A study of the effect of modern agricultural practice on the growth physiology of two crop plants, with special reference to fertilizer treatments

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A STUDY OF THE EFFECT OF MODERN AGRICULTURAL PRACTICE ON THE GROWTH PHYSIOLOGY OF TWO CROP PLANTS, WITH SPECIAL REFERENCE TO FERTILIZER TREATMENTS

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Thesis submitted as part of the Degree of Master of Science in the University of Durham,

September 1969.

ENVIRONMENT | NATURE. VOL. 223. AUGUST 9. 1969

Lovers of the Land Unite

Is the world heading for an environmental crisis if pollution continues unchecked? Professor Barry Commoner of Washington University, St Louis, has thought for some time that this will happen. He argued his case again at the conference last week in London on "The Future of Man's Environment", organized by the Soil Association. He cited examples of modern technology—nuclear reactors, artificial fertilizers, gasoline engines and pesticides—which have "stretched the web of the ecosystem". But he said there is hope of making "technology conform to the powerful constraints of the living environment". In the United States, one particularly optimistic sign of public concern about pollution is the formation in the past six months of student environmental groups.

Professor Commoner's audience of about 100 representatives of British societies and organizations concerned with the environment hardly needed persuading about the dangers of pollution. Their object, indeed, was to discuss ways of coordinating their work more effectively, and they were greatly encouraged by Professor Commoner's emphasis on the importance of voluntary bodies working together cooperatively.

There was therefore some surprise when it was learnt that such a body is already being planned by the standing committee of "The Countryside in 1970" conference. This committee has set up a voluntary bodies working party under the chairmanship of Lord Molson, chairman of the Council for the Preservation of Rural England, and Sir Landsborough Thomson, president of the Council for Nature, with the object of forming a "National Coordinating Committee for Environmental Conservation".

But will this committee embrace a sufficiently wide range of interests, and will it be effective enough? Several at the meeting raised these questions, and the Soil Association will organize another conference to see how things are going in about six months time. One obviously relevant consideration is that the European Conservation Year is only a few months away, and time should not be lost if advantage is to be taken of the current interest of European governments in tackling environmental problems.

If a coordinated body on environmental conservation is to be a successful pressure group it must have access to scientific information. Professor Commoner argued that one of the first steps should be the publication of a journal. Part of the difficulty in assessing the dangers of pollution is that too little is known. The Soil Association is helping in this direction in a small way through research on its farmland at Haughley near Stowmarket in Suffolk. There, the association is in the fortunate position of being able to compare farmland that has been managed without the use of chemical sprays and artificial fertilizers for many years with similar farmland which has received fertilizers and sprays. Among the projects based on the Haughley farm material are a comparative entomological survey, a study of radioactive fallout in food chains under different methods of crop production, an investigation of the toxic hazards of municipal composts and a small animals feeding experiment involving the study of the differences in health of small laboratory animals fed on diets from different sections of the Haughley farms and elsewhere. The association is hoping to attract other projects using its land for comparative studies.

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ACKNOWLEDGEMENTS

I wish to thank Mr. Douglas Campbell, Director of Haughley Research Farms, for supplying the seed samples and much useful information and discussion, about the work of the Soils Association and its experimental farms.

I wish to thank my supervisor, Dr. David Bellamy of the University of Durham, for enthusiastic help and advice throughout the duration of this work, and constructive criticism of the manuscript.

I wish to thank Mr. David Knox of the University of Durham, for many useful discussions and the introduction to Hughes' method of growth analysis.

The interest and help of these people has made this work possible.

I. ABSTRACT

Samples of 'tic' field beans and 'Atle' wheat from the separately farmed Organic, Mixed and Stockless sections of Haughley Research Farms have been examined, in order to determine whether any physiological differences have been evolved as a result of the three different farming methods over twenty nine years.

There were shown to be significant differences in germination success, the M seeds being only half as successful as seeds from the other two sections, a result which was probably dependent on the degree of fungal attack on the seeds.

There were some significant differences in plant growth rates, and response to fertilizer. In general, O plants showed the greatest growth rates but no response to fertilizer, whereas M and S plants showed poorer growth and required the stimulus of fertilizer to attain the same growth rate as the O plants. M and S plants without fertilizer showed a time-lag of some two weeks before growth began to increase rapidly, but subsequently over-topped the fertilized M and S individuals.

Potassium added as fertiliser was taken up, the highest concentrations being found in M tissues; nitrate

concentrations of wheat shoots were double those of bean shoots and M plants consistently showed the highest levels.

The implications of these results for agricultural practice are considered; but it is pointed out that the hypotheses must be tested and all results repeated and confirmed by extensive fertilizer trials and growth analyses of plants in the field and in constant environment chambers.

II. INTRODUCTION

Eighty per cent of the land surface of England and Wales is today affected by agricultural practice. Modern technology is providing the farmer with new materials, methods and techniques which are rapidly replacing the time-honoured practices of land-use. Farming is at present in the throes of what can be called a major 'chemical revolution', which is affecting not only the farmland and the crop plants themselves but also the whole environmental complex.

The problem of contamination of the biosphere by pesticides has been high-lighted in what has been criticized as an overdramatic manner by Rachael Carson (1963). Much research has however proved "Silent Spring" right on many counts and already remedial action has been taken at International level, prohibiting the use of the more persistent and non-biodisposable forms of these toxic contaminants.

Much less attention has been paid to the more insidious problem of environmental contamination by non-toxic substances, namely fertilizers and their break-down products. The problem is encompassed in the term "Eutrophication", which means over-enrichment of the ecosystem with nutrients, often nitrogen, potassium and phosphorous, one result being algal blooms producing deoxygenation and/or toxins and massive fish kills.

The blame is usually laid upon sewage and other piped effluents; non-contained run-off of fertilizers from agricultural land is in many cases as important a factor and in all cases a more intractable problem.

Because of the economic implications of this, much work is already underway studying these phenomena and related problems. What is really needed is a series of catchment balance sheets for all nutrients and for all ecosystems, a task of incredible magnitude fraught with many difficulties.

There is one other very important facet of eutrophication which has received much less publicity and hence much less study. That is, possible changes in crop plant physiology, induced by the continual use of high levels of fertilizers.

NITRATE EUTROPHICATION

(1) The case for the use of nitrate fertilizers.

Nitrogen is usually the most important fertilizer element applied to the soil, its effects being manifested quickly on plant growth and ultimately on crop yields.

Phosphorous, potassium and the other essential plant nutrients are very necessary, and essential for maximum efficiency in the use of the added nitrogen, but they are in a sense of less direct importance.

Fertilizer trials have been used to demonstrate the positive response of a wide range of crop plants to different fertilizer treatments.

For example, extensive nitrogen and phosphorus fertilizer trials have been carried out in Nigeria as part of a programme to improve production of the main food crops like maize and sorghum, and estimates have been made of the most profitable combinations and levels to use in each area. Goldsworthy (1967); Nitrogen-fertilization gave highly significant increases in millet, cotton and coffee yields, whilst super-phosphate produced similar results on groundnuts in Uganda. The optimum time of application to produce the greatest effect on yield was calculated. Stephens (1967); Nitrogen is the most important and usually the only nutrient necessary for high yields of rice on the Murrumbigea irrigation area of New South Wales. Boerema (1965); The marked increases in acre yields of crops that have occurred in the United States during the past thirty years, may be attributed in large part to the steadily increasing rates of addition of nitrogen in commercial forms. Allison (1966); Natural Veld grassland in Swaziland was changed into a more productive sward of different seral grasses by the application of nitrogen, phosphorus and lime. I'ons (1961).

So artificial fertilization with nitrogen and phosphorus will produce marked increases in the yields of economically important crops and of natural grassland swards.

(2) Problems arising from the use of nitrate fertilizers

Ellis *et al*. (1951) reported serious illness and death from methaemoglobinemia in both cattle and human infants, and demonstrated that these ill effects were a result of excessively high nitrate levels in Manitoba ground waters. Similar cases of this type, due to both ground-water enrichment and abnormally high levels of nitrate in fodder and cereals have been reported by Wright and Davison (1964) in many parts of the world.

Constant use of modern fertilizer methods appears therefore to lead to a change in the physiology of crop plants, allowing the uptake of nitrate far in excess of normal levels. For example, Mayo (1895) and Ackerson (1963) found abundant crystals of potassium nitrate in corn leaf axils and stalks; Theron (1957) has reported that turnip midrib tissue contained nearly 4% nitrate-nitrogen.

Thus, a new and comparatively unstudied problem is indicated: detrimental changes in crop plants brought about by modern farming practices. It would seem that perhaps the increasing use of fertilizers is in some areas, like Manitoba, reaching a critical level where 'benefit' must be carefully weighed against 'cost'.

There is much evidence that natural methods of fertilization can be just as effective in maintaining yield as continual application of inorganic fertilizers, without running the risk of unpredictable side-effects. For example, natural fertilization through the use of legume pasture phases in rotations, Boerema (1965), or even by growing adapted and mutually compatible legumes and grasses in mixtures, Tewan (1968), can produce equally high yields without the use of expensive commercial fertilizers. The use of natural fertilizers like farm-yard manure or groundnut cake is an effective method of fertilization, and will improve soil structure without introducing such great risks of eutrophicating the environment. The cumulative effect of the application of organic manures and inorganic fertilizers on the yield of sugar-cane and on soil fertility has been recorded for more than fourteen years in India. Both methods of fertilization produced a marked positive response in crop yields, Singh and Noysharma (1968).

There is in the literature much evidence regarding changes in crop physiology brought about by changing farm practice. It is important to consider the effect of fertilizer applications on the crop plants in the context of different agronomic practices. For instance, extensive field studies were made throughout the Prairie Provinces of Canada over a four-year period on the effect of four agronomic practices on the protein content of hard red spring wheat. Wheat grown on fallow was usually higher in protein percentage than that grown on stubble. Spraying with 2,4-D for weed control did not affect the protein content. The application of nitrogen, either as fertilizer to the soil or as a urea spray to the plants at flowering usually raised the protein content of the grain, Hill (1964). So the effect of fertilizer application on the growth physiology of the crop will depend in part on the farming methods used.

An important and powerful subject of research is therefore indicated: a study of the effect of modern agricultural practice on the growth physiology of crop plants, with special reference to fertilizer treatments. The experimental farms of the Soils Research Association at Haughley, Suffolk, offer unique possibilities of a study of this type.

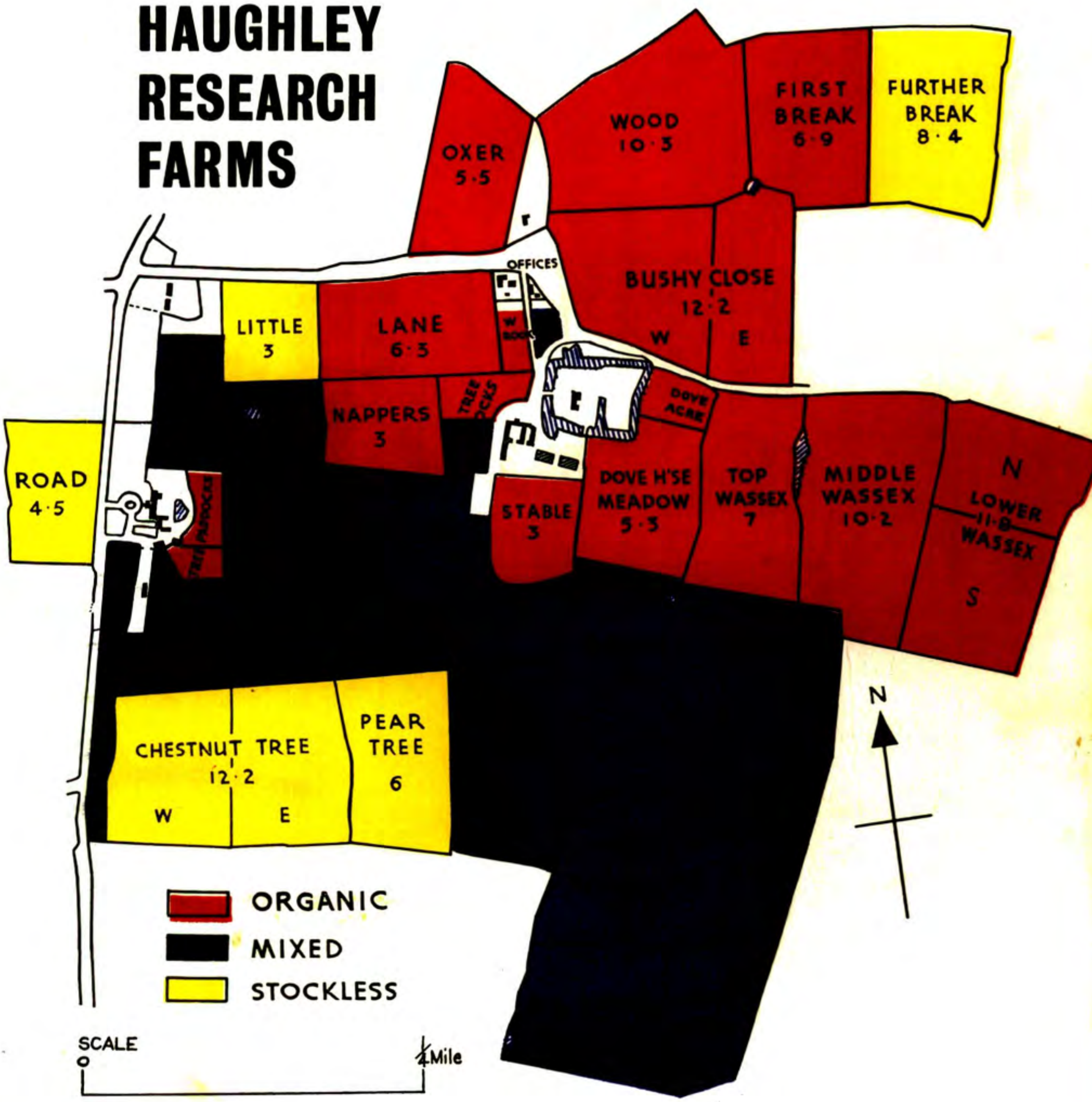
Haughley Research Farms have grown crop varieties of pure genotype under three different farming systems, 'Organic', 'Mixed' and 'Stockless', for more than twenty years. The three sections of the farm are kept quite separate with respect to the crops grown on them and the treatments which they receive (see Map).

On the 'Organic' section, no commercial fertilizers or sprays are used; it depends for its fertility upon farm-yard manure, rough composted with green weeds and ley mixtures, thus representing a natural farm ecosystem based on recycling not importation of nutrients. The 'Mixed' and 'Stockless' sections are treated with organic and synthetic inorganic fertilizers, pesticides, seed-dressings and all modern farming methods.

The Organic farm ecosystem may be considered as the control with which the crops grown within the Mixed and Stockless farm ecosystems, may be compared in order to assess their reaction to the modern, synthetic, artificial aids to farming.

Whilst detailed records of section treatments, regular

HAUGHLEY RESEARCH FARMS



soil analyses, weather recordings, field observations, gross crop yields, plant chemical analyses for total protein, etc., have been made at Haughley throughout the duration of the experiment, there has been little detailed analysis of crop growth and physiology under the three different farming systems.

Observation of the crops growing at Haughley has indicated that the plants, originally of a single "pure" genotype, are now phenotypically different and produce different yields on the three different farming systems (Plates 1 and 2). The aim of this work is to ascertain the effects, if any, which modern farm practices used at Haughley have had on the growth physiology of a legume and a cereal, with special reference to fertilizer treatments.

PLATE 1

O

M

S

WHEAT

1969

PLATE 2

O

M

BEANS
1969

III. PLAN OF EXPERIMENTS

In order to determine whether there was significant differences of any kind between seeds from the O, M and S sections at Haughley resulting from the different farming methods, it was decided, firstly, to conduct a series of preliminary experiments with the seed samples:

(1) Preliminary investigation of the O, M and S seed samples

A. Statistical Analysis of the distribution of dry and imbibed seed weights.

B. Timecourse of Germination of O, M and S seeds for one week.

C. Measurement of plumule and radicle growth during the first week after germination.

These preliminary studies showed that there were real statistically significant differences in the performance of the O, M and S seeds (see Section IV), and indicated that a further detailed study of the growth and nutrient status of the three seed types of beans and wheat would be worthwhile.

(2) Investigation of the Growth of O, M and S beans and wheat by Hughes (1967) method of growth analysis throughout a six-week period, with special reference to differences between experimental plants with and without fertilizer treatments

See Section IV Approach and Choice of Method of Analysis.

Section V Analytical Methods for the Growth Experiments.

Section VI Methods.

Section VII Results.

Appendix Tables.
Statistical Details.

(3) Evaluation and Comparison of the effect of fertilizer treatment on the growth physiology of O, M and S plants by Tissue Analysis.

See Section VI Methods

Section VII Results

and Appendix

IV. PRELIMINARY SEED STUDIES

Seed samples of Wheat variety Atle and Field Beans (*Vicia faba*) variety 'tic', which had been grown under similar conditions for twenty one years and obtained from original stock, were supplied by Haughley Research Farms.

1. Statistical Analysis of the Distribution of Dry and Imbibed Seed Weights

Samples of 100 seeds from the O, M and S sections at Haughley for each of beans and wheat were used for statistical analysis of the distribution of dry and imbibed seed weights. The samples for dry weight determination were dried to constant weight in an oven at 80 °C for 72 hours. The samples for imbibed weight determination were soaked in distilled water at room temperature for 24 hours, then drained and the excess water removed with blotting paper before weighing.

The lists of 100 weights in each sample were subjected to analysis of variance. The mean, standard error of the mean, variance and standard deviation of each sample were calculated, together with the estimated standard deviation of the population based on (n-1) degrees of freedom, and are presented in Table 1.

Let the Null Hypothesis state that there are no significant differences between O, M and S seed samples, with respect to weight; they are taken from a common parent population of bean or wheat seeds.

Since the samples were large, the calculated values of the mean, standard error, variance and standard deviation for each sample may be regarded as a good estimate of these parameters for the seed populations which the samples are taken to represent. That this is valid can be seen from the closeness of the values for the standard deviation of the samples (σ) and the estimated standard deviation of the populations which these samples represent ($\hat{\sigma}$).

Assuming the distribution to be normal, and taking 95 per cent confidence limits as twice the standard deviation either side of the mean to give the range within which

95% of the seed weights would be expected to fall, conincidence occurs in the ranges of the O, M and S seed samples for both beans and wheat. This indicates that there are no significant differences at the five per cent level between O, M and S seed samples so that Null Hypothesis is upheld.

Calculated values for the between sample variance ratio (f) and t-test are presented in Table 2. For a single normal population a variance ratio smaller than 1.8 would occur in 95 per cent of cases and larger than 1.8 in only five per cent of cases. The calculated variance ratios for O, M and S samples are all much less than 1.8 so are probably from a single population of seeds randomly sampled rather than from three separate seed populations of type O, M and S.

During the calculation of t it became evident that the difference in the means was always much less than twice the standard deviation of the difference of the means ($2\sigma_{\bar{d}}$). The null hypothesis requires that for more than 100 degrees of freedom and $p = 0.05$, the difference in the means is less than twice the standard deviation of the difference of the means for a single normal population. So the actual values support the Null Hypothesis in that there are no significant differences between the O, M and S seed samples of wheat and beans at the five per cent level. So the O, M and S seeds of beans and wheat are part of a single normal population with respect to weight and size.

2. Timecourse of Germination

O, M and S seeds of beans and wheat were soaked in distilled water for 48 hours and thus considered to be fully imbibed. Six, seven or eight replicate samples of 100 seeds of each seed type were placed on damp filter paper in petri dishes in the dark at room temperature. The per cent germination was recorded daily for a week, successful germination being indicated by a testa split to reveal the growing radicle. The mean per cent germination for seven days is recorded in Table 3 together with the standard error of the mean and standard deviation for each seed type. Plate 3 shows seed samples after one week.

The graphs in Figs. 1 and 2 illustrate the timecourse of germination. For the first three days, per cent germination increases rapidly, there being no significant differences at the 5% level between O, M and S seed samples of beans, but significant differences between O and M and S and M samples of wheat, the M seeds showing poorer germination success. Thereafter, on days 4, 5, 6 and 7 the per cent germination increases only slowly

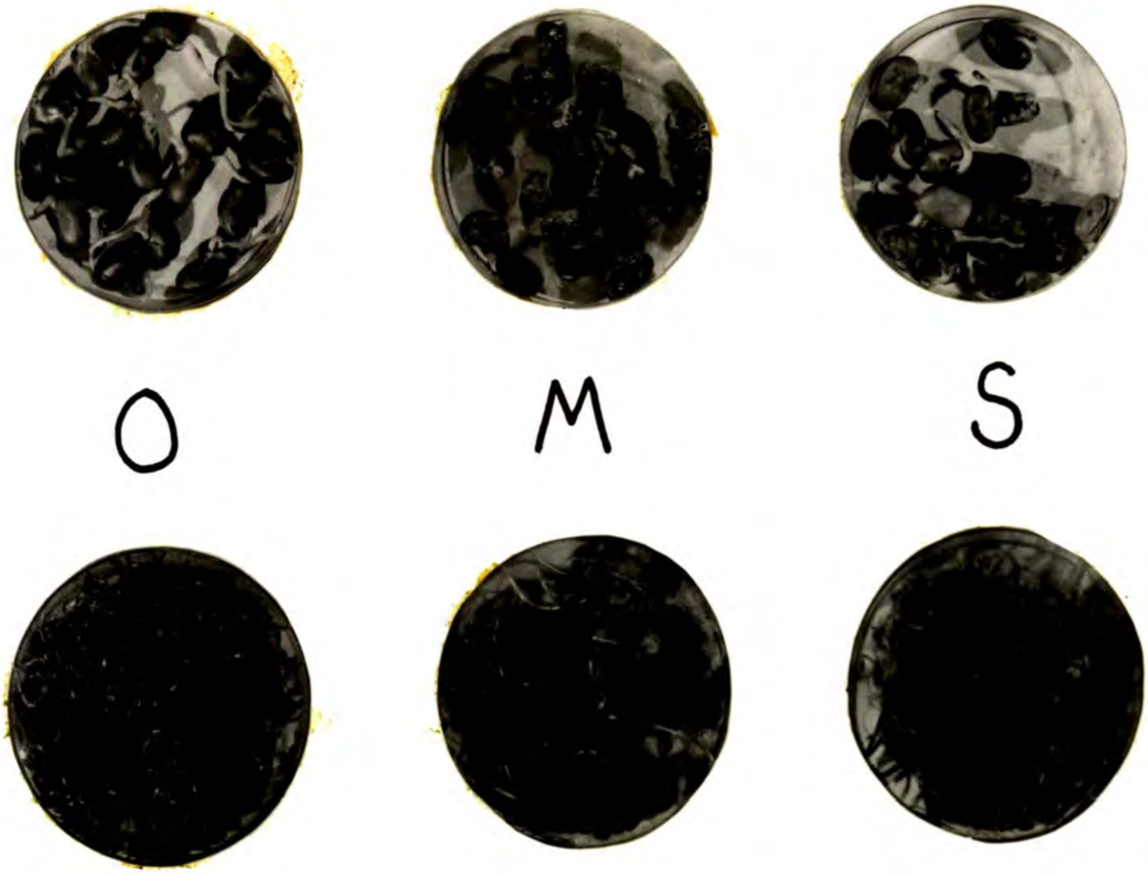


PLATE 3

SEED SAMPLES AFTER ONE WEEK

approaching a maximum value which for the O and S seeds is significantly different at the 5% level from the M seeds. The maximum mean per cent germination of the M seeds is only about half that reached by the O and S seeds.

The "Official Seed Testing Station for England and Wales" reported the following per cent germination success for wheat and beans:-

	WHEAT	BEANS
O	95	80
M	81	64
S	83	93

The M samples were lowest in both cases.

Plate 3 shows the different appearance of O, M and S seed samples of wheat and beans after one week under identical conditions. The heavy fungal attack on the M seeds may help to explain the low germination percentages which they show.

3. <u>The First Week of Growth</u>

The mean plumule length, and the mean primary radicle length, and mean total radicle length per <u>germinated</u> seed, for O, M and S beans and wheat was recorded on Day 3, 5 and 7 after germination. The results are recorded in

Table 4, and illustrated graphically in Figs. 3 and 4.

V. APPROACH AND CHOICE OF METHOD OF GROWTH ANALYSIS

It is frequently necessary to follow the growth of populations of plants undergoing a number of different treatments over periods of weeks or months. This is usually done by harvesting a number of plants from each treatment on the same day, at weekly or longer intervals. By comparing successive harvests in any treatment, mean values for various growth indices can be derived. Where the number of treatments is large the task of harvesting becomes a major limitation, and much information is at risk on each harvest occasion. Furthermore, the derivation of a number of useful growth indices demands some knowledge of the general trends of growth with time. Hughes and Freeman (1967) have devised a method of growth analysis using frequent small harvests which has proved to be most successful in studies of the growth of cultivars of *Callistephus chinensis* and *Chrysanthemum morifolium* in controlled environment cabinets over periods of up to three months. They suggested that the method may also be useful in glasshouse and field experiments.

It was decided to compare the growth of O, M and S seedlings of beans and wheat under conditions which were as controlled and uniform as possible, the only growth chamber available being a dutch light greenhouse. Because of limitations on space and time in which to conduct the experiments, but with the desire to have a sound statistical evaluation and comparison of seedling growth under several different treatments, it was decided to use a work pattern and analytical procedure after Hughes' (1967) method, which use frequent small harvests of only three or four individuals per sample.

VI. ANALYTICAL PROCEDURES FOR GROWTH ANALYSIS

The primary data required are the leaf areas and dry weights of the individual plants. As plants increase in size, so does their absolute variability. Transformation of the primary data to logs renders the variability more nearly homogenous with time. The polynomial regression line of sufficient fit to the logs of the weights and areas on time is determined by the "least squares" method, which makes the sum of the squares of discrepancies between the observed and fitted values as small as possible. A cubic has been found to give a good fit for the growth curves. Two equations are derived which in their simplest form are:-

$$\log_e W = a + bt + ct^2 + dt^3 \qquad (1)$$

$$\log_e A = e + ft + gt^2 + ht^3 \qquad (2)$$

using W for total plant dry weight (mg); A for leaf area (cm^2) for t for time in days.

The growth characteristics most often studied in classical growth analysis are:-

$$\text{Relative Growth Rate} = \frac{1}{W} \cdot \frac{dw}{dt}$$

$$\text{Leaf Area Ratio} = \frac{A}{W}$$

$$\text{Net Assimilation Rate} = \frac{1}{A} \cdot \frac{dw}{dt}$$

which are interrelated as R.G.R. = L.A.R. x N.A.R. R.G.R. can be derived directly by differentiation of regression equation (1), for

$$\frac{d\,(\log_e W)}{dt} = \frac{1}{W} \cdot \frac{dw}{dt} \qquad (3)$$

L.A.R. is

$$\text{antilog}_e\,(\log_e A - \log_e W) \qquad (4)$$

and a simple way to obtain N.A.R. is (3) ÷ (4).

Interpretation of the results is aided by comparing the fitted values with the observed values and by using an estimate of error for all the fitted values. The standard errors of the various items in the regression equations and also of the calculated values derived from them are estimated, together with the standard errors for R.G.R., L.A.R. and N.A.R. by the usual approximate formula (Lindley, 1965).

Confidence limits are obtained by multiplying the S.E. of the fitted value by the two-sided 5% significance level of Student's 't' distribution on n-4 d.f. (for a cubic), that is $t_{(n-4)}$ 0.05. They are the limits such that if they were calculated for each of an indefinitely long series of identical experiments, they would include the point on the "true" curve at that time on 95% of the occasions. As the number of observations increases, the S.E. will decrease and the value of '$t_{(n-4)}$ 0.05' will decrease towards its limiting value of 1.96, thus narrowing the confidence limits. The confidence limits for L.A.R. are obtained by taking antilogs of the corresponding confidence limits for $\log_e A - \log_e W$ and are slightly asymmetrical about the fitted value.

A computer programme which performs the above calculations is written in Algol using Elliot input/output procedures primarily for the 8D3 and 4130 machines. Its source listing is:-

The data for the computations are

M number of sets of data to be analysed

N	number of plants harvested	)	
T	significance level of Student's t on n - 4 d.f.	)	
t_1 t_n	times of harvesting	)	repeated M times
w_1 w_n	dry weights of plants harvested	)	
a_1 a_n	leaf areas " " "	)	

Twelve data sheets from twelve growth experiments are detailed in the Appendix under "Computer Input". The computer calculates the natural logarithms of the dry weights and leaf areas as they are read in, and sorts the harvesting times into ascending order.

The final computer print-out reads:-

(1) Fitted curve for log W, and S.E.'s of coefficients.

(2) Ditto for log A.

(3) Analysis of variance of linear, quadratic, cubic, residual and total, giving sums of squares for log W, sums of products for log W and log A, sums of squares for log A.

(4) For each harvesting time the fitted value of R.G.R. and its S.E., the fitted value of relative leaf area growth rate and its S.E.

(5) For each harvesting time the observed value of L.A.R., the fitted value of L.A.R. and its S.E., asymmetric confidence limits.

(6) For each harvesting time, the fitted value of N.A.R. and its S.E.

Twelve computer print-outs from the growth experiments are included in full in the Appendix under "Computer Output". The Statistical Appendix gives further details of fitting the growth curves, the confidence limits and derived functions of the fitted curves.

VII. METHODS

(1) The Greenhouse

All plants in the greenhouse growth chamber should be subject to identical conditions throughout one experimental run. But it is impossible to control temperature, light and humidity within narrow limits. There is bound to be some variability in these factors and in degree of shading from one part of the greenhouse to another. In order to minimise the effects of this variability, plants were grown in 3 x 3 latin square arrangements as explained under the Culture Technique.

In general, conditions in the greenhouse were:-

(i) natural daylight regime, with 16-18 hours light from April to July.

(ii) maximum day temperature 80 °F
minimum night " 75 °F

(iii) relative humidity up to 90% .

(2) The Culture Technique

The technique used to grow the experimental plants from seed was fundamentally one of water culture, in which additional support was provided for the plants by vermiculite. 3" plastic pots were filled with the substrate, pure new vermiculite, and placed inside square polythene washbowls which were subsequently filled with the appropriate culture solution. One bowl could accommodate nine 3" pots arranged in three rows of three. This was used as the basis of the latin square when planting the seeds in the following manner:-

M	O	S
S	M	O
O	S	M

Each bowl was sown with either wheat or beans, each pot holding ten wheat seeds or five bean seeds of appropriate type. Seeds were imbibed for two days in distilled water before sowing.

Two litres of culture solution were poured into each bowl, giving a final depth of about 2", which was sufficient to maintain.the vermiculite in a damp but not saturated condition for one week. The culture solutions were changed weekly, and on each changing occasion the bowls were wiped out and rinsed with distilled water to remove any traces of algal growth and iron precipitation.

The fact that the bowls contained a large excess of culture solution which was changed frequently reduced several sources of error in the culture technique:-

(i) pH drift was relatively small.

(ii) Nutrient concentration was maintained at a fairly constant value over each week, see Table 5.

(iii) It was thought unnecessary to aerate the culture solutions because of the large volumes of solution used and the large surface area of solution in each bowl.

(3) The Culture Solution

In carrying out these experiments it was decided to use as a basis a well-tried and successful culture solution, which gives adequate supply of all the macro- and micro-nutrients required by plants for healthy growth. The culture solution chosen to form the basic medium was that used at the Bristol (Long Ashton) Agricultural and Horticultural Research Station (Hewitt, 1952). The complete nutrient solution produces vigorous growth in a wide range of crops; no attempt was made to develop two different 'optimum' nutrient solutions to suit the needs of the beans and the wheat.

Concentrated stock solutions of each salt were prepared and stored in 2½ litre Winchester bottles. The concentration of these stock solutions was such that 50 ml. each stock solution on dilution to 10 litres gave the required ionic concentrations, see Table 6. pH was recorded, but not adjusted.

To half of the bowls, 1 ml. liquid fertilizer was added each week. The fertilizer used is manufactured under the brand-name "Liquinure" and contains nitrogen, potassium and phosphorous in the following proportions:

Analysis w/w:

Nitrogen.	9.0%
Phosphorus.	6.6% as phosphoric acid, P_2O_5
Potassium.	4.1% as K_2O

all in solution in water, with additional trace elements. Addition of this balanced N:P:K fertilizer produced changes in the composition of the nutrient solution as indicated in Table 5. The analysis shows an increase in potassium concentration but no change in sodium concentration, as would be expected.

VIII. RESULTS

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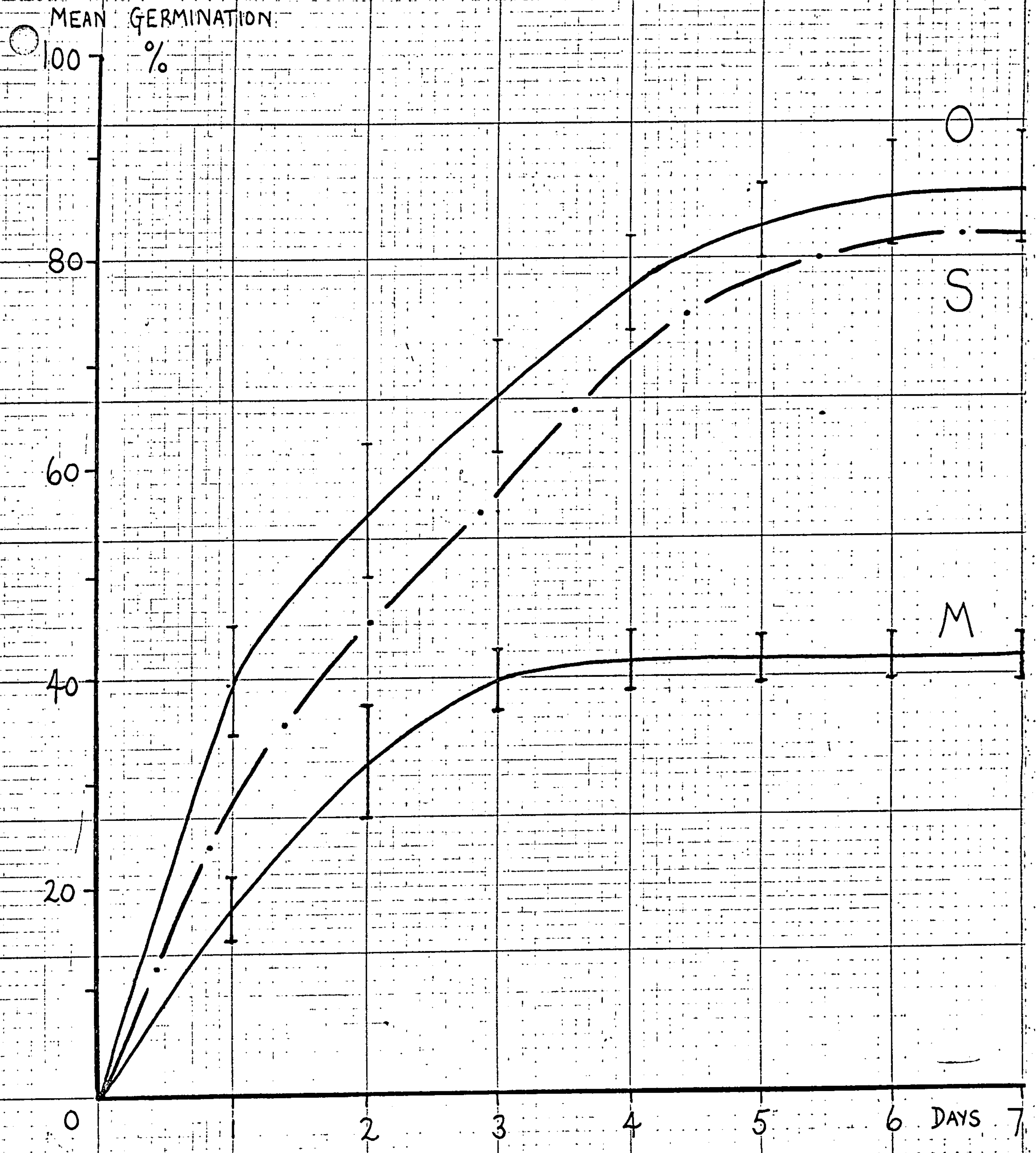

FIG. 1. BEANS. TIMECOURSE OF GERMINATION.
Bars indicate standard errors.

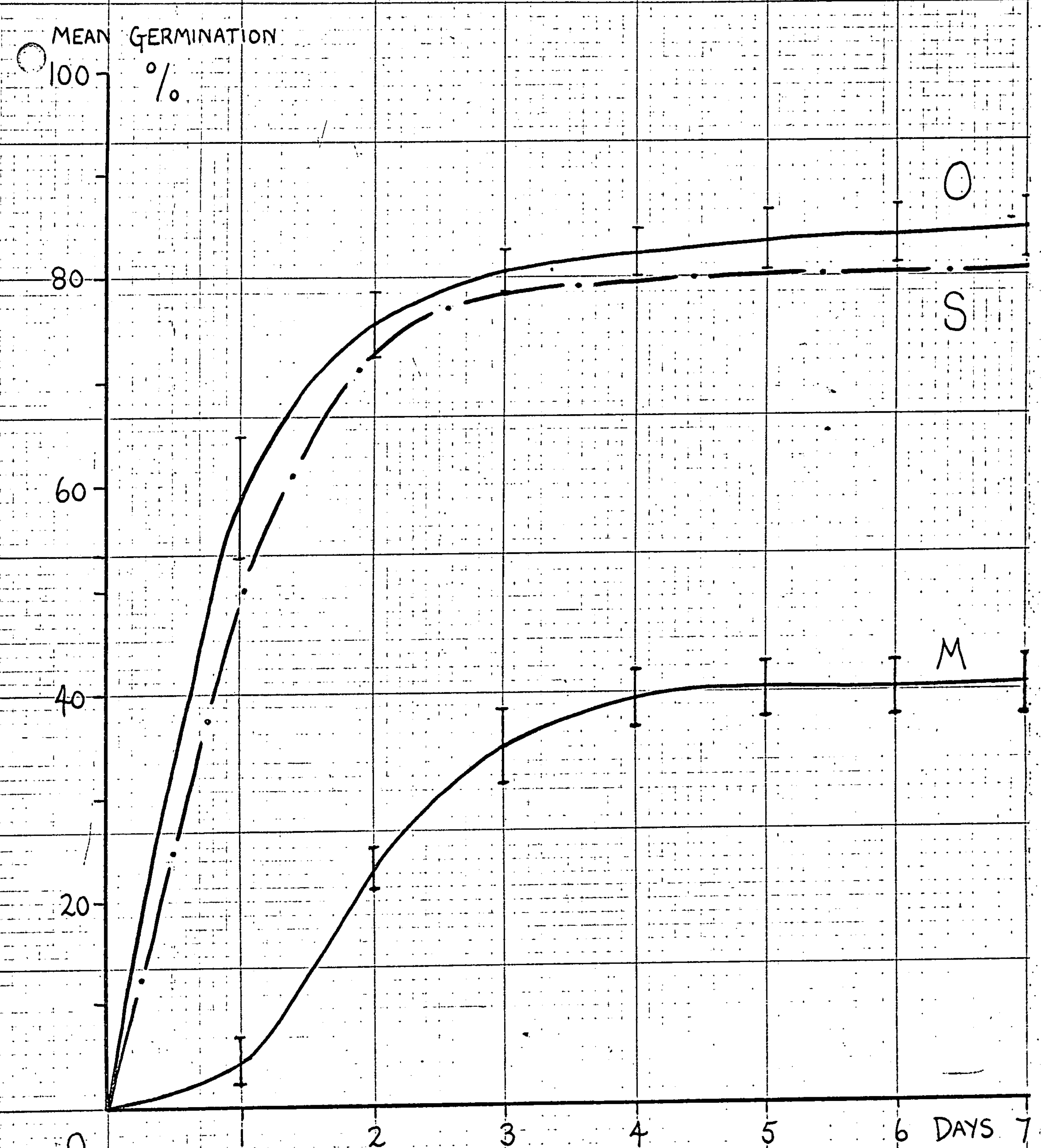

FIG. 2. WHEAT. TIMECOURSE OF GERMINATION.
Bars indicate standard errors.

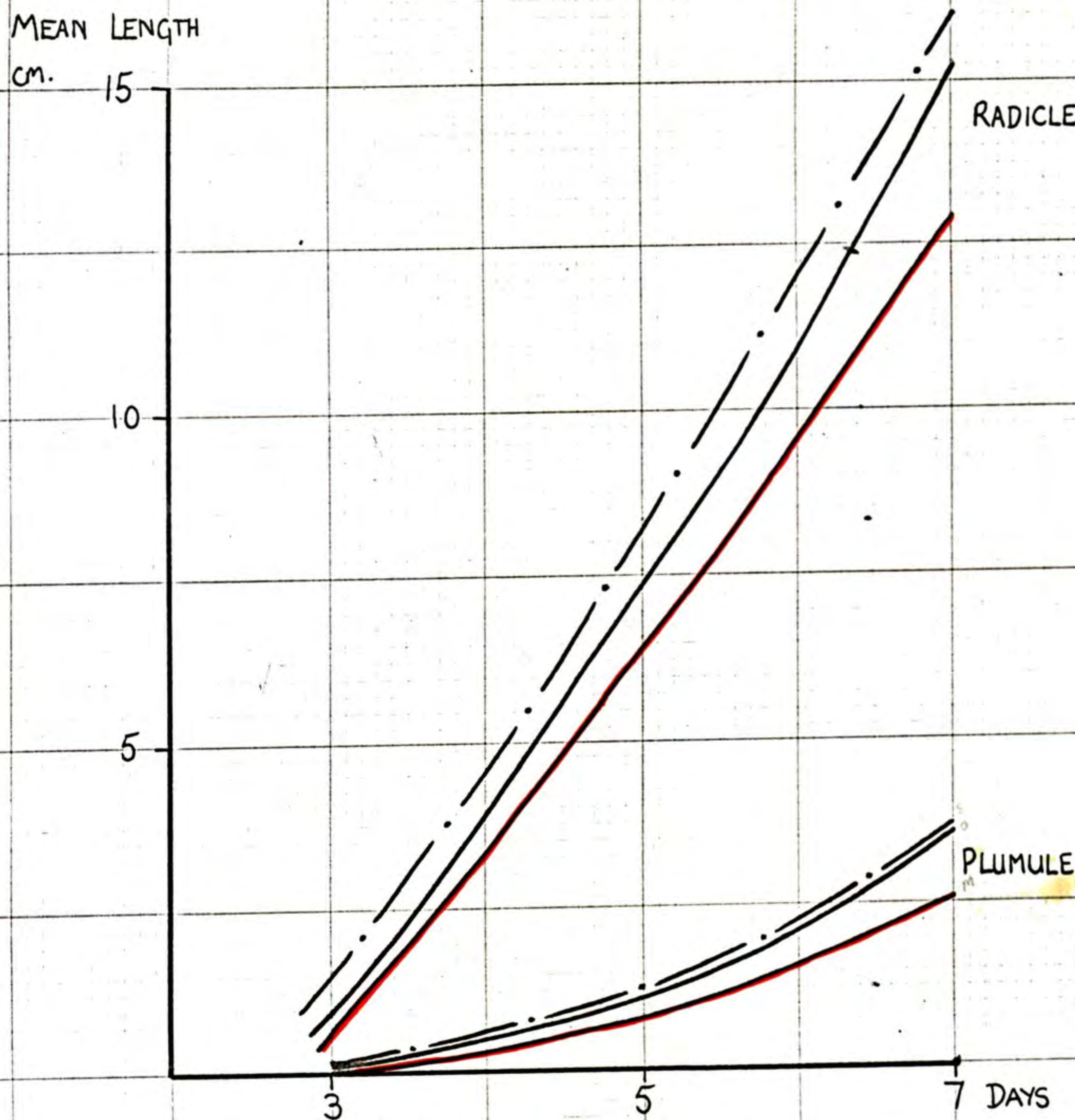

FIG. 3. WHEAT. FIRST WEEK OF GROWTH.
Black solid line = 'O' seedlings
Black broken line = 'S' seedlings
Red line = 'M' seedlings

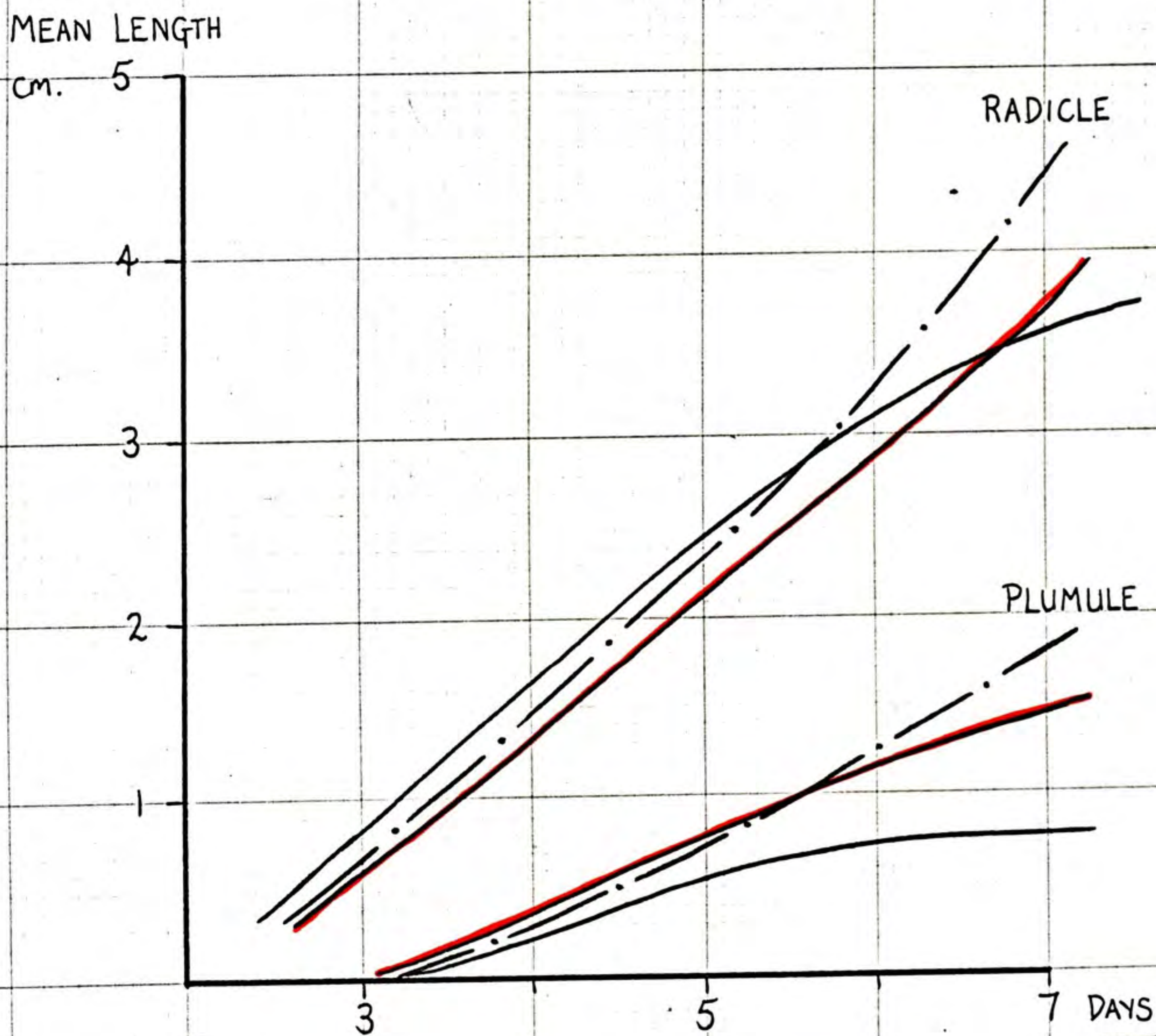

FIG. 4. BEANS. FIRST WEEK OF GROWTH.

Black solid line = 'O' seedlings
Black broken line = 'S' seedlings
Red line - 'M' seedlings

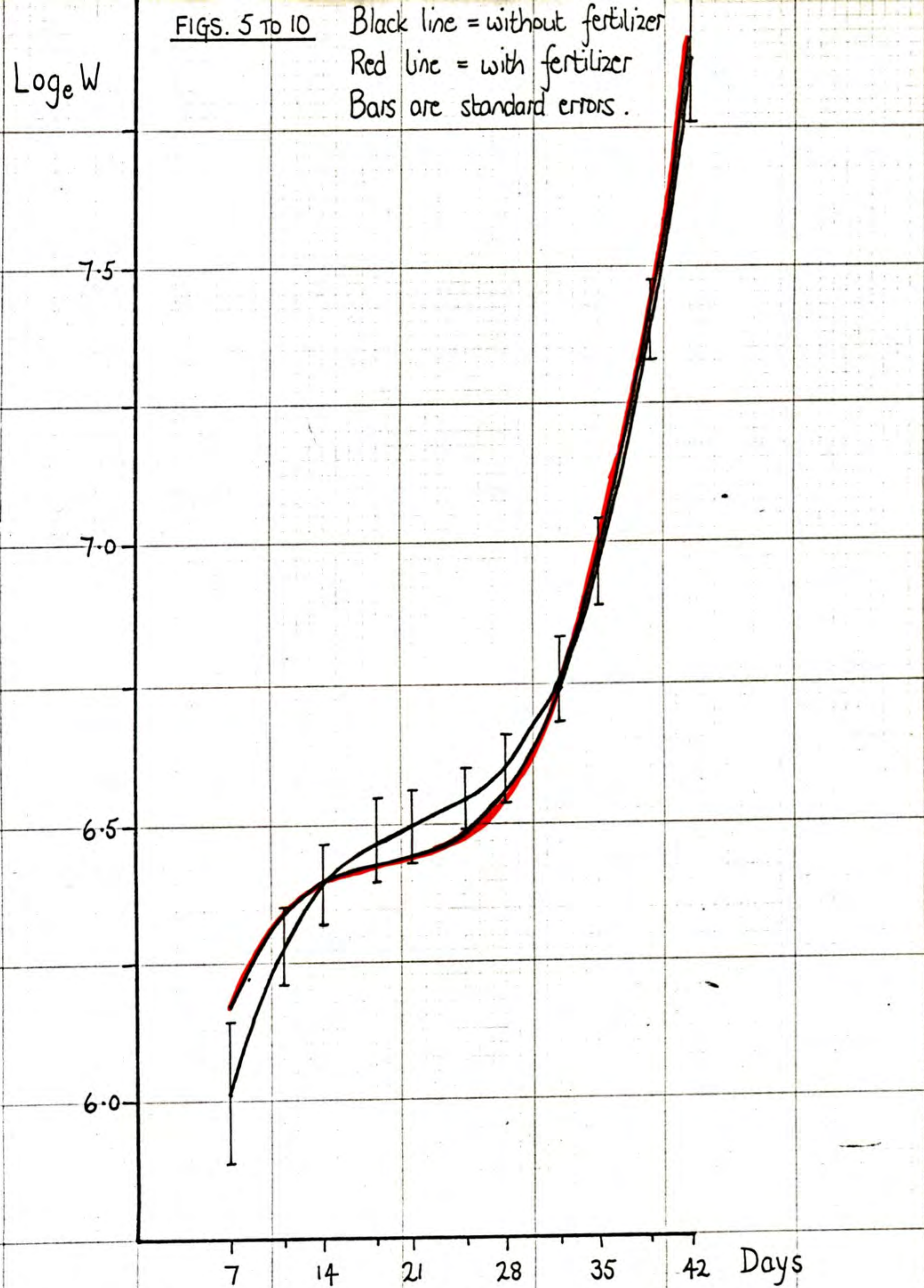

FIG. 5. 'O' BEANS. PROGRESS CURVES OF DRY WEIGHT.

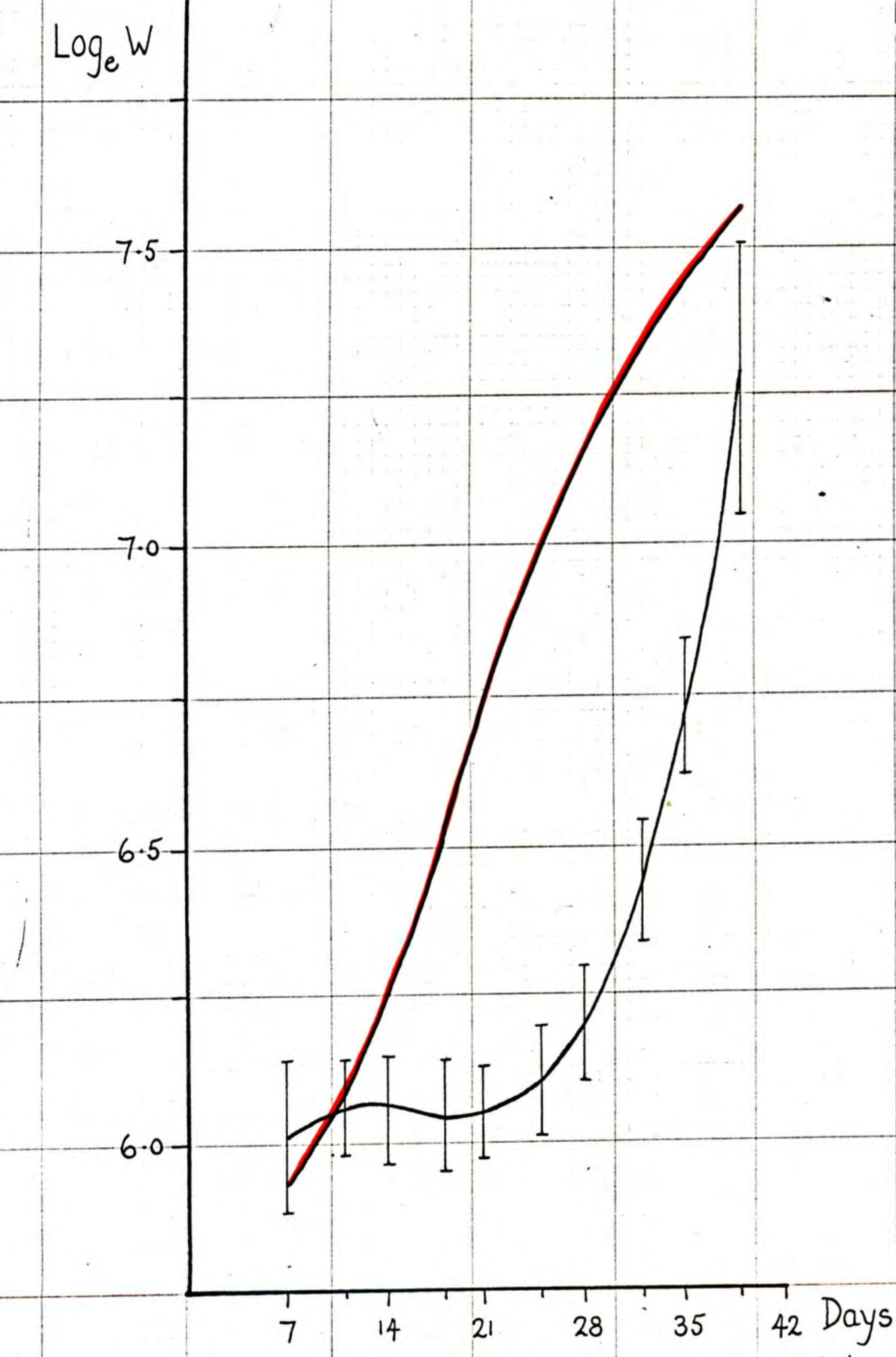

FIG. 6. 'M' BEANS. PROGRESS CURVES OF DRY WEIGHT.

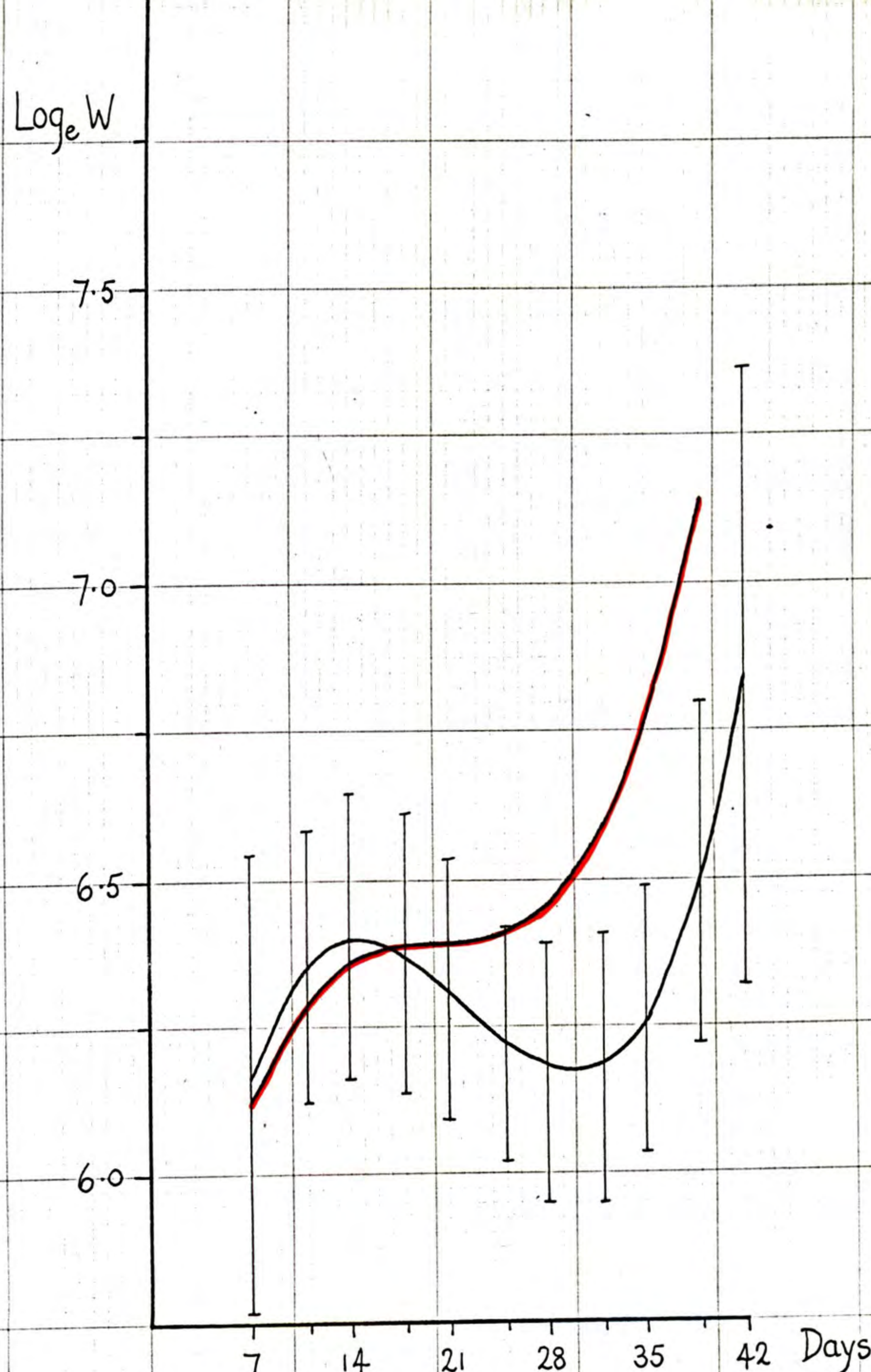

FIG. 7. 'S' BEANS. PROGRESS CURVES OF DRY WEIGHT.

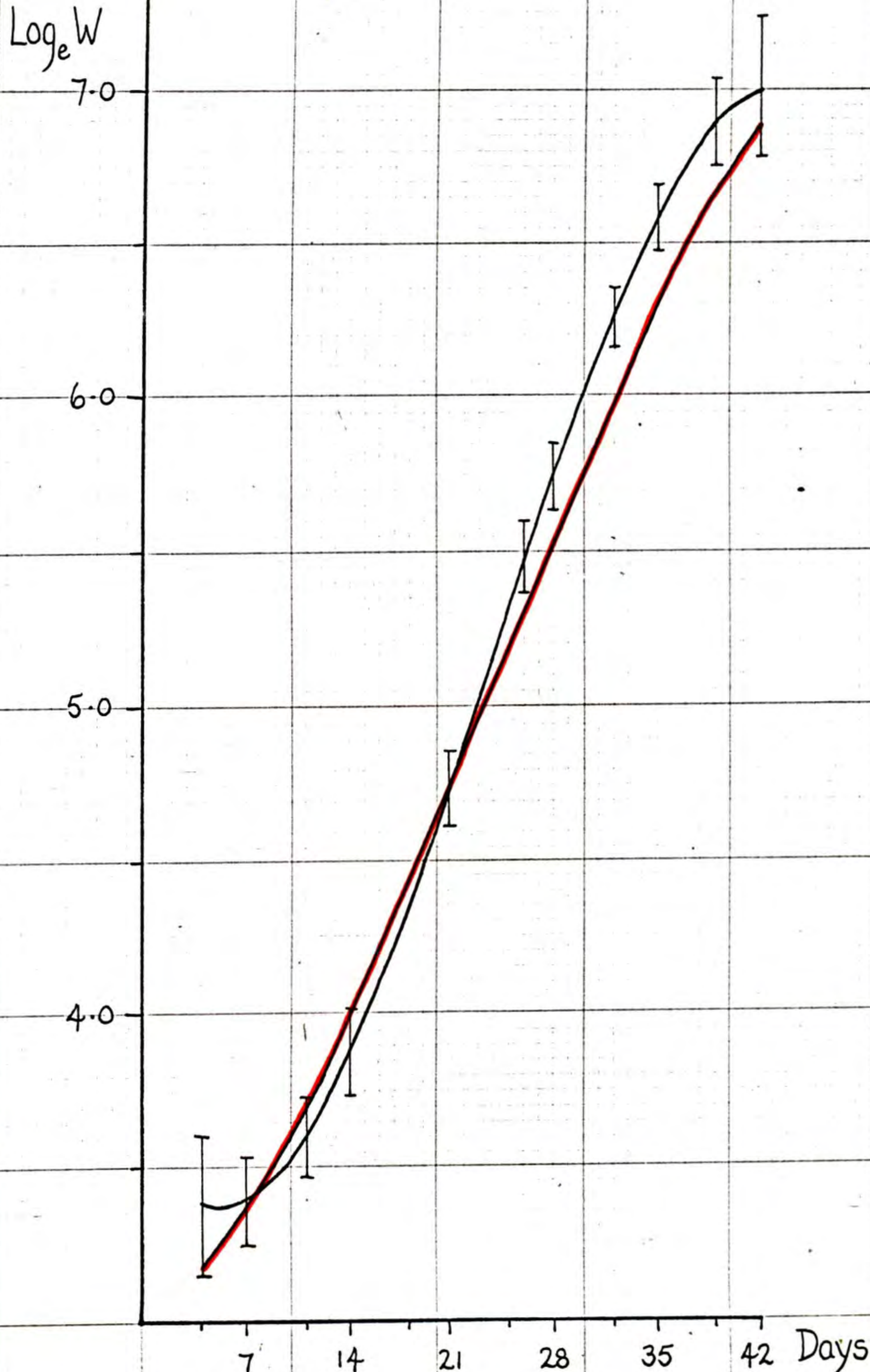

FIG. 8. 'O' WHEAT. PROGRESS CURVES OF DRY WEIGHT.

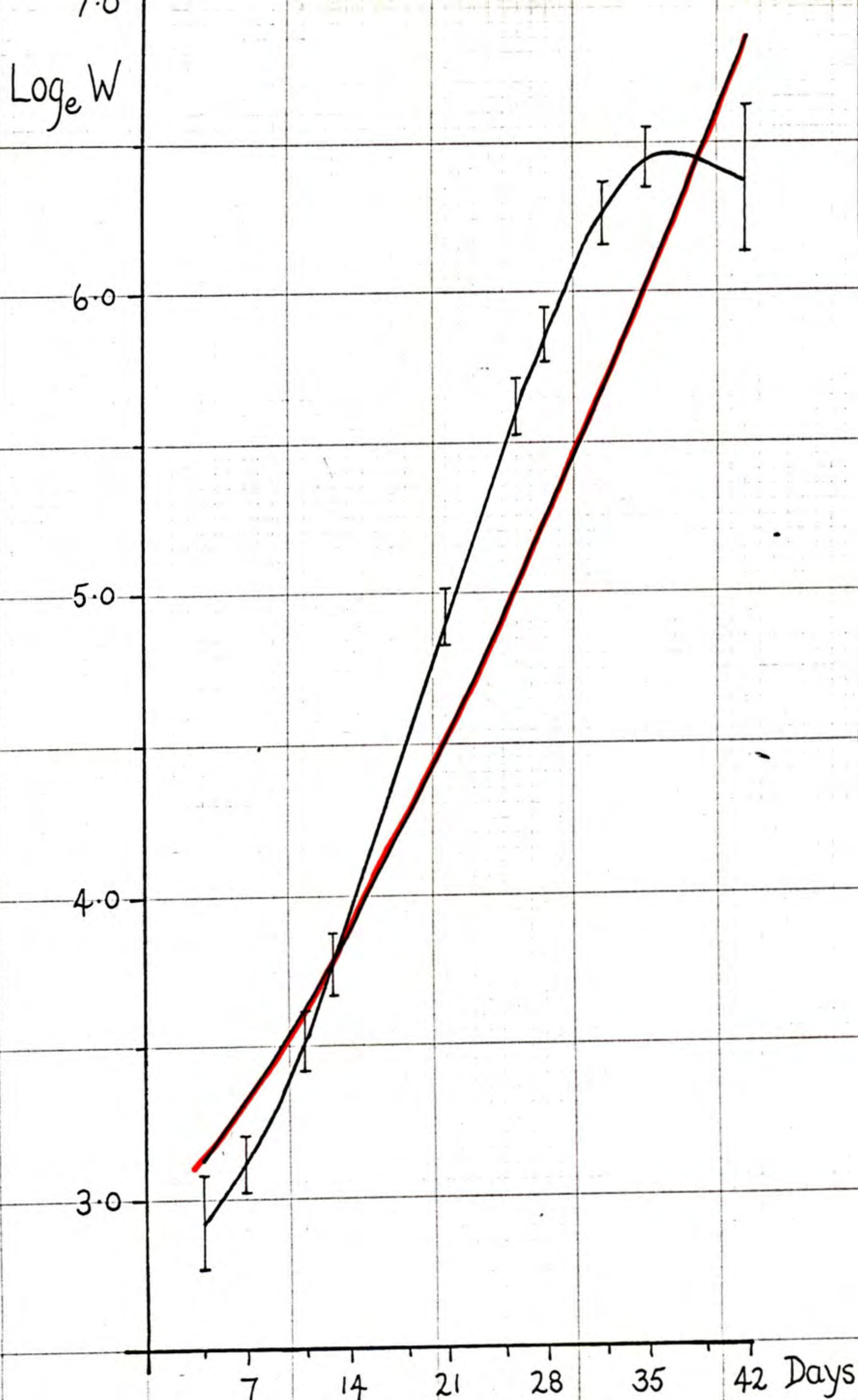

FIG. 9. 'M' WHEAT. PROGRESS CURVES OF DRY-WEIGHT.

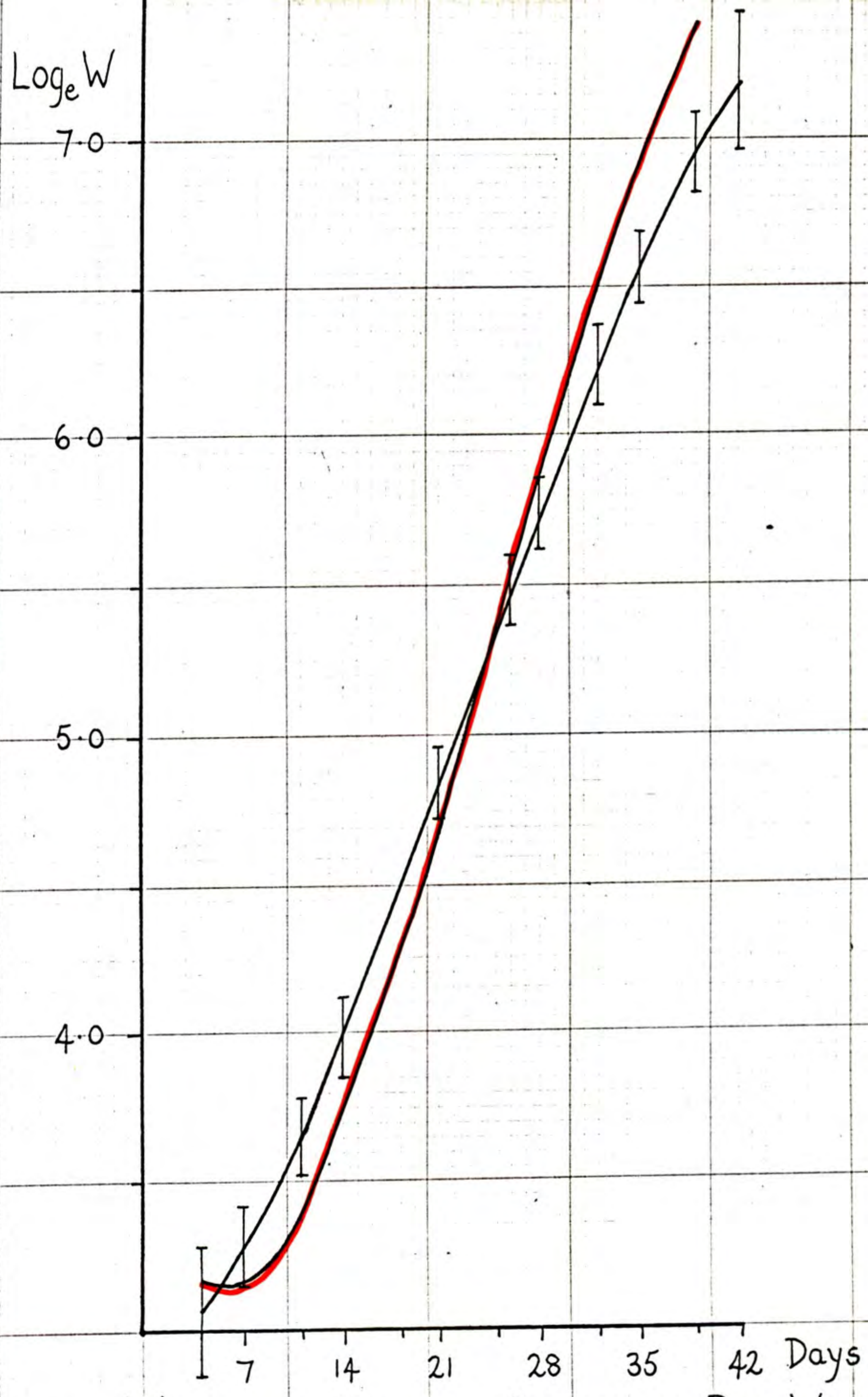

FIG. 10. 'S' WHEAT. PROGRESS CURVES OF DRY WEIGHT.

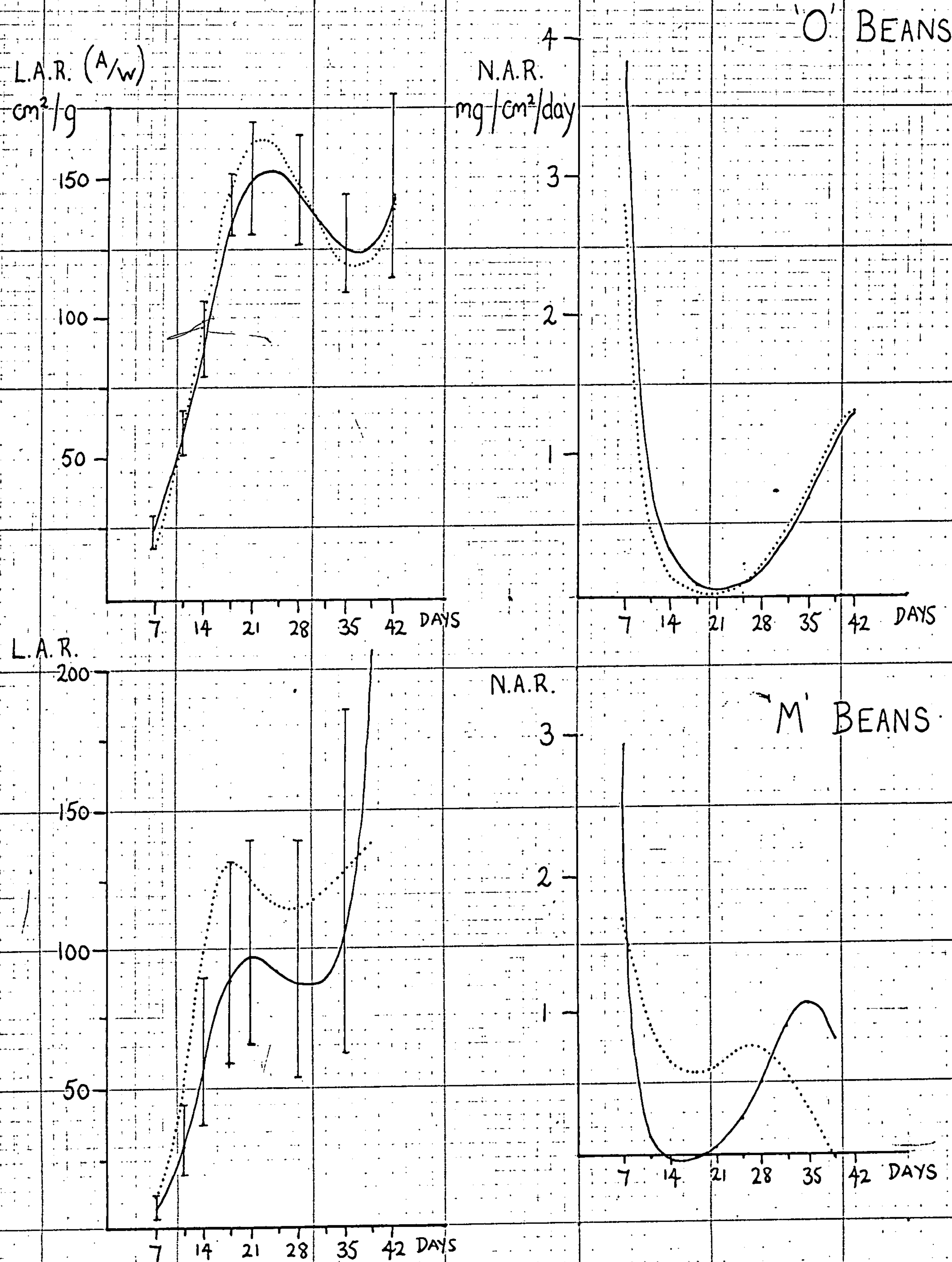

FIG. 11. BEANS. PROGRESS CURVES OF LEAF AREA RATIO AND NET ASSIMILATION RATE. —— = without fertilizer ······ = with fertilizer

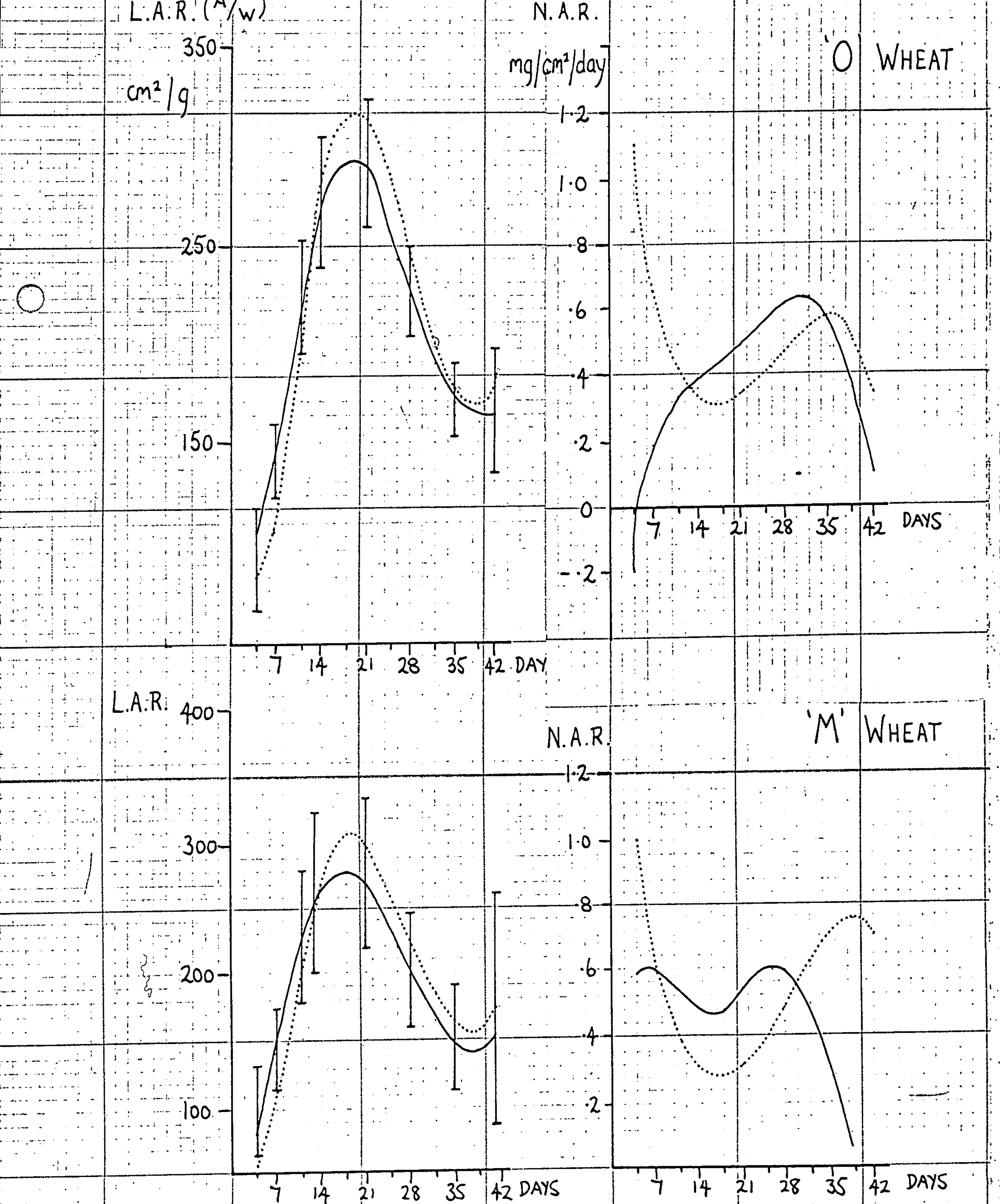

FIG. 12. WHEAT. PROGRESS CURVES OF LEAF AREA RATIO AND NET ASSIMILATION RATE. Lines derived from fitted cubics ; bars are 95 % confidence limits. —— without fertilizer ...... with fertilizer.

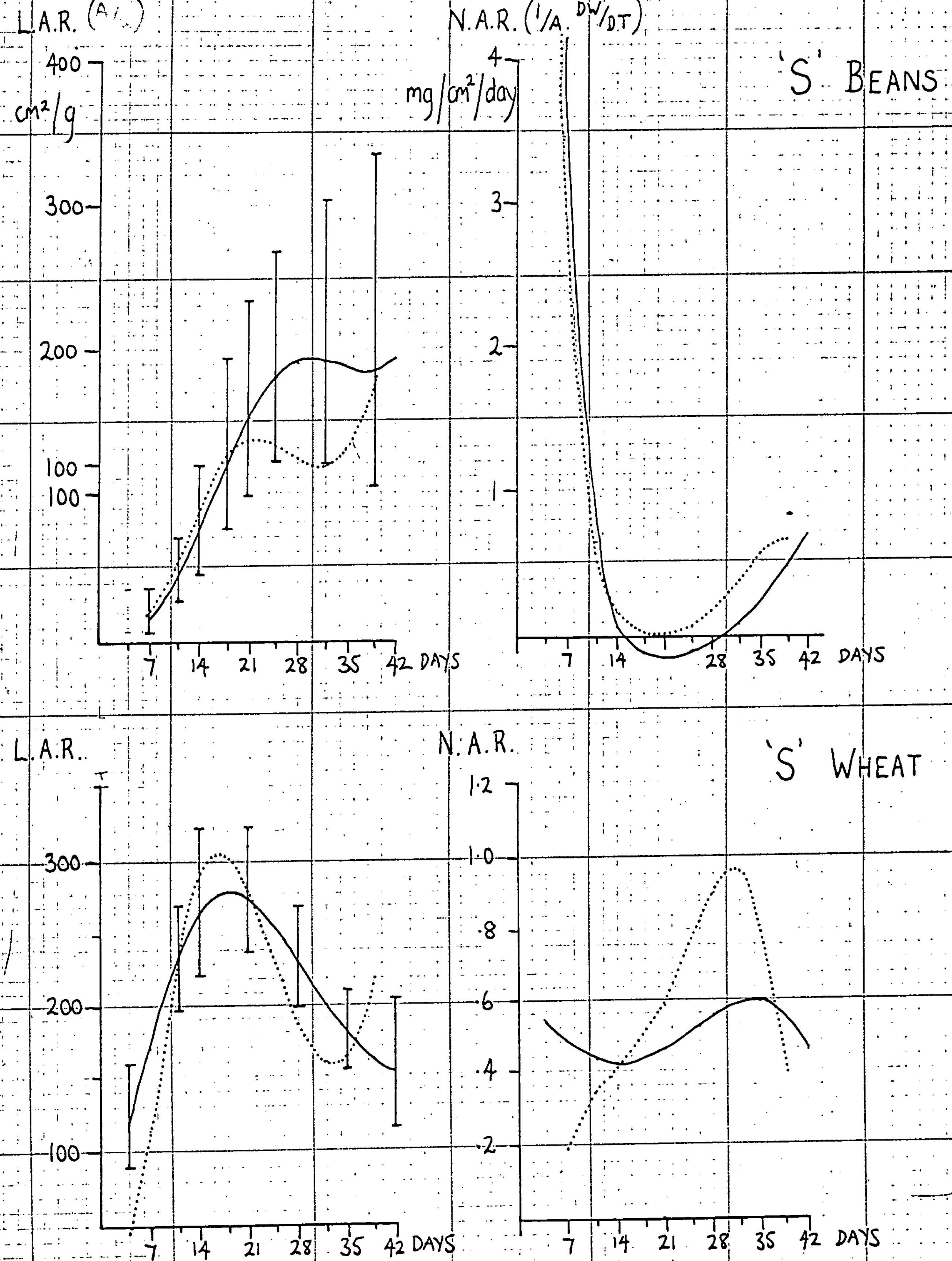

FIG. 13. PROGRESS CURVES OF LEAF AREA RATIO AND NET ASSIMILATION RATE. Lines derived from fitted cubics; bars are 95 % confidence limits.
—— without fertilizer; .... with fertilizer

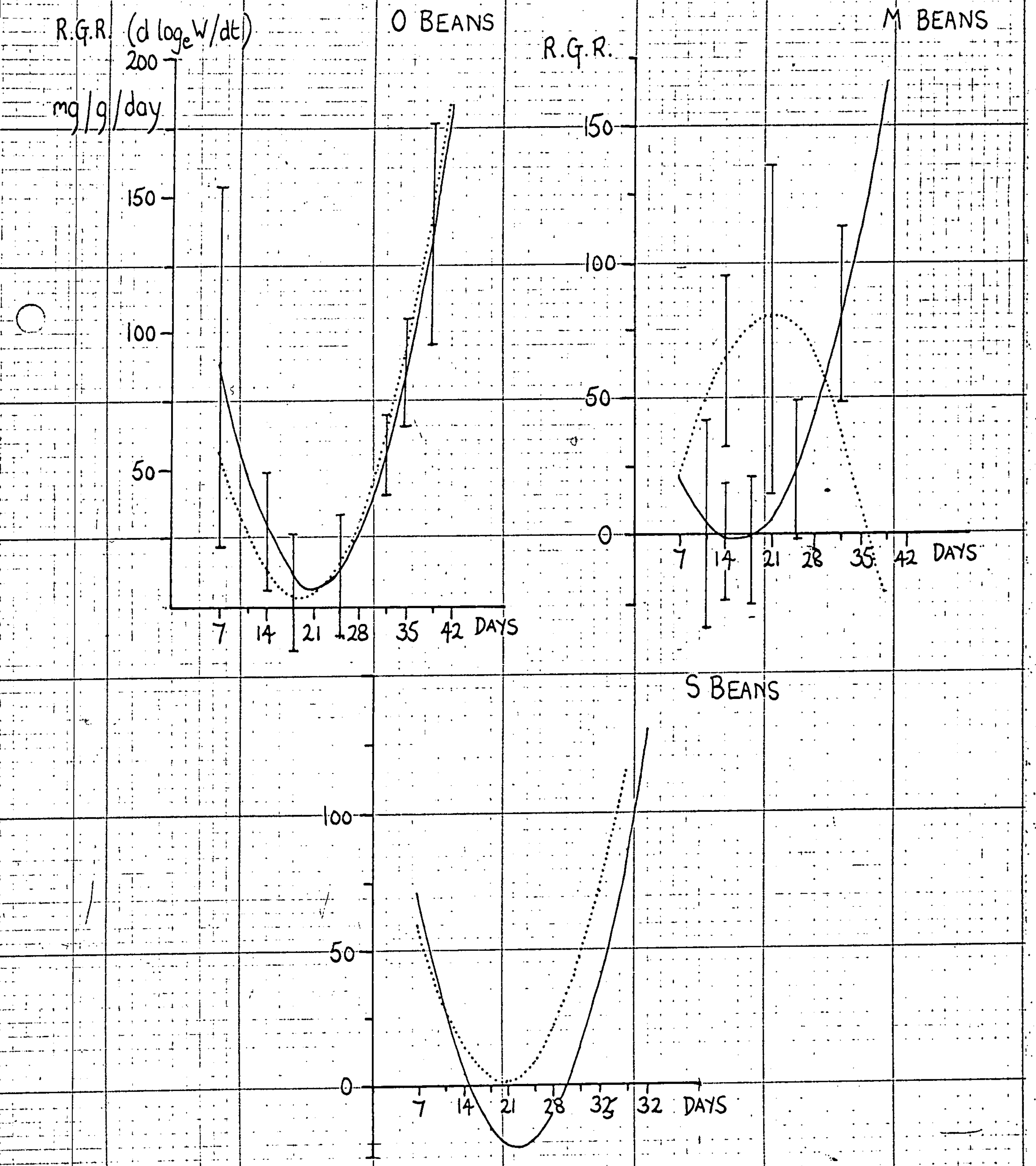

FIG. 14 BEANS. PROGRESS CURVES OF RELATIVE GROWTH RATE, DERIVED FROM FIGS. 1, 2 AND 3 BY DIFFERENTIATION. Lines from fitted cubics; bars are 95% confidence limits. —— without fertilizer ...... with "

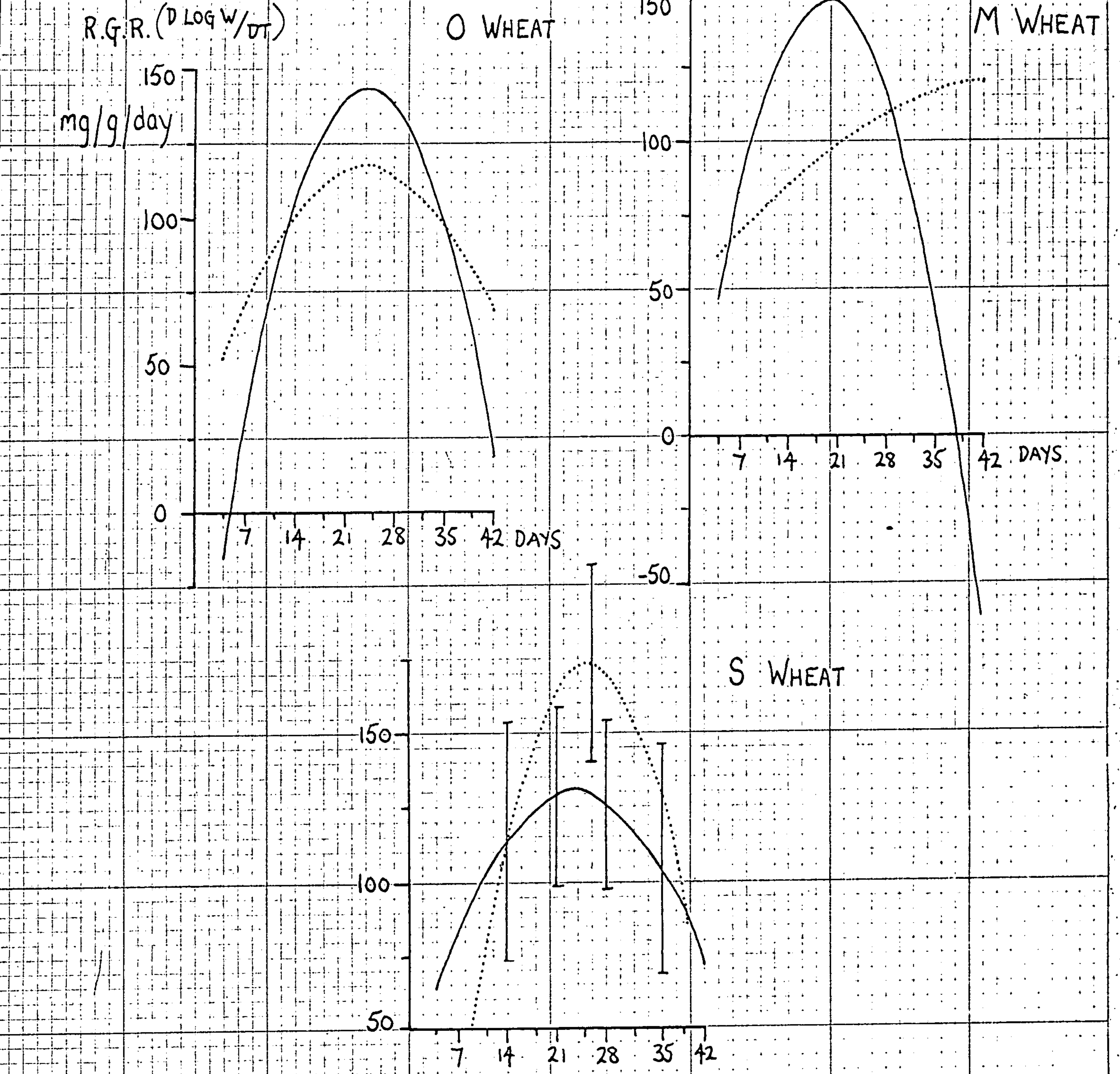

FIG. 15. WHEAT. PROGRESS CURVES OF RELATIVE GROWTH RATE, DERIVED FROM FIGS. 4, 5 AND 6 BY DIFFERENTIATION. Lines from fitted cubics; bars are 95% confidence limits.

— without fertilizer

······ with "

BEANS: TEN DAYS GROWTH

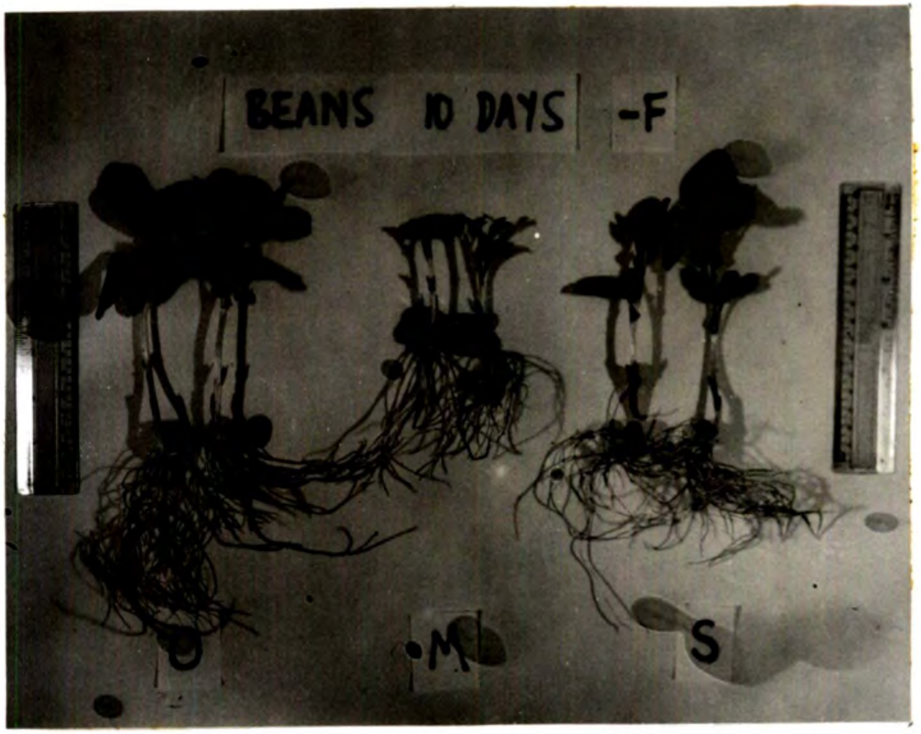

TABLE A

PLANT GROWTH CURVES : ANALYSIS OF VARIANCE

Figures used in the calculation of the variance ratio, F, are taken from the Computer output in the Appendix.

+ = with fertilizer

- = without "

* = significant at the 20% level

* * = " " " 5% "

* * * = " " " 1% "

N.S. = not significant.

1) SIGNIFICANCE OF FERTILIZER TREATMENTS

BEANS	+ and - O F	+ and - M F	+ and - S F
linear	0.063 N.S.	1.853 N.S.	15.46 *
quadratic	1.315 N.S.	67.90 *	1.773 N.S.
cubic	1.805 N.S.	4.286 N.S.	2.862 N.S.
Total	1.322 N.S.	1.554 *	3.937 * * *
WHEAT	**+ and - O**	**+ and - M**	**+ and - S**
linear	1.339 N.S.	0.011 N.S.	1.273 N.S.
quadratic	1.786 N.S.	0.312 N.S.	808.7 * *
cubic	8.890 N.S.	173.6 * *	3.000 N.S.
Total	1.090 N.S.	1.013 N.S.	1.123 N.S.

TABLE A

2) SIGNIFICANCE OF DIFFERENCES IN THE GROWTH CURVES OF O, M AND S PLANTS

BEANS WITHOUT FERTILIZER (-)

	O and M - F		O and S - F		M and S - F	
linear	6.470	N.S.	138.3	*	6.677	N.S.
quadratic	1.467	N.S.	8.513	N.S.	5.803	N.S.
cubic	5.293	N.S.	1.745	N.S.	3.033	N.S.
Total	2.198	* *	1.494	*	3.282	*
WITH FERTILIZER (+)						
	O and M + F		O and S + F		M and S + F	
linear	2.389	N.S.	6.312	N.S.	2.642	N.S.
quadratic	131.0	*	19.85	*	6.600	N.S.
cubic	12.57	*	2.767	N.S.	4.543	N.S.
Total	1.870	*	3.486	* * *	1.864	N.S.

TABLE A 2) Cont.

WHEAT WITHOUT FERTILIZER (-)

	O and M -	O and S -	M and S -
linear	1.692 N.S.	1.005 N.S.	1.683 N.S.
quadratic	14.13 *	36.41 *	514.6 * *
cubic	1.294 N.S.	5.541 N.S.	4.280 N.S.
Total	1.009 N.S.	1.114 N.S.	1.124 N.S.

WHEAT WITH FERTILIZER

	O and M + F	O and S + F	M and S + F
linear	1.332 N.S.	1.046 N.S.	1.394 N.S.
quadratic	8.095 N.S.	39.66 *	4.900 N.S.
cubic	25.278 *	4.813 N.S.	121.7 *
Total	1.085 N.S.	1.148 N.S.	1.245 N.S.

TABLE 7

Tissue Analysis for sodium and potassium

All concentrations in parts per million.

- F = without fertilizer

+ F = with fertilizer

	Sodium concentration	Potassium concentration
SEEDS		
O Beans	1.95	9.00
M "	2.33	10.75
S "	1.45	10.00
O Wheat	1.60	3.38
M "	0.94	3.88
S "	1.18	4.13
SHOOTS (6 weeks)		
O Beans - F	2.50	21.75
" + F	1.75	26.50
M Beans - F	2.90	26.50
" + F	2.65	22.00
S Beans - F	1.80	25.50
" + F	1.80	26.75
O Wheat - F	1.53	43.50
" + F	1.65	45.50
M Wheat - F	0.90	45.00
" + F	1.35	50.50
S Wheat - F	1.35	43.50
" + F	1.20	46.50
Reagent Blank 1	0.85	0
" " 2	0.73	0

TABLE 8

Tissue Analysis for Calcium and Magnesium

All concentrations in parts per million

- F = without fertilizer

+ F = with fertilizer

	Calcium concentration	Magnesium concentration
SEEDS		
O Beans	3.50	2.15
M "	3.00	2.30
S "	3.80	2.00
O Wheat	1.80	2.15
M "	2.00	2.00
S "	1.80	2.73
SHOOTS (6 weeks)		
O Beans - F	21.50	11.00
" + F	23.50	11.00
M Beans - F	12.00	8.50
" + F	27.00	12.25
S Beans - F	12.00	9.50
" + F	15.00	7.75
O Wheat - F	8.00	5.25
" + F	8.50	5.65
M Wheat - F	9.40	6.25
" + F	7.50	5.25
S Wheat - F	7.30	5.25
" + F	7.00	5.25
Reagent Blank 1	1.80	0.25
" " 2	2.00	0

TABLE 9

Tissue Analysis D) Nitrate - Nitrogen Concentrations

All values are expressed in parts per million nitrate nitrogen, i.e. micrograms nitrate-hitrogen per gram dry plant material.

F = fertilizer treatment

1) BEANS	
O seeds	0
M seeds	0
S seeds	0
5 - week plants:	
O Beans - F	1,464
O Beans + F	1,541
M Beans - F	1,619
M Beans + F	2,628
S Beans - F	1,567
S Beans + F	1,645
2) WHEAT	
O seeds	0
M seeds	15.5
S seeds	0
5 - week plants:-	
O wheat - F	5,834
O wheat + F	6,041
M wheat - F	6,093
M wheat + F	6,300
S wheat - F	6,040
S wheat + F	5,628

(4) Dry Weight Determinations

Sample plants were removed at random from bowls with and without fertilizer, twice weekly, as detailed in the Appendix under "Data Input". Two, three or four plants constituted a sample.

After removal, the roots were rinsed free of vermiculite using distilled water, then the shoot and root placed in separate labelled bags in a hot air oven at 80 °C for two days. This was long enough to obtain constant dry weights.

The samples were removed from the oven and placed in a desiccator until cool, then weighed accurately to three places of decimals. The weights are recorded in g. but transferred to computer punch-cards in mg., simply by ignoring the decimal points.

(5) Leaf Area Determinations

Measurement of leaf areas is important in many studies of plant growth and crop productivity, but remains a tedious and laborious process. For accurate determinations of small numbers of leaves relatively direct measurement by planimeter or the counting of projected squares is most suitable, but the time and work involved makes such methods impracticable for large numbers of leaves, as in these experiments. Some sacrifice in absolute accuracy is necessary when dealing with samples consisting of hundreds of leaves (Owen, 1968).

A photoelectric device called a "Leaf Area Meter" was used, this being most suitable for the rapid measurement of leaf areas. It consists basically of a dark box with a light source, separated by a screen of known area (100 or 400 cm^2) from a sensitive photocell which converts the flux of radiation into electric signals. Thus the change in radiation flux which occurs when leaves are placed flat on the screen can be measured and is directly proportional to the leaf area.

The 400 cm^2 screen was generally used as it enabled more leaf areas to be estimated at a time.

(6) Tissue Analysis

(A) Acid digestions

A strong oxidising mixture of the three acids, nitric, hydrochloric and perchloric, was used to digest samples of bean and wheat seeds, and shoots after six week's growth.

0.5 g dry samples were transferred to 250 ml. conical flasks on a sand-tray in a fume-cupboard. Then 40 ml. concentrated nitric acid, 10 ml. concentrated hydrochloric acid and 5 ml. concentrated perchloric acid was added to each flask, which was swirled gently to mix the contents thoroughly.

The flasks were heated carefully, with the sand-tray on 'low', in order to minimise foaming which would have resulted in a loss of sample. When foaming had ceased the rate of heating was increased, but not so much that copious nitric oxide fumes were lost. If nitric acid is lost too rapidly, acid is wasted and the oxidation is not carried as far as it should be: the nitric acid in the early stages is the only effective oxidising agent.

The digestions were continued until only a small volume of clear solution remained. After cooling, the neck of each flask was washed with about 10 ml. distilled water, the solution filtered and made up to 250 ml. with distilled water in a volumetric flask.

These solutions are now ready for analysis.

Analysis for Cations

Calcium, magnesium, sodium and potassium were determined in the solutions from the acid digestion technique. In all cases, sodium and potassium were determined using an 'Eel' Flame Photometer and calcium and magnesium by Atomic Absorption Spectrophotometry.

(B) Estimation of sodium and potassium by flame photometry (Dean, 1960)

An Eel Mark II flame photometer was used. Standard solutions were prepared and the instrument was calibrated for sodium then potassium determinations. Two ranges of standards were prepared for each element by dilution of the 1000 ppm stock solutions. 0-10 ppm and 10-100 ppm, for use depending on the concentration of these two elements in the sample solutions. It was found that the range most suitable for the plant digest solutions was 0-10 ppm for sodium and 10-100 ppm for potassium. Samples of the plant digest solutions were analysed directly.

(C) Estimation of calcium and magnesium by atomic absorption spectrophotometry (Allen, 1958; David, 1959)

A 'Hilger and Watts' Atomic Absorption Spectrophotometer was used. The instrument was set up as described in the instruction manual using an air/acetylene flame, then calibrated for calcium and magnesium respectively. A series of standard solutions to cover the range 0-100 ppm was prepared by dilution of the appropriate 1000 ppm stock solution. These were sprayed in turn into the acetylene flame and calibration curves constructed. When analysing for calcium, lanthanum chloride was added in equal proportion to the standard or plant digest solution in order to minimise phosphorus interference. The sample solutions were analysed directly, the scale reading being recorded and the concentration of each element obtained from the appropriate calibration curve.

Two reagent blanks were analysed for sodium, potassium, calcium and magnesium in the same manner.

The results are recorded in Tables 7 and 8, in all cases the concentrations being in parts per million (p.p.m.) or micrograms per ml/litre.

(D) Determination of Nitrate Nitrogen (Ulrich, 1958)

The standard method for the determination of nitrate in soil and plant extracts is based on the nitration of phenol-2:4-disulphonic acid by nitrates to form 6-nitrophenol-2:4-disulphonic acid, which gives rise to an intense yellow colour on the addition of alkali. The intensity of this colour is proportional to the nitrate concentration and is determined with a photo-electric colorimeter.

The standard method has however many disadvantages including that of the time required, interference by chloride ion, and the precipitation of some metallic hydroxides and phosphates under the test conditions.

Chloride in excess of 1 per cent of the dry plant material seriously interfered with the nitration process, so it is important to determine the chloride concentration of each sample before nitrate analysis. The chloride concentration in plant material may be estimated with sufficient sensitivity to determine whether silver sulphate or water only is required for nitrate extraction by titrating an aliquot of the water extract with silver nitrate using potassium chromate as indicator. Titration in this manner established that the chloride content of the samples ranged from 0.095 to 0.15 per cent of dry weight, and was therefore always much less than 1 per cent, a level which would not interfere with the nitrate determinations.

The nitrate concentration of water extracts of plant material may therefore be estimated accurately with phenoldisulphonic acid when the organic matter of the extract has been destroyed with hydrogen peroxide, (Johnson and Ulrich, 1950).

Reagents
- 25% $^{w}/v$ phenoldisulphonic acid
- Calcium carbonate suspension
- 30% hydrogen peroxide
- 1:1 ammonium hydroxide

Procedure

100 mg. samples of ground dried plant material were weighed into 100 ml. flasks and 30 ml. distilled water added, then they were placed on an automatic shaker for 15 minutes. The samples were filtered then 10 ml. aliquots of the water extract transferred to evaporating dishes, and 2 ml. of the calcium carbonate suspension and 1 ml. 30% hydrogen peroxide added. The evaporating dishes were covered and the contents digested on a steam bath for two hours. Timing here is critical. After uncovering, the samples were evaporated to dryness and left on the steam bath for an additional half-hour to destroy any residual hydrogen peroxide. Removal from the steam bath and cooling was followed by addition of 2 ml. of phenoldisulphonic acid. This reagent must be added rapidly, covering the entire residue at once. After ten minutes an excess of 1:1 ammonium hydroxide (20 ml.) was added, the solution cooled and made up to 50 ml. volume.

The colour of the solution after adding excess ammonium hydroxide should be pure yellow, as was usually found to be the case. A brown tinge in the solution is an indication of incomplete oxidation of organic matter in the oxidation step. Any such brown solutions were discarded.

The intensity of the yellow colour was measured with an 'Eel' photoelectric colorimeter using a blue filter.

A 50 microgram standard was prepared with 30 ml. of a 5 ppm nitrate nitrogen standard solution, aliquoting 10 ml. as with the extracts; a reagent blank was also prepared using distilled water.

50μg.

<u>NOTE</u>: Timing and temperature are critical throughout, but particularly in the digestion step where there is a direct effect on the nitration process and hence in the intensity of colour produced.

<u>Calculations</u>

$$\text{ppm } NO_3^{-}\text{-N} = \frac{\text{R-B x } \mu\text{g N in standard}}{\text{R std.}} \times \frac{30 \text{ ml.}}{\text{vol. of aliquot (10 ml.)}} \times \frac{1000}{\text{wt. sample in mg. (100)}}$$

where R = reading of sample

B = reading of blank

R std. = reading of standard

The results are presented in Table 9.

IX. DISCUSSION

The results will be considered in the order in which the experiments were carried out.

The preliminary seed studies demonstrated that the germination performance of the M seeds of beans and wheat was significantly different at the 5% level from that of the O and S seeds (Table 3). In fact, the M seeds showed suppression of germination to about half the final percentage shown by the O and S seeds (Figs. 1 and 2). It was observed that the M seeds always suffered heavy fungal attack, whereas only about half of the S seeds, and none of the O seeds were infected (Plate 3), although all samples received identical treatment. The extension of the plumule and radicle of M wheat seeds was markedly less and occurred more slowly than for the O and S wheat seeds, even when germination of the M seeds was successful (Table 4, Fig. 3), but this was not tested for significance.

A fundamental and important difference in the germination and early growth of seeds from the M sections as compared with seeds from the O and S sections, would seem to be indicated. The strong correlation between germination performance and degree of fungal attack suggests that this may be a causal factor:- M beans always suffered heavy fungal attack and a sour yeasty smell was associated with the M wheat seeds which did not germinate. The heavy fungal attack of the M seeds and their different germination performance may indicate some basic difference in their chemical composition and physiology of germination, or could just be a result of damp storage conditions and increased possibility of infection with fungal spores. However, the parallel behaviour of the beans and wheat suggests that there is a basic physiological or chemical difference in the M seeds. It would be possible to test this theory by many similar replicate experiments under sterile conditions after the seeds themselves had been treated with a seed dressing like copper sulphate solution, to remove any possible fungal or bacterial contamination.

It is possible that the heavy fungal attack on the M seeds and the intermediate attack on the S seeds indicates a richer nutrient status, resulting indirectly from eutrophication of the M and S farm ecosystems. The results of analysis (Table 7) show that the M seeds are higher in potassium but this difference is probably not significant. The nitrate analyses of the seed samples were inconclusive, probably because of an inefficient extraction procedure, or possibly because of low intrinsic free nitrate levels in the seeds (Table 9).

It is possible that the treatments on the O, M and S farm ecosystems have had an effect on the germination behaviour of the O, M and S "strains" of wheat and beans. If this were confirmed by more extensive and carefully controlled germination tests, it could have important implications for agricultural practice. A 50% reduction in germination on eutrophicated farmland would result in a reduction in final crop yield, or necessitate the use of twice as much seed to compensate for this reduction in germination.success. Both of these factors could cause financial loss to the farmer. However, there have been no significant differences in the crop yields on the three sections at Haughley so far, indicating saturation sowing levels.

It is necessary to consider the early growth of the seedlings, and the growth of mature established plants to flowering and fruiting, in order to determine whether the three different farming regimes have had any significant effect on the physiology of the crops. The growth physiology of O, M and S plants of beans and wheat with and without fertilizer was studied for six-weeks after germination. This time interval spanned the period of rapid exponential growth to flowering which occurred after six weeks.

The raw data collected was analysed by computer which produced cubic growth curves of best fit to the observed dry weight values, by regression analysis (see IV. Analytical Methods for Growth Analysis, and the Statistical Appendix). Analysis of variance of the regression equations indicated that there were significant differences both in the growth of the plants with and without fertilizer, and in the growth of the plants from the O, M and S sections (see Table A), but often only at the 20% level which is usually considered too low a level of significance for biological data. So only those experiments which showed significant differences at the 5% level will be considered.

(1) SIGNIFICANCE OF FERTILIZER TREATMENTS

There were significant differences in the progress curves of dry weight (Figs. 5 to 10), of:-

(i) S beans with and without fertilizer.

(ii) M wheat " " " "
significant in the cubic term.

(iii) S wheat with and without fertilizer,
significant in the quadratic term.

(iv) There were <u>no</u> significant differences
in the growth of O beans or wheat as
a result of fertilizer treatment.

It is most interesting that N.P.K. fertilizer addition does not cause a marked stimulation in the growth of O plants: the dry weight progress curves (Figs. 5 and 8) are almost coincident. However, where there are significant differences between the growth of M and S plants with and without fertilizer, the black and red curves (Figs. 6, 7, 9 and 10) are markedly divergent. The bean plants with fertilizer show an acceleration in growth one to two weeks before the plants without fertilizer; this does not occur in the wheat experiments.

Those differences in growth behaviour between O plants as compared with M and S plants, are well illustrated in Figs. 14 and 15, which give relative growth rate curves of quadratic nature derived from the cubic dry weight progress curves by differentiation. It is evident that the growth rates of O plants are not affected by fertilizer treatment: Fig. 15 shows that the growth rate of O wheat is actually depressed by fertilizer addition, although the difference is not significant. However, M and S plants show an increase in relative growth rate when fertilizer is added to the cultures. This is especially marked for M beans (Fig. 14) where, however, the growth rate of the fertilized plants begins to decline at 24 days when the growth rate of the unfertilized plants show slow initial growth, then an increase to a growth rate much higher than that ever shown by the fertilized beans.

(2) SIGNIFICANCE OF GROWTH OF PLANTS FROM THE THREE SECTIONS, O, M and S

There were significant differences in the growth of:-

(i) O and M beans without fertilizer;

(ii) O and S beans with fertilizer;

(iii) M and S wheat without fertilizer, significant in the quadratic term.

Comparison of the solid curves for O and M beans in Fig. 14 shows that the relative growth rate of the O beans without fertilizer, is consistently greater than that of the M beans without fertilizer. Comparison of the dotted lines for O and M beans shows that the growth of O beans with fertilizer lags behind that of M beans with fertilizer, but O beans show good recovery to a much greater final growth rate at 32 to 42 days.

Comparison of the relative growth rate progress curves of O and S beans in Fig. 14, shows that growth rates of the O plants are consistently higher than those of the S plants when no fertilizer is added to the cultures (solid lines); but the S plants show a stimulation in growth rate to almost the same level as the O plants when fertilizer is added (dotted lines).

Reference to Fig. 15 shows that the growth rate curves of O and M wheat without fertilizer (solid lines), follow a very similar pattern; but addition of fertilizer is necessary in order that S wheat can attain the same maximum growth rate at about 21 days. The growth rate peak occurs five days earlier in M wheat than in the other two types.

The relative growth rate of any plant is determined by the intraction of two components, one of which contains a term for leaf area while the other takes into account the rate of photosynthesis. These two components are the leaf area ratio (L.A.R.) and the net assimilation rate (N.A.R.) respectively, (Blackman, 1961). It is known that different factors in the environment have different effects on these two parameters. For example, nitrogenous fertilizers increase the leaf area ratio and thus the relative growth rate without any effect on the net assimilation rate; but phosphate fertilizers affect both parameters.

Figs. 11, 12 and 13 show the components of the growth rate curves in Figs. 14 and 15. It can be seen that the progress curves of L.A.R. and N.A.R. for O plants are very similar with and without fertilizer treatment;

but that addition of fertilizer to the O and M plants has caused alteration in the shape of the curves, and in general an increase in both the L.A.R. and N.A.R. peak values occurring earlier. However, these observations, though consistent with the expected result of adding an N.P.K. fertilizer to the cultures, were in most cases not significant and can only be regarded as a series of trends.

This work has indicated that:-

(1) Fertilizer has little effect on the growth of O plants; but appears to be necessary for an initial boost in the growth of M and S plants, though this good growth soon falls off to a level below that of the unfertilized plants.

(2) O plants show consistently better growth rates than M and S plants.

However, it is generally true to say that while the growth analysis has revealed a number of interesting facts, these must be considered with caution as much more work would be necessary to establish a difference between the growth of O, M and S plants beyond all reasonable doubt.

The results of the tissue analyses for sodium, calcium and magnesium are inconclusive (Tables 7,8).

The potassium analyses showed that fertilized plants always had higher levels of potassium than unfertilized plants, and that the potassium concentrations in M and S shoots were higher than in O shoots. This confirms that the potassium applied as fertilizer to half of the cultures was in fact taken up by the plants and used in their growth processes, and that the largest amounts were used by M plants.

The nitrate concentration of the shoots (Table 9) varies greatly. The wheat levels were consistently about double the bean levels. This indicates that there is a basic physiological difference between the beans and the wheat plants with respect to their nitrate balance and requirement. It is tempting to speculate on a fundamental difference between the nitrate metabolism of plants with symbiotic nitrogen-fixing bacteria and others, especially as only two individual bean plants had nodules (probably as a result of random, rare bacterial infection). It appears then that the beans may have some buffering mechanism against uptake of excess nitrate. As the nitrate concentrations of O shoots were the lowest and about the same with or without fertilizer, the buffering mechanism could be most effective in plants from the Organic Section. Since the M shoots grown with fertilizer have a nitrate content twice that of the M shoots without fertilizer, any such buffering mechanism seems to be relatively ineffective in these plants. A buffering mechanism similar to that suggested for heavy-metal tolerant plants could be involved, where the free ions are complexed with large organic molecules and so deactivated.

The occurrence of higher nitrate levels in cereals than in legumes could have important agricultural and human welfare implications. Cattle fed on legume mulch would have less chance of accumulating nitrate to dangerously high levels in their tissues,than cattle fed on cereal fodder, and hence mankind would run less risk of developing methaemoglobinurea nitrite poisoning by eating contaminated beef.

Had there been time to confirm the trends which have emerged from these experiments by an extended series of growth and nutrient analyses on beans and wheat grown in culture with two or three different levels of fertilizer, it would be possible to speculate about the kinds of adaptations which have been evolved by the plants on the three farm ecosystems at Haughley. It is conceivable that the M and S "strains" have evolved a physiological requirement of high nitrate and phosphate levels in order to sustain the same amount of growth shown by the O "strain" in the absence of fertilizer.

If it can be established beyond doubt that excessively high fertilizer application to farmland causes undesirable and dangerous changes, not only in the natural environment, but also in the physiology of the crop plants themselves as indicated above, it is possible that agricultural practice would be profoundly affected because of the economic incentives involved.

X. APPENDIX

TABLE 1.

Statistical Analysis of the Distribution of Dry and Imbibed Seed Weights. All weights in mg.

$\bar{x}$ = sample mean.
S.E. = standard error of the sample mean.
σ^2 = sample variance.
σ = standard deviation of the sample.
$\hat{\sigma}$ = estimated standard deviation of the population, based on (n-1) degrees of freedom.

1. BEANS

	Dry Weights (mg.)			Imbibed Weights (mg.)		
	O	M	S	O	M	S
$\bar{x}$	637.33	614.20	615.27	1200.61	1192.35	1311.38
S.E.	16.80	16.50	19.40	36.50	29.30	35.30
σ^2	12439.13	11993.05	15780.00	55986.62	36239.95	52265.57
σ	111.60	109.50	125.60	236.60	190.40	228.60
$\hat{\sigma}$	112.80	110.80	127.20	239.50	192.70	231.40

2. WHEAT

	Dry Weights (mg.)			Imbibed Weights (mg.)		
	O	M	S	O	M	S
$\bar{x}$	28.99	27.19	28.74	46.61	49.00	49.75
S.E.	0.98	0.89	1.06	2.00	1.97	2.49
σ^2	40.31	33.18	46.78	62.93	62.61	93.17
σ	6.35	5.76	6.84	7.93	7.91	9.65
$\hat{\sigma}$	6.40	5.83	6.90	8.20	8.10	9.90

TABLE 2.

Statistical Analysis of the Distribution of Dry and Imbibed Seed Weights. Between-Sample significance tests.

F = Snedecor's Variance Ratio.

t = Student's t test.

Dry weights were used to calculate F and t throughout.

1. BEANS

	F	t
O-M	1.037	0.097
O-S	1.269	0.849
S-M	1.316	0.419

2. WHEAT

	F	t
O-M	1.215	1.352
O-S	1.160	0.178
M-S	1.410	1.110

TABLE 3A

Timecourse of Germination

$\bar{x}$ = mean per cent germination recorded each day ± the standard error of the mean.

σ = standard deviation between replicate seed samples.

* = O and M significantly different at the 5% level.

** = O and M) AND) S and M) " " " " " "

N.S. = Not significantly different at the 5% level.

1. BEANS

TYPE	O		M		S		
DAY	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
1	41.30 ± 4.95	12.14	17.50 ± 3.10	7.60	29.10 ± 4.71	12.50	N.S.
2	56.70 ± 5.53	13.55	32.80 ± 4.49	11.00	53.40 ± 5.69	15.10	N.S.
3	66.70 ± 5.20	12.75	39.50 ± 3.26	8.00	55.70 ± 5.06	13.40	N.S.
4	78.20 ± 3.82	9.35	41.50 ± 3.04	7.40	72.40 ± 4.09	10.80	*
5	83.50 ± 3.53	8.64	41.80 ± 2.97	7.30	78.00 ± 4.97	13.10	**
6	86.33 ± 3.96	9.69	41.83 ± 2.97	7.27	81.66 ± 3.13	7.67	**
7	87.00 ± 4.05	9.92	41.83 ± 2.97	7.27	82.33 ± 3.13	7.67	**

TABLE 3B

2. WHEAT

TYPE	O		M		S		
DAY	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
1	61.00 + 3.48	9.84	4.80 ± 0.89	2.52	50.60 ± 4.99	13.21	**
2	76.60 ± 1.94	5.50	25.30 ± 1.06	2.99	74.60 ± 3.74	9.90	**
3	80.80 ± 2.06	5.85	34.90 ± 2.75	7.78	78.10 ± 3.84	10.15	**
4	82.80 ± 2.13	5.98	39.00 ± 2.76	7.81	79.60 ± 3.66	9.68	**
5	83.80 ± 2.22	6.27	39.80 ± 2.90	8.24	80.10 + 3.65	9.66	**
6	83.80 ± 2.30	6.50	40.30 ± 2.23	6.32	81.00 ± 3.68	9.75	**
7	85.25 ± 2.30	6.49	40.75 ± 2.45	6.92	81.86 ± 3.64	9.63	**

TABLE 4

All lengths in cm., and expressed per germinated seed.

$\bar{P}$ = mean plumule length.

$\bar{R}$ = mean total radicle length.

$\bar{r}$ = mean primary radicle length.

1. WHEAT

		O	M	S
DAY 3	$\bar{P}$	0.19	0.18	0.22
	$\bar{R}$	0.90	0.68	1.60
	$\bar{r}$	0.50	0.44	0.89
DAY 5	$\bar{P}$	1.17	0.85	1.30
	$\bar{R}$	7.76	6.59	8.34
	$\bar{r}$	2.98	2.80	3.30
DAY 7	$\bar{P}$	3.60	2.60	3.70
	$\bar{R}$	15.23	12.90	16.00
	$\bar{r}$	5.59	4.74	5.30

2. BEANS

DAY 3	$\bar{P}$	–	–	–
	$\bar{R}$	0.88	0.62	0.64
DAY 5	$\bar{P}$	0.56	0.76	0.73
	$\bar{R}$	2.44	2.10	2.37
DAY 7	$\bar{P}$	0.86	1.44	1.78
	$\bar{R}$	3.57	3.77	4.44

TABLE 5

Analysis of Nutrient Solutions Before and After use for one week

B = Before   A = After Use

	ppm Na	ppm K	pH
THEORETICAL CONCN.	31	78	
ACTUAL	32 B	76 B	5.65 B
CONCN.	33.5 B	75 B	5.20 B
BOWLS	32 A	78 B	5.20 B
WITHOUT	35 A	73 A	7.00 A
FERTILIZER	35 A	75 A	7.10 A
	33.5 A	72.5 A	7.15 A
	34 A	72 A	6.90 A
		76 A	
ACTUAL	33 B	100 B	6.30 B
CONCN.	32 B	98 B	6.20 B
BOWLS	33.5 A	85 A	7.20 A
WITH	34 A	82 A	7.40 A
FERTILIZER	35 A	81 A	7.40 A

TABLE 6

BASIC NUTRIENT SOLUTION

SALT	WEIGHT (g) FOR 10 LITRES DILUTED NUTRIENT SOLUTION	FINAL CONCENTRATION (Mg
KNO_3	2.020	140.0 N
$Ca(NO_3)_2$	6.560	78.0 K
$NaH_2PO_4 \cdot 2H_2O$	2.080	160.0 Ca
$MgSO_4 \cdot 7H_2O$	3.690	41.3 P 37.0 Mg
Ferric Citrate	0.245	5.6 Fe
$MnSO_4 \cdot 4H_2O$	0.020	0.55 Mn
$CuSO_4 \cdot 5H_2O$	0.002	0.064 Cu
$ZnSO_4 \cdot 7H_2O$	0.003	0.065 Zn
H_3BO_3	0.018	0.37 B
$(NH_4)_6MO_7O_{24} \cdot 4H_2O$	0.00035	0.019 MO

3. COMPUTER INPUT

For example, the data for experiment 1, 'O' beans minus fertilizer was

$M = 12$

$N = 43$ $\qquad T^{39}_{0.05} = 2.02$

t	7	7	7	7	11	11	11	11
w	0.336	0.515	0.419	0.457	0.522	0.452	0.520	0.516
a	5.200	7.500	8.000	10.90	44.80	30.40	36.00	48.00

t	14	14	14	time in days
w	0.495	0.618	0.605	dry weight in g.
a	70.80	78.00	71.20	leaf area in cm^2

and so on until day 42.

In punching the cards, the decimal points were ignored so that weights were in milligrams and areas in tenths of a cm^2. This means that the values of $^A/W$ in the print out should be multiplied by 100, and $^1/A \cdot {}^{dw}/dT$ by 10, and therefore the values of $^1/w \cdot {}^{dw}/dT$ by 1000.

4. COMPUTER OUTPUT

1. 'O' BEANS – F

$$\log_e W = a + bt + ct^2 + dt^3$$

```
FIRST  VARIABLE=  5.07294 +   .187283 T+ -.008498 TT+   .00013402 TTT
                  .4455690    .0688629     .0030788     .00004137

SECOND VARIABLE=  .927393 +   .680662 T+ -.025707 TT+   .00032487 TTT
                  .5294626    .0818287     .0036585     .00004916
```

$$\log_e A = e + ft + gt^2 + ht^3$$

LINEAR	1	9.40687	17.2750	31.7242
QUADRATIC	1	.996114	-1.22457	1.50543
CUBIC	1	.794248	1.92529	4.66699
RESID BET	7	.702041	.278888	1.82749
RESID WITH	32	2.24911	1.94872	2.33960
TOTAL	42	~~1964.81~~ 14.14838	~~42.0637~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	5.8171	6.0135	.12491	3.9512	4.5438	.14842
7.0	6.2442			4.3175		
7.0	6.0379			4.3820		
7.0	6.1247			4.6913		
11.0	6.2577	6.2831	.07387	6.1048	5.7365	.08778
11.0	6.1137			5.7170		
11.0	6.2538			5.8861		
11.0	6.2461			6.1738		
14.0	6.2046	6.3970	.07600	6.5624	6.3095	.09031
14.0	6.4265			6.6593		
14.0	6.4052			6.5681		
14.0	6.2025			6.4739		
18.0	6.6386	6.4721	.07633	6.6871	6.7448	.09070
18.0	7.0193			6.9470		
18.0	6.6921			6.6039		
21.0	6.3315	6.4992	.06957	6.4739	6.8930	.08267
21.0	5.8493			6.0776		
21.0	6.9334			7.1229		

1. OB-F

21.0	6.2615			6.5250		
25.0	6.8575	6.5375	.06370	7.0501	6.9530	.07569
25.0	6.6846			7.1655		
25.0	6.4232			6.3818		
25.0	6.5250			6.6695		
28.0	6.5294	6.5961	.06765	6.9078	6.9630	.08039
28.0	6.1137			6.7662		
28.0	6.7476			7.0975		
28.0	6.8046			7.1854		
32.0	6.9007	6.7551	.07507	7.0562	7.0297	.08921
32.0	6.3297			6.9078		
32.0	6.2672			6.5221		
32.0	7.1577			7.5175		
35.0	6.8721	6.9633	.07385	7.4360	7.1880	.08775
35.0	7.2108			7.7528		
35.0	6.9603			7.3588		
35.0	7.4731			7.6962		
39.0	7.0992	7.4007	.07508	7.5132	7.6435	.08922
39.0	7.3988			7.6069		
39.0	7.4905			7.6401		
39.0	7.0892			7.3778		
42.0	7.8804	7.8767	.11944	8.0340	8.2366	.14193
42.0	7.9977			8.2774		
42.0	8.1182			8.4207		
42.0	7.7138			7.9558		

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.08801	.03261	.36852	.03875
7.0				
7.0				
7.0				
11.0	.04897	.01782	.23303	.02118
11.0				
11.0				
11.0				
14.0	.02813	.01024	.15188	.01217
14.0				
14.0				
14.0				
18.0	.01160	.00731	.07098	.00869
18.0				
18.0				
21.0	.00765	.00881	.03076	.01047
21.0				
21.0				
21.0				
25.0	.01365	.00983	.00443	.01168
25.0				
25.0				
25.0				
28.0	.02658	.00893	.00515	.01061
28.0				
28.0				
28.0				
32.0	.05509	.00721	.03340	.00857
32.0				
32.0				
32.0				
35.0	.08491	.00983	.07505	.01169

1. OB-F

35.0				
35.0				
35.0				
39.0	.13593	.02031	.15788	.02413
39.0				
39.0				
39.0				
42.0	.18264	.03165	.24046	.03760
42.0				
42.0				
42.0				

DAY	OA/W	FA/W	SE	CONF	INT
7.0	.15476	.23000	.02729	.18099	.29230
7.0	.14563				
7.0	.19093				
7.0	.23851				
11.0	.85824	.57891	.04062	.50240	.66707
11.0	.67257				
11.0	.69231				
11.0	.93023				
14.0	1.4303	.91626	.06615	.79193	1.0601
14.0	1.2621				
14.0	1.1769				
14.0	1.3117				
18.0	1.0497	1.3135	.09524	1.1345	1.5207
18.0	.93023				
18.0	.91563				
21.0	1.1530	1.4827	.09798	1.2974	1.6944
21.0	1.2565				
21.0	1.2086				
21.0	1.3015				
25.0	1.2124	1.5152	.09168	1.3408	1.7121
25.0	1.6175				
25.0	.95942				
25.0	1.1554				
28.0	1.4599	1.4434	.09276	1.2677	1.6435
28.0	1.9204				
28.0	1.4190				
28.0	1.4634				
32.0	1.1682	1.3161	.09385	1.1395	1.5200
32.0	1.7825				
32.0	1.2903				
32.0	1.4330				
35.0	1.7575	1.2520	.08783	1.0866	1.4426
35.0	1.7194				
35.0	1.4896				
35.0	1.2500				
39.0	1.5128	1.2748	.09093	1.1038	1.4724
39.0	1.2313				
39.0	1.1614				
39.0	1.3344				
42.0	1.1660	1.4332	.16260	1.1396	1.8023
42.0	1.3228				
42.0	1.3532				
42.0	1.2738				

DAY (1/A)(DW/DT) SE

1. OB-F

7.0	.38263	.14002
7.0		
7.0		
7.0		
11.0	.08458	.03117
11.0		
11.0		
11.0		
14.0	.03070	.01148
14.0		
14.0		
14.0		
18.0	.00883	.00557
18.0		
18.0		
21.0	.00516	.00593
21.0		
21.0		
21.0		
25.0	.00901	.00651
25.0		
25.0		
25.0		
28.0	.01842	.00637
28.0		
28.0		
28.0		
32.0	.04186	.00632
32.0		
32.0		
32.0		
35.0	.06782	.00902
35.0		
35.0		
35.0		
39.0	.10663	.01816
39.0		
39.0		
39.0		
42.0	.12744	.02867
42.0		
42.0		
42.0		

② M BEANS-F

FIRST VARIABLE= 5.69434 + .074829 T+ -.004969 TT+ .00010503 TTT
.5285865 .0916250 .0046181 .00006987

SECOND VARIABLE= -1.58204 + .961992 T+ -.040557 TT+ .00056920 TTT
1.424497 .2469217 .0124455 .00018830

LINEAR	1	1.45373	6.22788	26.6807
QUADRATIC	1	.678988	-1.15414	1.96181
CUBIC	1	.150331	.814711	4.41528
RESID BET	6	.508919	-.032842	1.85847
RESID WITH	15	.888241	1.87913	8.28851
TOTAL	24	~~762.535~~ 3.680209	~~43.2048~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	6.0162	6.0107	.12197	3.3673	3.3599	.32871
7.0	6.2860			3.1781		
7.0	5.9216			3.6376		
7.0	5.8464			2.9957		
11.0	6.0913	6.0560	.08067	5.5910	4.8501	.21739
11.0	6.3226			4.7875		
11.0	6.1181			4.3820		
14.0	5.6836	6.0561	.08647	5.6058	5.4986	.23303
14.0	5.8805			6.0958		
14.0	5.7333			5.1705		
18.0	6.0799	6.0437	.08164	5.6204	5.9131	.22002
18.0	6.1506			6.0638		
18.0	6.3081			6.2265		
21.0	5.9135	6.0469	.07708	4.8040	6.0057	.20773
21.0	5.9687			6.1092		

2. MB-F

21.0	6.4313			7.0031		
25.0	6.3630	6.1003	.08713	6.5539	6.0136	.23481
25.0	5.7838			3.9120		
28.0	6.1356	6.1991	.09834	6.5511	6.0524	.26502
28.0	6.3044			6.4425		
32.0	6.8680	6.4418	.10066	7.0967	6.3233	.27127
32.0	6.1675			5.9915		
35.0	6.2785	6.7289	.10956	6.5903	6.8103	.29524
35.0	6.7441			7.0951		
39.0	7.4787	7.2844	.21919	7.7832	8.0134	.59071

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.02070	.03848	.47787	.10371
7.0				
7.0				
7.0				
11.0	.00363	.01843	.27637	.04967
11.0				
11.0				
14.0	-.00256	.01044	.16110	.02815
14.0				
14.0				
18.0	-.00198	.01139	.05522	.03069
18.0				
18.0				
21.0	.00507	.01325	.01167	.03570
21.0				
21.0				
25.0	.02329	.01225	.00141	.03301
25.0				
28.0	.04357	.01042	.02958	.02809
28.0				
32.0	.07944	.01660	.11495	.04474
32.0				
35.0	.11295	.02947	.21484	.07942
35.0				
39.0	.16646	.05398	.39583	.14546

DAY	OA/W	FA/W	SE	CONF INT	
7.0	.07073	.07059	.02041	.03858	.12919
7.0	.04469				
7.0	.10188				
7.0	.05780				
11.0	.60633	.29945	.05726	.20079	.44657
11.0	.21544				
11.0	.17621				
14.0	.92517	.57264	.11738	.37310	.87890
14.0	1.2402				
14.0	.56958				
18.0	.63158	.87753	.16984	.58558	1.3150
18.0	.91684				
18.0	.92168				
21.0	.32973	.95962	.17535	.65500	1.4059
21.0	1.1509				
21.0	1.7713				
25.0	1.2103	.91702	.18941	.59552	1.4121
25.0	.15385				
28.0	1.5152	.86356	.20131	.53051	1.4057

2-MB-F

28.0	1.1481				
32.0	1.2570	.88825	.21196	.53944	1.4626
32.0	.83857				
35.0	1.3659	1.0847	.28171	.63036	1.8666
35.0	1.4205				
39.0	1.3559	2.0730	1.0772	.69977	6.1410

DAY	(1/A)(DW/DT)	SE
7.0	.29317	.55969
7.0		
7.0		
7.0		
11.0	.01211	.06157
11.0		
11.0		
14.0	-.00447	.01827
14.0		
14.0		
18.0	-.00226	.01297
18.0		
18.0		
21.0	.00528	.01384
21.0		
21.0		
25.0	.02540	.01413
25.0		
28.0	.05045	.01656
28.0		
32.0	.08943	.02844
32.0		
35.0	.10413	.03743
35.0		
39.0	.08030	.04658

(3) S BEANS -F

FIRST VARIABLE=	5.32029 +	.174787 T+	-.008846 TT+	.00013203 TTT	
	1.433027	.2264621	.0103771	.00014345	
SECOND VARIABLE=	1.04407 +	.617963 T+	-.022004 TT+	.00026071 TTT	
	.8063369	.1274259	.0058390	.00008072	

LINEAR	1	.068375	1.02342	15.3183
QUADRATIC	1	.117462	-.620392	3.27669
CUBIC	1	.454560	.897619	1.77253
RESID BET	7	4.14228	-1.41064	.937359
RESID WITH	19	9.81007	4.12879	3.48009
TOTAL	29	~~1222.22~~ 14.59275	~~24.7850~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	6.3699	6.1556	.38649	4.1271	4.3810	.21747
7.0	6.3117			4.3944		
7.0	6.4677			4.4998		
11.0	5.8833	6.3483	.23055	5.6348	5.5262	.12972
11.0	6.2166			5.5607		
11.0	6.2265			5.2983		
14.0	6.1841	6.3957	.24055	6.2538	6.0982	.13535
14.0	6.0039			5.9915		
14.0	6.2422			6.6120		
18.0	6.4265	6.3703	.23909	6.5191	6.5587	.13453
18.0	6.6758			6.5132		
21.0	6.8916	6.3123	.21650	7.1309	6.7321	.12182
21.0	6.4052			6.7093		
21.0	5.3471			5.9402		
25.0	6.8265	6.2240	.20138	7.2313	6.8144	.11331
25.0	6.0307			6.8617		
25.0	6.7117			6.6871		
28.0	6.2066	6.1771	.21561	6.7334	6.8193	.12132
28.0	6.8233			6.8957		
28.0	6.2538			6.3969		
32.0	6.4568	6.1812	.23349	6.8752	6.8301	.13138
32.0	6.9256			7.2556		
32.0	6.0845			5.9135		
35.0	7.3877	6.2618	.22853	7.7354	6.8962	.12859

5

3.5B-F

35.0	4.1744			6.9117		
35.0	4.4886			7.2442		
39.0	7.5289	6.5135	.29305	7.6962	7.1422	.16489
39.0	6.1924			6.5624		
39.0	6.2106			6.5903		
42.0	7.3330	6.8382	.52095	7.5601	7.4996	.29313

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.07035	.10485	.34823	.05900
7.0				
7.0				
11.0	.02810	.05594	.22852	.03148
11.0				
11.0				
14.0	.00472	.03160	.15516	.01778
14.0				
14.0				
18.0	-.01535	.02406	.07924	.01354
18.0				
21.0	-.02208	.02914	.03873	.01639
21.0				
21.0				
25.0	-.01998	.03133	.00661	.01763
25.0				
25.0				
28.0	-.01008	.02773	-.00105	.01560
28.0				
28.0				
32.0	.01421	.02568	.01063	.01445
32.0				
32.0				
35.0	.04075	.04068	.03582	.02289
35.0				
35.0				
39.0	.08722	.08128	.09131	.04573
39.0				
39.0				
42.0	.13039	.12278	.14934	.06909

DAY	OA/W	FA/W	SE	CONF	INT
7.0	.10616	.16956	.06309	.07907	.36359
7.0	.14701				
7.0	.13975				
11.0	.77994	.43952	.09756	.27884	.69279
11.0	.51896				
11.0	.39526				
14.0	1.0722	.74266	.17200	.46195	1.1940
14.0	.98765				
14.0	1.4475				
18.0	1.0971	1.2073	.27792	.75315	1.9354
18.0	.84994				
21.0	1.2703	1.5216	.31718	.99248	2.3328
21.0	1.3554				
21.0	1.8095				
25.0	1.4989	1.8048	.34992	1.2129	2.6856
25.0	2.2957				
25.0	.97567				
28.0	1.6935	1.9005	.39453	1.2418	2.9087

3.SB-F

28.0	1.0751				
28.0	1.1538				
32.0	1.5196	1.9135	.43016	1.2069	3.0336
32.0	1.3910				
32.0	.84282				
35.0	1.4158	1.8859	.41496	1.2012	2.9609
35.0	15.446				
35.0	15.730				
39.0	1.1822	1.8750	.52903	1.0515	3.3435
39.0	1.4479				
39.0	1.4618				
42.0	1.2549	1.9376	.97184	.69296	5.4177

DAY	(1/A)(DW/DT)	SE
7.0	.41489	.53336
7.0		
7.0		
11.0	.06392	.12710
11.0		
11.0		
14.0	.00636	.04277
14.0		
14.0		
18.0	-.01271	.02071
18.0		
21.0	-.01451	.02004
21.0		
21.0		
25.0	-.01107	.01740
25.0		
25.0		
28.0	-.00530	.01441
28.0		
28.0		
32.0	.00743	.01356
32.0		
32.0		
35.0	.02161	.02193
35.0		
35.0		
39.0	.04652	.05093
39.0		
39.0		
42.0	.06729	.09067

(4)

O BEANS +F

FIRST VARIABLE=	5.53985 +	.130999 T+	-.006580 TT+	.00011437 TTT
	.8373745	.1290184	.0057565	.00007729
SECOND VARIABLE=	.722202 +	.723146 T+	-.027779 TT+	.00035323 TTT
	.7657822	.1179878	.0052643	.00007068

LINEAR	1	6.43816	12.0858	22.6874
QUADRATIC	1	1.30968	-1.17902	1.06139
CUBIC	1	.439828	1.35846	4.19576
RESID BET	7	2.60926	1.99541	2.29152
RESID WITH	21	3.01473	2.25263	2.41192
TOTAL	31	~~1462.68~~ 13.811658	~~32.6480~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	6.2538	6.1736	.23539	4.6347	4.5442	.21527
7.0	6.2785			4.0431		
7.0	6.3135			4.7095		
11.0	6.3421	6.3369	.13811	6.0403	5.7857	.12630
11.0	5.9713			5.8636		
11.0	6.3439			5.7683		
14.0	6.3404	6.3980	.14201	6.6386	6.3708	.12987
14.0	6.1527			6.3279		
14.0	6.1203			6.3279		
18.0	6.4473	6.4329	.14365	6.7452	6.7984	.13137
18.0	6.4441			6.6970		
18.0	6.4846			6.4378		
21.0	6.7935	6.4482	.13195	7.1389	6.9289	.12067

4.08+F

21.0	6.9460			7.4265		
25.0	6.7417	6.4893	.12159	7.1732	6.9581	.11120
25.0	6.5367			6.6958		
25.0	6.7190			6.9117		
28.0	7.0656	6.5597	.12854	7.3827	6.9456	.11755
28.0	6.4409			6.7382		
28.0	5.9216			6.4102		
32.0	6.4362	6.7415	.14142	6.3969	6.9917	.12933
32.0	5.1648			5.8579		
32.0	6.6821			7.1639		
35.0	6.9856	6.9678	.13865	7.3926	7.1476	.12680
35.0	7.7089			7.9157		
35.0	7.6416			7.7142		
39.0	7.2689	7.4248	.14119	7.6816	7.6261	.12912
39.0	7.2204			7.5412		
39.0	7.8450			8.1887		
42.0	8.3163	7.9080	.22462	8.3309	8.2621	.20541
42.0	7.6183			7.9010		
42.0	7.6487			7.9530		

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.05569	.06125	.38616	.05601
7.0				
7.0				
11.0	.02776	.03360	.24023	.03073
11.0				
11.0				
14.0	.01401	.01941	.15303	.01775
14.0				
14.0				
18.0	.00529	.01374	.06644	.01257
18.0				
18.0				
21.0	.00595	.01644	.02375	.01503
21.0				
25.0	.01644	.01832	-.00350	.01675
25.0				
25.0				
28.0	.03151	.01669	-.00169	.01526
28.0				
28.0				
32.0	.06122	.01363	.03041	.01246
32.0				
32.0				
35.0	.09070	.01860	.07673	.01701
35.0				
35.0				
39.0	.13962	.03812	.16817	.03487
39.0				
39.0				
42.0	.18351	.05928	.25900	.05421
42.0				
42.0				

DAY	OA/W	FA/W	SE	CONF	INT
7.0	.19808	.19604	.02633	.14905	.25784
7.0	.10694				
7.0	.20109				

4. DB+F

11.0	.73944	.57626	.04542	.49067	.67677
11.0	.89796				
11.0	.56239				
14.0	1.3474	.97318	.07886	.82489	1.1481
14.0	1.1915				
14.0	1.2308				
18.0	1.3471	1.4412	.11815	1.2193	1.7036
18.0	1.2878				
18.0	.95420				
21.0	1.4126	1.6172	.12177	1.3869	1.8857
21.0	1.6169				
25.0	1.5396	1.5980	.11088	1.3871	1.8410
25.0	1.1725				
25.0	1.2126				
28.0	1.3732	1.4708	.10789	1.2664	1.7083
28.0	1.3461				
28.0	1.6300				
32.0	.96154	1.2843	.10364	1.0893	1.5141
32.0	2.0000				
32.0	1.6190				
35.0	1.5023	1.1970	.09470	1.0186	1.4066
35.0	1.2298				
35.0	1.0754				
39.0	1.5108	1.2230	.09853	1.0376	1.4415
39.0	1.3782				
39.0	1.4101				
42.0	1.0147	1.4250	.18264	1.0971	1.8508
42.0	1.3268				
42.0	1.3556				

DAY	(1/A)(DW/DT)	SE
7.0	.28409	.30195
7.0		
7.0		
11.0	.04816	.05823
11.0		
11.0		
14.0	.01439	.02006
14.0		
14.0		
18.0	.00367	.00952
18.0		
18.0		
21.0	.00368	.01014
21.0		
25.0	.01029	.01149
25.0		
25.0		
28.0	.02142	.01161
28.0		
28.0		
32.0	.04767	.01144
32.0		
32.0		
35.0	.07578	.01628
35.0		
35.0		
39.0	.11416	.03360
39.0		

39.0		
42.0	.12878	.04952
42.0		
42.0		

4. OB+F

FIRST VARIABLE= 6.02835 + -.052694 T+ .006282 TT+ -.00010048 TTT
.7765465 .1490961 .0081331 .00012441

SECOND VARIABLE= -1.18243 + .945285 T+ -.036107 TT+ .00045733 TTT
1.479713 .2841033 .0154976 .00023706

5. M BEANS+F

LINEAR	1	2.69529	6.81118	17.2123
QUADRATIC	1	.009772	.230209	5.42350
CUBIC	1	.035290	-.160621	.731060
RESID BET	2	.213363	.221319	.247610
RESID WITH	9	.381745	.499911	1.91319
TOTAL	14	~~545.661~~ 3.33546	~~25.5277~~	

5. MB+F

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	5.8289	5.9328	.13162	4.3820	3.8222	.25081
7.0	6.0730			3.4657		
7.0	5.9322			3.6109		
11.0	6.3044	6.0751	.09878	5.6348	5.4554	.18822
11.0	5.8972			5.4806		
14.0	6.3544	6.2461	.09909	6.5453	6.2295	.18882
14.0	6.1800			6.4552		
14.0	5.8081			5.1705		
18.0	6.6983	6.5291	.07938	6.9058	6.8011	.15126
18.0	6.6921			6.9603		
18.0	6.8134			7.1213		
21.0	6.8763	6.7614	.11898	7.2004	6.9806	.22672
21.0	6.4216			6.5568		
21.0	6.6733			6.9177		
39.0	7.5725	7.5673	.23256	7.8966	7.8929	.44315

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.02048	.05487	.50701	.10456
7.0				
7.0				
11.0	.04903	.02015	.31694	.03840
11.0				
14.0	.06411	.01422	.20319	.02711
14.0				
14.0				
18.0	.07578	.02609	.08995	.04971
18.0				
18.0				
21.0	.07820	.03052	.03383	.05816
21.0				
21.0				
39.0	-.02122	.08491	.21571	.16180

DAY	OA/W	FA/W	SE	CONF	INT
7.0	.23529	.12116	.02369	.07865	.18665
7.0	.07373				
7.0	.09814				
11.0	.51188	.53815	.07897	.38910	.74431
11.0	.65934				
14.0	1.2104	.98349	.14478	.71036	1.3616
14.0	1.3168				
14.0	.52853				
18.0	1.2306	1.3126	.15479	1.0115	1.7034
18.0	1.3077				
18.0	1.3604				
21.0	1.3829	1.2451	.22008	.84244	1.8401
21.0	1.1447				
21.0	1.2769				
39.0	1.3827	1.3849	.47848	.64537	2.9718

DAY	(1/A)(DW/DT)	SE

5. MB+F

7.0	.16902	.45722
7.0		
7.0		
11.0	.09110	.03937
11.0		
14.0	.06519	.01773
14.0		
14.0		
18.0	.05773	.02093
18.0		
18.0		
21.0	.06281	.02586
21.0		
21.0		
39.0	-.01532	.06180

6

6. S BEANS + F

FIRST VARIABLE=	5.46889 +	.133857 T+	-.006538 TT+	.00010773 TTT
	.6521858	.1091762	.0053853	.00008050
SECOND VARIABLE=	.186864 +	.797091 T+	-.032216 TT+	.00042903 TTT
	.7298753	.1221815	.0060269	.00009009

LINEAR	1	1.01975	3.68418	13.3102
QUADRATIC	1	.066386	-.411020	2.54478
CUBIC	1	.158792	.632364	2.51829
RESID BET	6	1.11118	.937463	1.14704
RESID WITH	16	.839437	.536511	1.29598
TOTAL	25	~~1036.80~~ 3.19555	~~20.0163~~	

6. SB +F

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
7.0	6.2086	6.1225	.15964	4.6151	4.3351	.17865
7.0	6.3986			4.1431		
7.0	6.2285			4.4427		
11.0	6.0958	6.2936	.09555	5.0752	5.6278	.10693
11.0	5.9375			5.7930		
11.0	5.8551			5.2983		
14.0	6.3439	6.3570	.09941	6.5848	6.2091	.11125
14.0	6.2265			6.0868		
14.0	6.3986			6.3351		
18.0	6.4249	6.3882	.09449	6.7452	6.5987	.10575
18.0	6.8638			7.0984		
18.0	6.6039			6.5653		
21.0	6.6399	6.3942	.08763	6.9177	6.6919	.09806
21.0	6.5765			6.6490		
21.0	6.2729			6.1738		
25.0	6.5177	6.4122	.09441	6.6333	6.6829	.10566
25.0	6.5525			6.9489		
28.0	5.8916	6.4559	.10462	6.1485	6.6663	.11708
28.0	6.6161			6.6746		
28.0	6.0450			6.5396		
32.0	6.0845	6.5873	.10517	6.4615	6.7632	.11770
32.0	6.7105			6.6695		
35.0	7.1277	6.7636	.11515	7.5175	7.0153	.12887
35.0	6.7202			7.0665		
35.0	7.1245			7.5197		
39.0	6.9939	7.1352	.24246	7.3447	7.7228	.27135

DAY	DLOGW/DT	SE	DLOGA/DT	SE
7.0	.05816	.04704	.40914	.05264
7.0				
7.0				
11.0	.02912	.02325	.24408	.02602
11.0				
11.0				
14.0	.01413	.01297	.14732	.01452
14.0				
14.0				
18.0	.00320	.01254	.05434	.01403
18.0				
18.0				
21.0	.00178	.01461	.01163	.01635
21.0				
21.0				

6. SB+F

21.0				
25.0	.00894	.01367	-.00927	.01530
25.0				
28.0	.02110	.01160	.00208	.01298
28.0				
28.0				
32.0	.04636	.01836	.05326	.02055
32.0				
35.0	.07210	.03286	.11867	.03678
35.0				
35.0				
39.0	.11546	.06064	.24192	.06786

DAY	OA/W	FA/W	SE	CONF	INT
7.0	.20322	.16740	.02301	.12578	.22279
7.0	.10483				
7.0	.16765				
11.0	.36036	.51387	.04227	.43306	.60976
11.0	.86544				
11.0	.57307				
14.0	1.2724	.86251	.07382	.72187	1.0306
14.0	.86957				
14.0	.93844				
18.0	1.3776	1.2343	.10041	1.0421	1.4618
18.0	1.2644				
18.0	.96206				
21.0	1.3203	1.3467	.10159	1.1511	1.5754
21.0	1.0752				
21.0	.90566				
25.0	1.1226	1.3108	.10654	1.1069	1.5522
25.0	1.4864				
28.0	1.2928	1.2342	.11116	1.0234	1.4885
28.0	1.0602				
28.0	1.6398				
32.0	1.4579	1.1923	.10796	.98766	1.4394
32.0	.95981				
35.0	1.4767	1.2863	.12751	1.0466	1.5808
35.0	1.4138				
35.0	1.4847				
39.0	1.4202	1.7995	.37563	1.1657	2.7779

DAY	(1/A)(DW/DT)	SE
7.0	.34743	.27475
7.0		
7.0		
11.0	.05667	.04543
11.0		
11.0		
14.0	.01639	.01514
14.0		
14.0		
18.0	.00259	.01015
18.0		
18.0		
21.0	.00132	.01084
21.0		
21.0		
25.0	.00682	.01048

25.0		
28.0	.01710	.00961
28.0		
28.0		
32.0	.03888	.01574
32.0		
35.0	.05605	.02670
35.0		
35.0		
39.0	.06416	.03918

6. SB+F

7. O WHEAT-F

FIRST VARIABLE= 3.57638 + -.086171 T+ .009508 TT+ -.00013122 TTT
.4776619 .0847075 .0040651 .00005725

SECOND VARIABLE= 2.37207 + .209680 T+ -.002314 TT+ .00000549 TTT
.4390272 .0778561 .0037363 .00005262

LINEAR	1	54.7023	56.4883	58.3326
QUADRATIC	1	.037530	-.251979	1.69183
CUBIC	1	.808799	-.033865	.001418
RESID BET	7	1.98909	1.54911	1.65370
RESID WITH	21	2.32219	1.98498	1.98836

TOTAL 31 [illegible] [illegible]

7. OW-F

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	3.3673	3.3754	.22655	3.1781	3.1741	.20822
4.0	3.4965			2.8904		
7.0	3.1355	3.3941	.13573	3.5553	3.7284	.12475
7.0	3.4340			3.6889		
7.0	3.4012			4.0943		
11.0	3.6376	3.6043	.12785	4.6052	4.4059	.11751
11.0	3.6109			4.6052		
11.0	3.7612			4.7875		
14.0	4.0604	3.8735	.13746	4.8203	4.8692	.12634
14.0	3.8067			4.8203		
14.0	3.5835			4.4998		
21.0	4.8598	4.7447	.11656	5.6348	5.8059	.10713
21.0	4.7707			5.6058		
21.0	4.9053			5.7557		
26.0	4.9836	5.4571	.10543	5.9915	6.3563	.09691
26.0	4.1431			5.2781		
26.0	5.5452			6.5903		
28.0	6.2046	5.7375	.10833	6.9470	6.5499	.09956
28.0	6.0426			6.9078		
28.0	6.2897			7.0527		
28.0	6.1883			6.9373		
32.0	6.7912	6.2555	.11453	7.2668	6.8927	.10527
32.0	5.7557			6.5793		
32.0	6.4425			7.1229		
35.0	6.7523	6.5819	.11318	7.3576	7.1123	.10403
35.0	5.9814			6.5396		
35.0	6.4862			6.9847		
39.0	7.1884	6.8939	.13548	7.6592	7.3565	.12452
39.0	6.6809			7.2556		
39.0	6.5525			7.0211		
42.0	7.2027	7.0079	.22177	7.5066	7.5045	.20384
42.0	7.0699			7.5989		

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	-.01640	.05560	.19143	.05111
4.0				
7.0	.02765	.03762	.17810	.03458
7.0				
7.0				
11.0	.07538	.01942	.16077	.01785
11.0				
11.0				
14.0	.10290	.01177	.14813	.01082
14.0				
14.0				
21.0	.13957	.01437	.11978	.01321
21.0				

7. DW-F

21.0				
26.0	.14214	.01463	.10051	.01344
26.0				
26.0				
28.0	.13766	.01342	.09304	.01234
28.0				
28.0				
28.0				
32.0	.11925	.01238	.07849	.01138
32.0				
32.0				
35.0	.09717	.01791	.06792	.01647
35.0				
35.0				
39.0	.05672	.03407	.05429	.03132
39.0				
39.0				
42.0	.01811	.05089	.04441	.04677
42.0				

DAY	OA/W	FA/W	SE	CONF	INT
4.0	.82759	.81767	.08394	.66182	1.0102
4.0	.54545				
7.0	1.5217	1.3969	.08592	1.2307	1.5856
7.0	1.2903				
7.0	2.0000				
11.0	2.6316	2.2291	.12913	1.9783	2.5116
11.0	2.7027				
11.0	2.7907				
14.0	2.1379	2.7066	.16858	2.3807	3.0771
14.0	2.7556				
14.0	2.5000				
21.0	2.1705	2.8901	.15264	2.5921	3.2222
21.0	2.3051				
21.0	2.3407				
26.0	2.7397	2.4576	.11741	2.2273	2.7118
26.0	3.1111				
26.0	2.8437				
28.0	2.1010	2.2533	.11060	2.0366	2.4930
28.0	2.3753				
28.0	2.1447				
28.0	2.1150				
32.0	1.6090	1.8913	.09815	1.6995	2.1047
32.0	2.2785				
32.0	1.9745				
35.0	1.8318	1.6996	.08716	1.5292	1.8890
35.0	1.7475				
35.0	1.6463				
39.0	1.6012	1.5882	.09750	1.3996	1.8023
39.0	1.7767				
39.0	1.5977				
42.0	1.3552	1.6431	.16512	1.3359	2.0210
42.0	1.6973				

DAY	(1/A)(DW/DT)	SE
4.0	-.02006	.06869
4.0		
7.0	.01980	.02676

7. DW-F

7.0		
7.0		
11.0	.03381	.00910
11.0		
11.0		
14.0	.03802	.00504
14.0		
14.0		
21.0	.04829	.00529
21.0		
21.0		
26.0	.05784	.00661
26.0		
26.0		
28.0	.06109	.00682
28.0		
28.0		
28.0		
32.0	.06305	.00735
32.0		
32.0		
35.0	.05718	.01091
35.0		
35.0		
39.0	.03571	.02198
39.0		
39.0		
42.0	.01102	.03135
42.0		

8

8. M BEANS -F

FIRST VARIABLE=	2.84366 +	-.012743 T+	.008315 TT+	-.00014320 TTT
	.3391283	.0642088	.0031803	.00004591
SECOND VARIABLE=	1.57956 +	.300212 T+	-.004764 TT+	.00001350 TTT
	.3408893	.0645422	.0031968	.00004614

LINEAR	1	32.3372	34.8351	37.5260
QUADRATIC	1	.529755	1.37949	3.59221
CUBIC	1	.625106	-.058951	.005559
RESID BET	6	.606439	.163786	.668408
RESID WITH	9	.357158	.256965	.305222
TOTAL	18	~~508.232~~	~~42.0974~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	2.8904	2.9166	.15062	2.3026	2.7050	.15140
4.0	3.0445			2.6391		
7.0	3.2581	3.1128	.09066	3.9120	3.4522	.09113
7.0	3.0910			3.6889		

8. MB-F

7.0	3.1781			3.6889		
11.0	3.2189	3.5190	.09905	4.2195	4.3234	.09957
11.0	3.4965			4.1589		
13.0	3.7136	3.7687	.10691	4.6052	4.7068	.10747
13.0	3.4012			4.6052		
21.0	5.2040	4.9169	.09403	5.7038	5.9079	.09452
21.0	5.2523			5.7683		
26.0	5.5835	5.6166	.08964	6.5396	6.4016	.09010
26.0	5.7004			6.4862		
28.0	5.8201	5.8625	.09384	6.5681	6.5466	.09433
28.0	6.2246			6.9431		
32.0	5.7004	6.2584	.10454	6.3969	6.7500	.10508
32.0	6.2558			6.9256		
35.0	6.3063	6.4442	.11419	6.6771	6.8295	.11479
42.0	6.5280	6.3673	.24121	6.8244	6.7844	.24246

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	.04691	.04152	.26274	.04174
4.0				
7.0	.08262	.02760	.23549	.02774
7.0				
7.0				
11.0	.11821	.01376	.20030	.01383
11.0				
13.0	.13085	.00965	.18318	.00970
13.0				
21.0	.14705	.01188	.11797	.01194
21.0				
26.0	.12924	.01226	.07985	.01233
26.0				
28.0	.11611	.01171	.06516	.01177
28.0				
32.0	.07953	.01267	.03677	.01273
32.0				
35.0	.04307	.01813	.01633	.01823
42.0	-.07207	.04557	-.02854	.04581

DAY	OA/W	FA/W	SE	CONF	INT
4.0	.55556	.80934	.12999	.57485	1.1395
4.0	.66667				
7.0	1.9231	1.4041	.13575	1.1428	1.7252
7.0	1.8182				
7.0	1.6667				
11.0	2.7200	2.2352	.23609	1.7849	2.7991
11.0	1.9394				
13.0	2.4390	2.5551	.29130	2.0043	3.2574
13.0	3.3333				
21.0	1.6484	2.6939	.27012	2.1758	3.3353
21.0	1.6754				
26.0	2.6015	2.1924	.20956	1.7886	2.6875
26.0	2.1940				
28.0	2.1128	1.9818	.19833	1.6014	2.4527
28.0	2.0515				
32.0	2.0067	1.6349	.18225	1.2894	2.0731
32.0	1.9539				
35.0	1.4489	1.4700	.17900	1.1341	1.9052
42.0	1.3450	1.5176	.39035	.87743	2.6248

SWHEAT -F

FIRST VARIABLE=	2.86334 +	.034165 T+	.004054 TT+	-.00005746 TTT
	.4707864	.0839741	.0040670	.00005772
SECOND VARIABLE=	2.39648 +	.222817 T+	-.003197 TT+	.00002036 TTT
	.4457179	.0795026	.0038505	.00005465

LINEAR	1	54.4077	53.9659	53.5277
QUADRATIC	1	.001026	-.036328	1.28615
CUBIC	1	.146262	-.051812	.018354
RESID BET	7	1.63571	1.25716	1.80444
RESID WITH	17	1.90630	1.44079	1.37040
TOTAL	27	~~917.916~~	~~58.0870~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	3.2958	3.0612	.22232	3.1355	3.2379	.21048
4.0	2.7081			3.1781		

9.SW-F

7.0	3.5264	3.2814	.13300	3.8067	3.8065	.12591
7.0	3.1355			3.5835		
7.0	3.1781			3.6889		
11.0	3.5264	3.6532	.12581	4.6052	4.4877	.11911
11.0	4.0431			5.0752		
11.0	3.8918			4.7875		
14.0	4.0431	3.9786	.13558	5.2364	4.9451	.12836
14.0	4.0254			5.1358		
14.0	3.5553			4.6052		
21.0	4.5433	4.8366	.11943	5.0752	5.8541	.11307
21.0	4.6151			5.4638		
21.0	5.1930			5.8289		
26.0	5.7398	5.4824	.11530	6.7708	6.3860	.10916
26.0	5.5872			6.6490		
28.0	5.5568	5.7371	.11981	6.4362	6.5754	.11343
28.0	5.5607			6.4489		
28.0	5.5255			6.3969		
32.0	6.5695	6.2253	.12635	7.2356	6.9194	.11962
32.0	5.5872			6.2615		
35.0	7.2298	6.5619	.12349	7.7107	7.1510	.11691
35.0	6.8947			7.4731		
35.0	6.9305			7.4961		
39.0	6.8926	6.9537	.14264	7.5240	7.4305	.13505
39.0	5.9108			6.9078		
42.0	7.1989	7.1927	.22910	7.4955	7.6226	.21690
42.0	7.5126			7.6401		

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	.06384	.05495	.19821	.05202
4.0				
7.0	.08248	.03708	.18104	.03511
7.0				
7.0				
11.0	.10250	.01920	.15986	.01818
11.0				
11.0				
14.0	.11390	.01203	.14526	.01139
14.0				
14.0				
21.0	.12842	.01479	.11545	.01400
21.0				
21.0				
26.0	.12845	.01479	.09783	.01400
26.0				
28.0	.12605	.01355	.09164	.01283
28.0				
28.0				
32.0	.11711	.01281	.08071	.01213
32.0				
35.0	.10679	.01880	.07380	.01780
35.0				
35.0				
39.0	.08819	.03546	.06630	.03357
39.0				
42.0	.07063	.05264	.06196	.04984
42.0				

DAY OA/W FA/W SE CONF INT

9. SW-F

4.0	.85185	1.1933	.16201	.90214	1.5784
4.0	1.6000				
7.0	1.3235	1.6905	.13730	1.4301	1.9984
7.0	1.5652				
7.0	1.6667				
11.0	2.9412	2.3035	.17698	1.9663	2.6985
11.0	2.8070				
11.0	2.4490				
14.0	3.2982	2.6286	.21764	2.2164	3.1174
14.0	3.0357				
14.0	2.8571				
21.0	1.7021	2.7662	.20176	2.3803	3.2147
21.0	2.3366				
21.0	1.8889				
26.0	2.8039	2.4686	.17382	2.1353	2.8539
26.0	2.8914				
28.0	2.4093	2.3124	.16919	1.9889	2.6886
28.0	2.4308				
28.0	2.3904				
32.0	1.9467	2.0021	.15448	1.7079	2.3470
32.0	1.9625				
35.0	1.6174	1.8023	.13592	1.5430	2.1052
35.0	1.7832				
35.0	1.7605				
39.0	1.8802	1.6110	.14033	1.3463	1.9276
39.0	2.7100				
42.0	1.3453	1.5372	.21506	1.1523	2.0507
42.0	1.1360				

DAY	(1/A)(DW/DT)	SE
4.0	.05350	.04430
4.0		
7.0	.04879	.02167
7.0		
7.0		
11.0	.04450	.00928
11.0		
11.0		
14.0	.04333	.00594
14.0		
14.0		
21.0	.04642	.00608
21.0		
21.0		
26.0	.05203	.00717
26.0		
28.0	.05451	.00732
28.0		
28.0		
32.0	.05849	.00784
32.0		
35.0	.05925	.01125
35.0		
35.0		
39.0	.05474	.02333
39.0		
42.0	.04594	.03675
42.0		

0 WHEAT + F

FIRST VARIABLE=	3.00562 +	.028596 T+	.003601 TT+	-.00004956 TTT
	.8333318	.1629276	.0082051	.00011961
SECOND VARIABLE=	.842500 +	.457363 T+	-.013366 TT+	.00014894 TTT
	.4577065	.0894878	.0045066	.00006570

LINEAR	1	40.8546	49.9936	61.1771
QUADRATIC	1	.020597	-.282025	3.86167
CUBIC	1	.090988	-.273444	.821771
RESID BET	7	5.20265	1.56151	1.00440
RESID WITH	15	6.45782	3.40779	2.51327
TOTAL	25	~~768.034~~	~~69.3782~~	

10. DW+F

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	3.3322	3.1744	.36803	2.8332	2.4676	.20214
4.0	3.2958			2.3979		
4.0	3.1781			1.9459		
7.0	3.4340	3.3652	.23953	3.6889	3.4402	.13156
7.0	3.3673			3.8067		
7.0	3.0445			3.0445		
11.0	3.4340	3.6899	.27243	4.5218	4.4545	.14963
11.0	3.6109			4.5218		
13.0	3.7377	3.8770	.28995	4.9127	4.8566	.15926
13.0	3.7842			4.7875		
21.0	5.6348	4.7351	.24346	6.2146	5.9321	.13372
21.0	5.4250			5.9915		
21.0	5.2679			5.8289		
26.0	5.8230	5.3121	.22557	6.7452	6.3164	.12389
26.0	2.4849			5.2575		
28.0	5.0752	5.5413	.23190	5.9506	6.4394	.12737
28.0	5.7430			6.5793		
28.0	5.9189			6.6333		
32.0	5.6699	5.9838	.24050	6.1738	6.6720	.13209
32.0	6.2364			6.8244		
35.0	6.7044	6.2924	.23841	7.1989	6.8629	.13095
35.0	6.8783			7.5000		
35.0	6.5765			7.1974		
39.0	6.0450	6.6577	.31991	6.8330	7.1853	.17571
39.0	6.4907			7.0901		
42.0	7.0605	6.8865	.54151	7.4265	7.5092	.29742

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	.05502	.10445	.35759	.05737
4.0				
4.0				
7.0	.07172	.06870	.29214	.03773
7.0				
7.0				
11.0	.08982	.03366	.21738	.01849
11.0				
13.0	.09709	.02385	.18537	.01310
13.0				
21.0	.11426	.03092	.09305	.01698
21.0				
21.0				
26.0	.11532	.03005	.06439	.01650
26.0				
28.0	.11367	.02742	.05919	.01506
28.0				
28.0				
32.0	.10679	.02807	.05950	.01542
32.0				
35.0	.09851	.04307	.06911	.02365
35.0				
35.0				
39.0	.08331	.07994	.09445	.04391
39.0				
42.0	.06878	.11697	.12283	.06425

DAY	OA/W	FA/W	SE	CONF	INT
4.0	.60714	.49321	.12168	.29524	.82393

ID- DW+f

4.0	.40741				
4.0	.29167				
7.0	1.2903	1.0779	.17307	.77182	1.5052
7.0	1.5517				
7.0	1.0000				
11.0	2.9677	2.1481	.39227	1.4692	3.1406
11.0	2.4865				
13.0	3.2381	2.6634	.51768	1.7777	3.9904
13.0	2.7273				
21.0	1.7857	3.3104	.54027	2.3575	4.6485
21.0	1.7621				
21.0	1.7526				
26.0	2.5148	2.7301	.41280	1.9933	3.7390
26.0	16.000				
28.0	2.4000	2.4550	.38162	1.7767	3.3921
28.0	2.3077				
28.0	2.0430				
32.0	1.6552	1.9901	.32084	1.4232	2.7830
32.0	1.8004				
35.0	1.6397	1.7691	.28273	1.2688	2.4668
35.0	1.8620				
35.0	1.8607				
39.0	2.1991	1.6949	.36347	1.0850	2.6477
39.0	1.8209				
42.0	1.4421	1.8640	.67661	.87609	3.9659

DAY	(1/A)(DW/DT)	SE
4.0	.11156	.19556
4.0		
4.0		
7.0	.06654	.06332
7.0		
7.0		
11.0	.04181	.01942
11.0		
13.0	.03645	.01239
13.0		
21.0	.03451	.00963
21.0		
21.0		
26.0	.04224	.01304
26.0		
28.0	.04630	.01398
28.0		
28.0		
32.0	.05366	.01645
32.0		
35.0	.05568	.02621
35.0		
35.0		
39.0	.04915	.05336
39.0		
42.0	.03690	.07309

11. M WHEAT + F

FIRST VARIABLE=	2.89514 +	.050372 T+	.001486 TT+	-.00001056 TTT
	.6705618	.1240770	.0063004	.00009209
SECOND VARIABLE=	1.00970 +	.434741 T+	-.013866 TT+	.00016991 TTT
	.7618085	.1409607	.0071578	.00010463

LINEAR.	1	30.6668	34.7850	39.4562
QUADRATIC	1	.169699	-.523372	1.61415
CUBIC	1	.003569	-.057419	.923900
RESID BET	6	1.38832	1.27970	2.21715
RESID WITH	9	2.68301	2.67438	3.03759
TOTAL	18	~~470.347~~	~~47.2490~~	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	3.2958	3.1197	.30676	2.4849	2.5377	.34850
4.0	2.9957			2.7081		
7.0	3.0910	3.3169	.18122	2.8904	3.4318	.20588
7.0	3.2581			3.0445		
7.0	3.2958			3.4657		
11.0	3.9120	3.6150	.17807	4.7875	4.3403	.20230
11.0	3.8286			4.6821		
11.0	3.4965			4.6052		
14.0	3.9890	3.8626	.19537	5.2364	4.8447	.22196
14.0	3.8712			4.9416		
14.0	3.6636			4.7875		
21.0	3.7612	4.5105	.20941	4.1589	5.5981	.23791
21.0	5.4596			6.1738		
28.0	4.3438	5.2388	.26685	5.4293	6.0418	.30316
32.0	6.2558	5.6827	.28066	6.9470	6.2907	.31885
35.0	6.0186	6.0258	.26182	6.6490	6.5253	.29745
39.0	6.8309	6.4935	.23670	7.4097	6.9541	.26891
42.0	7.4230	6.8497	.33694	7.7493	7.3984	.38279
42.0	5.9940			6.5793		

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	.06175	.07970	.33197	.09054
4.0				
7.0	.06962	.05293	.26560	.06013
7.0				
7.0				
11.0	.07923	.02786	.19138	.03165
11.0				

11. MW +F

14.0	.08577	.02051	.14641	.02330
14.0				
14.0				
21.0	.09881	.02633	.07718	.02991
21.0				
28.0	.10875	.02145	.05790	.02437
32.0	.11304	.01988	.06931	.02259
35.0	.11559	.03099	.08858	.03520
39.0	.11810	.05969	.12853	.06781
42.0	.11932	.08849	.16920	.10053
42.0				

DAY	OA/W	FA/W	SE	CONF	INT
4.0	.44444	.55876	.10115	.37998	.82165
4.0	.75000				
7.0	.81818	1.1217	.11996	.89318	1.4086
7.0	.80769				
7.0	1.1852				
11.0	2.4000	2.0653	.21704	1.6511	2.5835
11.0	2.3478				
11.0	3.0303				
14.0	3.4815	2.6699	.30783	2.0885	3.4131
14.0	2.9167				
14.0	3.0769				
21.0	1.4884	2.9672	.36669	2.2805	3.8607
21.0	2.0426				
28.0	2.9610	2.2322	.35152	1.5961	3.1218
32.0	1.9962	1.8368	.30423	1.2908	2.6139
35.0	1.8783	1.6479	.25462	1.1858	2.2902
39.0	1.7840	1.5850	.22140	1.1771	2.1342
42.0	1.3859	1.7309	.34417	1.1333	2.6437
42.0	1.7955				

DAY	(1/A)(DW/DT)	SE
4.0	.11052	.14325
4.0		
7.0	.06207	.04754
7.0		
7.0		
11.0	.03836	.01413
11.0		
11.0		
14.0	.03213	.00855
14.0		
14.0		
21.0	.03330	.00981
21.0		
28.0	.04872	.01240
32.0	.06154	.01483
35.0	.07014	.02155
39.0	.07451	.03914
42.0	.06893	.05337
42.0		

.3377039	.0707140	.0038752	.00006136

12. SW+F

LINEAR	1	42.7494	51.6462	62.3947
QUADRATIC	1	.833373	-.789573	.748075
CUBIC	1	.437790	-.475697	.516888
RESID BET	6	1.13813	.089389	.397327
RESID WITH	10	.742451	.716781	.750165
TOTAL	19	-511.970	64.8071	

DAY	OLOGW	FLOGW	SE	OLOGA	FLOGA	SE
4.0	3.4012	3.1712	.17697	2.4849	2.4163	.13824
4.0	3.1355			2.0794		
4.0	3.2958			2.3026		
7.0	3.2189	3.1591	.11491	3.6636	3.2876	.08976
7.0	3.1781			3.6376		
7.0	2.7081			3.2189		
11.0	3.3673	3.3705	.13608	4.1589	4.2098	.10630
11.0	3.2581			4.1589		
13.0	3.3322	3.5574	.14273	4.3820	4.5861	.11149
13.0	3.5835			4.6821		
21.0	5.0173	4.6759	.12634	5.6348	5.7103	.09869
21.0	5.3132			5;8749		
21.0	4.7875			5.4806		
26.0	4.7362	5.5287	.13938	5.9402	6.2638	.10888
28.0	5.6802	5.8711	.14481	6.3801	6.4878	.11312
28.0	6.0137			6.9508		
32.0	6.5667	6.5182	.14274	7.0630	6.9834	.11150
35.0	6.5511	6.9417	.15298	7.1033	7.4280	.11950
35.0	7.3428			7.8192		
39.0	7.4372	7.3773	.28697	8.0659	8.1688	.22417

DAY	DLOGW/DT	SE	DLOGA/DT	SE
4.0	-.03159	.05558	.31954	.04342
4.0				
4.0				
7.0	.02217	.03480	.26279	.02719
7.0				
7.0				
11.0	.08111	.01613	.20097	.01260
11.0				
13.0	.10513	.01270	.17599	.00992
13.0				
21.0	.16480	.01824	.11559	.01425
21.0				
21.0				
26.0	.17254	.01542	.10996	.01205

28.0	.16927	.01455	.11462	.01137	
28.0					
32.0	.15181	.02299	.13582	.01796	
35.0	.12917	.03853	.16209	.03010	
35.0					
39.0	.08624	.06772	.21095	.05290	

12-SW+F

DAY	OA/W	FA/W	SE	CONF	INT
4.0	.40000	.47004	.07217	.33892	.65190
4.0	.34783				
4.0	.37037				
7.0	1.5600	1.1371	.11337	.91950	1.4061
7.0	1.5833				
7.0	1.6667				
11.0	2.2069	2.3147	.27331	1.8000	2.9766
11.0	2.4615				
13.0	2.8571	2.7976	.34646	2.1489	3.6420
13.0	3.0000				
21.0	1.8543	2.8133	.30840	2.2275	3.5532
21.0	1.7537				
21.0	2.0000				
26.0	3.3333	2.0857	.25223	1.6121	2.6985
28.0	2.0137	1.8526	.23277	1.4176	2.4211
28.0	2.5526				
32.0	1.6428	1.5924	.19721	1.2231	2.0730
35.0	1.7371	1.6264	.21587	1.2258	2.1577
35.0	1.6104				
39.0	1.8751	2.2067	.54945	1.2984	3.7503

DAY	(1/A)(DW/DT)	SE
4.0	-.06721	.12356
4.0		
4.0		
7.0	.01949	.03059
7.0		
7.0		
11.0	.03504	.00885
11.0		
13.0	.03758	.00671
13.0		
21.0	.05858	.00912
21.0		
21.0		
26.0	.08273	.01330
28.0	.09137	.01440
28.0		
32.0	.09534	.01827
35.0	.07942	.02789
35.0		
39.0	.03908	.03688

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