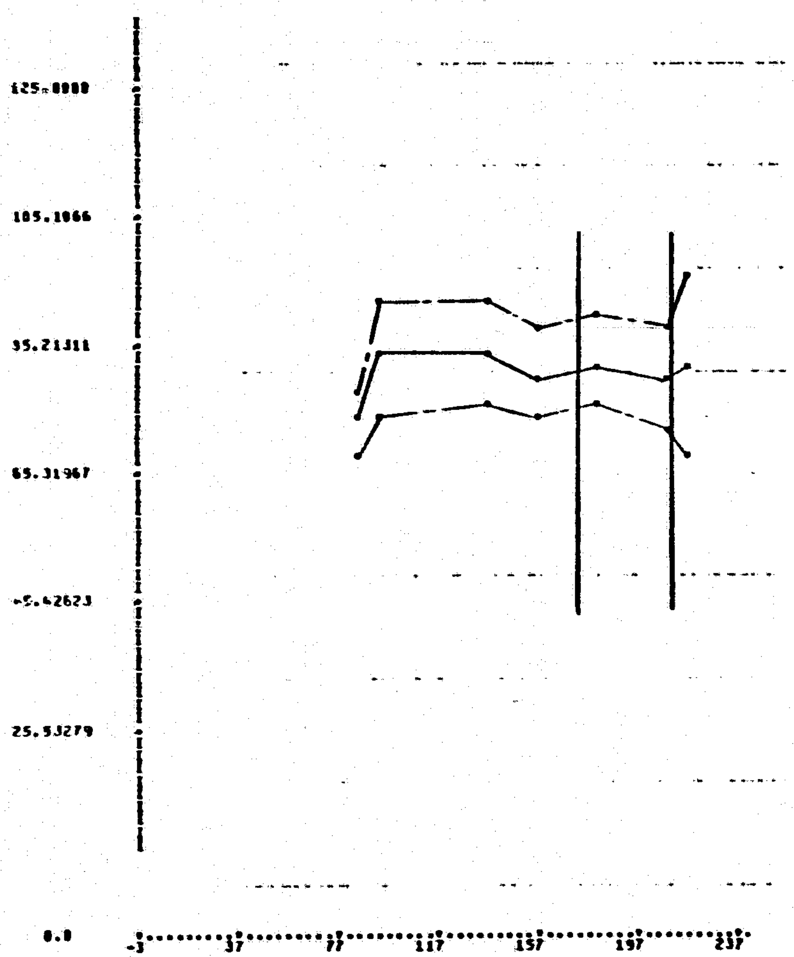
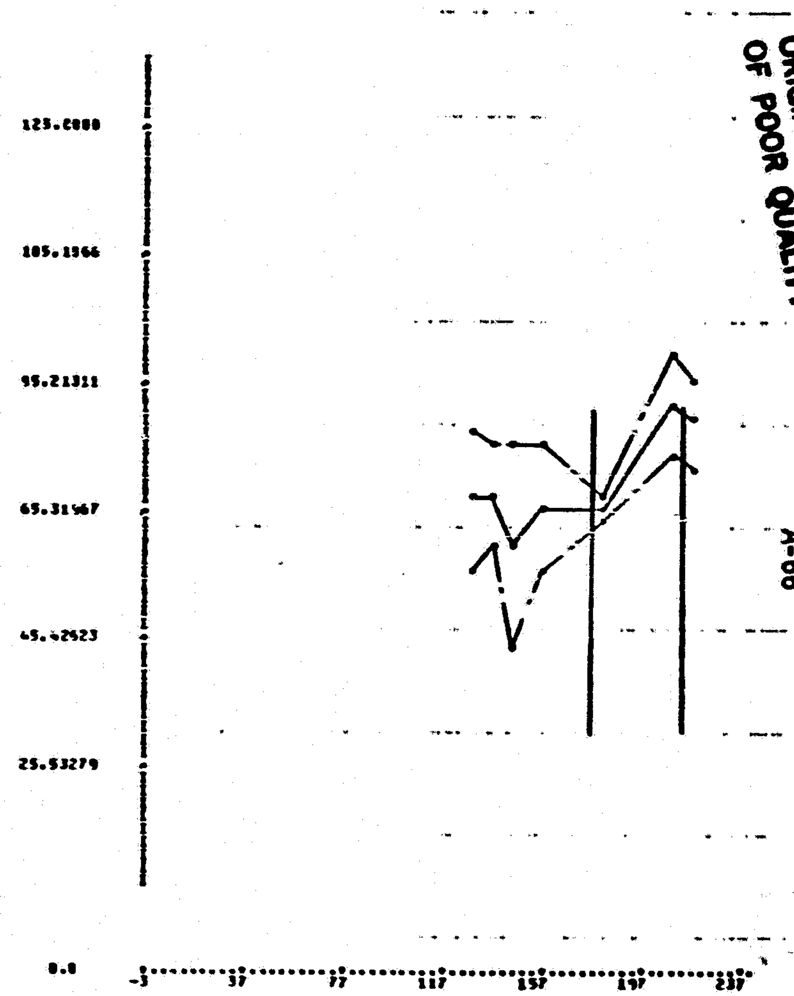
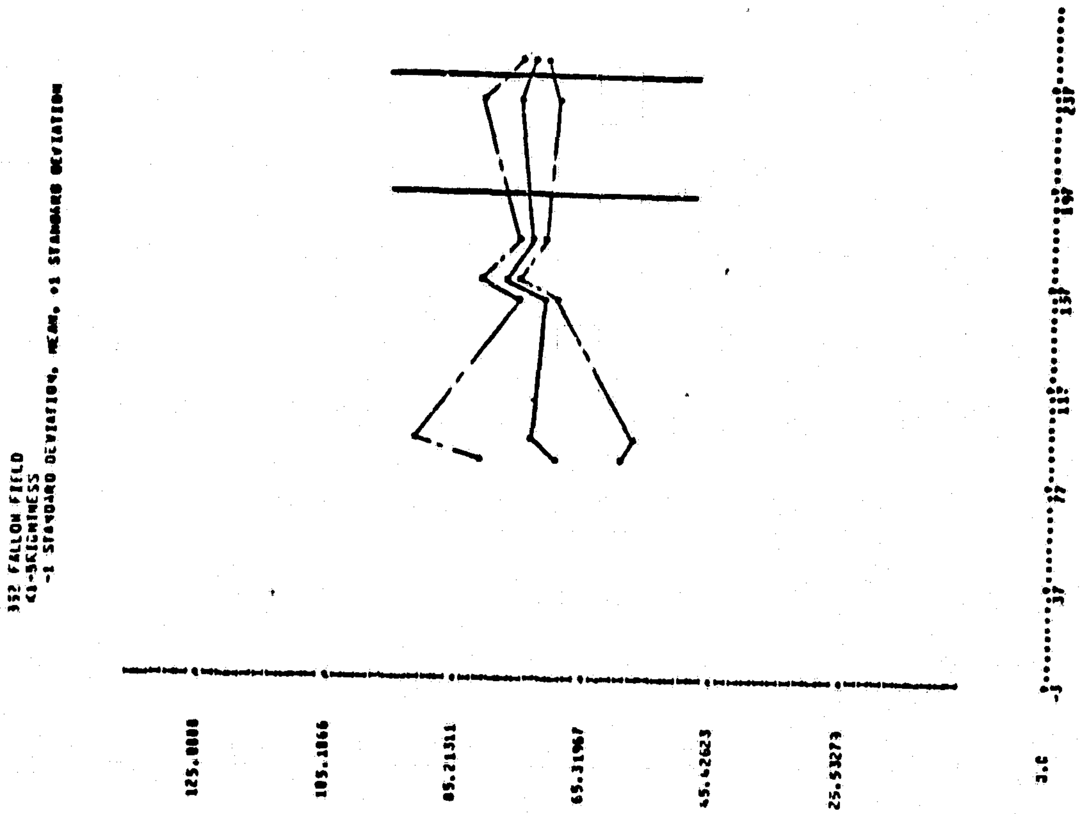
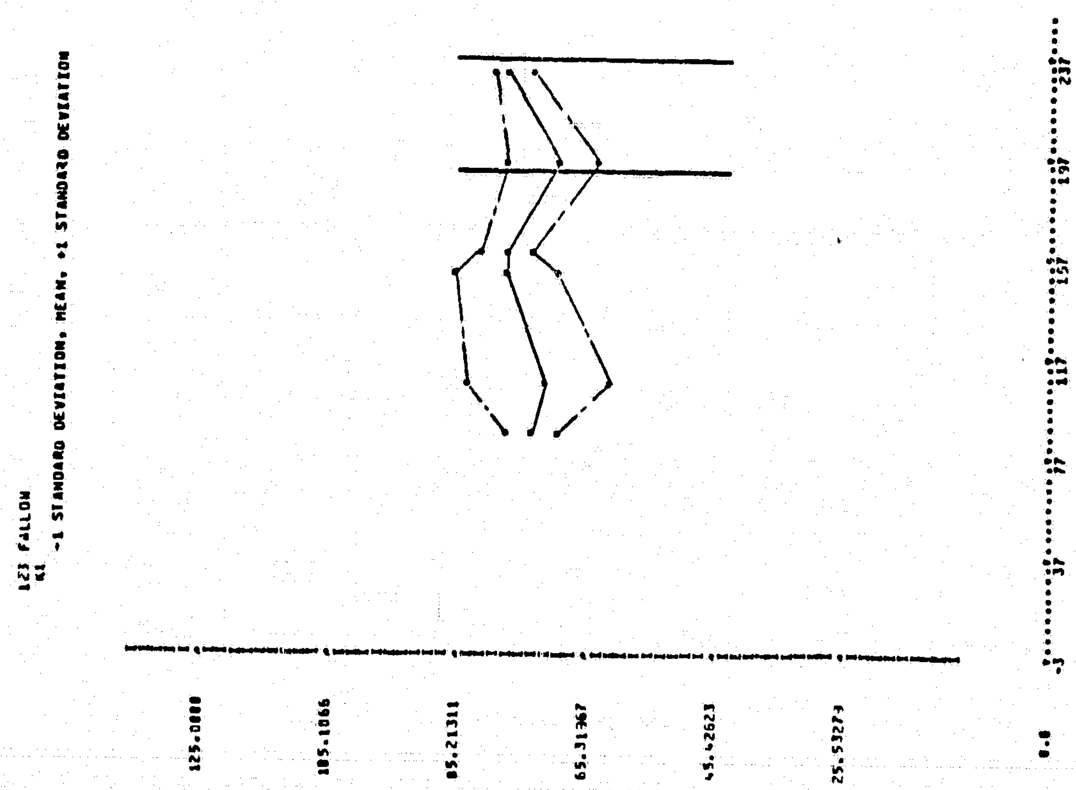
001 IDLE COVER
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION



002 IDLE COVER
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION




352 FALLON FIELD
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
125.0000
105.1066
85.21311
65.31967
45.42623
25.53279
0.0
-3
37
77
117
157
197
237


123 FALLOW
K1
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
125.0000
105.1066
85.21311
65.31967
45.42623
25.53279
0.0
-3
37
77
117
157
197
237

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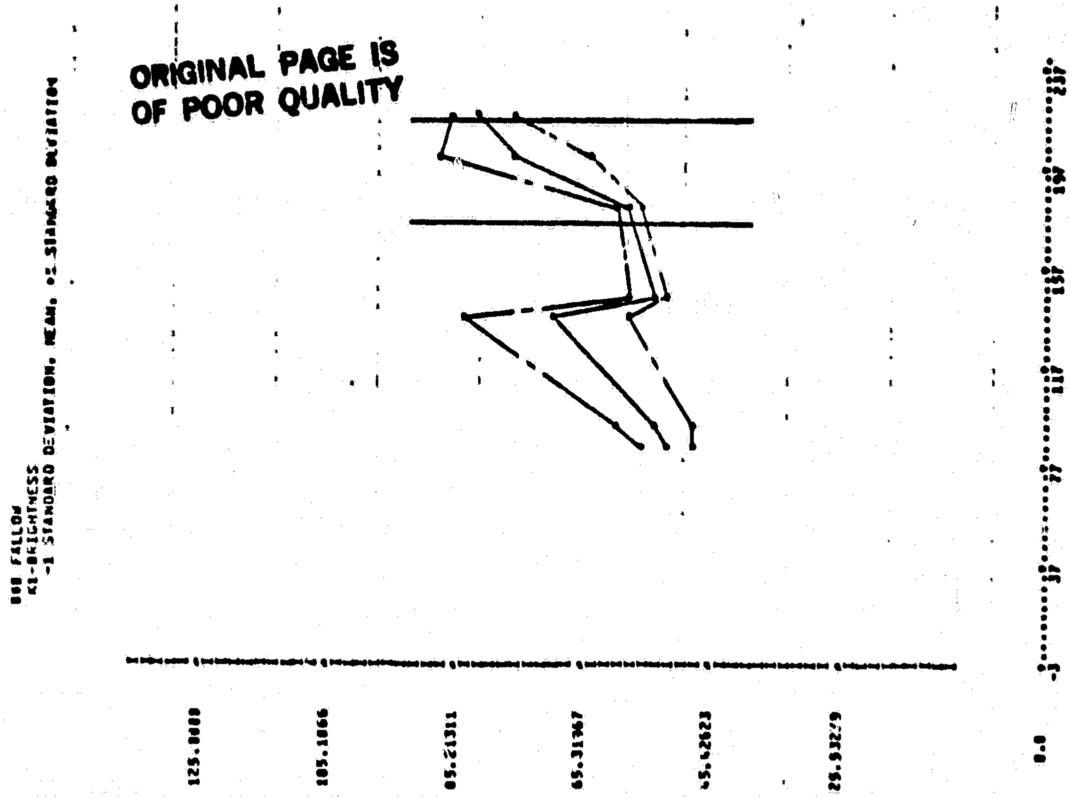
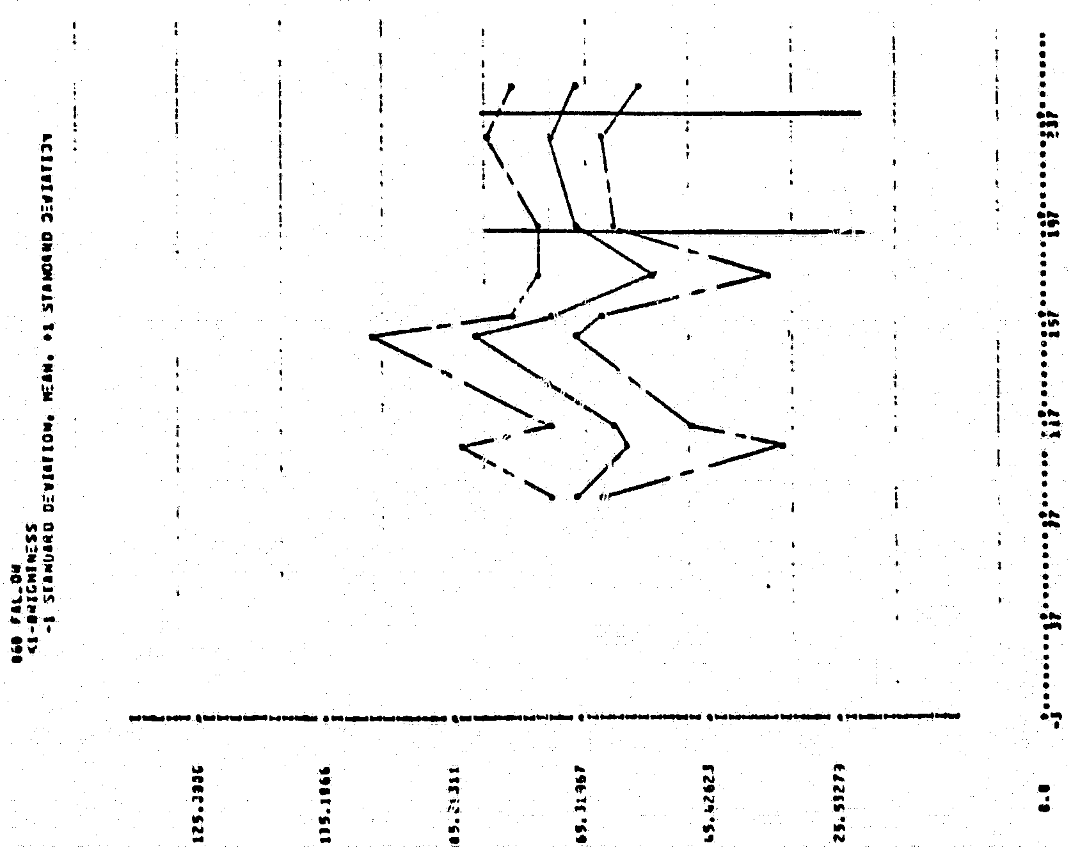
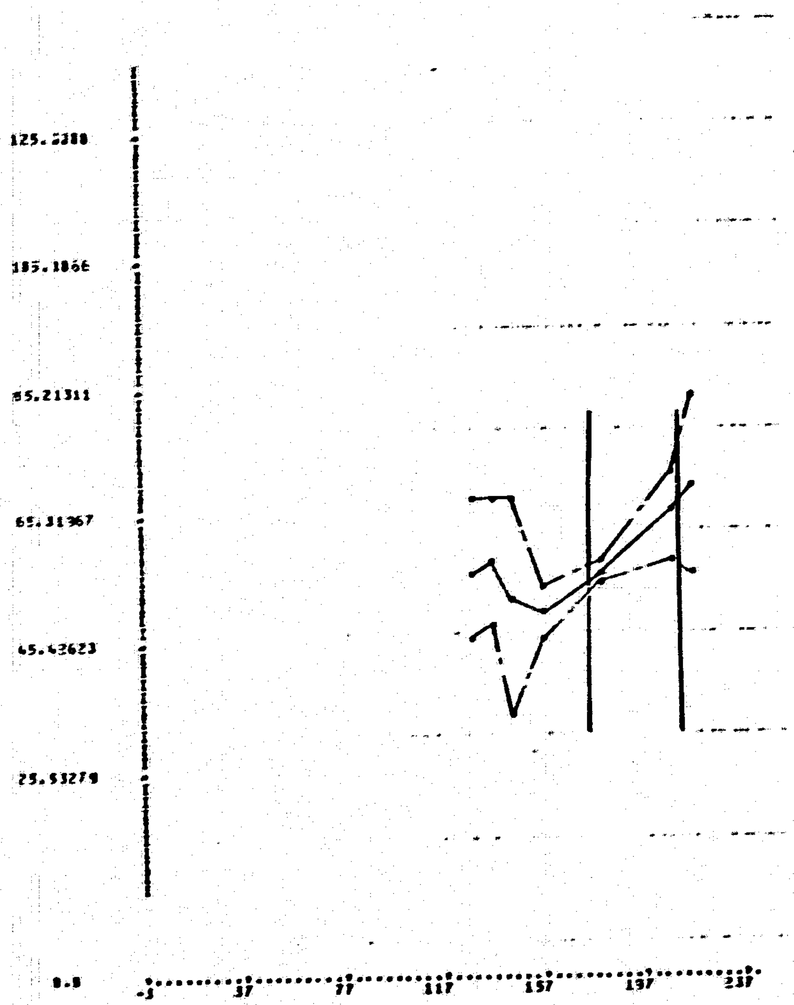
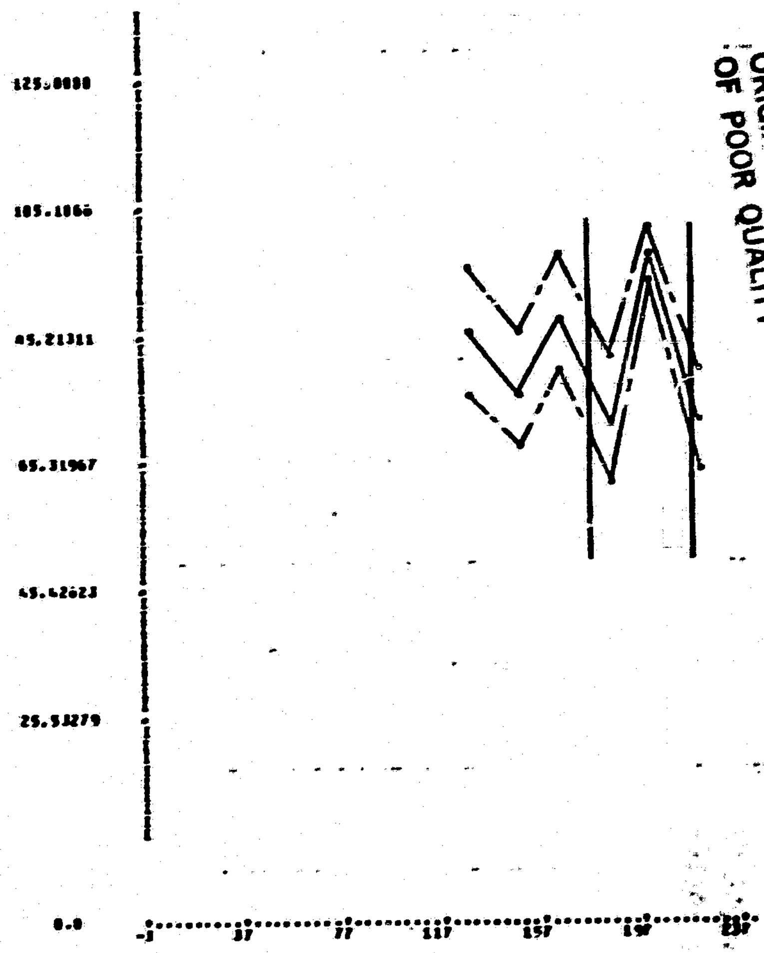


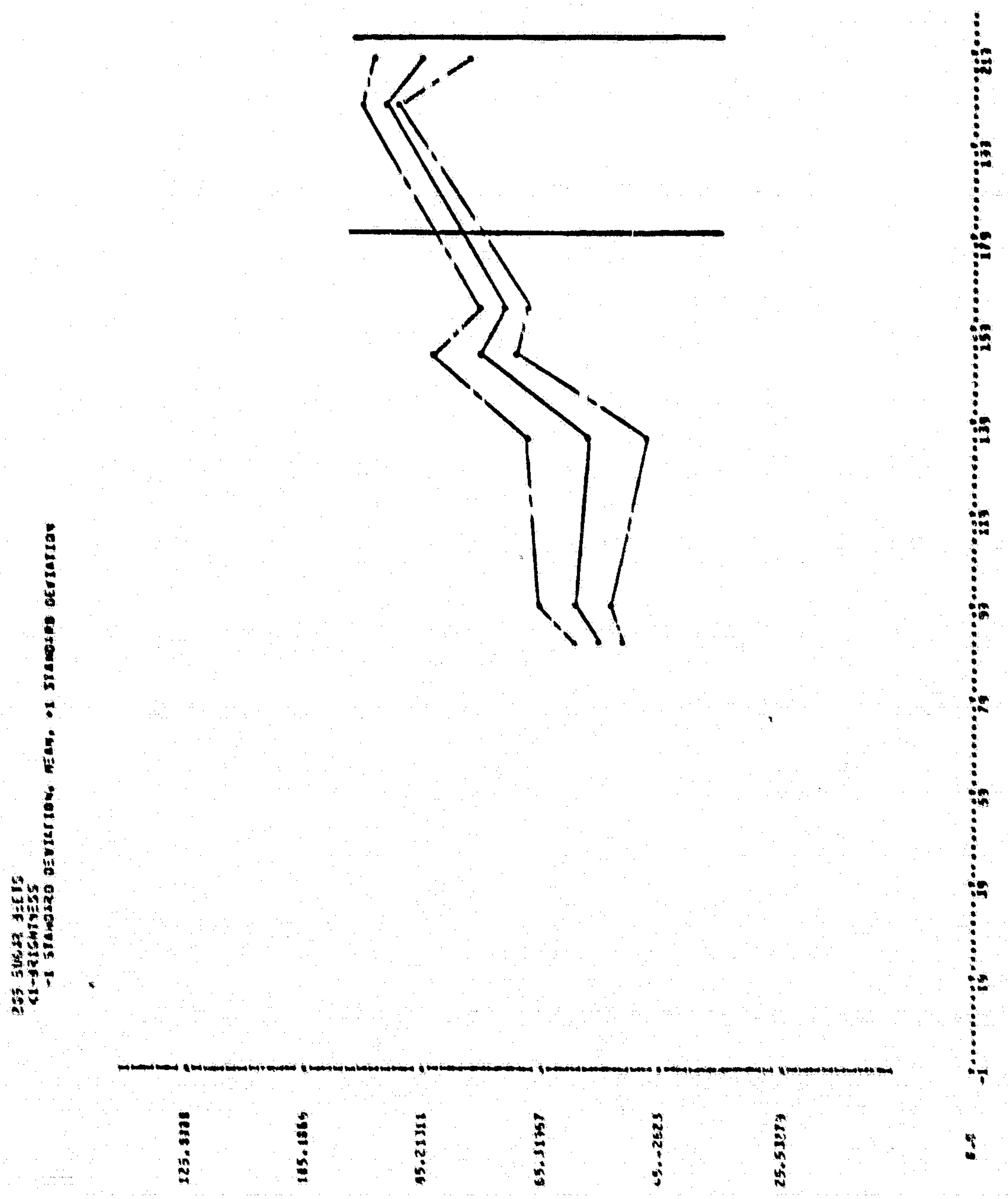


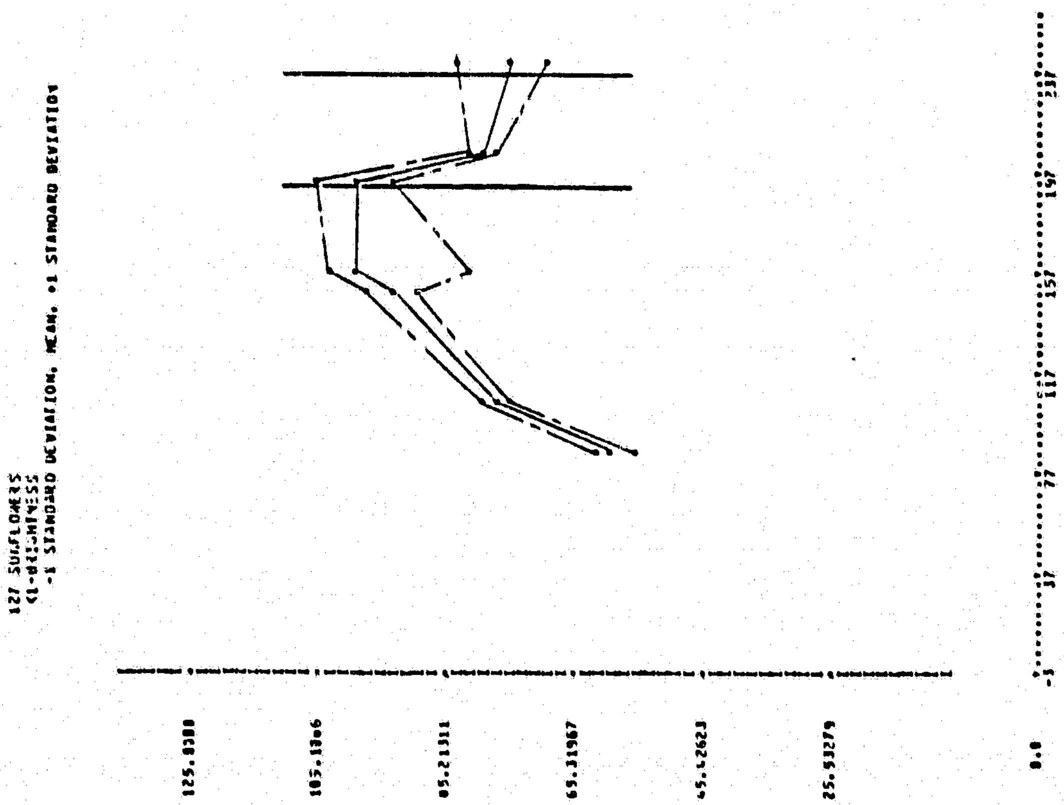
882 FALLOW
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION

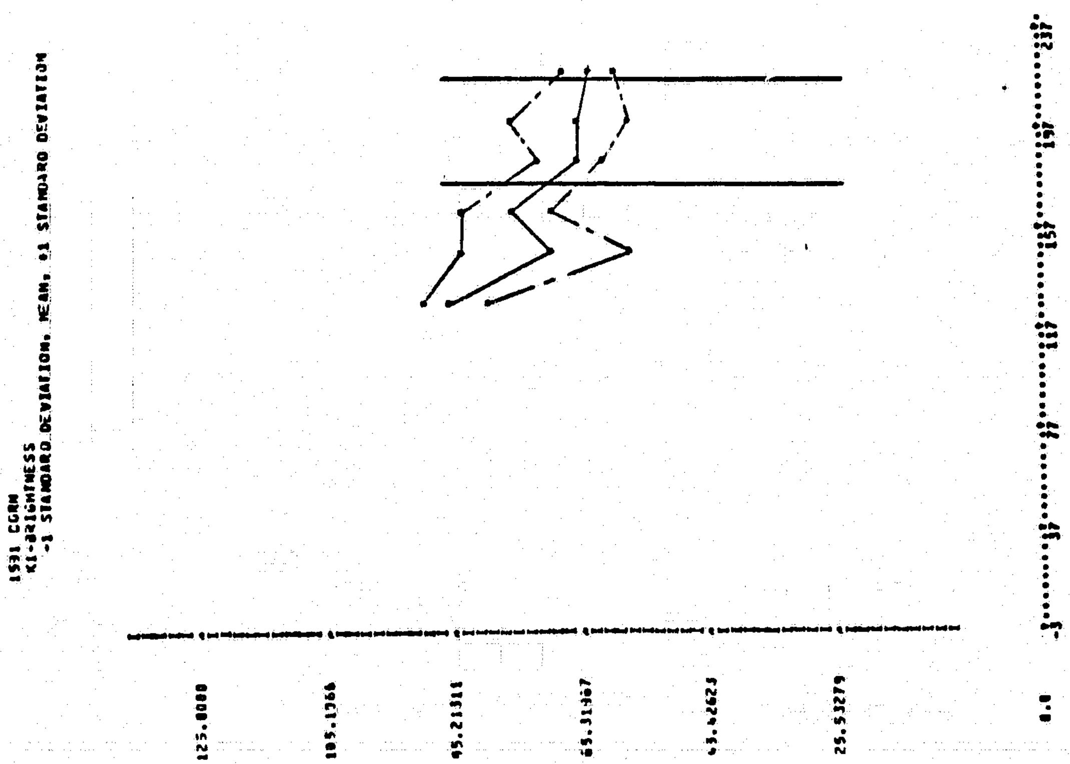


1572 FALLOW
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION






127 SUNFLOWERS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
-3
37
77
117
157
197
237


1531 CORN
K1-BRIGHTNESS
-1 STANDARD DEVIATION, MEAN, +1 STANDARD DEVIATION
125.0000
105.1366
85.21311
65.31967
45.42623
25.53279
0.0
-3
37
77
117
157
197
237