SUMMARY RESEARCH PROGRESS REPORT FOR 1989-90

SUBMITTED TO:
SLV RESEARCH CENTER COMMITTEE
AND THE
AREA II POTATO ADMINISTRATIVE
COMMITTEE

POTATO PLANT GROWTH ANALYSIS UNDER SAN LUIS VALLEY FIELD CONDITIONS

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INTRODUCTION

Plant growth analysis is essentially a research tool used to learn how the potato plant grows and produces a crop under any given set of environmental conditions. The methods used to gather data are relatively simple but quite laborious and time consuming. Although we have considerable experience in potato production under San Luis Valley conditions we don't really know the rate at which different varieties proceed from one growth stage to the next. The SLV has a relatively short growing season that doesn't allow much leeway for getting "out of sync" with the development of the potato plant.

The potato plant has 4 rather distinct growth stages---- each stage has cultural management requirements that must be met if the grower is to achieve maximum tuber yield and quality. The data presented later in this report clearly point out the marked differences in the rate of tuber growth between some early and late maturing varieties. The timing of planting, fertility application, irrigation scheduling and some types of pest management can be critical. A better understanding of the growth stages of the potato under SLV conditions should also help prepare the grower to work toward the goal of minimizing chemical usage. In fact, a good understanding of potato growth stages must be coordinated with the development of diseases like early blight or verticillium wilt if the goal of a "reduced chemical approach" to pest control is to be realized.

Another facet of plant growth analysis relates to the photosynthetic efficiency of the leaves which is based in part on stem/canopy architecture and stems. This question becomes a bit more complex than determining growth stages but nevertheless is equally important.

The potential benefits of an improved understanding of potato plant growth stages for all potato varieties grown in the San Luis Valley are enormous. It is highly probable that the results of plant growth analysis research will have immediate application for growers who are highly focused in their approach to crop management. It is with these thoughts in mind that the two year study reported herein was launched.

<u>Objectives</u>

1. To analyze the major growth parameters of 3 potato varieties under SLV field conditions and determine the relative rate at which each progresses through the four arbitrarily established growth stages.

2. To develop improved methods for conducting plant growth analysis research---- toward the goal of making such studies more efficient and practical.

MATERIALS AND METHODS

<u>Basic Plot Design</u>:

Three potato varieties, Centennial, Russet Nugget and Sangre were included in this study. The seed tubers were produced and stored at the SLV Research Center. The seed was cut 8 to 10 weeks prior to planting and all seed preparation was done according to methods commonly used by SLV potato growers. The plot was machine planted; seedpieces were spaced 12" apart and in rows 34" apart. The plot was planted on May 15 in 1989 and May 22 in 1990. Each plot consisted of three rows 100 feet long (seedpieces spaced 1 foot apart); the center row being used for sampling and the two outer rows serving as guard rows. Each plot was replicated 5 times in 1989 and 6 times in 1990. Approximately 140 lbs. N, 52 lbs. P, and 33 lbs. K per acre were banded (broadcast) preplant. The plot was sprinkler irrigated. Weed control consisted of cultivation and dual herbicide applied preemergence. The following insecticides were applied: one application each of Disyston and Monitor.

As soon as the first plants started to emerge, daily plant counts were taken until 100% emergence had been achieved.

Plant Sampling:

The plants in each test row were numbered from 1 to 100. Prior to any plant removal for data purposes, a randomized plant sampling scheme was established to determine which plant would be removed from each plot during each week of the growing season. In the event that randomization resulted in adjacent plants being selected for sampling, field technicians were instructed to move to the next plant in order that all sampled plants would have had a properly spaced plant growing next to it. A flag was placed in the space where each plant was removed to identify the location of sampled plants. Plant sampling was started as soon as emergence was complete. Each plant was carefully dug to make sure that all of the tubers were recovered. The plant tops and roots were immediately placed into a large, properly labeled plastic bag. The tubers were placed into a correspondingly labeled paper bag. Immediately after each harvest, all of the plants and tubers were placed in a refrigerated room maintained at 40 degrees F until leaf area measurements were completed. The weekly sampling continued until plant maturity and/or foliage blight caused deterioration of the leaf tissue.

Leaf Area Measurements:

1989 -- The total leaf length was determined by removing each leaf and measuring the distance from the point of petiole attachment to the tip of the primary leaflet. One plant of each variety was removed from a guard row of 3 reps at each sampling date and actual leaf area measured by removing each leaflet and putting it through a LICOR Model 3100 leaf area meter. The total leaf length of each guard row plant was also measured and a leaf length:leaf area ratio determined. This ratio was then used to verify the leaf area of test plants via the total leaf length data.

1990 -- Direct leaf area measurements were made by removing all of the leaflets from each test plant at each sampling date and putting them through either a LICOR Model 3100 or Model 3000A leaf area meter. Leaf areas per plant are converted to a leaf area index (LAI); the ratio of leaf area to ground area.

Additional Efforts to Measure Leaf Area Index:

1990 -- A relatively new instrument, the LAI 2000 LICOR Plant Canopy Analyzer (PCA) was used to estimate LAI. A series of four readings were made on four separate dates. Although the methods for using the PCA on potatoes are not as well established as for certain other crop plants, the results were encouraging; it is very likely that this technique will become a valid way to measure LAI.

Penetration of Photosynthetically Active Radiation:

1989 -- Light penetration into the foliage canopy was measured about a week before LAI maximized using two instruments, LICOR #190 and #191, in tandem. These highly sensitive instruments are placed above and under the foliage. The difference between the two measurements represents the degree of light interception by the canopy; plant size, density and gross geometry of the canopy are involved. Light penetration into the foliage canopy was again measured in 1990 using the LICOR point sensor/light bar method used in 1989. The data gathered was considerably more extensive than collected in 1989.

Plant Dry Matter:

Following leaf area determinations, the leaf, stem, and root tissue were placed in paper bags and dried for approximately 48 hours at 70 C. Tubers were sliced prior to being placed in the drier. During the latter stages of the experiment, when the biomass of the plants became extensive, the percent tuber dry matter was established by drying a sub-sample of the tubers and using the data to calculate the dry matter based on fresh weight of the main tuber yield.

Final Tuber Harvest:

Approximately two weeks after the last weekly plant sampling, a tuber harvest was made to estimate total yield. The tubers from 5 consecutive plants were hand dug from each plot. The final tuber harvest was conducted on Sept. 16 in 1989 and on Sept. 20 in 1990.

Weather Data:

The daily maximum, minimum and average air temperature recorded at the San Luis Valley Research Center during the months of June, July and August for 1989 and 1990 are presented in Figures 1 through 6 (attached as Appendix). It may be of interest to note that although the two seasons were quite different, the Colorado Crop Reporting Service data indicated record potato yields for both years. Perhaps the most significant difference was the unusual hot weather during the last ten days of June and first four days of July in 1990, followed by a relatively cool period during the balance of July and the first three weeks of August. These air temperature effects very likely had a measurable influence on the time of tuberization and the rate of tuber growth of the three potato cultivars included in this study. Weather is often the most important variable the potato grower has to contend with; air temperature is only one factor of many that affect crop production. Seasonal differences in weather are essential to interpretation of plant growth analysis results---- the comparision of the 1989 and 1990 data presented herein are no exception. We would encourage the reader to take this into account as he reads this report.

EXPERIMENTAL RESULTS

1. Plant Emergence: Table 1 provides information to show that in both years the plants emerged (visible green sprout tips) during an 8 to 10 day period. The pattern of emergence in 1990 was 3 to 4 days later than in 1989, which most likely reflected the one week later planting date in 1990. Also the data suggest that Sangre and Centennial were quite similar, while Nugget tended to emerge a few days earlier. Plant sampling from the plot was started only after 100% emergence had occurred.

TABLE 1-Emergence

PERCENT PLANT EMERGENCE DATA FOR 1989 AND 1990					
CULTIVAR	**6/14/89**	**6/16/89**	**6/19/89**	**6/21/89**	**6/23/89**
Centennial	15	48	92	95	98
Sangre	17	51	98	100	100
Nugget	71	85	98	100	100
CULTIVAR	**6/15/90**	**6/16/90**	**6/19/90**	**6/21/90**	**6/23/90**
Centennial	0	2.7	51	70	94
Sangre	0	3.0	46	70	95
Nugget	0	15	84	92	94

2. Tuberization: The time of tuberization is an important event since it indicates the stage of plant growth when the genetic instructions of the variety result in enlargement of the stolon tip and initial tuber formation. Data presented in Table 2 clearly indicate that tuberization occurs relatively quickly. In fact, it seems that a majority of the tubers were formed within a week's time in both 1989 and 1990; all of the tubers one fourth inch and greater were counted. The time required for complete tuberization to occur appeared to be no more than 10 to 15 days for Centennial and Sangre. The data clearly indicate that tuber formation for Nugget is perhaps a week or so later than for the other two cultivars---- a fact that most potato growers of Nugget also noticed from the outset. This becomes important as the subsequent data on the rate of tuber dry matter accumulation will indicate.

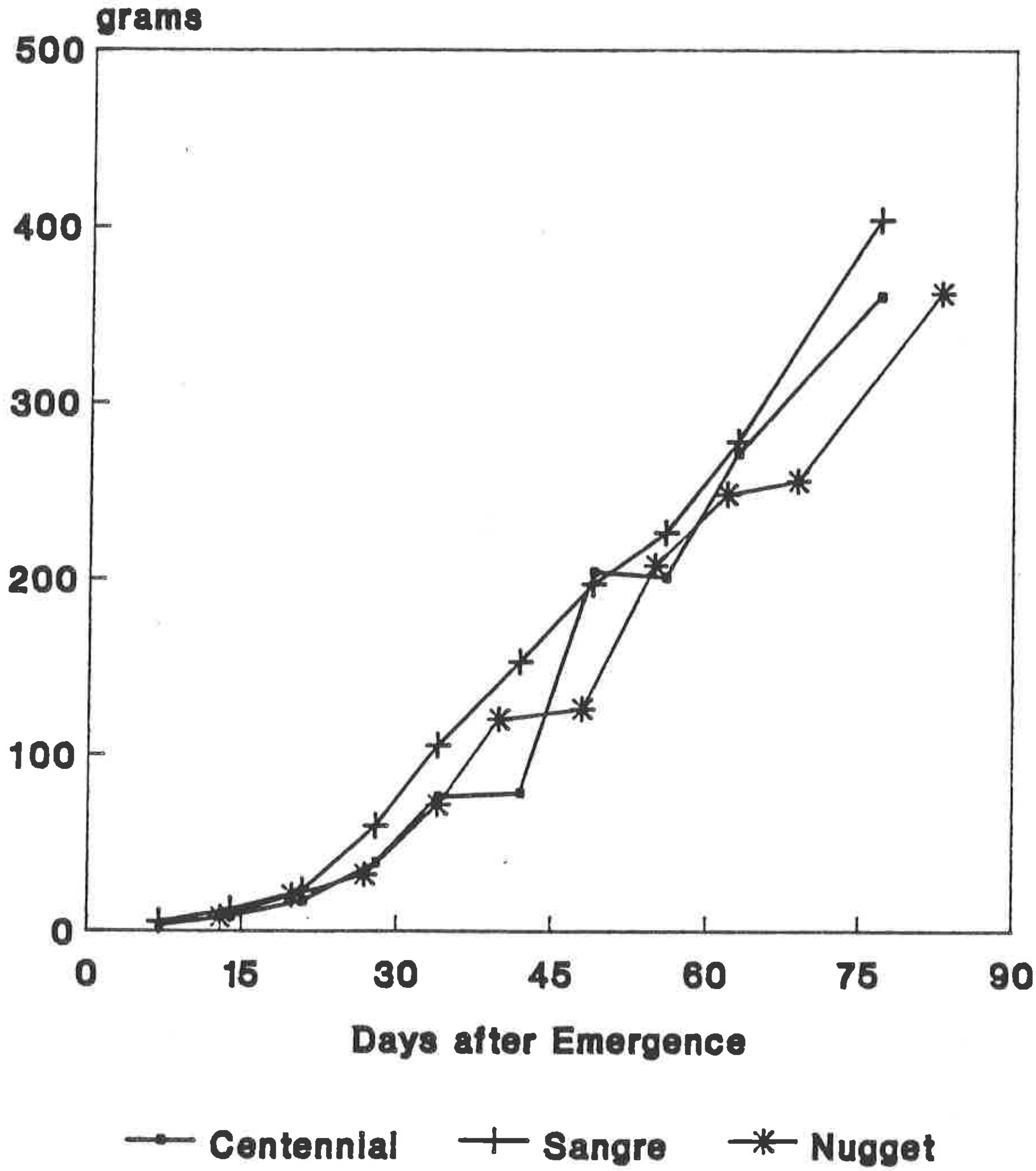
TABLE 2-Tuberization

1989 TUBERIZATION DATA: Number of Tubers Per Plant						
Cultiv	June 20	June 29	July 6	July 13	July 19	
Centen	0	0	9.3	11.8	12.2	
Sangre	0	0	11.6	20.8	16.4	
Nugget	0	0	4.0	5.7	11.5	

1990 TUBERIZATION DATA: Number of Tubers Per Plant						
Cultiv	June 26	July 3	July 10	July 17	July 24	July 31
Centen	0	0	0	14.5	10.2	11.5
Sangre	0	0	0	16.8	9.3	14.5
Nugget	0	0	0	8.5	7.8	12.3

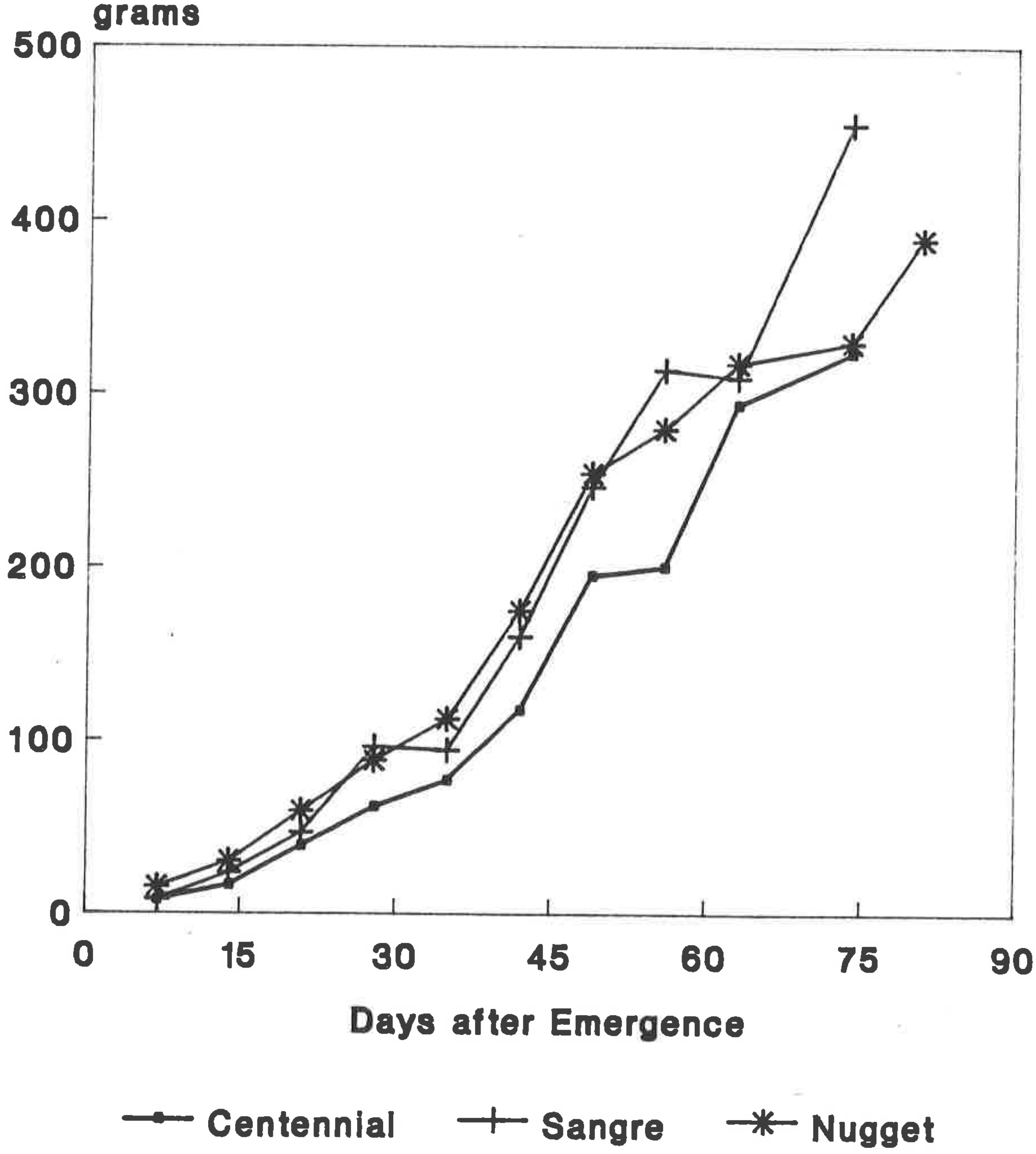
3. Total Dry Weight: Total dry weight is the combined values for both top and tuber dry weight. The results of the 10 to 11 weekly plant harvests for 1989 and 1990 are presented in Figures 7 and 8. The overall rate of increase, i.e. the slope of the curves, is somewhat steeper for 1990 than 1989; this could indicate the effect of the higher than average 1990 hot weather in late June and early July. In 1989, Sangre had a greater accumulation of total dry matter than either Centennial or Nugget. However, in 1990, Nugget exceeded Sangre through the first 45 days after emergence. The dry weight for Centennial was markedly less than the other two cultivars in 1990, but less so in 1989. While total dry weight is a useful and interesting type of evaluation, it does not provide the specific information that points toward cultivar differences which are most relevant to critical crop management practices.

FIGURE 7
POTATO CULTIVARS
Total Dry Weight



primary data, 1989.

FIGURE 8
POTATO CULTIVARS
Total Dry Weight

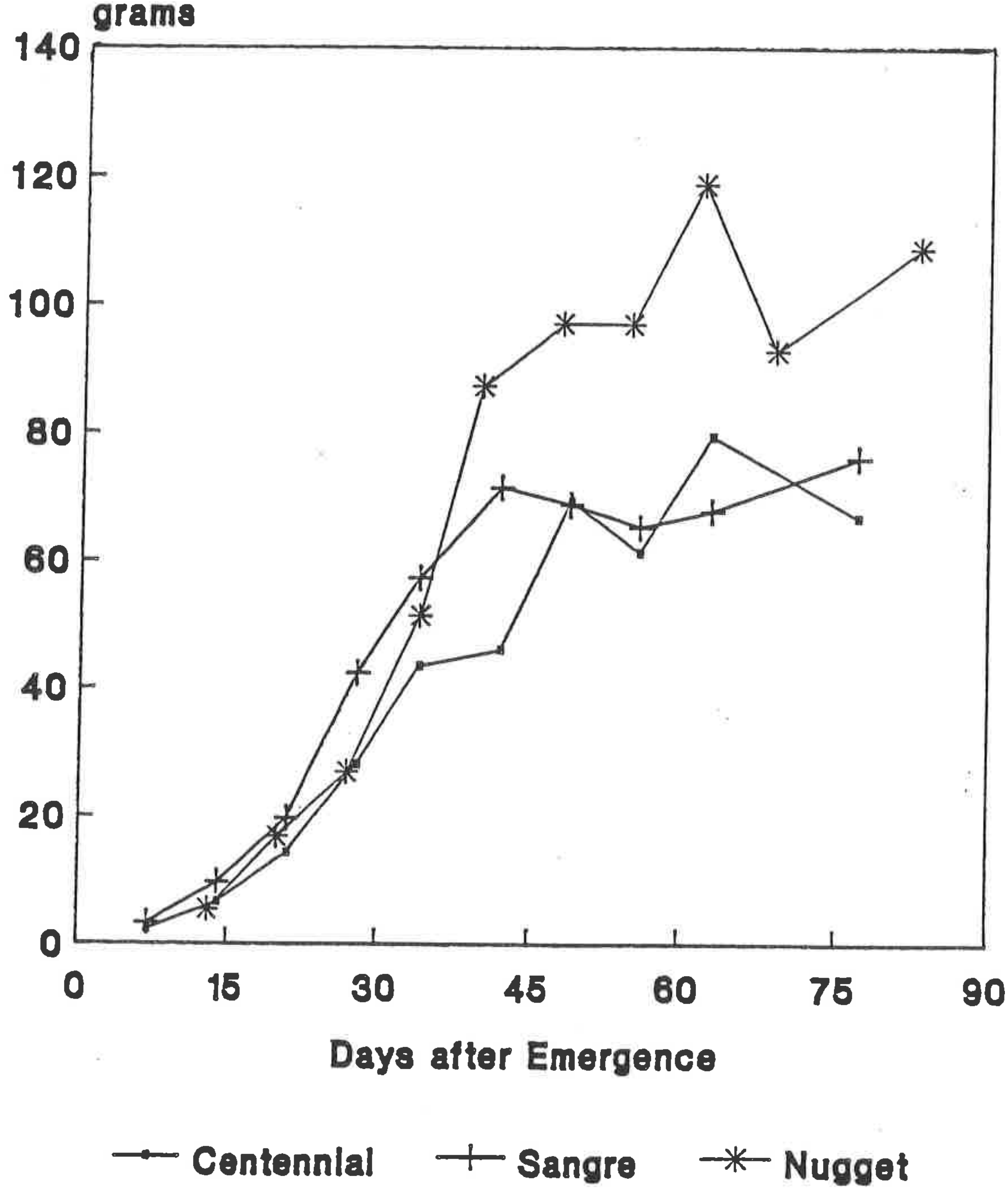


primary data 1990.

4. <u>Top Dry Weight</u>: Top dry weight includes all of the plant except the tubers. No attempt was made to recover the extensive root system of the plants. Figures 9 and 10 present the top dry weight (season long) accumulation for both 1989 and 1990. The most striking and obvious result was the relatively large top growth of Nugget; Sangre was next, followed by Centennial. For example, in 1990, during the period of approximately 40 to 60 days after emergence, Nugget exceeded Centennial by well over 100% and exceeded Sangre by 50-75%. In 1989, the midseason to late season development of Centennial and Sangre was similar, while Nugget produced 50% or more top dry matter than the other two during 30 to 75 days after emergence. Top dry matter production reflects a plant's potential capacity to generate carbohydrates for tuber growth. The genetic instructions, inherent in each variety, that direct the photosynthetic capacity towards tuber production, should be of critical interest to most potato growers. An important measure of this photosynthetic capacity is illustrated in the data presented in the next section.

5. <u>Leaf Area Index</u>: The great majority of the photosynthetic capacity is represented by the amount of green leaf area available. The degree to which the leaves are exposed to sunlight is a function of "stem archtitecture" and crowding, or shading of the leaf area by adjacent plants or even its own leaves. Leaf Area Index (LAI) is merely a **ratio** of the total leaf area per plant present at any given time in the season to the ground area allotted to each plant. For example, potato plants spaced 12 inches apart and in rows 36 inches apart would have 3 square feet of field space to reside in. Thus if a variety had an LAI of 2, it would have a total of 6 square feet of leaf area compared to the 3 square feet of field space it occupies. The information presented in Figures 11 and 12 clearly shows that LAI progresses along a similar pattern to the top dry weight curves in Figs. 9 and 10. Furthermore, Figs. 11 and 12 indicate that the LAI tends to decrease about the 60th day after emergence. This is obviously due to senescence and death of lower leaves and the effects of early blight and other types of leaf damage. In 1989, Nugget had a significantly greater LAI than either Sangre or Centennial. However, in 1990, Sangre had LAI's that were very

FIGURE 9
POTATO CULTIVARS
Top Dry Weight

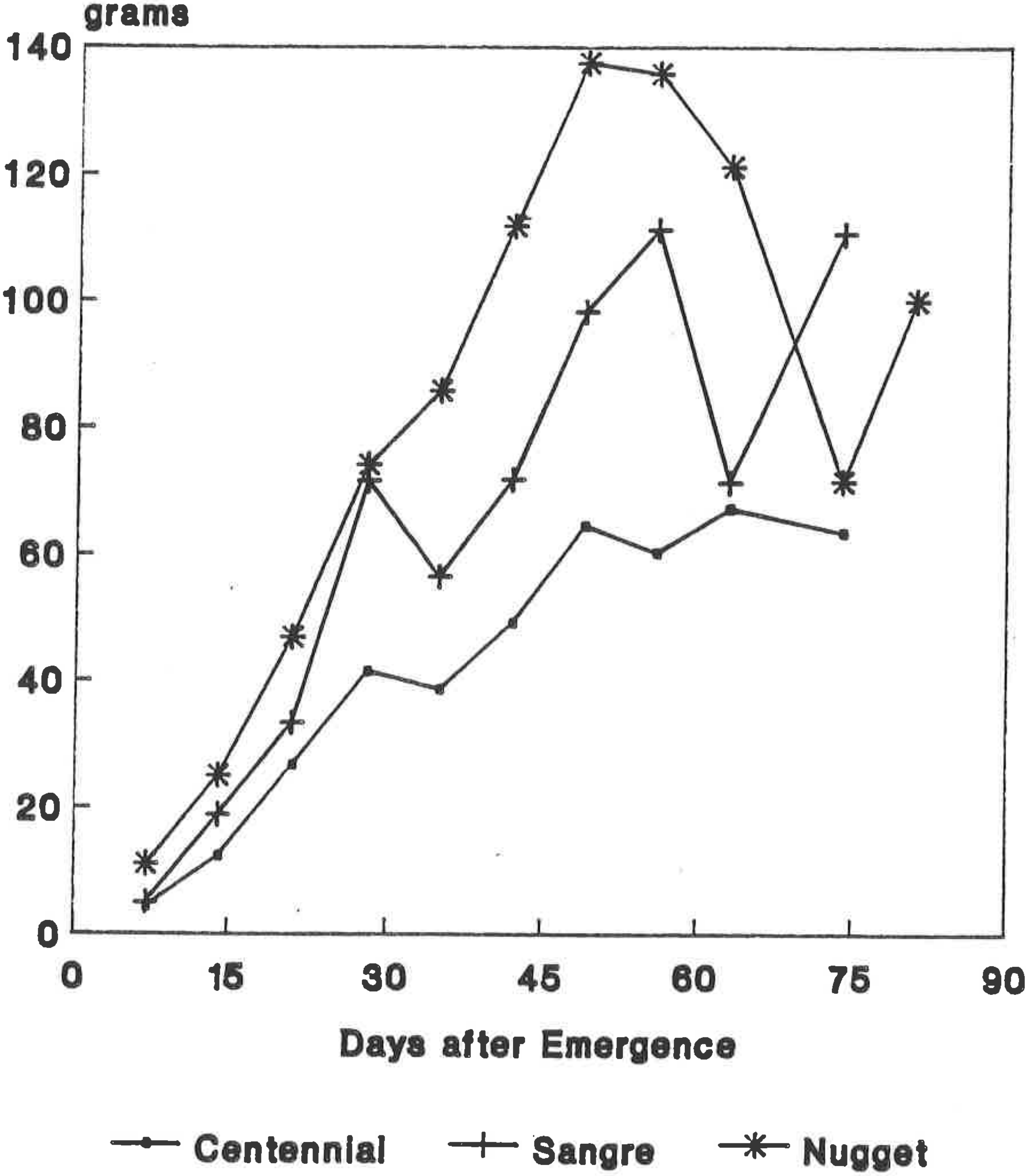


primary data, 1989.

FIGURE 10

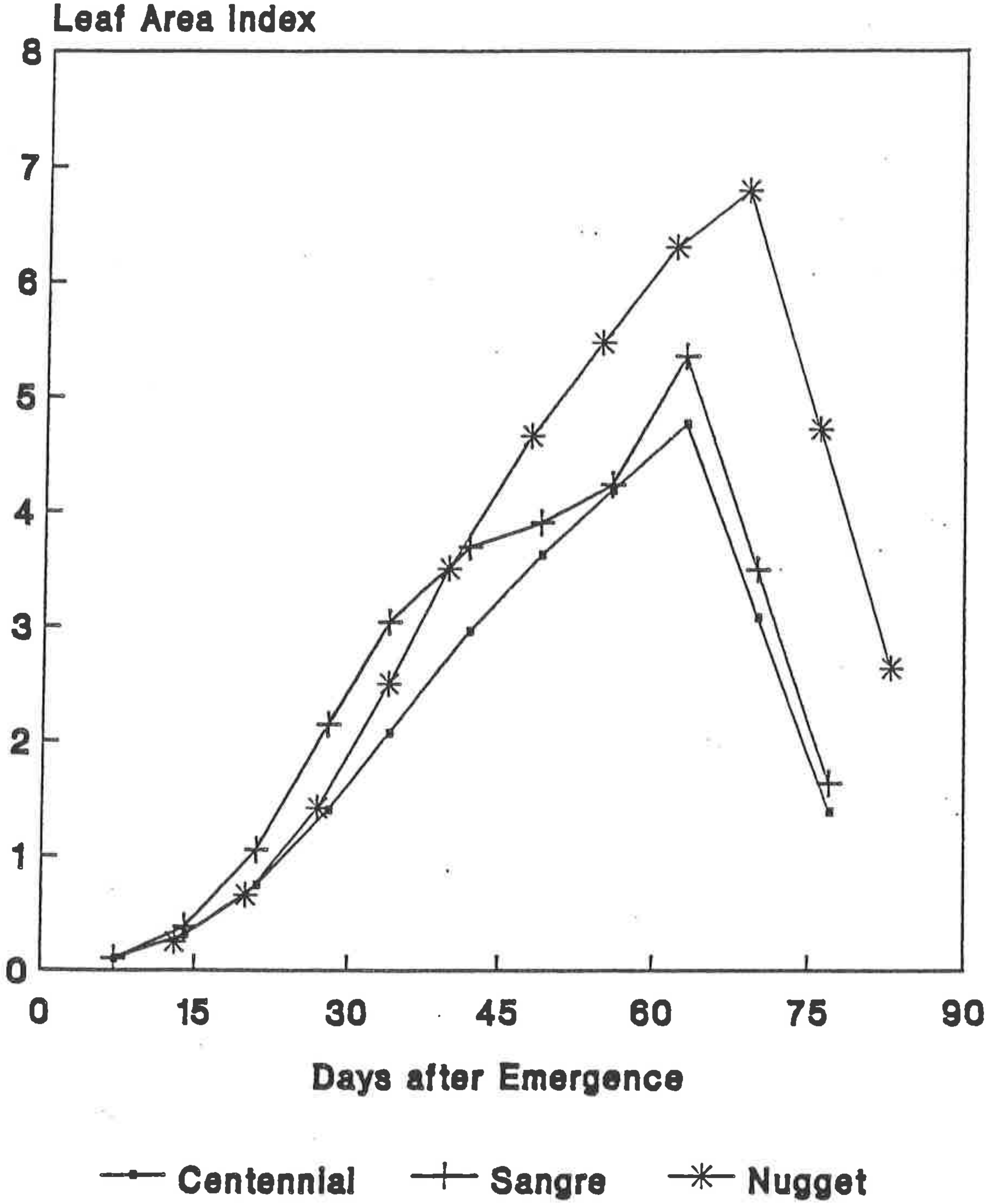
POTATO CULTIVARS

Top Dry Weight



primary data 1990.

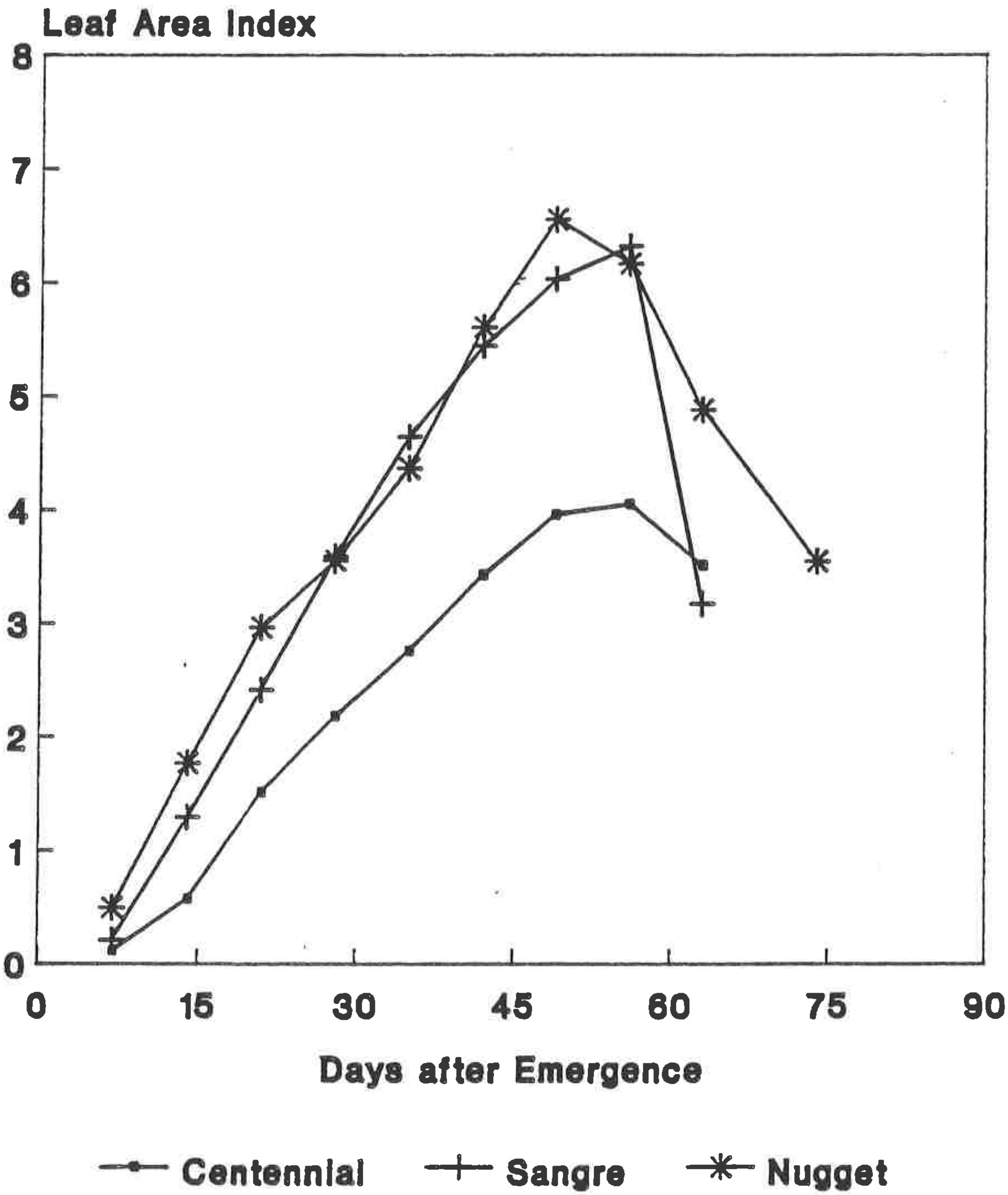
FIGURE 11
LEAF AREA INDEX



data derived from splines, 1989.

FIGURE 12

LEAF AREA INDEX



LA derived from splines, 1990.

comparable to Nugget up until about the 55th day after emergence. Centennial had the lowest LAI's in both years.

An important question arises regarding how much of the leaf area may be functional and how much could be excess or "non useable" due to self shading or competition for space from adjacent plants. We do not know under San Luis Valley conditions if this could be the case. It has been pointed out by others (Khurana and McLaren - 1982. Potato Res. 25:329-42) that an LAI of greater than 4 or 5 may become less efficient as canopy density increases. On the other hand, the information shown in Fig. 13 illustrates an interesting relationship between LAI and light energy that could be important under San Luis Valley field conditions. It merely shows that as light energy increases, the potential for effective growth at higher LAI's increases---- therefore the relatively high LAI's measured for Nugget and Sangre may be functional.

6. Tuber Dry Weight: One of the most interesting and possibly the most important aspects of this study, from a grower's standpoint, are Figures 14 and 15 showing tuber dry weight accumulation. These data point out that Nugget, although producing much larger top growth and substantially higher LAI's than Sangre or Centennial, produced less tuber dry weight. The data show that Nugget starts producing tubers somewhat later and then basically proceeds at a rate of growth similar to Sangre and Centennial. The late start appears to put it at a disadvantage considering the short San Luis Valley growing season. Considerably more research would be needed to adequately explain the reason for Nugget's later tuberization. It has been well known, since Nugget was being tested for eventual release and naming, that it was a later maturing potato than Sangre or Centennial. The late start in tuber production probably would not be a problem under a longer growing season than exists in the San Luis Valley. This aspect of the comparison is clearly illustrated in the next two Figures.

7. Rate of Tuber Dry Matter Accumulation: Figures 16 and 17 show rate of dry matter accumulation; note that the values on the Y axis are presented on a log scale. The 1989 data show a clear separation between the three cultivars; Sangre

FIGURE 13

RELATIONSHIP BETWEEN LAI, LIGHT INTENSITY AND GROWTH RATE

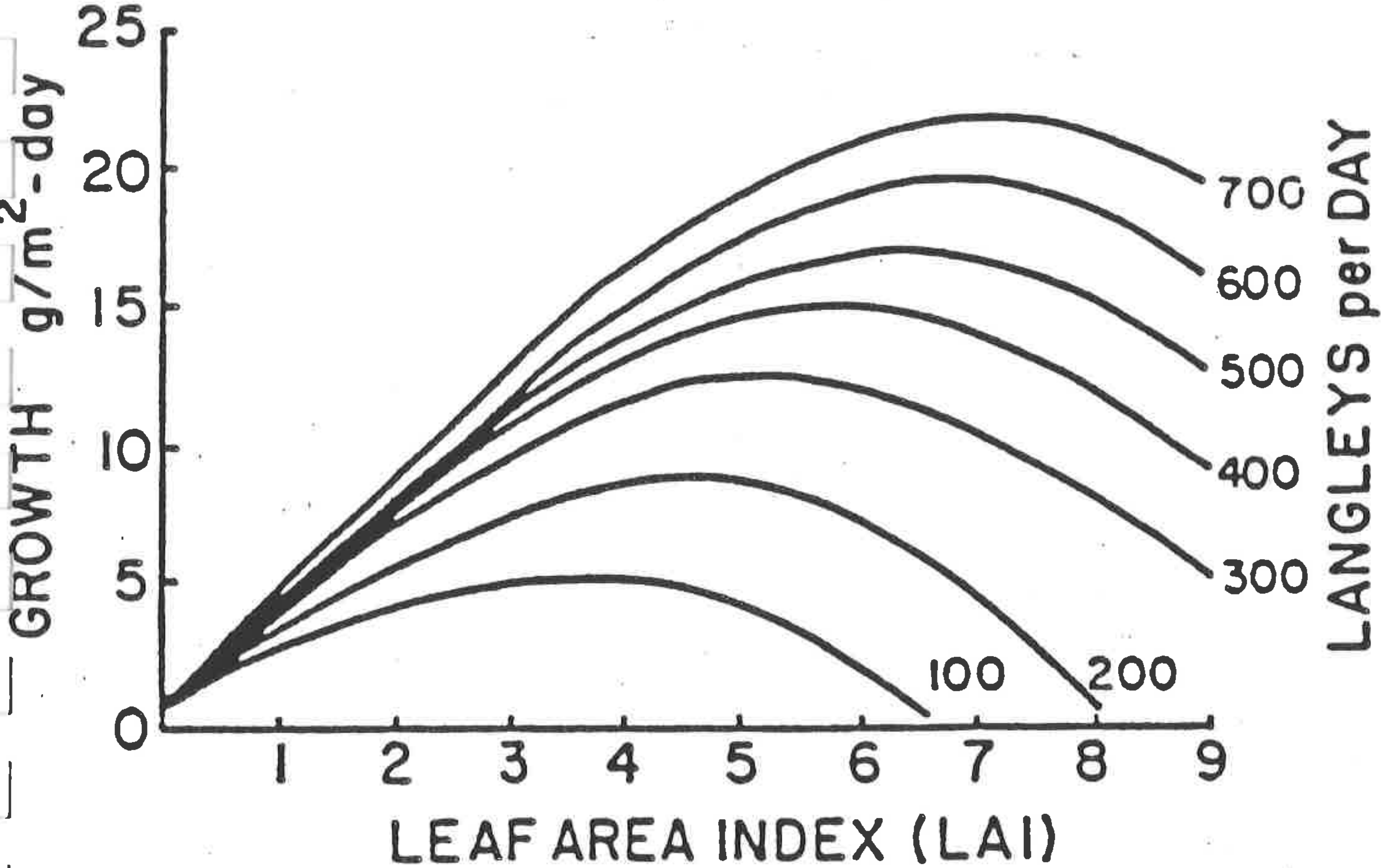
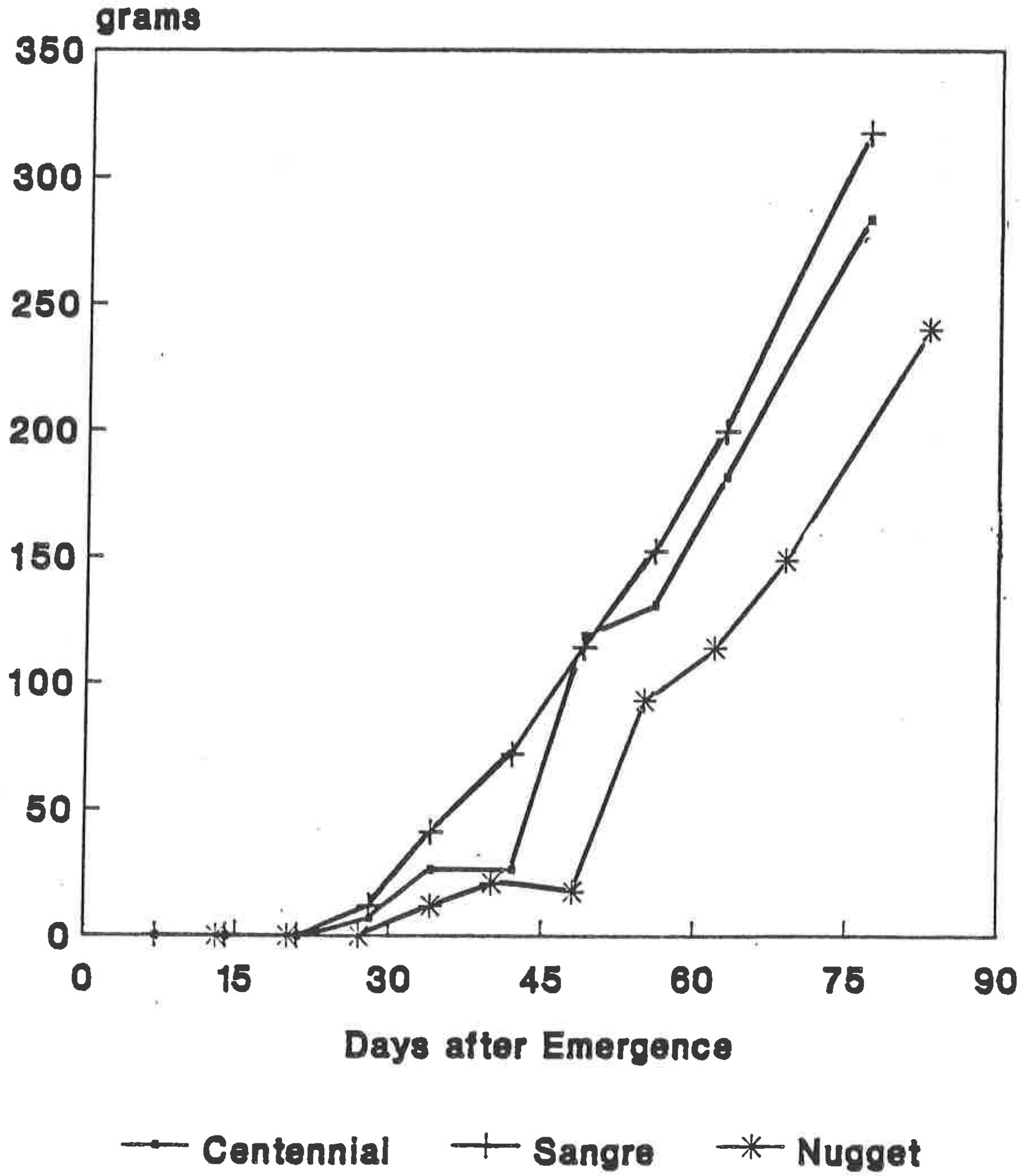
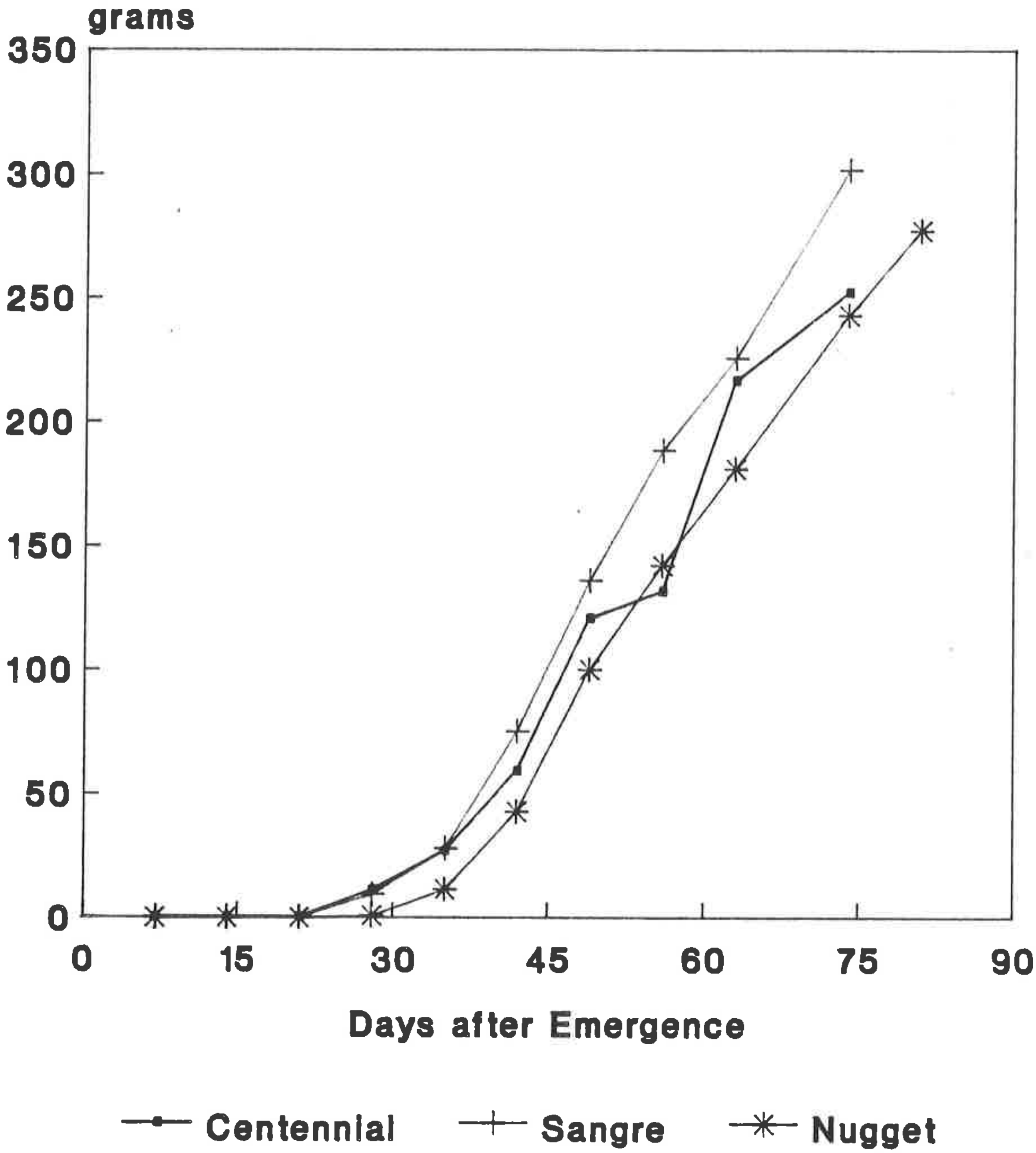


FIGURE 14
POTATO CULTIVARS
Tuber Dry Weight



primary data, 1989.

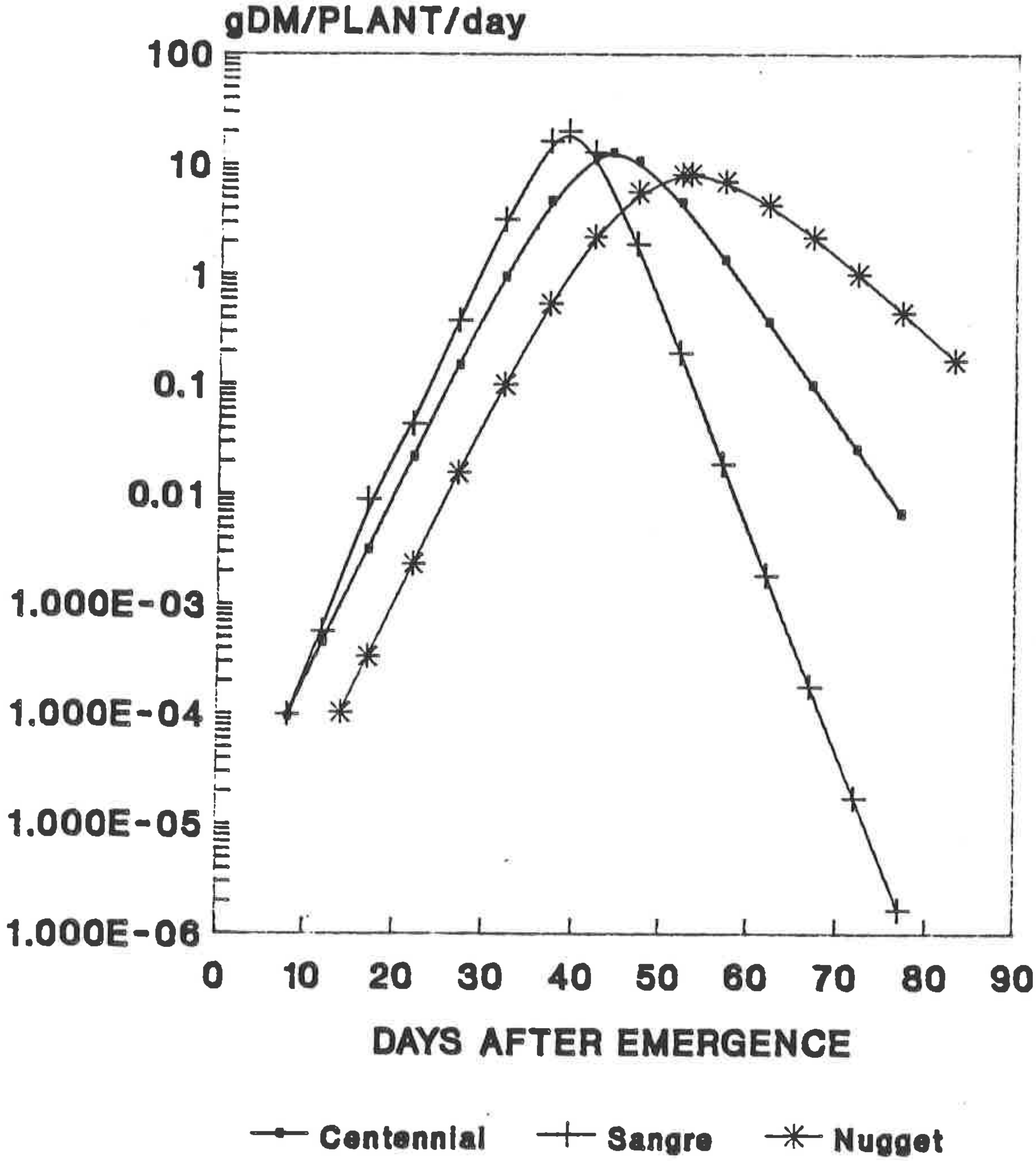
FIGURE 15
POTATO CULTIVARS
Tuber Dry Weight



primary data 1990.

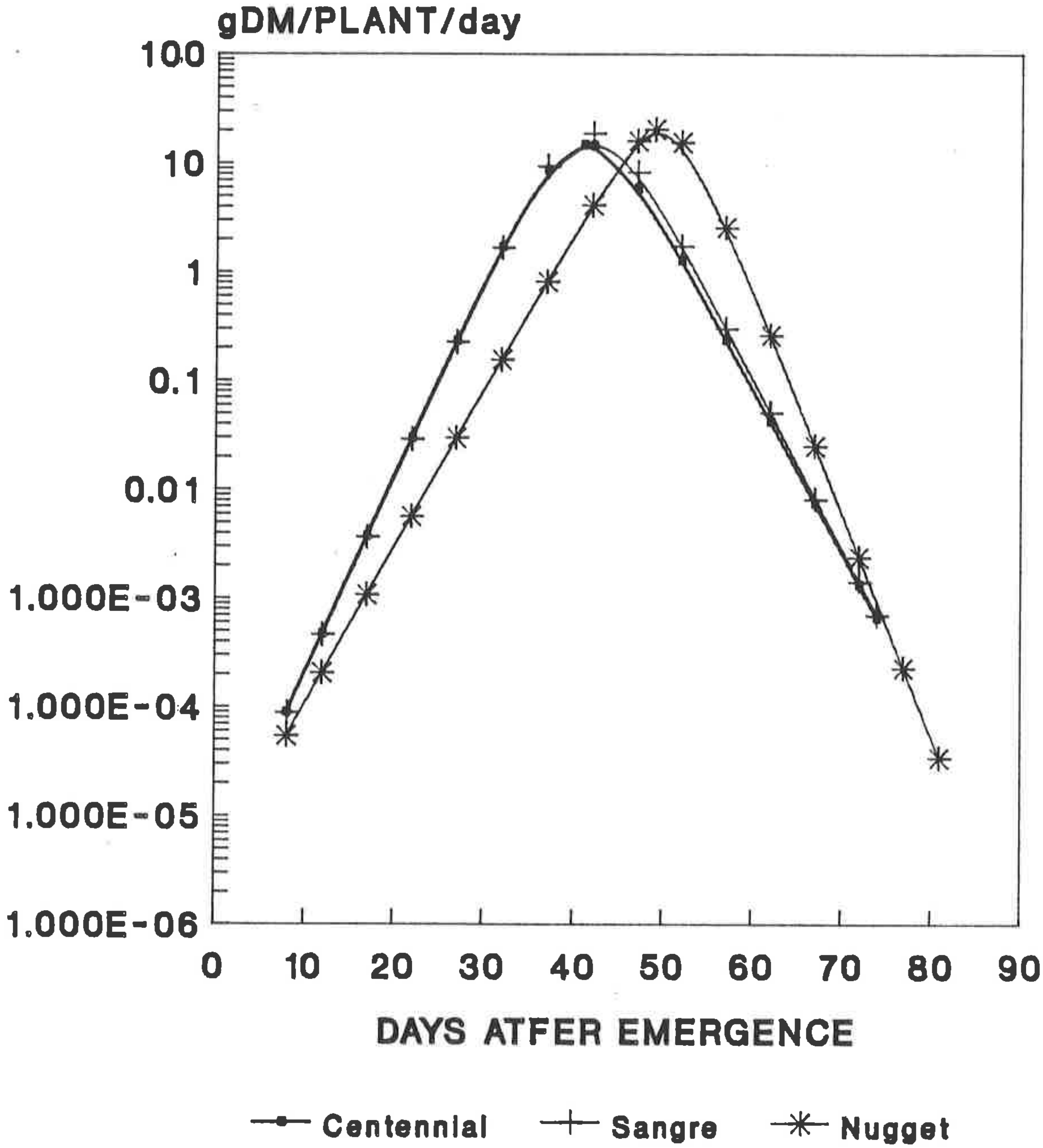
FIGURE 16

RATE OF TUBER DRY MATTER ACCUMULATION



1989 Growing Season.

FIGURE 17
RATE OF TUBER DRY MATTER ACCUMULATION



1990 Growing Season.

having the capacity to generate a higher (and earlier) rate of tuber dry matter accumulation than either Centennial or Nugget. In 1990, Nugget and Centennial performed similarly, but Nugget again peaked out relatively later. It is important to note that Nugget, presumably related to its inherent later maturity, can sustain a higher dry matter rate well past the time that Sangre and Centennial are "programmed" to quit producing tubers. The success that Nugget has enjoyed in the San Luis Valley presents an interesting situation to speculate about since, in some respects, it does not appear that this cultivar is well adapted to a short growing season. In fact, the data from this study suggest that unless it may have resistance to frost or other environmental threats, its yield potential could be at risk more often than Sangre or Centennial.

8. Seasonal Growth Characteristics-1989: The LAI and a function of LAI and time after emergence called Leaf Area Duration (Table 3), are not the only determinants of tuber yield. Leaf thickness (leaf area/leaf weight) and dry matter per unit sunlight absorbed, i.e. light use efficiency, are also important. The proportion of light intercepted by the canopy per unit LAI is another determinant. During 1989 and 1990, we used LICOR instruments to determine proportionality constants, relating canopy light penetration to LAI. It has been shown, using other species, that varieties exhibiting lower values (less light penetration per unit LAI) were most productive.

TABLE 3. LEAF AREA DURATION IN DAYS; 1989 and 1990

Cultivar	1989	1990
Centennial	167 days	142 days
Sangre	197 days	220 days
Russet Nugget	263 days	265 days

9. <u>Final Tuber Yield</u>: A tuber yield harvest was made approximately two weeks after the last scheduled weekly plant sampling. A block of 5 plants were hand dug from each plot and the tubers graded for size. A market yield estimate consisted of sorting all tubers less than 2 inches in diameter into a "non marketable" category. The data presented in Table 4 illustrate that overall average yields in 1990 at 437 cwt/acre were considerably higher than the 325 cwt/acre for 1989. However, the 1989 vs 1990 increases for Centennial and Nugget, at 49% and 44% respectively, were substantially higher than for Sangre, which had only an 18% boost. This may be partially explained by examining Figs. 14 and 15 (Tuber Dry Weight) which indicate that in 1989, Sangre achieved a substantially greater tuber dry weight within 45 to 50 days after emergence, while Centennial and Nugget lagged considerably during this same period. In 1990, all 3 cultivars did quite well up to the 50 day period.

Table 4. Final Harvest Yield

TOTAL AND MARKETABLE YIELD FOR 1989 AND 1990 -Cwt per acre						
	CENTENNIAL		SANGRE		NUGGET	
Year	Market	Total	Market	Total	Market	Total
1989	268	291	390	419	242	266
1990	362	435	439	494	271	382

10. <u>Measurement of Light Penetration Into The Foliage Canopy</u>:

Measurement of light penetration into the foliage canopy with electronic instruments can provide useful data to evaluate the capacity of leaves and stems to intercept light. Leaf area, as measured in this study, reflects the surface area which potentially could intercept light if the angle of petiole attachment and the stem and general plant architecture orients the leaves properly. Thus, if one is to more realistically understand the relationship between leaf area and photosynthetic effectiveness, it becomes helpful to supplement empirical leaf area data with light measurements. Furthermore, it is possible that light penetration measurements could reduce or eliminate the need for the time consuming and costly chore of putting individual leaflets through a leaf area meter. Two different approaches were tried during the 1989 and 1990 study to learn more about the feasibility of using light measurement to quantify the photosynthetic potential of potato varieties growing in the field. All of the instrumentation used was provided by the Department of Horticulture; both instruments were manufactured by the LICOR Co. of Lincoln, Nebraska.

Light Bar Readings: This method involves placing a one meter long light sensitive bar (on the soil surface) "across the rows" - under the foliage canopy. Thus the amount of light which penetrates the foliage canopy is electronically recorded and compared with a similar light reading made above the foliage----unobstructed by leaves and stems. These measurements were taken at two different times in 1989 and again in 1990. The 1989 information was useful from the standpoint of gathering experience with the equipment under field conditions. However, the 1990 data was much more meaningful and is presented in Table 5.

Table 5. 1990 - Light Penetration Into Foliage Canopy

CULTIVAR	K Values Recorded 8/14
Centennial	0.48
Sangre	~~0.49~~ 0.36
Russet Nugget	~~0.36~~ 0.49

LICOR Plant Canopy Analyzer LAI 2000: This instrument is newly developed by the LICOR Co. and utilizes a special lens for measuring not only the amount of light that penetrates the foliage, but also five angles of incoming light, each of which are measured and recorded separately. The instrument utilizes a computer to "integrate" the various readings into an LAI value. Our purpose in using the LAI 2000 was to determine if this instrument may be able to reduce our dependence on actual leaf area measurements, and of course improve our overall ability to evaluate varietal differences. A series of four different readings were obtained with the LAI 2000 and are shown in Table 6, compared with the actual leaf area index readings obtained by direct measurement. In general, the results were very encouraging and we would like to continue learning how to improve our skills with the LAI 2000 in 1991. The Plant Canopy Analyzer readings had to be made in the same plot where the plants were being sampled for the other phases of the experiment. On several dates, the sampling harvests were done prior to the plant canopy analyzer readings, thus the plants were partially knocked down at the time the readings were taken. This may explain the rather wide discrepancy between Actual and Plant Canopy Analyzer for Nugget on Aug. 8 and 21, and for Sangre on Aug. 14. On the other hand, it also must be kept in mind that lack of close agreement between the Actual Data and the Plant Canopy Analyzer data may not necessarily mean that the latter are not providing a useful source of information. When plants mature, the stems sometimes get weak and tend to fall down---- as a result, the leaves may not be in a position to effectively intercept light.

Table 6

COMPARISON OF LEAF AREA INDEX VALUES: Actual vs. Plant Canopy Analyzer								
	July 17		Aug. 8		Aug. 14		Aug. 21	
Cultiv	Actual	Pl.Can Anal.	Actual	Pl.Can Anal.	Actual	Pl.Can Anal.	Actual	Pl.Can Anal.
Centen	2.15	2.69	4.14	3.46	3.79	3.54	3.61	2.63
Sangre	3.58	2.52	5.80	4.08	6.38	3.17	3.17	3.04
Nugget	3.61	3.04	6.70	3.25	6.63	4.04	4.62	2.88

<u>SUMMARY</u>: The plant growth analysis studies conducted the past two years have demonstrated the potential value of a new research tool for studying the potato crop under field conditions. The data collected have illustrated the importance of being able to identify how the stages of growth differ for three commonly planted potato cultivars---- Centennial, Sangre and Russet Nugget. As the methods become more routine and reliable, we should be able to accurately analyze the adaptability and production potential of any cultivar to San Luis Valley growing conditions. Expanded knowledge of each cultivar should also enable individual growers to devise variations in their crop management practices to more effectively capitalize on cultivar strengths and/or avoid known weaknesses.

It is anticipated that plant growth analysis methods will be useful to devise better strategies for reducing the damage due to diseases such as early blight and verticillium wilt. The timing of fertilizer applications to more closely meet the needs of the crop may be another opportunity for improving crop management.

Computer simulation of crop growth is not yet an established and functional part of potato crop management. However, the "state of the art" is rapidly advancing, and it is likely that within a few years, simulation models will be used by growers. The data gathered through the plant growth analysis experiments has provided a good data base with which to start the process of calibrating a growth simulation model known as SUBSTOR. When this model becomes calibrated for San Luis Valley growing conditions using the above mentioned data base, we will be able to start the process of validating its application and gradually add other data base information as it becomes available. This will be an ongoing effort that will enable a wide range of scientists and other potato professionals to share their experience.

FIGURE 1 APPENDIX

Air Temperatures
June 1989

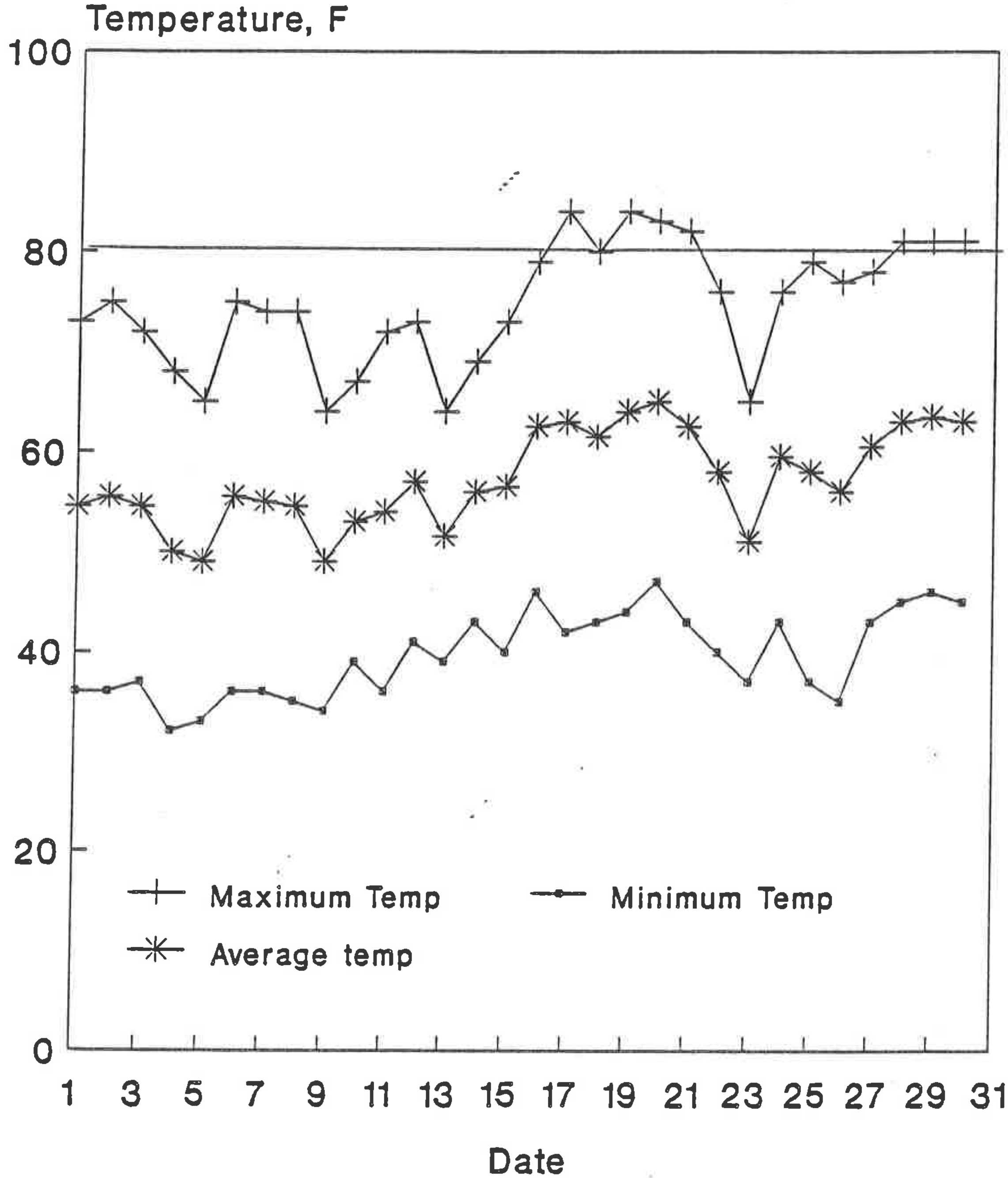


FIGURE 2
Air Temperatures
July 1989

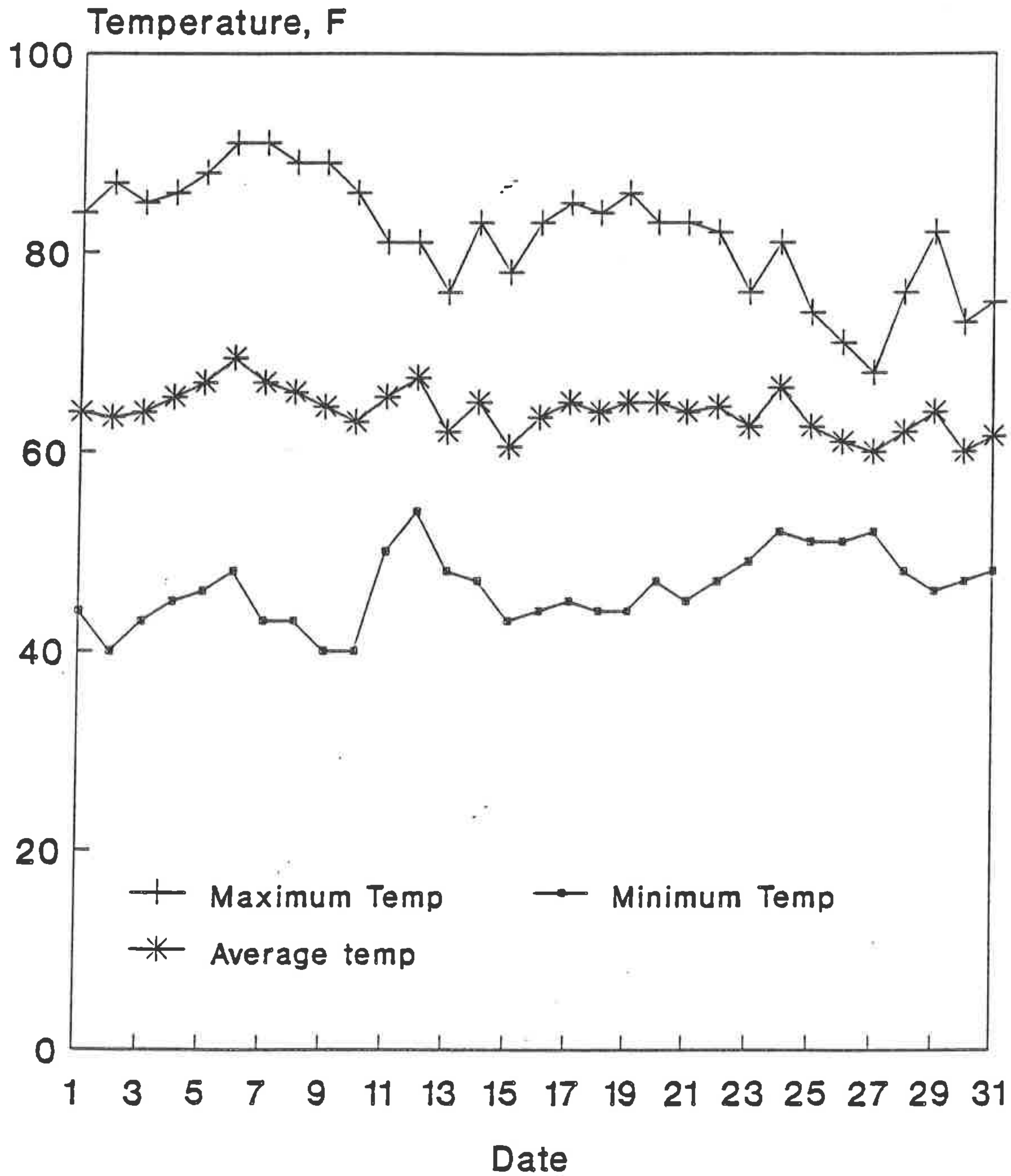


FIGURE 3
Air Temperatures
August 1989

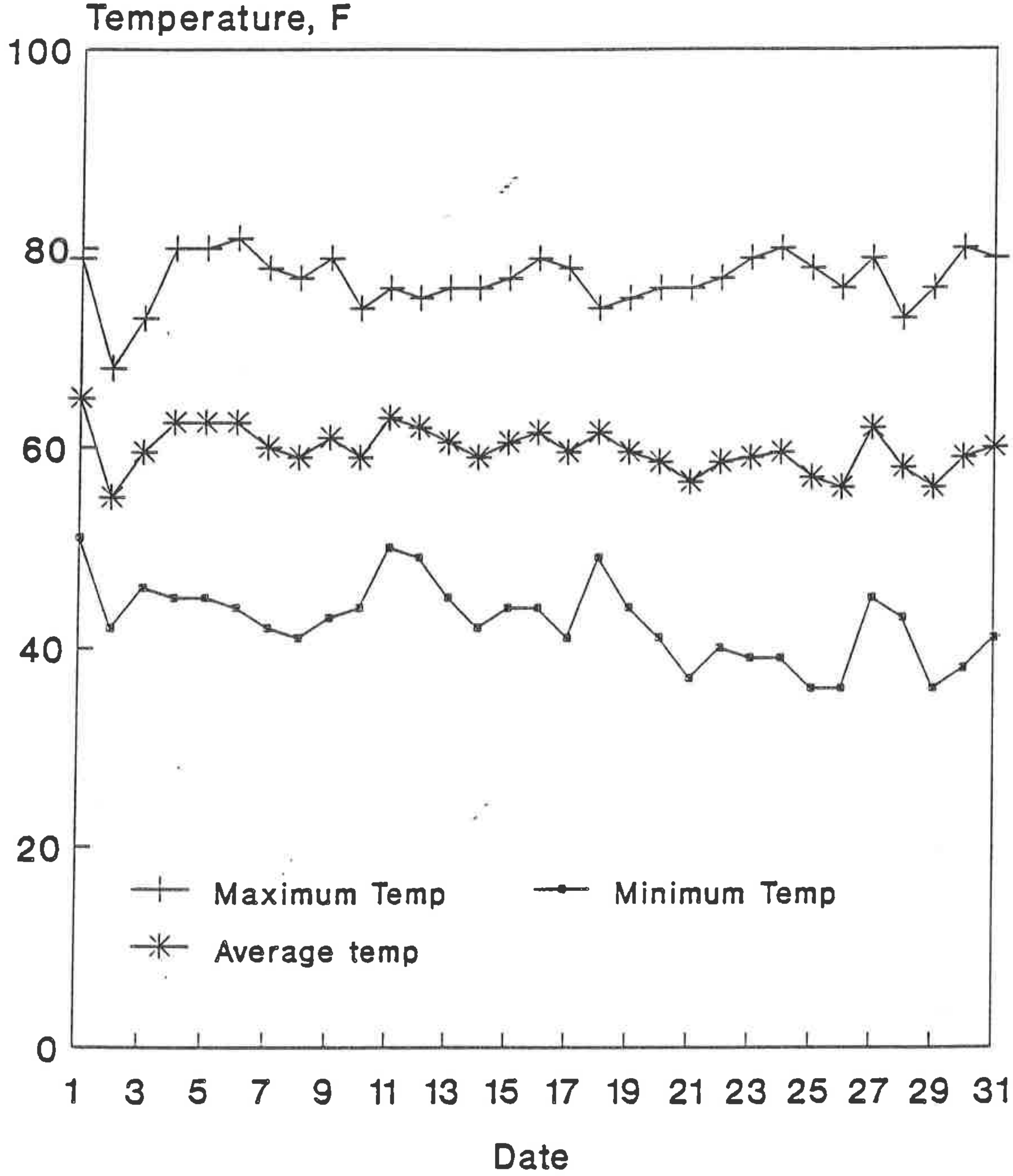


FIGURE 4

Air Temperatures
June 1990

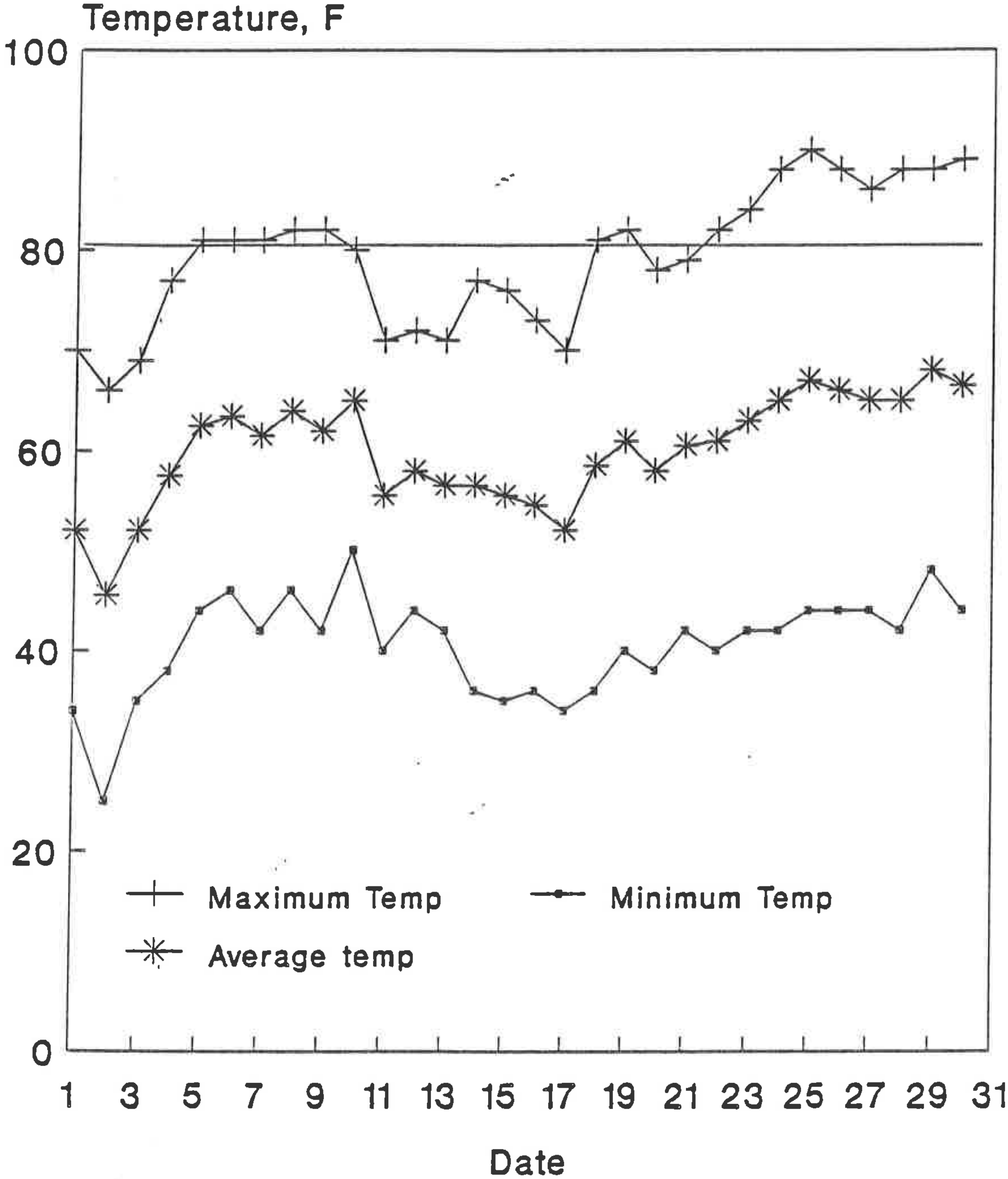


FIGURE 5

Air Temperatures
July 1990

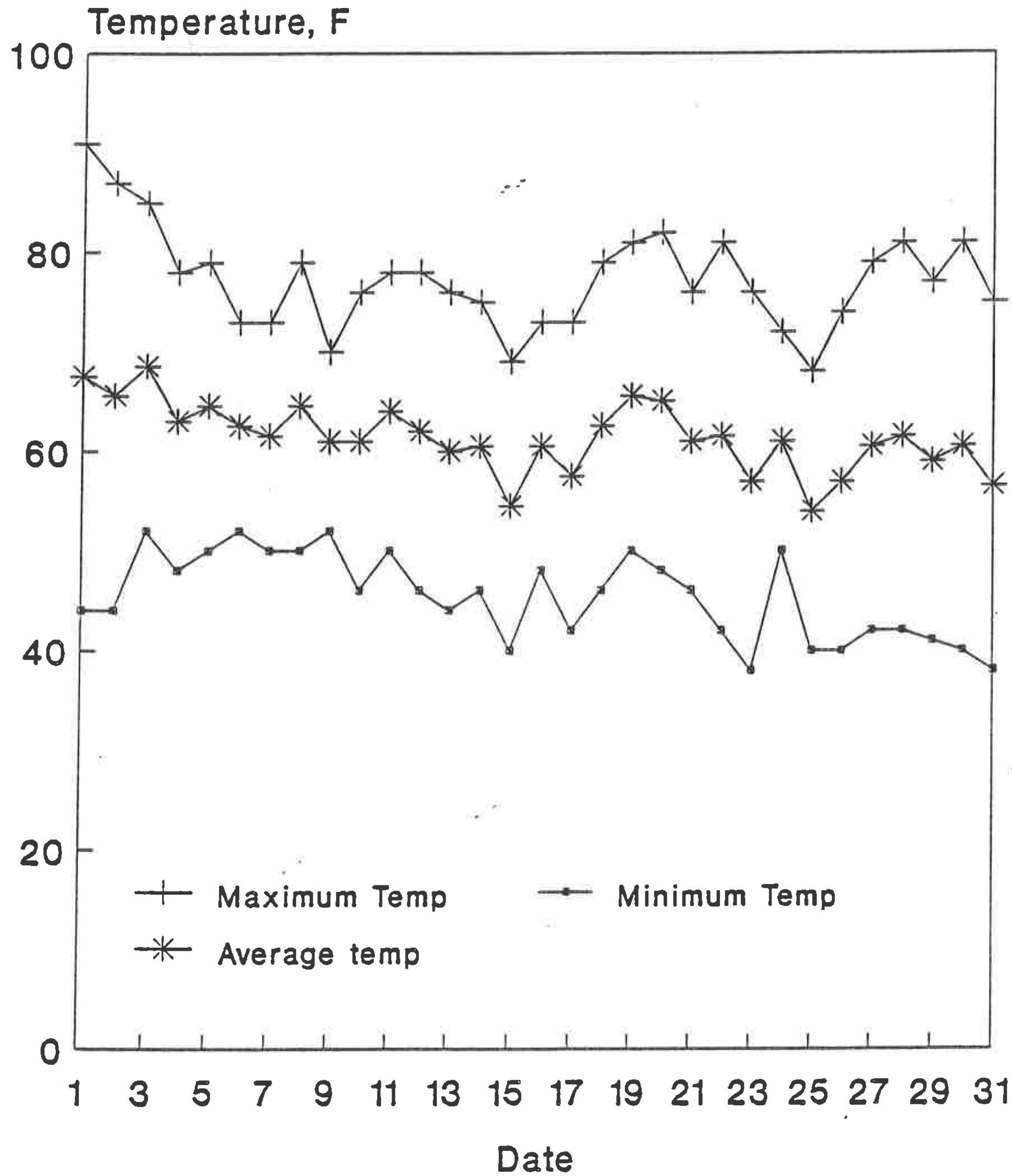


FIGURE 6

Air Temperatures
August 1990