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The Effects of Wide Variations in Soil and Weather on the Growth and Nutritive Value of Turnip Greens

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by

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INTRODUCTION

Crop response to weather has been a subject of interest in plant science for many decades. Much has been written on the subject, and many experimental projects have been directed toward a better understanding of crop-weather relationships. In the late 1800's and early 1900's, investigators were particularly prolific on the subject of crop-weather relations. A selected and annotated bibliography published by the United States Department of Agriculture, entitled "The Influence of Weather on Crops", lists approximately 2400 papers and bulletins published between 1900 and 1930. More recently, there has been a revival of interest in crop-weather studies because of the increased awareness of the necessity of studying the whole environmental picture if sound predictions are to be made about the performance of any crop.

Statistical Procedure

There are certain, basic characteristics of the study of soil and weather effects on the growth and nutritive value of plants which are common to both laboratory investigations and field studies. It seems pertinent to present, briefly, these points of similarity since strong emphasis is given to them in the Soils-Weather Project.

Error. Control of error variation is essential in order that the errors do not mask the differences in response or relationships being studied. Material for experimentation should be well selected biologically, thus reducing error; steps should be taken to reduce errors of measurement (growth), errors of chemical determination, and errors of sampling. Only when error variation is reduced to a point where it is small relative to the true variation among plants treated differently, can one establish the existence of a treatment difference or relationship and make a sound inference. Of course, error can not be eliminated, but often it can be reduced by modifying experimental procedures and/or techniques. Further advantage is to be gained if the design of the experiment is such that

unavoidable errors are randomly distributed. The results of research undertaken to reduce error variability in this project have been presented in earlier progress reports,

Range of response. Once error variations are reduced to a satisfactory level, it would be desirable to observe the widest possible variability in plant response due to an environmental factor or group of factors. In studying crop-weather relationships, the researcher is attempting to establish one or more response curves, the character of which can be expressed in a mathematical function. If plant response were studied over a ten degree temperature range, the relationship between temperature and response might be characterized best by a straight line. With a wide range of temperature "treatment", the relationship might be found to be a curve; that is, a unit increase in temperature would not have the same effect on response at all temperature levels. The latter relationship should be more nearly correct, and would have a much larger area of application. The cooperation, in the Soils-Weather Project, of five experiment stations ranging from Puerto Rico to Texas and Oklahoma, makes it possible to study crop-environment relationships under a wide range of soil properties, weather factors and plant responses.

Models. Cooperators in Soils-Weather project work with various mathematical models which are expected to be descriptive of the relationships between given weather factors, say, and certain measures of plant response. Because of the inter-correlations between measured responses within a plant, there are many imperical formulae which will fit any set of observed data closely. Yet no one of a number of such formulae would necessarily be expressive of the true functional relationship existing between some weather factor or group of factors and plant response. For predictive purposes, an imperical formula will often be quite satisfactory even though no cause-effect relationship exists between the measured predictors and predictand. The purpose of this project, however, is to establish

the existence and nature of fundamental relationships which will be indicative of the cause-effect relations. It would seem more logical, therefore, to have plant physiologists, horticulturalists, soils specialists and so forth develop a theoretically sound hypothetical model. This could be done in cooperation with a statistician who could assist in the mathematical formulation which, admittedly, might be quite complex. The model then should be put to a test by determining the extent to which the observed data fit the mathematical model. Once a reasonably good model is developed, minor changes could be made. This procedure should lead, upon successive testing against the data, to a mathematical form which is not only descriptive of the observed phenomena but, more important, is fundamentally sound. The cooperators in the Soils-Weather project, representing research scientists in plant science and allied fields, have a unique opportunity to pool their knowledge in the formulation of such models or hypotheses.

From this brief discussion of the importance of models and the suggestion that each model must be tested against the concordant sets of observational data, it follows that the results to be presented in subsequent sections of this report should not be considered as final. Changes will come as more data are accumulated and as the models are altered to conform with the best thinking of the cooperating research workers.

Variations in Nutritive Value and Weather Factors

Generally speaking, real variation in nutritive value from sampling day to sampling day has been considerably larger than the combined error variation from chemical determinations and field sampling. Significant differences between the nutritive levels of crops in different plantings within a season have been less prominent with the exception of dry matter and carotene and riboflavin. Variation in nutritive content among seasons has been generally non-significant.

On the average over many seasons, it appears that the time of harvest is more important than where the plants are grown in obtaining crops of high vitamin content. In a given season, differences in vitamin content from location to location may be as marked as the content from time to time within a station, but no consistency has been observed. Thus, weather effects are more prominent than soil effects.

The average vitamin contents of turnip greens are shown by stations in Table 1, along with the ranges and standard deviations. For every vitamin studied the range of observations within stations is considerably greater than the mean differences among stations. While the ranges for a given vitamin do overlap to a considerable extent among stations, it is clear from these data that use of observations from all five stations effectively extends the range of observed response. If the Texas station were omitted, for example, the over-all range of observed response in ascorbic acid content would have been reduced from 2744 mg. per 100 gms. of dry material to 1694 mg. If North Carolina were omitted the observed range in thiamine content would have been reduced from 1654 mcg. per 100 gms. of dry material to 1491 mcg. Thus, while variation in vitamin response is greater within stations than between them, each station contributes to extension of the range of observed vitamin response. The standard deviations given in Table 1 are indicative of the variability of vitamin response within each station. A small standard deviation means that the observations were less variable.

Table 2 presents average values and ranges of the four factors which appear most consistent in their effects on vitamin content from station to station. On the average Oklahoma had the least amount of radiation, North Carolina had less moisture in the soil, and Puerto Rico observed the highest soil temperatures. Here as in vitamin response, inclusion of five stations in the experiment makes it possible to study crop-weather relationships under a wide range of conditions. As a result, response curves should be more basic in character and have greater applicability within the region.

Table 1 . Mean Ascorbic Acid, Riboflavin, Thiamine and Carotene Content of Turnip Greens (Dry Basis) With Range and Standard Deviation Shown by Stations, (1949).

Station		Ascorbic Acid mg./100 gms.	Riboflavin mcg./100 gms.	Thiamine mcg./100 gms.	Carotene mg./100 gms.
Ga.	mean	1202	2931	1522	59.86
	range	954-1497	1897-3651	1168-2337	38.90-77.17
	st'd dev.	141	402	234	8.92
N.C.	mean	1127	2225	1898	45.06
	range	655-2242	1160-3528	956-2610	29.78-70.76
	st'd dev.	274	667	445	9.70
Okla.	mean	1027	2416	1344	41.97
	range	692-1298	2556-3706	1172-1860	27.20-61.30
	st'd dev.	154	846	204	9.17
P. R.	mean	1085	2223	1637	37.51
	range	740-2648	1286-3656	994-2485	12.61-60.70
	st'd dev.	341	546	336	12.32
Texas	mean	1185	2698	1455	49.21
	range	935-3679	2056-3850	1124-2016	36.11-64.95
	st'd dev.	176	665	372	8.56
Combined Mean		1125	2499	1571	46.72

Table 2. Daily Means of Selected Weather Factors for the Three Days Preceding Sampling with Range.

Station		Days from planting	Solar Radiation (gm. cal./cm^2 per day)	Soil Moisture (atmosphere's tension)	Soil Temperature (degrees F)
Ga.	mean	55	428	2.2	72
	range	34-87	125-752	0.3-11.8	56-85
N. C.	mean	63	520	(6.0)1/	71
	range	40-97	208-747	0.3-15.0	63-75
Okla.	mean	62	368	(0.211)2/	68
	range	49-88	129-557	0.0-1.09	48-88
P. Rico	mean	50	479	(0.82)2/	80
	range	36-75	210-631	0.0-2.80	78-83
Texas	mean	49	414	1.0	68
	range	41-99	103-673	0.1-6.0	48-83
Combined	mean	56	442	---	72

1/ Soil moisture at 12" depth.

2/ Inches precipitation.

EFFECT OF WEATHER ON THE VITAMIN CONTENT OF TURNIP GREENS

The effects of selected weather factors on the vitamin content of turnip greens are presented in this section. Various functions of six weather factors have been tested against plant response as measured by the ascorbic acid, riboflavin, thiamine and carotene content of crops grown at five locations.

Models

There are two criteria for judging which of two or more mathematical models is best. The most common criterion is the reduction in variability of the measured response associated with the weather factors involved in the model. Under this criterion, a weather factor or set of weather factors which accounts for, say, 60 per cent of the variation in response is considered to be good. That is, it is desirable to explain as large a portion of variation in vitamin content as possible. A second criterion of a good model is that the weather factor or factors included in the model give consistent results year after year and from station to station. If consistent results are not obtained from a model year by year or station by station, the model certainly cannot be considered as fundamental.

This inconsistency may be due, in part, to selection of correlated weather factors. A factor such as air temperature, which is not limiting to response may, never-the-less, be highly correlated with an unknown weather factor which is limiting. If these two weather factors are highly correlated in one season, and not so highly correlated in another season, use of air temperature in the model will lead to inconsistencies among seasons or stations. Apparent inconsistency of a weather factor in explaining variations in response may also be due to the occurence of unusual or infrequent weather phenomena. While it is desirable to observe a wide range of weather conditions, observation of large samples is essential. If a small sample of weather conditions is observed, extreme or

infrequent conditions may be included in the sample which carry too much weight as compared with the few normal conditions observed. This leads to inconsistency.

Weather Factors

General. It is assumed that a given response, Y, is the result of one or more mutually independent effects as measured by selected weather factors (X_1, X_2, X_3, etc.). It is assumed further that the effects are additive in their action of modifying the response. It was reported in the "Annual Progress Report on the Soils-Weather Project, 1949", that while sometimes accounting for large and statistically significant portions of the variability in response, the linear model did not adequately define the weather-response relationship for the purpose of the Soils-Weather project. For this reason curvilinearity has been introduced in each of the five models tested this year.

Since the true curvilinear relationship existing between the effect of a given weather factor and the vitamin or mineral response is unknown, two types of curvilinearity have been introduced. The first is where the response is a steadily increasing or decreasing function of a weather factor. The second type is where response reaches a maximum or minimum and then returns to the initial level.

The five models tested include certain combinations of the following factors:

1. days from planting
2. radiation
3. soil moisture
4. soil temperature
5. radiation x soil temperature
6. air temperature range
7. soil moisture x soil temperature
8. evaporation
9. wind flow
10. logarithm of radiation
11. square of soil temperature
12. logarithm of soil temperature
13. square of radiation

Each model was tested against the vitamin responses at every station, resulting in a total of 120 regression equations which could then be checked for consistency from station to station. One model proved particularly successful in explaining the variability in response as measured by ascorbic acid and riboflavin content of turnip greens. A second model was effective in explaining variation in carotene content of the plants. A third model explained a considerable amount of the variability in thiamine content, though the effect of any one factor was not consistent from station to station. The remaining two models were neither effective in explaining response nor consistent among the five stations and will not be discussed.

Table 3 presents, in a general way, the relative merit of each of four models in explaining the variability in ascorbic acid content of turnip greens at each of the stations. The bar charts included on the right-hand-side of the table show what per cent of the observed variability in ascorbic acid content is explained by the weather factors included in each model. Consider model I for Georgia as an example. Six factors are involved in the model as indicated by the presence of a number or an "X" in appropriate cells. These six factors, taken in this combination, accounted for 30 per cent of the variability in ascorbic acid content of plants sampled during the year. Soil moisture was the most effective factor (number 1) as measured by the size of the standard partial regression coefficient. Solar radiation was second in importance (number 2). The interaction of radiation and soil moisture (number 3) was next in importance. That is, some of the variability in ascorbic acid content could be explained by the fact that radiation did not have the same effect at all levels of soil moisture. This was explained variability above and beyond that associated with the radiation effect and soil moisture effect per se (so called "main" effects). Soil temperature and air temperature (number 6) were about equally ineffective in explaining variability in ascorbic acid content. Days from planting, used here as an

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Table 3. Percentage Reduction in the Variability of Ascorbic Acid Content of Turnip Greens (mg./100 gms, dry basis) Attributable to Selected Factors.[1]

Station	Model	Days from Planting	Solar Radiation	(Solar Radiation)^2	Log (Solar Radiation)	Radiation x Soil Moist	Soil Moisture	Soil Temperature	Log (Soil Temp.)	Soil Temp. x Soil Moist	(Soil Temp.)^2	Air Temp. (range)
Ga.	I	X	2			3	1	6				6
	II	X	3			X	1	6		2		
	IV	X			1		X	X			6	
	V	X	1	2			X		X			
			X	X								
									X			
N.C.	I	6	2			X	6	1				X
	II	6	X			6	1	6		2		
	IV	6			6		X	2			1	
	V	6	1	2			6		X			
			X	X								
									X			
Okla.	I	X	1			X	6	2				X
	II	6	6			3	2	X		1		
	IV	X			6		X	2			1	
	V	6	2	1			X		6			
			X	X								
									X			

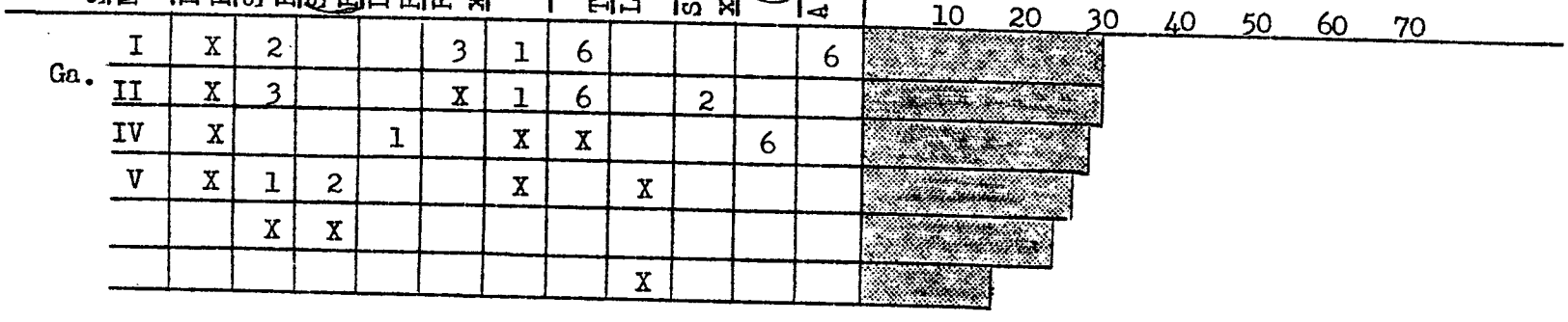

Table 3 . Percentage Reduction in the Variability of Ascorbic Acid Content of Turnip Greens (mg./100 gms, dry basis) Attributable to Selected Factors. (Continued).

Station	Model	1 Days From Planting	2 Solar Radiation	13 (Solar Radiation)^2	10 Log (Solar Radiation)	5 Radiation x Soil Moisture	3 Soil Moisture	4 Soil Temperature	12 Log (Soil Temperature)	7 Soil Temperature x Moisture	11 (Soil Temp.)^2	6 Air Temperature (range)	Percent Reduction
P.R.	I	X	X			2	1	X				6	
	II	X	X			3	1	6		2			
	IV	X			X		6	1			6		
	V	X	1	2			X		6				
			X	X									
									X				
Tex.	I	X	6			X	6	1				X	
	II	6	6			6	1	X		2			
	IV	6			X		X	2			1		
	V	6	1	3			6		2				
			X	X									
									X				

10 20 30 40 50 60 70

1/ Factors are ranked in order of relative importance for each regression model; 1 = best; 2 = second best; 3 = third best; 6 = worst; X = neither very good nor very poor.

adjustment for maturity, was neither very effective nor very ineffective (indicated in Table 3 by an "X"). It should be kept in mind that the relative importance of each factor in a given model, as indicated by the numbers in the cells, is based to some extent on the particular combination of factors involved in the model. Thus solar radiation is second in effectiveness in model I for Georgia. Model II has the same set of factors as model I except that the product of soil temperature and soil moisture has replaced air temperature. In the latter model the second most effective factor is the soil temperature x soil moisture interaction rather than solar radiation. It is clear, them, that in Table 3 the effectiveness of each factor depends to some extent on the factors with which it is combined in the model. The first line below the line designated as model V (Georgia) indicates the effectiveness of the linear and quadratic effects of solar radiation alone on ascorbic acid content. Solar radiation (in this functional form) accounts for 24 per cent of the variability in ascorbic acid content. Though important, then, something is to be gained by knowledge of other weather factors in addition to radiation. This type of summary can be made for each station on the basis of results given in Table 3. However, it would make the report unduly long. Let us consider only the most pertinent results from this point.

First, the differences in per cent reduction in variability of ascorbic acid content from station to station are large. The best model, from the point of view of accounting for large portions of variability in response, explains 30 per cent of the variation or less at Georgia, North Carolina and Oklahoma. At Puerto Rico and Texas reductions of 55 to 57 per cent were obtained using the same models. This is due, in part, to the fact that different degrees of correlation exist among the weather factors at the several stations. It is probable too that the particular weather effects studied were more limiting to ascorbic acid response at Puerto Rico and Texas than at the other stations. It should be clear that the criterion of reduction in variability of the measured response associated with the weather factors

involved in the model is not sufficient, though large reductions are favorable.

Second, two weather factors are particularly consistent in their effect among stations. These factors are radiation and soil temperature. While not always contributing most to explaining variability in ascorbic acid content, the regression coefficients were markedly consistent in sign and magnitude. This will be discussed in greater detail in next section.

Table 4 presents the relative merit of each of the four models in explaining the observed variability in riboflavin response at all stations. A detailed discussion of the general results for ascorbic acid (Table 3) was given to show how the summary may be interpreted. Table 4 is of the same type and only the most pertinent results are to be mentioned. The weather factors accounted for larger portions of the variability in riboflavin response than they did for ascorbic acid response. The reductions range from 40 to 90 per cent. The two factors most consistent among all stations in explaining variability in riboflavin content were day from planting (i.e.: maturity) and solar radiation.

The same sort of general summary for carotene is given in Table 5. Again the reductions were large, ranging from 35 to 85 per cent of the variability observed in carotene content. The most consistent factors were days from planting, solar radiation and soil temperature.

Table 6 gives the percentage reduction in variability of vitamin content of turnip greens attributable to the best one and the best combination of two factors studied. Judging from the size of these reductions as compared with the reductions shown in Tables 3, 4 and 5, it is apparent that some factors included in each model are not efficient. In many cases, two factors account for nearly as much of the variability in response as five or six factors as shown earlier. Selection of the most effective weather factors is made possible by this sort of comparison. The effect of specific factors are to be discussed in greater detail in succeeding sections where each vitamin is considered independently.

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Table 4. Percentage Reduction in the Variability of Riboflavin Content of Turnip Greens (mcg./100 gms, dry basis) Attributable to Selected Factors. /1

Station	Model	Days From Planting	Solar Radiation	(Solar Radiation)^2	Log (Solar Radiation)	Radiation x Soil Moisture	Soil Moisture	Soil Temperature	Log (Soil Temperature)	Soil Temp. x Soil Moisture	(Soil Temp.)^2	Air Temp. (range)
Ga.	I	1	X			6	X	2				X
	II	3	X			X	2	6		1		
	IV	1			2		X	3			6	
	V	3	1	2			6		6			
			X	X								
		4										
							X					
N.C.	I	6	X			2	X	X				1
	II	6	X			X	1	6		2		
	IV	6			6		X	2			1	
	V	6	2	1			X		3			
			X	X								
		X										
Okla.	I	X	1			6	6	X				X
	II	X	2			6	X	1		6		
	IV	6			X		6	2			1	
	V	X	6	2			6		1			
			X	X								
		X										

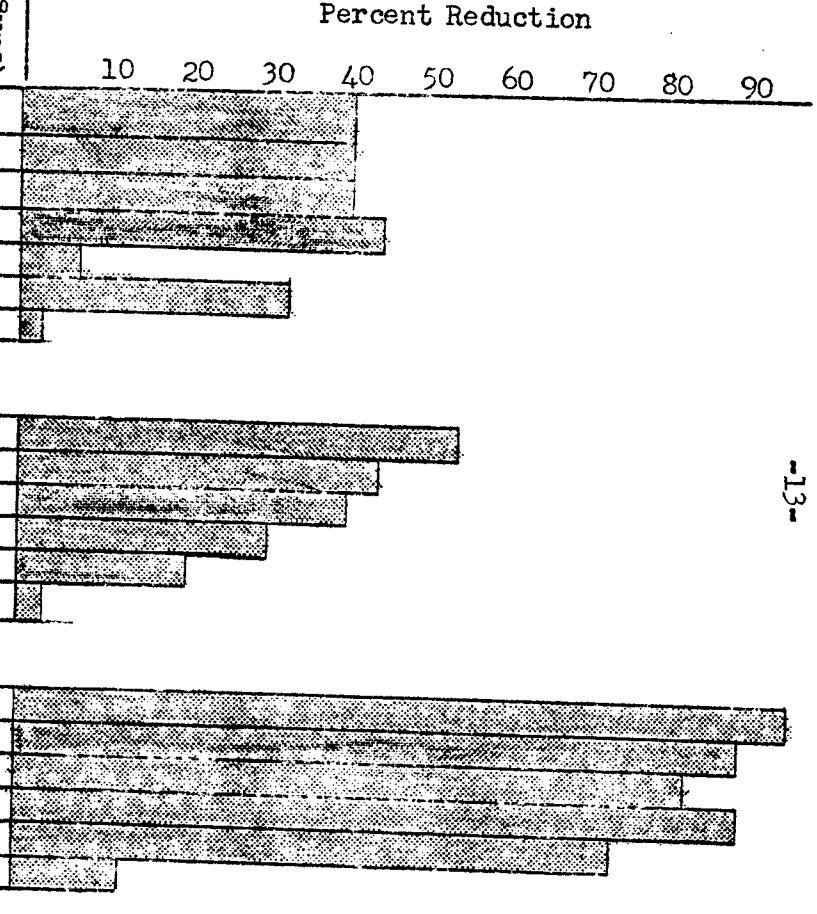

Table 4. Percentage Reduction in the Variability of Riboflavin Content of Turnip Greens (mcg./100 gms, dry basis) Attributable to Selected Factors. (Continued).

Station	Model	Days From Planting	Solar Radiation	(Solar Radiation)^2	Log (Solar Radiation)	Radiation x Soil Moisture	Soil Moisture	Soil Temperature	Log (Soil Temperature)	Soil Temp. x Soil Moisture	(Soil Temperature)^2	Air Temp. (range)	Percent Reduction
P.R.	I	X	X			2	1	X				6	
	II	X	X			3	2	6		1			
	IV	1			X		X	6			X		
	V	X	2	1			X		X				
			X	X									
		X											
Tex.	I	2	1			6	X	X				X	
	II	X	3			6	1	X		2			
	IV	X			X		X	2			1		
	V	X	X	1			X		6				
			X	X									
		X											
							X						

10 20 30 40 50 60 70 80 90

/1 Factors are ranked in order of relative importance for each regression model; 1 = best; 2 = second best; 3 = third best; 6 = worst; X = neither very good nor very poor.

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Table 5 . Percentage Reduction in the Variability of Carotene Content of Turnip Greens (mg./100 gms, dry basis) Attributable to Selected Factors. /1

Station	Model	Days From Planting	Solar Radiation	(Solar Radiation)^2	Log (Solar Radiation)	Radiation x Soil Moisture	Soil Moisture	Soil Temperature	Log (Soil Temperature)	Soil Temperature x Soil Moisture	(Soil Temp.)^2	Air Temperature (range)
Ga.	I	1	6			6	6	3				2
	II	2	6			6	X	3		1		
	IV	2			3		X	1			6	
	V	3	1	2			6		X			
								X			X	
		X										
					X							
N.C.	I	X	3			2	1	6				X
	II	X	X			2	3	6		1		
	IV	X			6		6	1			2	
	V	X	1	2			6		X			
								X			X	
		X										
					X							
Okla.	I	X	1			6	X	2				X
	II	6	X			3	2	X		1		
	IV	X			X		6	2			1	
	V	X	2	1			X		X			
								X			X	
		X										
					X							

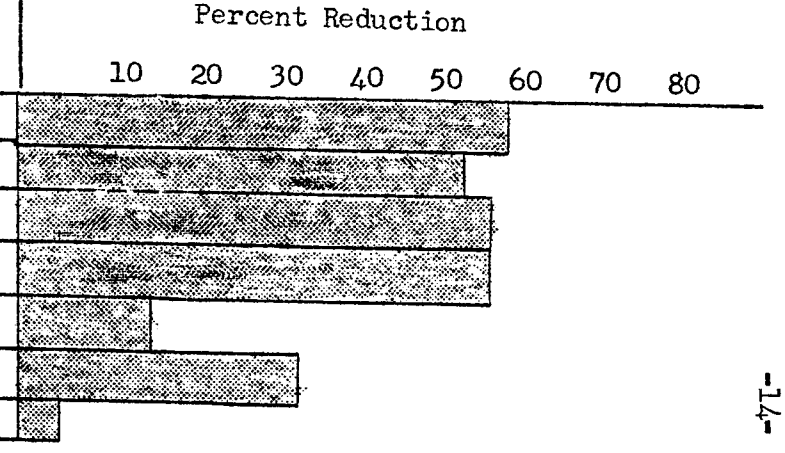

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Table 5. Percentage Reduction in the Variability of Carotene Content of Turnip Greens (mg./100 gms, dry basis) Attributable to Selected Factors. (Continued).

Station	Model	Days From Planting	Solar Radiation	(Solar Radiation)^2	Log (Solar Radiation)	Radiation x Soil Moisture	Soil Moisture	Soil Temperature	Log (Soil Temperature)	Soil Temperature x Soil Moisture	(Soil Temperature)^2	Air Temp. (range)	Percent Reduction
P.R.	I	X	3			2	1	6				X	
	II	X	X			3	2	6		1			
	IV	X			X		X	1			2		
	V	X	2	1			X		X				
								X			X		
		X											
					X								
Texas	I	3	2			1	6	X				X	
	II	2	1			6	X	X		3			
	IV	2			3		6	X			1		
	V	2	1	X			6		X				
								X			X		
		X											
					X								

1/ Factors are ranked in order of relative importance for each regression model; 1 = best; 2 = second best; 3 = third best; 6 = worst; X = neither very good nor very poor.

Table 6 . Percentage Reduction in Variability of Vitamin Content (dry basis) of Turnip Greens Attributable to the Best Single Factor and the Best Combination of Two Factors by Stations (1949).

Station		Days From Planting	Radiation (08-08)	Soil Moist. (8" depth)	Soil Temp. (8" depth)	Air Temp. (range)	Log Radiation (08-08)	[Soil Temp. (8" depth)]^2	Radiation^2 (08-08)	Reduction (per cent)
Ascorbic Acid (mg./100 gms.)										
Ga.	O /1						X			24
	T		X		X					26
N.C.	O					-X				16
	T		X			-X				22
Okla.	O								-X	7
	T									-
P.R.	O			X						23
	T			X	-X					32
Texas	O				-X					48
	T				-X	X				54
Riboflavin (mcg./100 gms)										
Ga.	O	-X								34
	T	-X			X					35
N.C.	O						X			34
	T						X	-X		40
Okla.	O							-X		85
	T		-X						-X	90
P.Rico	O	-X								46
	T	-X				X				47
Texas	O							-X		14
	T	-X						-X		36

/1
O = Best One
T = Best Two

Table 6 . Continued.

Station		Days From Planting	Radiation (08-08)	Soil Moisture (8" depth)	Soil Temperature (8" depth)	Air Temperature (range)	Log Radiation (08-08)	[Soil Temperature]^2 (8" depth)	[Radiation]^2 (08-08)	Reduction (percent)
Thiamine (mcg./100 gms)										
Ga.	O							X		24
	T	X						X		50
N.C.	O		X							32
	T	X	X							48
Okla.	O								-X	22
	T		-X						-X	65
P.Rico	O				-X					21
	T				-X			-X		34
Texas	O				-X					14
	T	-X			-X					26
Carotene (mg./100 gms)										
Ga.	O	-X								37
	T	-X				-X				52
N.C.	O	-X								23
	T	-X		-X						25
Okla.	O	-X								12
	T	-X	-X							20
P.Rico	O	-X								22
	T		-X						-X	60
Texas	O							-X		59
	T	-X						-X		77

Before discussing the effects of weather factors on nustitive value in a more detailed manner, it should be of interest to note the extent to which various weather factors are correlated. The correlation coefficients among selected weather factors are given by stations in Table 7. The correlations observed between some weather factors are not entirely compatible with common beliefs. Others merely serve to substantiate those beliefs. Note, for example, the consistency of the correlation between solar radiation and soil temperature among stations. These two factors are quite highly correlated. That is, as radiation increases soil temperature increases, as is commonly known. However, the relationship observed between soil moisture and soil temperature at North Carolina and Texas were not as commonly expected. As soil moisture increased, soil temperature also increased. It was to be expected, also, that as the range of air temperature increased, soil temperature would decrease because a wide range in air temperature would be indicative of variable temperature conditions over a short period of time. This would not be conducive to increasing soil temperature. However, the situation was reversed at the Puerto Rico station. Differences between the types of weather affecting response at the different stations are well illustrated by the correlation between solar radiation and soil moisture at Georgia and Texas. Increased radiation had very slight effect on the soil moisture level at Georgia. At Texas, however, increased radiation was accompanied by increased soil moisture. Evidently, the field plots in Texas were subjected to a shower type of precipitation which was increased by intense radiation. The Georgia plots evidently were not.

Factors Affecting Ascorbic Acid. As mentioned in the general discussion, solar radiation and soil temperature were the two factors which were most consistent in their effect on the ascorbic acid response of turnip greens. The model which included these variables is shown at the top of Table 8. The ascorbic acid content

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Table 7 . Correlation Between Three Days Sums [1] of Selected Weather Factors by Stations (1949).

Georgia	Soil Moisture (8")	Soil Temp. (8")	Air Temp. (range)	Evaporation	Wind Flow
Solar Radiation (08-08)	-.09	.68	.29	.91	.02
Soil Moisture (8")		-.01	.11	-.13	-.16
Soil Temperature (8")			-.23	.76	.24
Evaporation					.23

North Carolina	Soil Moisture (12")	Soil Temp. (8")	Air Temp. (range)	Wind Flow
Solar Radiation (08-08)	.35	.62	-.18	.28
Soil Moisture (12")		.64	-.52	.34
Soil Temperature (8")			-.41	.14

Oklahoma	Precipitation	Soil Temp. (8")	Air Temp. (range)	Relative Humidity	Wind Flow
Solar Radiation (08-08)	-.14	.87	.07	.24	-.52
Precipitation		.09	.55	.70	-.15
Soil Temperature (8")			-.43	.46	-.50
Relative Humidity					-.62

Table 7 . (Continued).

Puerto Rico	Precipitation	Soil Temperature (8")	Air Temperature (Range)	Relative Humidity	Wind Flow
Solar Radiation (08-08)	-.72	.44	.17	-.76	.49
Precipitation		-.52	-.50	.66	.09
Soil Temperature (8")			.63	-.64	.17
Relative Humidity					-.39

Texas	Soil Moisture (8")	Soil Temperature (8")	Air Temperature (Range)	Evaporation	Wind Flow
Solar Radiation (08-08)	.54	.72	.36	.72	.06
Soil Moisture (8")		.47	.30	.38	-.03
Soil Temperature (8")			-.13	.56	.31
Evaporation					.12

/1 Three day sums were used except for soil moisture and soil temperature; the latter were based on a 24-hour period.

Table 8 . Standard Partial Regression Coefficients for the One Model Which Was Most Consistent Among All Stations for Each Constituent (1949).

Model 1/: $Y = a + b_1X_1 + b_2X_2 + b_3(X_2^2) + b_4X_3 + b_5(\log X_4) + E$

Ascorbic Acid:

	X_1	X_2	X_2^2	X_3	$\log X_4$
Ga.	0.1834	0.6718	-0.2984	-0.1441	0.1526
N. C.	0.1094	1.2784	-0.8636	(0.1366) 2/	-0.3332
Okla.	-0.0116	1.3758	-1.5976	(0.1894) 3/	-0.0160
P. Rico	0.2239	-3.6713	3.4892	(0.2042) 3/	-0.0091
Texas	-0.1209	0.8061	-0.7360	0.1515	-0.7961

Riboflavin:

Ga.	-0.5732	0.8391	-0.7382	0.0828	0.1168
N.C.	-0.4098	-3.1160	3.5249	(0.9885) 2/	-1.5299
Okla.	-0.2467	-0.0154	-0.3457	(-0.0237) 3/	-0.5065
P.Rico	-0.6957	2.1314	-2.4032	(-0.2949) 3/	-0.3128
Texas	-0.3824	0.4391	-1.1873	0.3734	0.1196

1/

X_1 = days from planting

X_2 = radiation (08-08)

X_3 = soil moisture (8" depth)

X_4 = soil temperature (8" depth)

2/

Soil moisture at 12" depth.

3/

Used precipitation in order to utilize greater number of observations.

Table 8. (Continued)

Model[1]: $Y = a + b_1X_1 + b_2(\log X_2) + b_3X_3 + b_4X_4 + b_5(X_4^2) + E$

Carotene:

	X_1	$\log X_2$	X_3	X_4	X_4^2
Ga.	-0.5066	-0.3909	-0.1221	0.5467	-0.0002
N. C.	-0.5248	-0.0620	(0.0681)[2]	10.1863	-10.1710
Okla.	-0.1353	-0.1158	(0.0481)[3]	6.8525	-6.9913
P. Rico	-0.4325	-0.5149	(-0.3177)[3]	-1.3089	1.2091
Texas	-0.4920	-0.4217	-0.0125	0.2447	-0.5679

Model[1]: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5(X_2X_3) + b_6(X_3X_4) + E$

Thiamine:

	X_1	X_2	X_3	X_4	(X_2X_3)	(X_3X_4)
Ga.	0.5169	0.0070	-0.9484	0.3704	0.2844	0.6933
N. C.	0.4232	0.5754	(5.6876)[2]	0.5781	-1.0308	-5.2336
Okla.	0.2567	-0.7288	(-0.7705)[3]	0.1231	0.1575	0.3103
P.Rico.	-0.1387	-0.7115	(-1.2507)[3]	-0.5170	0.8623	-0.0254
Texas	-0.2809	-0.2684	5.1736	-0.1410	0.0652	-5.0671

1/
X_1 = days from planting

X_2 = radiation (08-08)

X_3 = soil moisture (8" depth)

X_4 = soil temperature (8" depth)

2/ Soil moisture at 12" depth.

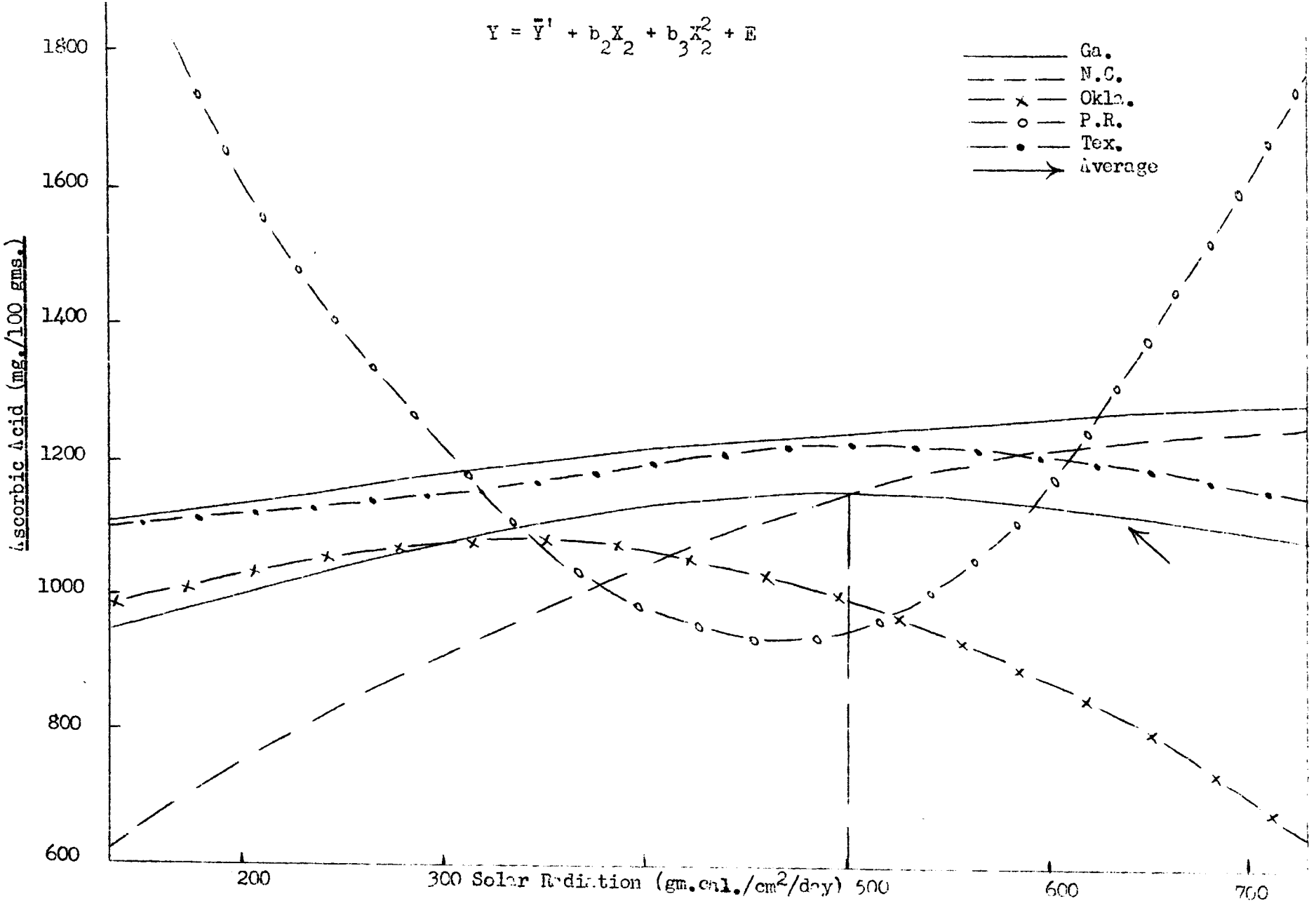
3/ Used precipitation in order to utilize greater number of observations.

(Y) is shown as a function of maturity (X_1), solar radiation (X_2 and X_2^2), soil moisture (X_3), soil temperature (log X_4) and an unexplained error (E). On the average over all stations, this model accounted for 32 per cent of the variability observed in ascorbic acid response. At the Puerto Rico and Texas stations 52 and 53 per cent of the variability in response was accounted for.

The values of the standard partial regression coefficients (b_1, b_2, . . . b_5), which were obtained by fitting the observed data from each station to the model, are shown immediately below the model in Table 8. The coefficients for X_2, X_2^2 and log X_4 are surprisingly consistent from station to station both in magnitude and sign. For the purpose of the Soils-Weather project, these factors are most pertinent. It is interesting to note that maturity is not consistent in its effect on ascorbic acid content.

The best estimate of the functional relationship between solar radiation and ascorbic acid content is shown graphically in Figure 1. The model is the same as shown in Table 8. The simple partial regression coefficients were used instead of the standard partial coefficients, and in order to plot the ascorbic acid response against solar radiation alone, each of the other factors was adjusted to their respective mean values. Thus, the equation given under the heading in Figure 1 indicates that the ascorbic acid response (Y) is equal to the algebraic sum of the average ascorbic acid response after adjustment for the mean values of days from planting soil moisture and soil temperature ($\bar{Y}'$), the linear effect of solar radiation (b_2X_2) and the quadratic effect of solar radiation ($b_3X_2^2$) plus an error (E). The response curve is given for each station. It is obvious that the response curve for Puerto Rico is entirely different from those of the other station. Further, the response curve for Puerto Rico appears to be highly improbable in that high ascorbic acid responses were observed under both very low and very high amounts of radiation with a minimum response in the middle range. This suggests that while observed radiation and observed response were related in the manner shown, the

Figure 1. Regression of Ascorbic Acid Content (mg./100 gms, dry basis) on Solar Radiation When Days From Planting, Soil Moisture and Log Soil Temperature Are Held Constant at Their Mean Values (1949).

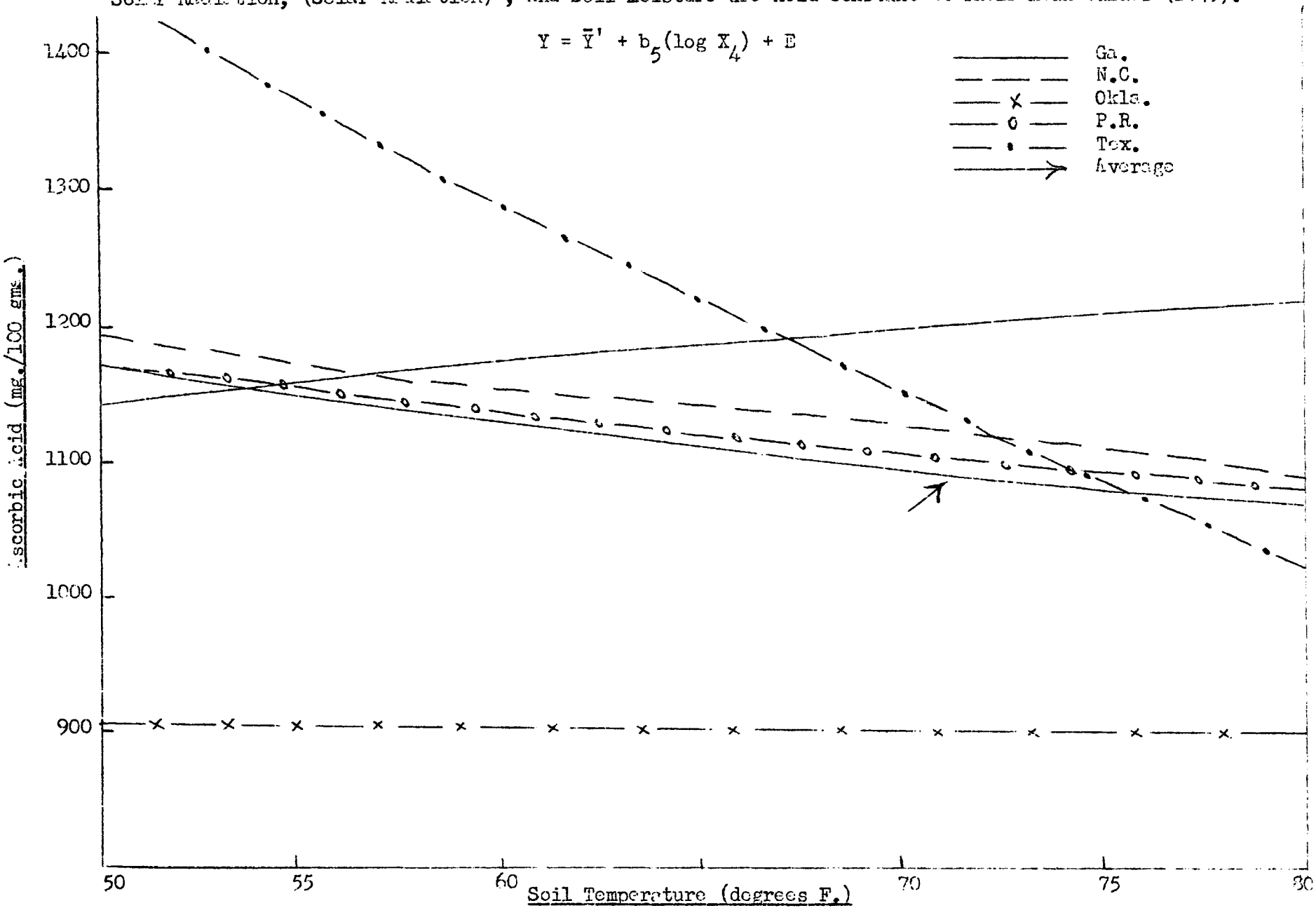


radiation did not cause the response. That is, some factor other than radiation was the limiting effect. The remaining four stations show considerable consistency. The average response curve for Georgia, North Carolina, Oklahoma and Texas is indicated by the arrow in Figure 1. This curve indicates that increasing solar radiation is associated with increasing ascorbic acid content of turnip greens until approximately 500 gm. cal./cm^2/day are received by the plants. This is a maximum. Solar radiation in excess of this daily amount has a detrimental effect on ascorbic acid response.

Figure 2 shows the effect of soil temperature on ascorbic acid response after the average response has been adjusted for the mean levels of all factors in the model other than soil temperature. From the equation given under the heading in Figure 2 it is seen that a logarithmic function was most consistent in explaining variation in ascorbic acid response; a steadily increasing or decreasing function in contrast to that observed in the case of solar radiation. It should be noted that the slopes of the response curves for the various stations are not as different as they appear. The large apparent differences would be greatly reduced if each curve were plotted about a common mean value for ascorbic acid content. This, of course, would completely mask the actual differences in mean level observed at the various stations. Since the slopes are not very different with the possible exception of Georgia, the average response curve is based on information from all stations. The average response curve, designated by the arrow in Figure 2, indicates that increasing soil temperature has a depressing effect on ascorbic acid response in the range from 50 to 80 degrees Fahrenheit.

Other weather factors in the model were too inconsistent to attempt similar analyses and interpretation. This situation should be clarified, however, as more data are included in the analyses and a wider range of weather conditions are observed in succeeding seasons.

Figure 2. Regression of Ascorbic Acid Content (mg./100 gms, dry basis) on Soil Temperature When Days From Planting, Solar Radiation, (Solar Radiation)^2, and Soil Moisture Are Held Constant at Their Mean Values (1949).



Factors Affecting Riboflavin. As indicated in Table 8, the most consistent model in accounting for variability in ascorbic acid response was also the most consistent in accounting for variation in riboflavin content of turnip greens. On the average over all stations, this model accounted for 54 per cent of the variability observed in riboflavin response. At the Oklahoma and Puerto Rico stations 90 and 64 per cent of the variability in response was accounted for respectively. From Table 8 again, it is seen that the most consistent factors were days from planting and solar radiation. Soil temperature was not at all consistent in its effect from station to station.

Figure 3 is a graphical presentation of the effect of solar radiation on riboflavin response for each station. An average response curve is given also. As for ascorbic acid response, the results from one station produced a response curve which is not consistent with the general form of the response curves at the other stations. The station, in this case, is North Carolina. And it appears that even though solar radiation and riboflavin response were related in the manner shown, the reality of a functional relationship is unlikely in this case. Some other factor is actually limiting, not solar radiation. The average response curve, therefore, does not include information from North Carolina.

It is seen from the average response curve that a slight positive response in riboflavin content is associated with increasing solar radiation in the lower portion of the range. A maximum is attained at about 400 gm. cal./cm^2/day. Solar radiation in excess of this amount is increasingly detrimental to riboflavin response.

Though maturity (days from planting) does not appear to be related to ascorbic acid response in any consistent manner, it is related to variation in riboflavin content. Figure 4 presents the effect of maturity on riboflavin content of turnip greens. As the plants become more and more mature, riboflavin decreases steadily. Over all stations, the average loss is approximately 800 mcg./100 gms. (dry basis)

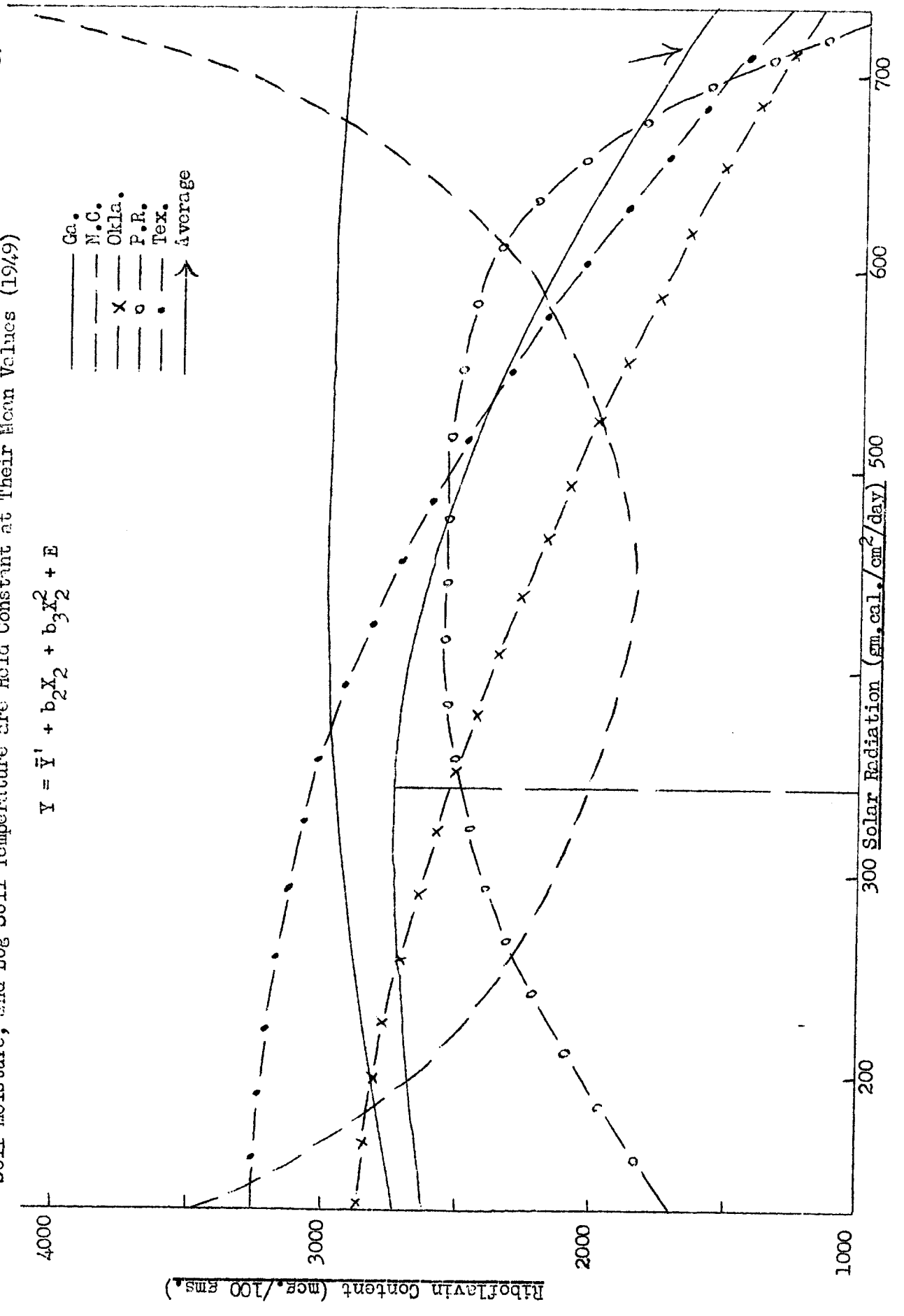


Figure 3. Regression of Riboflavin Content (mcg./100 gms, dry basis) on Solar Radiation When Days From Planting, Soil Moisture, and Log Soil Temperature are Held Constant at Their Mean Values (1949)

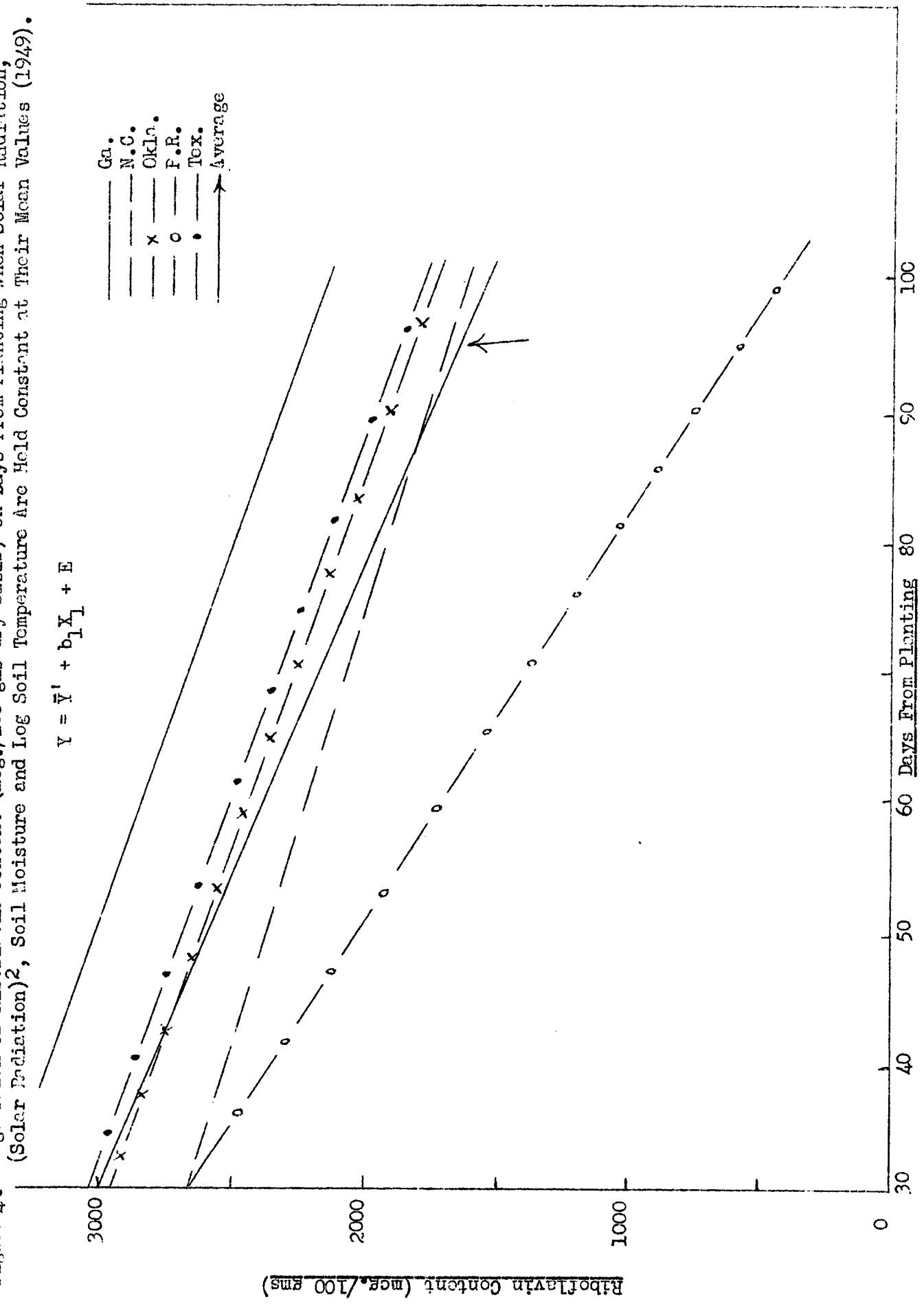


Figure 4. Regression of Riboflavin Content (mcg./100 gms dry basis) on Days From Planting When Solar Radiation, (Solar Radiation)^2, Soil Moisture and Log Soil Temperature Are Held Constant at Their Mean Values (1949).

between plants harvested 40 days after planting and plants harvested 80 days after planting; that is, a loss of 20 mcg./100 gms./day.

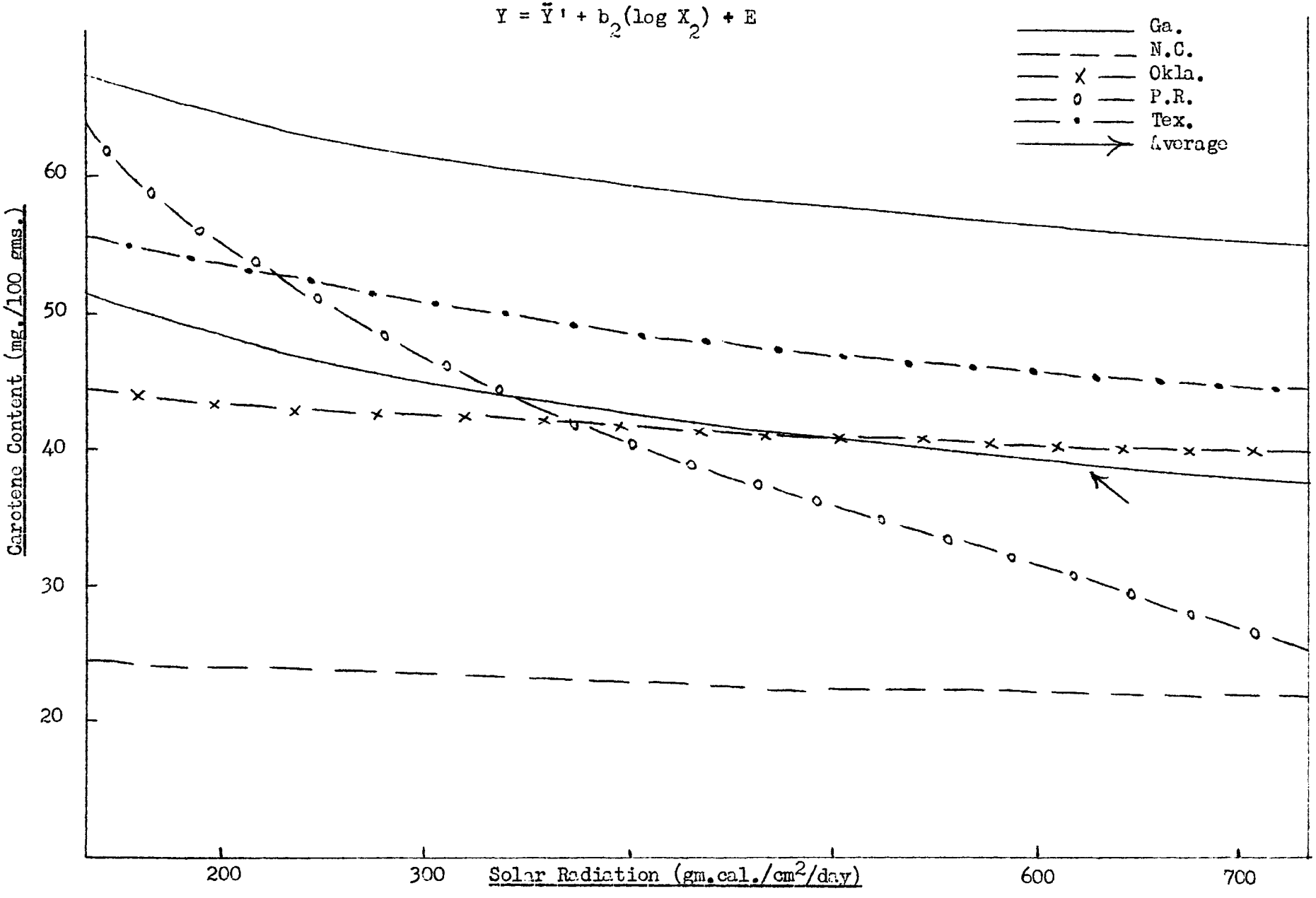
Factors Affecting Carotene. The model which results in greatest consistency for carotene response among all stations is entirely different from that which is effective for ascorbic acid and riboflavin. In Table 8 the carotene content (Y) is shown as a function of maturity (X_1), solar radiation (log X_2), soil moisture (X_3), soil temperature (X_4 and X_4^2) and an unexplained error (E). On the average over all stations, this model accounted for 48 per cent of the variability observed in carotene content. At Georgia and Texas 55 and 53 per cent of the variability in response was accounted for. The three most consistent factors were solar radiation, soil temperature and maturity.

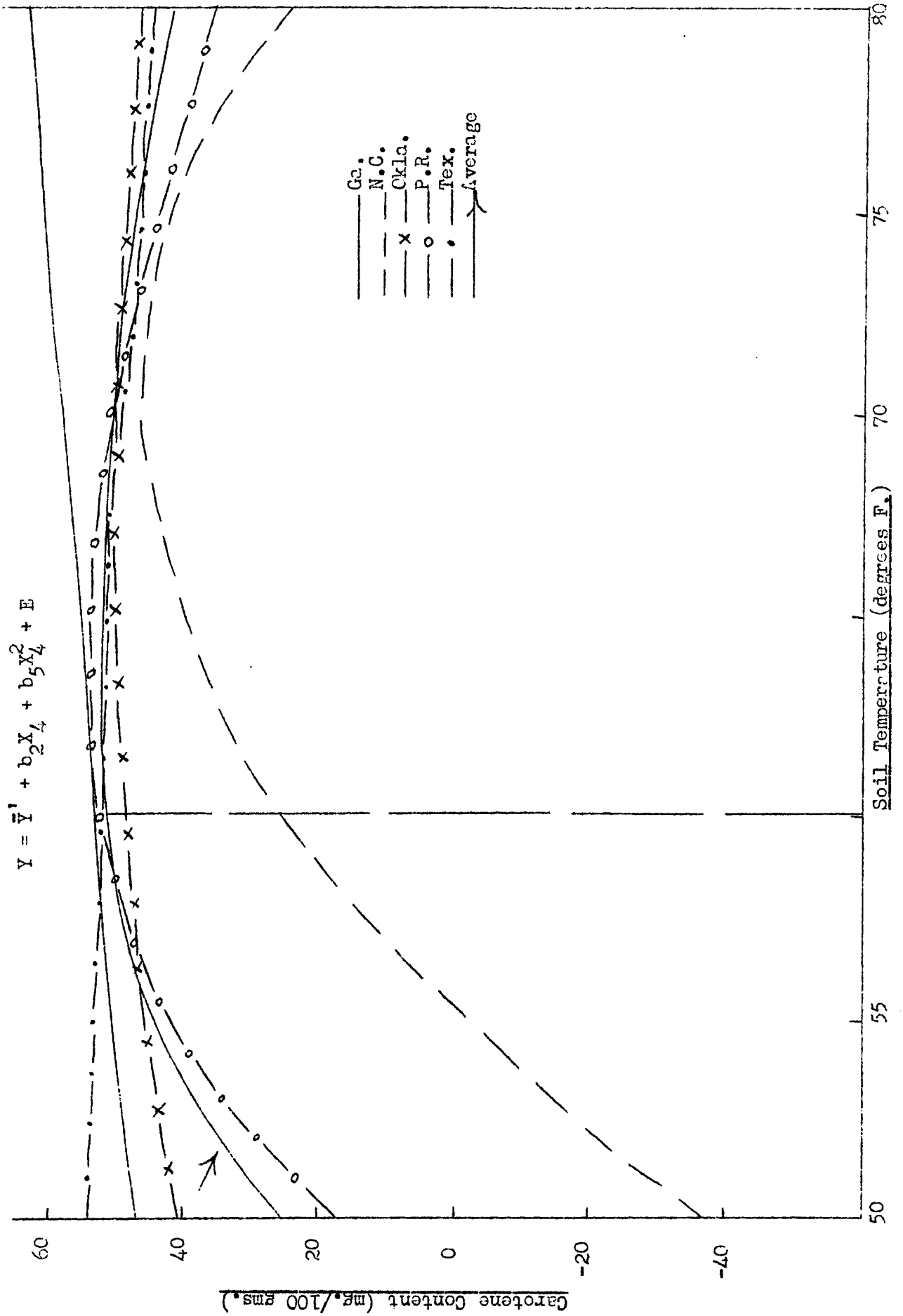
Figure 5 shows the functional relationship between carotene content and solar radiation. Contrary to the effect of solar radiation on ascorbic acid or riboflavin response, carotene response is a steadily decreasing function of radiation. Throughout the observed range of solar radiation, carotene steadily decreases as radiation increases; this effect is above and beyond the maturity effect which is also negative. Again, while the slopes of the individual station response curves are very similar, the mean levels of carotene content varied considerably from station to station.

From Figure 6 it is seen that carotene response is not a steadily decreasing function of soil temperature as was the case for ascorbic acid. The increase in carotene content of turnip greens is quite rapid for increasing soil temperature in the range from 50 to 60 degrees. Soil temperatures above 60 degrees, however, are associated with gradual reduction in carotene response. It appears that for favorable carotene response it is more important to have soil temperatures of at least 60 degrees Fahrenheit than to be concerned about the soil temperature being too high.

Figure 5. Regression of Carotene Content (mg./100 gms, dry basis) on Solar Radiation When Days from Planting, Soil Moisture, Soil Temperature, and (Soil Temperature)^2 Are Held Constant at Their Mean Values (1949).

$$Y = \bar{Y}' + b_2(\log X_2) + E$$





$$Y = \bar{Y}' + b_2X_4 + b_5X_4^2 + E$$

Figure 6. Regression of Carotene Content (mg./100 gms, dry basis) on Soil Temperature When Days From Planting, Log Solar Radiation, and Soil Moisture Are Held Constant at Their Mean Values (1949).

Figure 7 presents the effect of maturity on carotene response. For all stations carotene content decreases steadily as the plants become more mature. On the average, the loss is about 0.38 mg./100 gms. (dry basis) per day.

Factors Affecting Thiamine. The model which accounted for the largest proportion of variation in thiamine response was one involving interaction effects of different weather factors. Interestingly, this model was not most effective or consistent when tested by the responses of any other vitamin. As shown in Table 8, two interactions were included. The first is a measure of the interaction of solar radiation and soil moisture $b_5(X_2X_3)$. That is, if thiamine response is affected differently by solar radiation (X_2) depending upon the levels of soil moisture (X_3), this product term in the model can be expected to reduce the unexplained variability in thiamine response. Similarly for the other interaction included in the model $b_6 (X_3X_4)$; this is a measure of the extent to which soil temperature (X_4) fails to have the same effect on thiamine response throughout the observed range of soil moisture (X_3). It is seen from the values of the standard partial regression coefficients that the only factor that can be considered as reasonably consistent among stations is the interaction of solar radiation and soil moisture. On the average, this model accounted for 42 per cent of the variability in thiamine response. Georgia and North Carolina accounted for 53 and 55 per cent respectively. With regard to the interaction of solar radiation and soil moisture, it is tentatively suggested that increasing solar radiation is associated with increasing thiamine content of turnip greens so long as soil moisture is adequate. Further definition of the functional relationship should await additional data. It does not suffice to observe that thiamine content increases as does the product of the observed radiation and soil moisture. The most important point is how each member of the product varies in relation to the other.

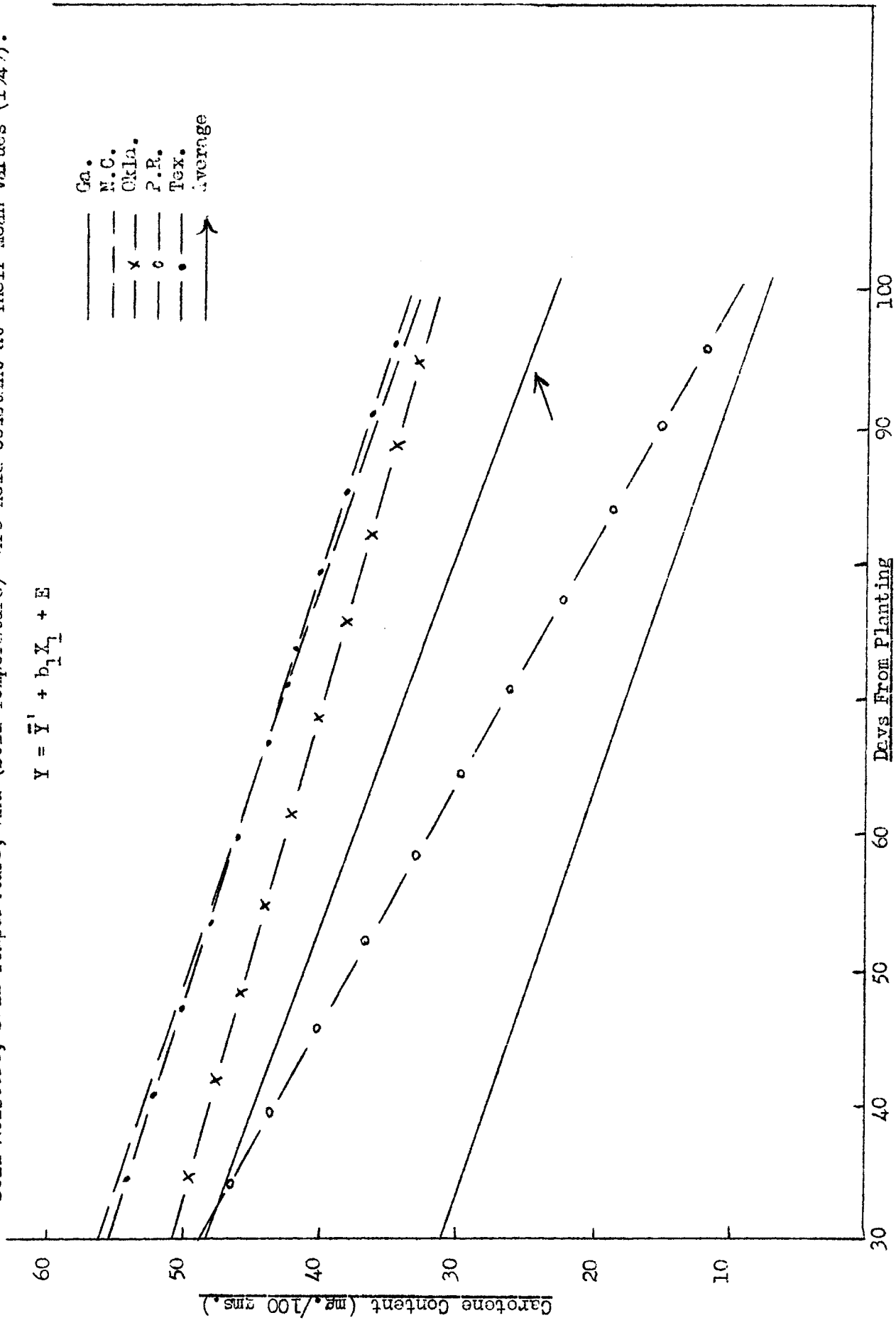


Figure 7. Regression of Carotene Content (mg./100 gms, dry basis) on Days From Planting When Log Solar Radiation, Soil Moisture, Soil Temperature, and (Soil Temperature)^2 are Held Constant at Their Mean Values (1949).

Summary

This section is devoted to a brief summary of the most pertinent results obtained on the effect of weather on vitamin response in turnip greens. These results, as stated earlier, should not be considered final. Changes will come as more data are incorporated in the analyses, and as the models are altered to conform more precisely with the best judgement and thought of the research specialists cooperating in this work.

Vitamin response is affected more by variation in weather than by variation in soil properties. This is substantiated by the fact that on the average over many seasons, time of harvest is more important than where the plants are grown in obtaining crops of high vitamin content.

A mathematical model or expression has been formulated which, on the average, accounts for 32 per cent of the variability in ascorbic acid response. This model expresses the response in terms of solar radiation, soil moisture, soil temperature and plant maturity. Of these four factors, two are reasonably consistent in their effect from station to station; they are solar radiation and soil temperature. Increasing solar radiation is associated with increasing ascorbic acid content of turnip greens until a maximum of 500 gm. cal./cm^2/day are received by the plants. Solar radiation in excess of this daily amount has a detrimental effect on ascorbic acid response. Increasing soil temperature, within the range of 50 to 80 degrees Fahrenheit, has a depressing effect on ascorbic acid response.

In the study of riboflavin response as affected by weather, a model has been developed which accounted for 54 per cent of the variability observed in response. The most consistent effects among stations are solar radiation and maturity. A slight positive response in riboflavin content is associated with increasing solar radiation up to approximately 400 gm. cal./cm^2/day. Solar radiation in excess of this daily amount becomes increasingly detrimental to riboflavin

response. As the plants become more and more mature, riboflavin decreases steadily. On the average, this loss amounts to about 20 mcg./100 gms./day on a dry basis.

A model which expresses carotene response as a function of maturity, solar radiation, soil moisture and soil temperature has been developed. For all stations, this model accounted for 48 per cent of the variability observed in carotene content of turnip greens. At Georgia and Texas 55 and 53 per cent of the variation respectively was accounted for. Solar radiation, soil temperature and maturity are most consistent. Contrary to the affect of solar radiation on ascorbic acid or riboflavin response, carotene content is a steadily decreasing function of radiation in the range from 200 to 800 gm.cal./cm^2/day. This effect is above and beyond the maturity effect which is also negative. However, carotene response is not a steadily decreasing function of soil temperature. Soil temperatures below 60 degrees Fahrenheit are associated with increasing response. The increase in carotene content of turnip greens is relatively rapid for soil temperatures from 50 to 60 degrees, amounting to approximately 2.0 mg./100 gms. (dry basis) for each degree increase in temperature. Soil temperatures above 60 degrees are associated with a gradual decrease in carotene content. For all stations carotene content decreases steadily as the plants become more mature. The average loss is approximately 0.38 mg./100 gms. (dry basis) per day.

The only model which is reasonably effective in accounting for variability in thiamine response as well as giving consistent results for one of the weather factors, is a model involving the interaction of solar radiation and soil moisture. On the average, the model accounted for 42 per cent of the variability in thiamine response at all stations. This model is not effective or consistent in any respect when tested by the response of any other vitamin. Thiamine content of turnip greens is affected differently by solar radiation depending upon the level of soil moisture. Further investigation of the exact relationship should be made.

EFFECT OF SOIL PROPERTIES ON THE VITAMIN CONTENT OF TURNIP GREENS

Preliminary results on the effect of five soil properties on the vitamin content of turnip greens can be reported. The five soil properties selected for study are percent cation saturation, percent phosphorus saturation, the ratio of cation and anion sorption capacities, exchangeable magnesium, and the level of organic matter.

The plant responses observed in the field plots are the result of weather effects, soil effects and their interaction effects. At each station turnip greens are grown in sand culture pots set into the ground adjacent to the field plots. These sand cultures are treated identically at all stations. It is assumed, therefore, that differences in response from time to time within each station or among the stations are due to variations in weather alone. Thus, the effect of variation in soil properties on plant response is measured by the differences between field response and sand culture response. The sand culture response is used as a control or standard whereby the main effects of weather can be eliminated from the responses observed in the field. In the study of soil effects, then, attention is given to the differences between field and sand culture response at each station.

Models

The inconvenience of testing five interacting variables in a single preliminary model led to the regrouping of the five soil properties into simpler groups of three properties. Three such models were tested against each of four vitamins studies; ascorbic acid, riboflavin, thiamine and carotene.

The first model included those three soil properties which might represent the stable fertility status of the soils. These properties were per cent cation saturation, per cent phosphate saturation and per cent organic matter. These

properties are not adequate to represent either potash status or nitrogen status as might be desired, but it should be remembered that supposedly adequate levels of these two mobile nutrients were provided in the standard fertilizer. In this model, as in the others, it was assumed that the vitamin response was a resultant of the algebraic sum of the effects of the three properties cited.

The second model, again with the limitation of three factors, was formed to test the importance of clay-mineral type jointly with the cation status. The ratio of cation capacity to anion capacity has been shown by Mehlich to indicate, by its relative magnitude, the clay-mineral type. Low values of 3 to 6 indicate kaolinite predominant, whereas high values of 9 to 12 indicate predominance of clay with a 2:1 lattice type. Since cation activities in the soils are markedly affected by clay-mineral type, the second model includes the per cent cation saturation and exchangeable magnesium in addition to the ratio of cation capacity to anion capacity. The cation, magnesium, was singled out because of its importance in chlorophyll and because previous studies in bins have suggested an interaction of magnesium with clay mineral type on vitamin content of turnips.

The third model tests the effects of cation saturation, phosphate saturation, and clay-mineral type, the latter being indicated by the cation exchange - anion exchange ratio. In addition to these properties of the soil, the interaction effect of cation saturation by phosphate saturation was also included in this model as a study of the effects of saturation status of the more stable and abundant nutrients in the soil and clay mineral type upon vitamin content.

Soil Properties

General. It was shown earlier that the ranges of plant response and weather conditions have been effectively extended through the cooperation of five experiment stations. Cooperative effort has also effectively extended the range of soil properties under study. Table 9 presents the mean values and ranges of the soil

Table 9 . Mean Values and Ranges of the Soil Properties Included in the Regression Studies Based on Information From All Stations (1949 - Spring, 1950).

Soil Properties	Mean	Range
Per cent C. Saturation	0.511	0.252 - 1.000
Per cent P. Saturation	0.198	0.010 - 0.300
Organic Matter (%)	1.52	0.58 - 2.76
Ratio of Cation Cap. to Anion Cap.	6.69	3.04 - 12.00
Exchangeable Magnesium (me.)	0.965	0.06 - 4.05

properties available for study at this time. To illustrate the contribution of each station in extending the range of soil properties, consider the following examples. If the data from Texas were omitted, the range of observed ratios of cation exchange capacity to anion exchange capacity would be reduced from 8.96 to 5.96; that is, the range of this soil factor would be reduced by 34 per cent. If both Oklahoma and Texas were omitted, the range of values for cation saturation would be reduced from 0.748 per cent to 0.258 per cent. Ommission of site 1 at Oklahoma would reduce the range in exchangeable magnesium level of the soils from 3.99 me. to 1.43 me. While these examples are indicative of some of the more extreme contributions, it should be emphasized that inclusion of five stations in the experiment makes it possible to study crop-soil relationships under a wide range of conditions. As a result, response curves should be more basic in character and have greater applicability within the region.

As expected, vitamin responses are strikingly different as a result of the particular soil in which the plants are grown. Table 10 shows the differences between the average vitamin response (dry basis) of turnip greens grown in sand culture and in the field. The figures may be compared within each vitamin heading only, since the basic units of measure differ from vitamin to vitamin and each set has been coded differently. Coding was necessary to eliminate the negative values resulting from the fact that the field responses were frequently greater than the sand culture responses. Thus, in Table 10, a high coded value indicates that response in sand culture exceeds response in the field, and conversely, a low coded value indicates that response in the field exceeds response in sand culture. It should be pointed out, too, that the relative magnitude of these values is indicative of variations in vitamin response after adjusting all locations for the "main effects" of weather. It is clear that cooperative effort among the stations has made a valuable contribution to extending the range of response due to soil conditions in this experiment.

Table 10. Coded Differences Between Average Vitamin Responses (dry basis) of Turnip Greens Grown in Sand Cultures and in the Field (1949-Spring,1950).

Year	Site	Station	Ascorbic Acid/1		Riboflavin/2		Thiamine/1		Carotene/3	
			Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1949	1	Ga.	497	599	340	527	59	68	5.58	4.47
		N.C.	317	154	603	413	103	28	17.32	3.26
		Okla.	377	340	774	94	96	24	15.78	
		P. Rico		629		487		229		7.01
		Texas	439	177	1144	671	489	350	22.40	14.71
	2	Ga.		325		758		212		10.15
		Okla.	250		707		151		16.36	
		Texas		21		1238		542		20.20
1950	1	Ga.	456		906		356		15.54	
		N.C.	167		247		153			
		P. Rico	377		354		377		11.27	
		Texas	344		1426		332		24.64	
	2	Ga.	453		1323		284		22.13	

/1 Numbers were coded by adding 300 to each mean difference.

/2 Numbers were coded by adding 500 to each mean difference.

/3 Numbers were coded by adding 15 to each mean difference.

Factors Affecting Ascorbic Acid. Table 11 gives the percentage reduction in variability of vitamin content of turnip greens associated with the three models defined earlier. The size of the reductions appears larger than one might expect to obtain, on the average, over a large number of repeated trials. This is,in fact, the case. Due to the relatively small number of observations available at this time, fairly large reductions can be expected due to chance alone (see Soils-Weather Project Report, 1949). A reduction of approximately 44 per cent can be expected 5 per cent of the time if no relation exists between the soil properties and the measured response. This situation, however, does not detract from the importance of the relative magnitudes of the reductions attributable to different models or among the four vitamins. It is seen that models II and III were equally effective in explaining variability in ascorbic acid content of turnip greens. That is, of the total variability observed in ascorbic acid response, either of these models explains about 64 per cent of the variation in ascorbic acid content. There are two soil properties common to both models; they are per cent cation saturation and the ratio of cation capacity to anion capacity as shown in Table 12. If magnesium level is omitted from model II and the interaction of per cent cation saturation with per cent phosphorus saturation is omitted from model III, a reduction of 62.5 per cent is obtained. Of all soil factors used in the three models, then, per cent cation saturation and the ratio of cation capacity to anion capacity are most closely associated with ascorbic acid response. After adjustment is made for the mean ratio of cation capacity to anion capacity, increasing per cent cation saturation is associated with increasing ascorbic acid response. On the other hand, ascorbic acid content decreases as the soil becomes more and more of the 2:1 lattice type after adjustment is made to the average cation saturation.

Factors Affecting Riboflavin. From Table 12 it is seen that no model was as effective in explaining variation in riboflavin response as in explaining ascorbic

Table 11. Percentage Reduction in Variability of Vitamin Content of Turnip Greens Associated with Selected Soil Characteristics (1949, Spring 1950).

Soil Characteristics /1	Vitamin			
	Ascorbic Acid	Riboflavin	Thiamine	Carotene
I. Stable Fertility Status	46.8	18.0	26.7	35.7
II. Clay-Mineral Type Including Cation Status	64.7	32.8	62.3	29.7
III. Clay-Mineral Type Including Cation and Phos. Sat.	63.9	47.9	44.7	46.8

/1 Stable Fertility Status: %C. Saturation, % P. Saturation, % Organic Matter.

Clay-Mineral Type (II) : %C. Saturation, ratio of Cation Capacity to Anion Capacity, Exchangeable Magnesium level.

Clay-Mineral Type (III): %C. Saturation, % P. Saturation, ratio of Cation Capacity to Anion Capacity, interaction of % C. Saturation and % P. Saturation.

Table 12. Percentage Reduction in Variability of Vitamin Content of Turnip Greens Associated with Selected Combinations of Soil Properties Used in the Models. (1949, Spring, 1950).

Vitamin	Model	Cation Saturation (%)	Phosphorus Saturation (%)	Organic Matter (%)	Cation Cap. / Anion Cap.	Mg. (me.)	Cation Sat. x Phos. Sat.	Percent reduction
Ascorbic Acid	I	X	X	X				46.8
	II	X			X	X		64.7
	III	X	X		X		X	63.9
		X	X					32.9
		X	X		X			63.8
		X			X			62.5
		X		X				43.1
Riboflavin	I	X	X	X				18.0
	II	X			X	X		32.8
	III	X	X		X		X	47.9
		X	X					17.3
		X	X		X			29.1
		X			X			9.0
		X		X				18.0
Thiamine	I	X	X	X				26.7
	II	X			X	X		62.3
	III	X	X		X		X	44.7
		X	X					20.8
		X	X		X			26.2
		X			X			22.5
		X		X				22.2
Carotene	I	X	X	X				35.7
	II	X			X	X		29.7
	III	X	X		X		X	46.8
		X	X					35.3
		X	X		X			37.0
		X			X			27.2
		X		X				35.2

acid response. Model III, involving measures of cation and anion saturation, is most effective. Four soil properties are associated with riboflavin response in such a manner as to account for about 48 per cent of the total variability in response due to differences in soil properties. Each of the soil properties appear equally important. It is particularly interesting to note that differences in per cent cation saturation and the ratio of cation capacity to anion capacity, so effective in accounting for variation in ascorbic acid response, are the least effective (9 per cent reduction) in accounting for riboflavin content.

Factors Affecting Thiamine. A most interesting result is observed in the case of thiamine response. Model II, developed to indicate the effect of clay-mineral type and cation status on vitamin response, is most effective. It is seen from Table 12 that per cent cation saturation, the ratio of cation capacity to anion capacity, and the level of exchangeable magnesium in the soil accounts for approximately 62 per cent of the variation in thiamine response ascribable to differences in soil properties. If the level of exchangeable magnesium is omitted, only 22.5 per cent reduction is obtained. Thus, the level of magnesium in the soil, when considered in relation to cation saturation and the ratio of cation capacity to anion capacity, accounts for nearly 40 per cent of the variability in thiamine content. Both the ratio of cation capacity to anion capacity and the level of soil magnesium are negative in their effect; that is, high soil magnesium is associated with low thiamine content after adjustment is made for the average per cent cation saturation. Level of exchangeable magnesium on the other hand, does not appear to be associated with ascorbic acid or riboflavin response to any large degree.

Factors Affecting Carotene. It appears that no one of the soil factors included in the models to date is particularly limiting in its effect on carotene response. Table 12 shows that per cent cation saturation, per cent phosphorus saturation, the ratio of cation capacity to anion capacity, and interaction of cation saturation by phosphorus saturation account for the largest portion (46.8%)

of the variation in carotene response. It is seen that each of these factors is equally efficient in this combination. The fact remains that no combination of these soil factors is very effective in explaining variability in carotene content of turnip greens. No factor or pair of factors is limiting response.

Summary

By comparison with the progress on the effect of weather on plant response, progress on the effect of soil properties may appear rather limited. However, the rate of accumulation of information is much lower in the case of soil property effects. Under the present procedure, each cooperating station can contribute a maximum of four observations per year. One observation is obtained from each site each season.

Three linear models have been tested against observed vitamin response. The first model was formed to determine the effect of those soil properties which define the stable fertility status of the soil. The second model was developed to indicate the effect of variation in clay-mineral type including cation status on vitamin response. The third model was formed to determine the extent to which clay-mineral type including cation and phosphate saturation are associated with response. The results should not be considered final. The consistency of the results should be checked as more data becomes available, and the models should be improved. It is reasonable to assume, for example, that the relationships between soil properties and response are not defined best by straight lines. Provision for curvilinearity should be incorporated in the models so that possible maxima and minima may be determined as in the case of weather effects. None-the-less, results are available which indicate the general nature of the effect of certain soil properties on vitamin response. These results have been made possible by the contribution of each station in extending the range of soil properties and the vitamin responses associated with them.

Of all soil factors considered, per cent cation saturation and the ratio of cation capacity to anion capacity are most closely associated with ascorbic acid response. These soil properties account for approximately 60 per cent of the variability observed in ascorbic acid content of turnip greens after adjustment for "main effects" of weather. After adjustment for the mean ratio of cation capacity to anion capacity, increasing per cent cation saturation is associated with increasing ascorbic acid response. On the other hand, ascorbic acid content decreases as the soil more nearly approaches a 2:1 lattice type after adjustment is made for the mean value of cation saturation.

Variation in per cent cation saturation and the ratio of cation capacity to anion capacity, closely associated with ascorbic acid response, is least effective in accounting for variability in riboflavin content of turnip greens. The model descriptive of clay-mineral type including cation status is most effective in explaining variability in riboflavin content, but no factor or pair of factors is particularly effective.

A model developed to indicate the effect of clay-mineral type including cation status is most effective in accounting for thiamine response. The ratio of cation capacity to anion capacity, per cent cation saturation, and level of exchangeable magnesium in the soil combine to account for about 62 per cent of the variation in thiamine content of turnip greens after adjustment for "main effects" of weather. Considered in relation to per cent cation saturation and the ratio of cation capacity to anion capacity, the level of magnesium in the soil accounts for nearly 40 per cent of the variability; high soil magnesium is associated with low thiamine content after adjustment for the average values of the other properties.

None of the soil properties considered at this time, either singly or in combination, appear to be limiting carotene response.