THE RATE OF NUTRIENT ABSORPTION

BY LETTUCE UNDER FIELD CONDITIONS IN THE SALT RIVER VALLEY

by

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INTRODUCTION

The irrigated areas of Southern and Central Arizona with their mild winter climates and controllable water application are ideal for the production of vegetable crops. Lettuce is the major crop grown at the present time, with 25,000 carloads being shipped in 1951 (1). This constitutes about half the total number of carloads of vegetables shipped from the State during that year. The Salt River Valley, located in the south-central part of the State produced a little more than half of the vegetables shipped from the State in 1951. The growing season favorable for the production of lettuce extends from early September to the middle of April, during which two crops are grown. The fall crop is planted in late August or early September and is harvested from the middle of November to early in January. This planting date is earlier than it was at one time, due to the development of new varieties such as Great Lakes, which are more heat resistant and can be planted earlier. These varieties also extend the winter growing season later into the spring because of their heat and disease resistance. The other most important variety grown as the fall crop is Imperial 44. The winter crop is planted about November 1st to 15th, and is harvested from March 15th to April 15th, depending upon growing conditions. The important variety grown other than Great Lakes is Imperial 615.

Fertilization is restricted mainly to the addition of nitrogen and phosphorus, as most of the soils in the irrigated areas are well supplied with available potassium. The application of certain minor elements has also gained popularity in recent years. Fertilizers are usually banded at planting time, and often planting and fertilization are carried out in one operation. Later applications are made by banding or in the irrigation water.

Keen competition, high prices, and lack of land for lease in recent years have been discouraging to rotation plans and many growers depend on cover crops and the addition of manure as well as commercial fertilizers in large quantities to maintain the fertility level of their soil. The year-long growing season is favorable to double cropping and cantaloupes usually follow the lettuce crop in the summer time.

The ultimate goal of the grower is to produce solid heads of good size and marketable quality. In past years, especially 1950-51, considerable loss was incurred when many plants formed seedstalks prematurely and never produced marketable heads. Little is known as to the cause of this phenomenon. Some growers attribute it to temperatures higher than normal during the early part of the growing season, and it remains an unsolved problem of considerable importance.

The cost of growing lettuce is extremely high, requiring much hand labor, large applications of fertilizers, frequent use of insecticides, and intensive tillage practices as well as high harvesting, packing, and shipping costs. Moreover the value of the crop is dependent upon market conditions, which fluctuate from year to year. As a result growers depend upon diversification, or upon profits from seasons of favorable market conditions balancing losses from poor ones.

LITERATURE REVIEW

Davidson et al. (7) after examining several vegetable crops including lettuce for total ash and mineral constituents concluded that there was considerable variation in the mineral content in all vegetables, but that each had its own range of variation in mineral content. The work of Bear et al. (2) showed that lettuce plants grown in different localities have different composition. Samples collected in the eastern coastal states were higher in sodium, while plants grown on calcareous soils of the north central states and Colorado were higher in ash, Ca, Mg, and K. Phosphorus seemed to remain fairly constant in all locations.

Considerable variations have also been noted in content of certain minerals throughout the growing period. Lettuce plants grown in Arizona as shown by McGeorge, Wharton, and Frazier (17) remained fairly constant in percentage of calcium and phosphorus on the dry matter during the growing period. There was considerable fluctuation in nitrogen and potassium, however. Beginning at the early stage, these elements reached one or two peaks, with a final decline at maturity. Lettuce plants grown in the Salinas Valley in California did act in this same manner. Lorenz and Minges (14) have shown that such plants decrease in calcium markedly with maturity, while nitrogen decreases slightly. The phorphorus and potassium contents in plants in this study remained practically constant at all sampling dates. Their study also showed that the addition of P or K to the soils of that locality did not increase the content of either in the plant.

A study by Woodman (23) where lettuce plants were grown in nutrient solutions with varied amounts of K over a wide range, pointed out that the yield was not affected by an increased concentration of potassium, but that a high concentration of potassium decreased root growth. Other work by the same author (24) emphasizes the importance of an adequate supply of nitrogen. Lettuce plants grown in sand cultures were treated with varying amounts of $NaNO_3$. A progressive reduction of N applied resulted in a progressive reduction of size and weight of heads. Owen (19) found that as compared with lettuce plants receiving a complete fertilizer, the dry matter of those plants receiving only P and K or N and K was significantly higher in ash and K, whereas the plants receiving only N and P were lower in ash and very much lower in K. The omission of N, P, or K did not greatly affect the percentage of N and P in the dry matter. However the omission of one nutrient caused the plant to take up smaller amounts of all other nutrients.

There seems to be a definite interrelation of Ca and

N in the soil which controls the availability and uptake of either. Wittwer et al. (22) have shown by lettuce plant and soil studies that high calcium levels must be accompanied by adequate amounts of nitrogen, and high nitrogen levels must have sufficient amounts of calcium for best growth responses. They also found that when plants were grown at low phosphorus levels and calcium was increased, phosphorus deficiency was accentuated. It was concluded that a lack of balance was more detrimental to plant growth than a deficiency of any of the variable nutrients which were studied. A study by Walker (21) also indicates a definite Ca:N interrelationship in the soil. Soil solutions and lettuce plants were analyzed at different dates and the results showed that fluctuations in the NO_3 content of the soil solution, whether cropped or fallow, were paralleled by fluctuations in the Ca content.

Griffiths (12) has shown with lettuce experimental plots that in general inorganic sources of plant nutrients gave best results on manured plots, while fertilizers in which part of the nitrogen was contributed from organic sources gave best results on non-manured plots. Experimental plots and soil culture experiments conducted by Woodman (25) showed that fertilizer mixtures high in N gave the best growth response in lettuce.

Phosphorus fertilization on Arizona soils was deemed necessary by Crider (6), where the application of acid phosphate hastened maturity and increased the size and compactness of the head.

Experimental plots on lettuce fertilization in Arizona conducted by Griffiths and Finch (11) produced the following results: Band placement of fertilizers gave higher yields than plots where the fertilizer was broadcast. Simple chemical fertilizers gave good results on fertile land with sufficient organic matter content. On such land best yields resulted when phosphates were applied at planting time and nitrogen applied later as a side dressing. Not over twenty pounds of actual N could be applied when temperatures were high nor over thirty pounds at any time without toxic results. On a heavy soil depleted of organic matter, ten tons of manure gave improved results. This increase in yield exceeded that of any chemical fertilizer during the same period.

Experiments by McGeorge and Wharton (16) on salt movement in lettuce beds have shown that there is considerable movement and accumulation of soluble salts in the beds during growth. Salt movement was shown to be a function of the type of bed used and the amount of irrigation water used. The most mobile compounds were the nitrates, chlorides, and sulfates of the alkali and alkaline earth bases. The least mobile was phosphate which is held by fixation. The most satisfactory type bed as shown by the study was the one inch crown bed, because there was less salt concentration at the shoulder of the bed where the plants are located.

Brown (5) found that in Ohio soils good heads of lettuce were usually obtained when the content of nitrate N in the soil at heading time was reduced to less than 5 ppm by copious irrigation. Loose heads were obtained when the N level was 10-15 ppm. However, plant analyses of Arizona grown lettuce by McGeorge, Wharton and Frazier (17) showed no significant difference in the nitrogen content of loose and compact heads.

PURPOSE OF THE INVESTIGATION

The purpose of this study was to determine the rate of nutrient uptake of lettuce during the entire period of growth to harvest by making chemical analyses of plants grown under actual field conditions. Along with these plant studies, soil analyses were made to note possible changes in certain soil constituents throughout the period of growth. Six growers who were willing to cooperate were contacted, and permission was granted to sample from their fields. Locations were chosen which were well separated and represented different soil types. Four fall crops and two winter crops were sampled, three varieties being represented. The fertilization practices followed by these growers were quite different. Sampling was carried on through harvest time and chemical analyses made on both plant and soil samples. Fertilization and irrigation data were obtained where possible for correlation purposes.

EXPERIMENTAL PROCEDURE

Sampling was begun in each field at or soon after thinning time and carried on until plants were mature enough for harvest. A random sampling plan was followed, with soil samples being taken from the first foot between plants on the shoulder of the beds. Whole plant samples were taken including the roots. Soil samples were taken close to the place where each plant sample was taken. Many plants were required early in the season, and at least ten plants were taken later on to give a representative sample.

Upon returning to the laboratory the soil samples were spread out and allowed to air-dry. Then they were passed through a 2 mm sieve, thoroughly mixed and stored in sealed quart bottles until analyzed. Plant samples were separated into roots and tops and rinsed thoroughly in tap water to remove soil particles. Then they were cut up and dried at 65^{o} C. in a ventilated drying oven. Fresh weights and dry weights were recorded for both roots and tops. After drying, the plant samples were ground to 40 mesh in a Wiley mill, thoroughly mixed and stored in sealed bottles.

Plant Analysis

Nitrogen was determined by the Kjeldahl method, using a micro-digestion and distillation apparatus. A 50 mgm. sample was weighed onto a piece of nitrogen-free cigarette paper which was then folded, enclosing the sample and placed in a 50 ml. micro-digestion flask. One to one and a half ml. of digestion mix of the following composition was used: 300 ml. conc. H_2SO_4, 50 ml. 85% H_3PO_4, 25 gms. anhydrous Na_2SO_4, 5 gms. Na_2SeO_3, and 3 gms. $CuSO_4 \cdot H_2O$.

Digestion required about 30 minutes, after which the samples were allowed to cool and transferred to the distillation flask with three or more rinsings of distilled water. The ammonia distillate was received in a 50 ml. Erlenmeyer flask in 5-7 ml. of saturated boric acid to which 2-3 drops of mixed methyl indicator had been added. Distillation was carried four minutes beyond the time of color change of the indicator. The ammonia was titrated with approximately .03 N HCl which had been standardized with a known solution of NH_4Cl following the same procedure.

Phosphorus was determined colorimetrically following the molybdivanadophosphoric acid method as described by Kitson and Mellon (13). An Evelyn photoelectric colorimeter fitted with a 420 u filter was used to measure transmittancy.

Sodium and potassium were determined spectrophotometrically using an aliquot from the same sample solutions as prepared for the phosphorus determination. These aliquots were placed in 100 ml. volumetric flasks and made to volume adding lithium so that the final solution contained 50 ppm Li to serve as an internal standard. Determinations were made with a Perkin Elmer Model 52C flame photometer which had been calibrated to sodium and potassium in the nitrate form.

Soil Analysis

Mechanical analysis was carried out following the hydrometer method of Bouyoucos (4). 50-gram samples were used for heavy soils and 100-gram samples for sandy soils. Sodium hexametaphosphate was used as a dispersing agent instead of sodium oxalate.

pH value was determined with a Beckman pH meter on the soil paste using air dry soil and a suitable amount of water.

Total soluble salts were determined on a 1:5 soil-water extract by measuring conductivity with an Industrial Instruments Co. Bridge. Temperature corrections were made and conductivity converted to ppm using tables and graphs from the Regional Salinity Laboratory Manual (8).

Total nitrogen was measured in soils as directed in the A.O.A.C. manual (20), with two exceptions. Selenium (Hengar granules) was used as an additional catalyst during digestion and the ammonia distillate was received in 100 ml. of saturated boric acid containing 5-6 drops of mixed methyl-red indicator and titrated with .02 N hydrochloric acid.

Nitrate nitrogen was determined colorimetrically on a 1:5 soil water extract which had had CO_2 gas bubbled through it for 15 minutes and was then filtered. A 25 ml. aliquot was taken and evaporated to dryness in a porcelain casserole and color was developed according to the phenoldisulphonic acid method as described in the A.O.A.C. manual (18). Transmittancy was measured on a Cenco Photelometer, fitted with a 420 u filter after appropriate dilutions had been made.

Phosphorus was determined colorimetrically on a 1:5 soil-water extract which was made as described in the soil nitrate procedure. The CO_2 soluble extract has been found to be a good measure of available phosphorus in alkaline calcareous soils as it is thought to simulate the action of plant roots (15). Acid extracts are not suitable for use on alkaline soils because they put more phosphorus into solution than is actually available to plants. Organic matter often goes into solution during extraction, and it is necessary to decolorize the CO_2 extracts with a small amount of acid-washed, phosphorus-free carbon black. Color was developed according to the ammonium molybdate-stannous chloride method as described by Dickman and Bray (9). Transmittancy was measured with an Evelyn photoelectric colorimeter fitted with a 660 u filter.

Exchangeable-plus-water-soluble sodium and potassium were determined following a modification of the method set forth by Fieldes, King, Richardson and Swindle (10). The modified method used was as follows: 10 grams of air-dry soil was weighed into a 400 ml. beaker and allowed to stand for 16 hours after adding 100 ml. of neutral 1 N ammonium acetate. The sample was then extracted under suction through a medium-porosity fritted glass filter fitted with a paper filter disc. The soil was transferred to the funnel and washed with four 25 ml. portions of neutral Normal ammonium acetate, allowing the filter to suck dry between washings. The extracts were transferred to 400 ml. beakers and evaporated to dryness on a steam bath. The residue was ignited in a muffle furnace at 450° C. for about 2 hours to remove organic matter. After cooling, the residue was taken up in 5 ml. of 1:1 HCl and allowed to stand 30 minutes to insure solution. The sample was then filtered into a 100 ml. volumetric flask, using Whatman 40 filter paper and rinsing the beaker and filter paper several times. The solution was made to volume to include 50 ppm of lithium as required by the internal standard method. Sodium and potassium were determined with the same flame photometer which in this case had been calibrated with standards in the chloride form.

During the course of the laboratory work calibration curves were made for the flame photometer for sodium and potassium in both the chloride and nitrate form. It was noted that the curves very closely approximated each other. The differences between them were so slight that either curve could have been used in converting scale readings to parts per million for both elements, with negligible error in the results.

EXPERIMENTAL RESULTS

Field A

This field was located in Deer Valley, about twelve miles northwest of Phoenix on State Highway 69. The soil was well suited to vegetable production, for its mechanical analysis showed it to be a loam. The source of irrigation water for this area is entirely from pumpage. The effective date of growth starts in all vegetable crops upon the date of "watering up";* that is, the first irrigation after planting. Very often for the convenience of the grower's tillage and planting schedule, seed is planted a week or so in advance of the first irrigation with no apparent unfavorable effect on germination.

This field of 40 acres had been previously cropped as follows: Fall of 1948-carrots, Spring of 1949-potatoes, Spring of 1950-carrots, Fall of 1950-carrots, Summer of 1951-melons. Liquid phosphoric acid was applied in March of 1950 at the rate of 100 pounds/acre. An identical application of phosphoric acid was again made in October of 1950. Manure was applied in August of 1951 at the rate of 6 tons/acre in preparation for planting the lettuce crop which was included in the study presented in this thesis.

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*post-planting irrigation

Imperial 44 variety was planted and watered up on September 6th. The field was irrigated again October 2nd; other irrigation dates were unavailable. Considerable rainfall occurred September 29th, October 26-30-31, and November 23-24. $Ca(NO_3)_2$ was applied in November as a side dressing at the rate of 185 pounds/acre. The lettuce plants reached maturity quite rapidly and harvest was begun about the 25th of November. The growing period was 82 days. The crop was of high quality and yielded 251 crates of lettuce of 4 and 5 dozen size, per acre.

Plant analyses are shown in Table 1 and graphically in Figure 1. The amounts of different constituents present as per cent on the basis of dry matter followed the same order in both roots and tops, potassium being present in the highest concentration, followed by nitrogen, phosphate and sodium in that order. The percentage of potassium was considerably higher than that of the other constituents and fluctuated during the period of sampling, being higher in the tops than in the roots. Nitrogen concentrations experienced a decline in both tops and roots as maturity was approached. However, the decline was greater in the roots. The percentage of phosphate remained fairly constant with a small drop undergone by the roots. Sodium concentrations were fairly constant in the tops, with a slight decrease approaching maturity. In general, young plants are more

TABLE I

COMPOSITION OF LETTUCE PLANTS FROM FIELD A, VARIETY: NO. 44

		Tops					Roots				
Date sampled	Days after watering up	Dry matter gms./plant	Per cent dry basis				Dry matter Gms./plant	Per cent dry basis			
			N	PO_4	K	Na		N	PO_4	K	Na
10/4/51	30	.17	4.77	1.36	7.65	.41	.02	4.08	1.39	5.49	.24
10/15/51	41	2.15	4.18	1.35	8.01	.37	.27	2.66	1.03	5.46	.33
10/25/51	51	5.20	3.89	2.05	10.66	.49	.68	2.36	1.06	5.11	.37
11/5/51	62	12.56	3.87	1.50	7.36	.40	1.04	1.95	.97	5.23	.51
Bolter 11/15/51	72	16.00	4.07	1.88	6.70	.29	2.70	1.97	.99	4.51	.42
11/15/51	72	29.25	3.54	1.57	6.70	.41	2.00	1.93	1.01	4.66	.58
11/25/51	82	22.25	3.15	1.34	7.68	.30	1.77	1.91	.64	4.44	.35

SOIL ANALYSES FROM FIELD A (PPM DRY SOIL)

Date sampled	pH	TSS	Total N	CO_2-soluble NO_3	CO_2-soluble PO_4	Exchangeable K	H_2O soluble Na
10/4/51	7.99	705	481	9.8	22.4	152	117
10/15/51	7.88	785	460	26.6	16.3	124	114
10/25/51	7.88	580	424	7.3	16.3	123	110
11/5/51	7.95	705	476	8.8	17.5	106	122
11/15/51	8.01	533	422	4.7	18.8	102	132
11/25/51	7.91	550	565	7.3	10.5	214	136

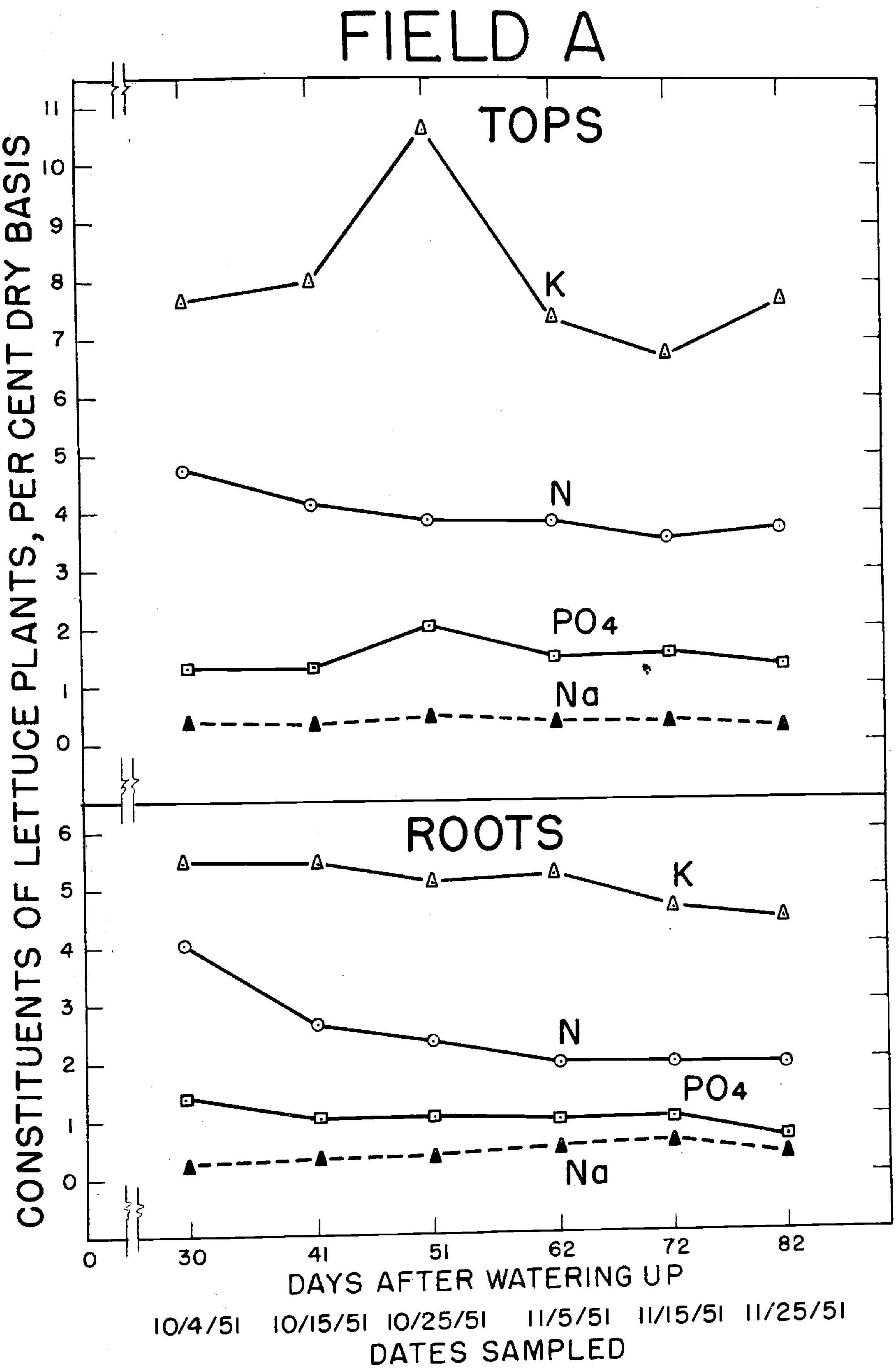

Figure I.- Changes in N, PO_4, K and Na in Lettuce plants during growth, Field A.

highly vegetative and contain higher concentrations of mineral constituents.

The soil analyses are shown in Table 1 and Figure 2. The amounts of exchangeable-plus-water-soluble sodium and potassium were almost equal and remained fairly constant during the period of sampling. The quantitities present for these two constituents were not high due to the coarse texture of the soil and low amount of clay which holds such cations in exchange. The total nitrogen values were fairly high, but it should be remembered that they are measures of potentiality and not availability. Most of the nitrogen represented in such a determination is tied up in complex organic compounds and is not available to the plant. The nitrate nitrogen level experienced a sharp rise as of the second sampling, otherwise it remained fairly constant. The amount of CO_2-soluble phosphate started off fairly high and decreased toward the end of the sampling period. The variations were not very great considering that phosphate is held in part as slightly soluble calcium salts and partly by anion fixation and is very immobile in comparison with nitrates which are water-soluble and extremely mobile.

Soluble salts as shown in Table 1 were very low in general, and decreased somewhat toward the latter part of the growth period. Salts are brought to the surface by capillary action and by evaporation of moisture. Rains when not too

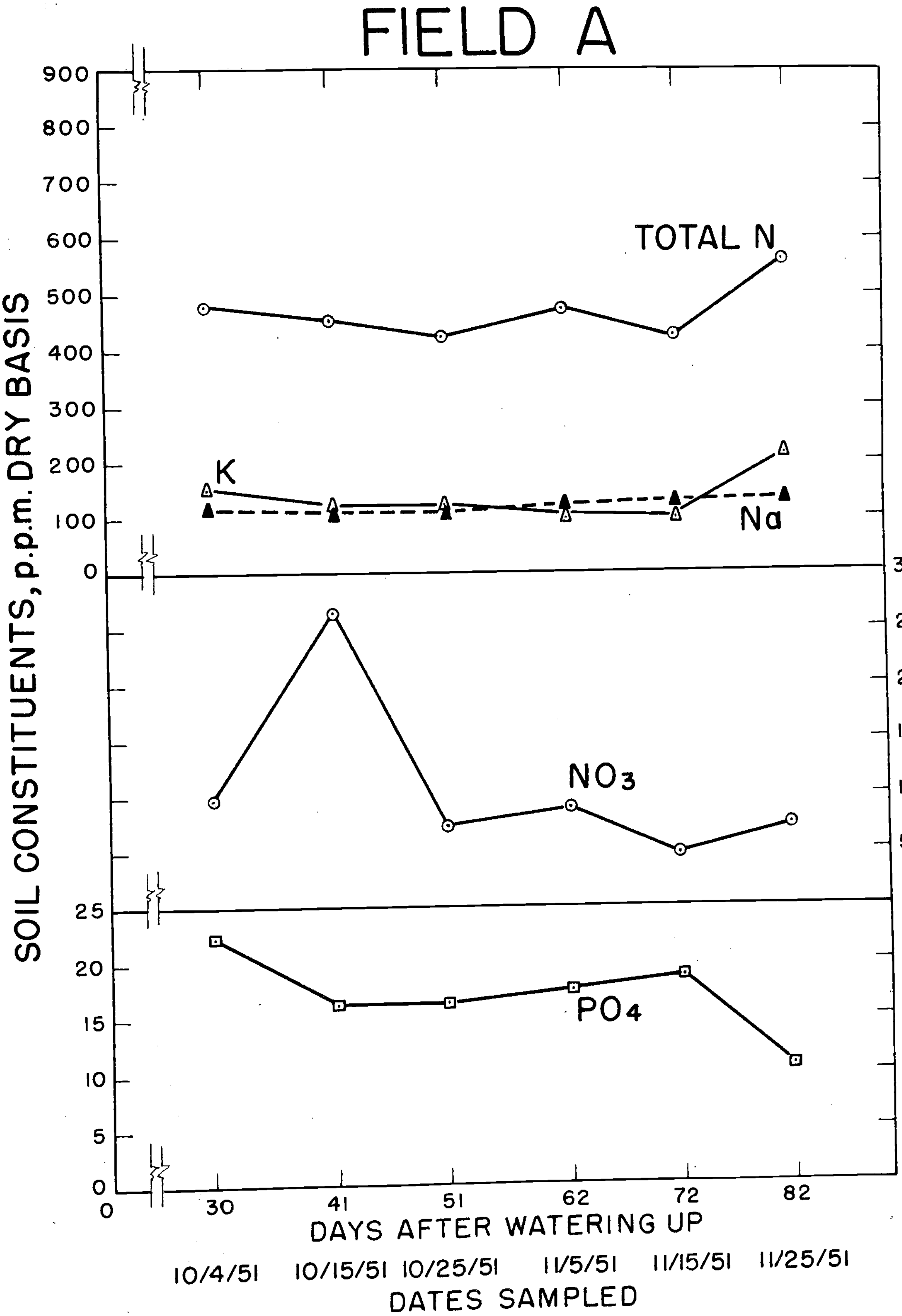

Figure 2.- Changes in total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field A.

heavy tend to leach and remove salts from the surface. The pH values remained very constant, within only slight variations through the growing period.

All the nutrients analyzed for were present in sufficient amounts to be considered adequate for rapid and vigorous growth of the crop.

Field B

Field B was located at Lateral 22 and Maricopa Road, about nine miles west of Phoenix. The soil in this area is definitely heavy textured. Mechanical analysis showed the textural classification of a composite sample of this field to be clay loam. This field had been cropped to lettuce in the spring of 1951. Great Lakes variety was planted and it was watered up on the 29th of August, which is considered an early date. Other irrigation dates were September 10th, September 28, October 16th, and October 29. Two hundred pounds of 10-20-0 fertilizer per acre was applied by banding on September 25, and 30 pounds per acre of nitrogen applied October 28, as ammonia gas in the irrigation water. Harvesting was begun on the 15th of November, making a growing period of 84 days. Heads were of large size as shown by the dry weight data, and the yield of 272 dry packed crates per acre was very good.

The results of the plant analyses are shown in Table 2 and Figure 3. Examination of these results shows that the

TABLE II

COMPOSITION OF LETTUCE PLANTS FROM FIELD B, VARIETY: GREAT LAKES

		Tops					Roots				
Date sampled	Days after watering up	Dry matter gms./plant	Per cent dry basis				Dry matter gms./plant	Per cent dry basis			
			N	PO_4	K	Na		N	PO_4	K	Na
10/4/51	42	1.00	3.88	1.06	8.11	.81	.09	2.57	.85	5.74	.60
10/15/51	53	7.12	3.85	1.13	9.12	.89	.72	2.55	.76	4.59	.67
10/25/51	63	11.15	3.70	1.17	8.34	.83	1.02	2.04	.75	4.63	.72
11/5/51	74	17.97	3.61	1.29	7.48	.75	1.17	2.07	.94	5.75	.85
Bolter 11/15/51	74	39.00	4.31	1.43	7.69	.62	4.10	2.09	.90	4.34	.96
11/15/51	84	46.67	3.22	1.22	7.18	.61	2.57	2.10	1.05	4.98	1.02

SOIL ANALYSES FROM FIELD B (P.P.M. DRY SOIL)

Date sampled	pH	TSS	Total N	CO_2-soluble NO_3	CO_2-soluble PO_4	Exchangeable--H_2O soluble K	Exchangeable--H_2O soluble Na
10/4/51	7.79	1380	720	40.0	10.2	468	328
10/15/51	7.68	1340	744	18.7	6.3	434	328
10/25/51	7.71	1320	694	9.4	8.2	405	376
11/5/51	7.81	1180	724	22.8	6.2	375	324
11/15/51	7.78	1275	720	15.9	11.5	532	289

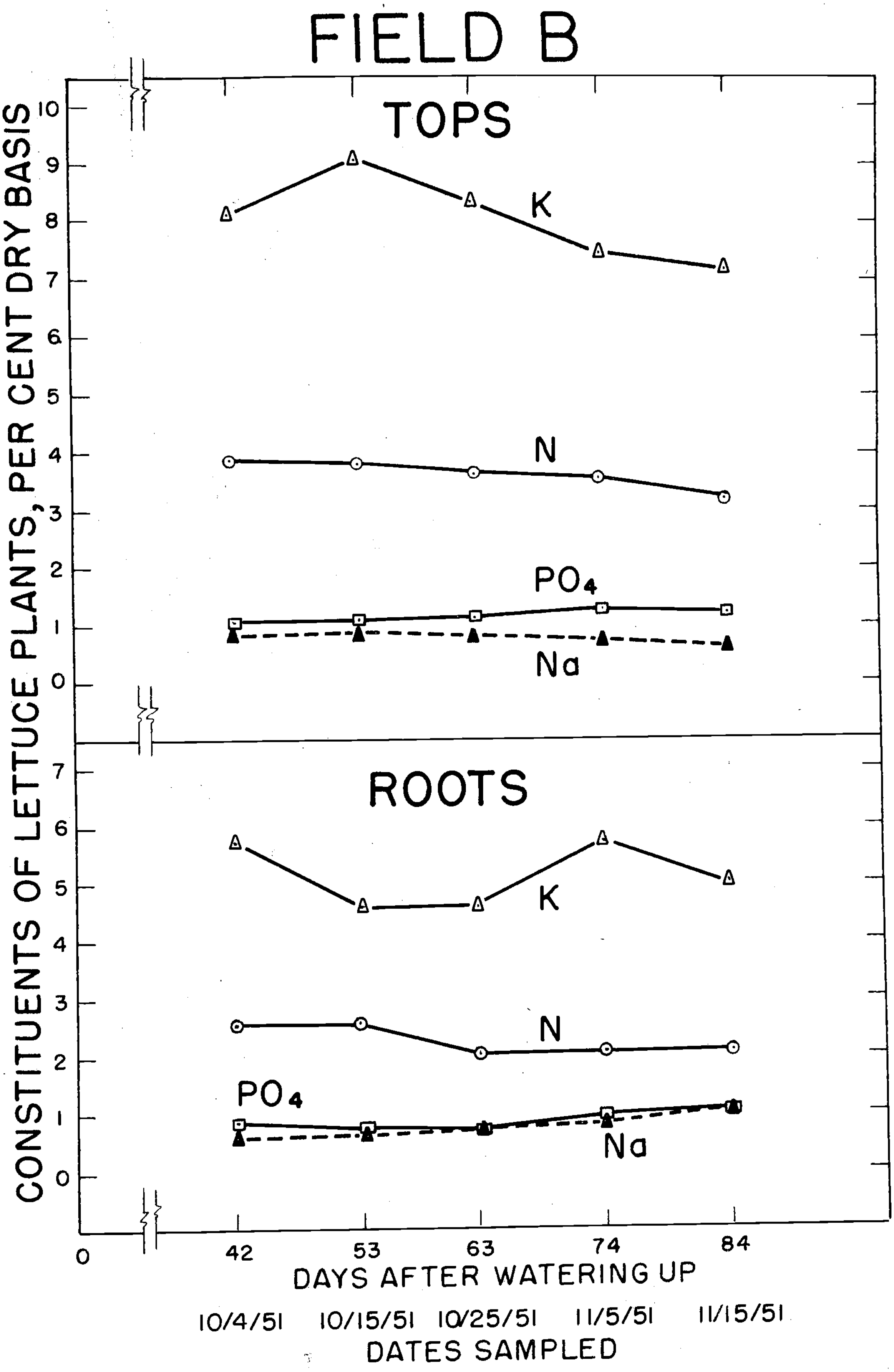

Figure 3.-Changes in N, PO4, K and Na in Lettuce plants during growth, Field B.

levels of constituents follow the same general order as in those from Field A. However, the per cent of sodium in this case is almost as high as that of phosphate. The per cent of nitrogen shows a decline again, in both tops and roots: while the phosphate level experiences a gentle rise. The sodium percentages remain practically constant in the tops and increase slightly, but steadily in the roots.

Soil analyses are shown in Table 2 and Figure 4. The total nitrogen level was fairly high and remained relatively constant during the sampling period. Both the potassium and sodium levels were higher than in Field A, and both experienced greater fluctuation. The nitrate nitrogen values varied widely during the sampling period. A marked depletion is shown in the first three samplings, after which ammonia was applied and there was an increase followed by a drop. The available phosphate supply was fairly low and fluctuated between 6 and 11 ppm. Hence its adequacy was questionable, in the light of the criteria of McGeorge (16a). All other constituents were present over and above the amounts thought to be necessary for good plant growth. The total soluble salt concentration was quite high and fluctuated very little. pH values remained constant throughout the growing period.

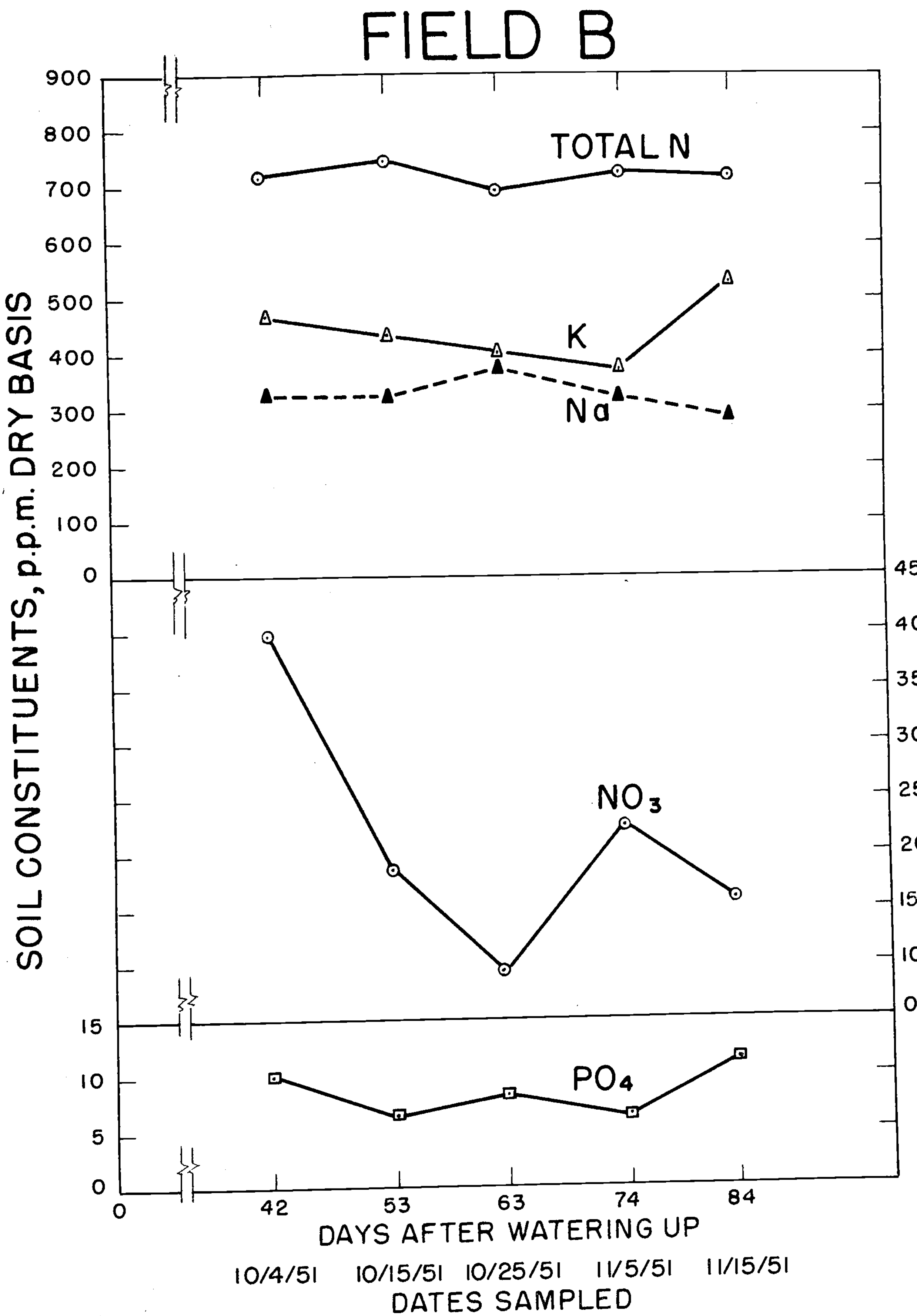

Figure 4.– Changes in Total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field B.

Field C

Field C was located at Lateral 24 and Christy Road, about eleven miles west of Phoenix. The soil was shown by mechanical analysis to be a clay loam, but it was not as high in clay as the soil of Field B. The variety planted was Imperial 44 and was watered up September 5th. Two hundred and sixty pounds of 10-20-0 super per acre was banded under the seed before planting. In addition 250 pounds of NH_4NO_3 per acre was applied as a side dressing October 10th, and 240 gallons of liquid 16-14-0 was applied to the entire 40 acres in the irrigation water of November 8th. Other irrigation dates were unavailable for this field. Harvest was begun the 6th of December, terminating a growing period of 92 days. This was about ten days longer than the growth period of field A. Differences in soil texture and locality would probably account for these differences in growth periods.

The results of plant analyses from field C are presented by Table 3 and Figure 5, and indicate about the same general trends as occurred in the two fields previously discussed. The potassium percentage in the tops started high and then dropped sharply after the second sampling. The nitrogen levels gradually decreased approaching maturity, but the percentage in the tops was higher at the start than in samples from the two fields previously discussed. The phosphate

TABLE III

COMPOSITION OF LETTUCE PLANTS FROM FIELD C, VARIETY: 44

		Tops					Roots				
Date sampled	Days after watering up	Dry matter gms./plant	Per cent dry basis				Dry matter gms./plant	Per cent dry basis			
			N	PO_4	K	Na		N	PO_4	K	Na
10/15/51	40	1.89	4.20	1.26	9.40	.69	.14	2.56	.89	4.95	.48
10/25/51	50	4.33	4.17	1.33	9.33	.72	.43	2.19	.82	4.95	.53
11/5/51	61	7.18	4.29	1.10	7.15	.47	.90	2.40	.86	4.94	.56
11/15/51	71	13.85	3.81	1.43	7.28	.44	2.33	2.33	.77	4.59	.61
11/25/51	81	31.00	3.80	1.36	7.15	.42	2.38	2.01	.73	4.58	.57
12/6/51	92	37.50	3.28	1.46	7.13	.47	2.55	2.10	.83	4.41	.66

SOIL ANALYSES FROM FIELD C (p.p.m. dry soil)

Date sampled	pH	TSS	Total N	CO_2-soluble NO_3	CO_2-soluble PO_4	Exchangeable--H_2O soluble K	Exchangeable--H_2O soluble Na
10/15/51	7.82	1070	649	8.3	7.1	559	235
10/25/51	7.76	1215	710	45.2	8.4	509	245
11/5/51	7.71	1633	729	72.6	12.0	536	205
11/15/51	7.68	1430	732	64.2	11.5	506	237
11/25/51	7.70	2065	871	137.2	10.6	569	255
12/6/51	7.71	1465	794	52.2	9.4	525	228

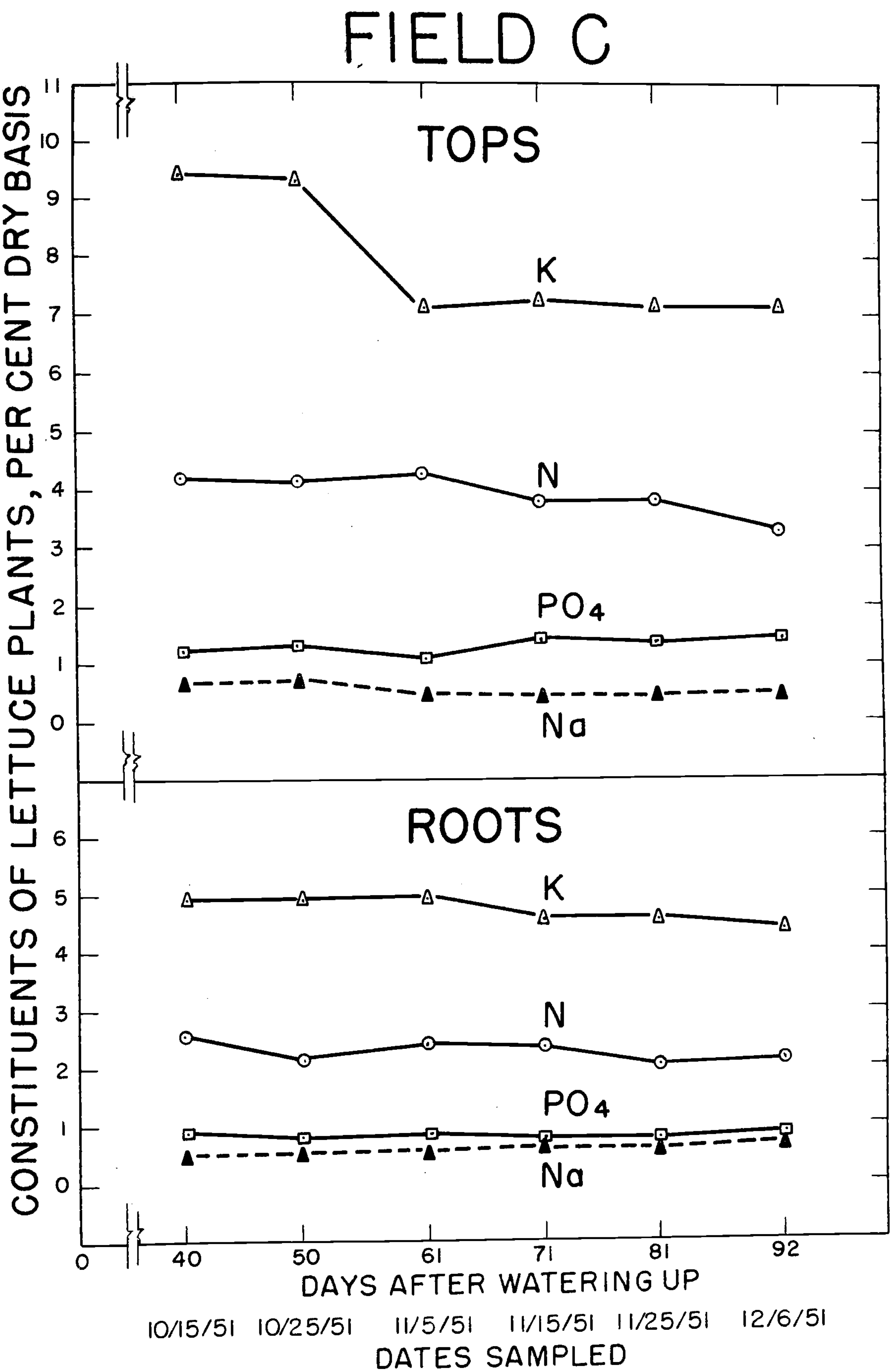

Figure 5.-Changes in N, PO_4, K and Na in Lettuce plants during growth, Field C.

level in the tops increased very slightly, while remaining remarkably constant in the roots. Sodium concentrations dropped slightly in the tops, and rose slightly in the roots.

Soil analyses for this field are shown in Table 3 and Figure 6. The total nitrogen values start quite high and go considerably higher with a sharp increase between the fourth and fifth sampling dates. The levels for nitrate nitrogen follow the same pattern rather closely, both being in good correlation with the addition of 16-14-0 fertilizer on November 9th. The supply of nitrate or available nitrogen is several times the amount considered essential for plant growth. Potassium levels are high in this soil and sodium much lower. Available phosphate increases somewhat and then gradually decreases. The amount of phosphate is on the borderline, first below and then above the amount deemed sufficient. Total soluble salts were quite high showing an increase and rising to a maximum at the 5th sampling, and then dropping off. The total difference of concentrations high and low is significant. pH values changed very little throughout the entire growth period.

Field D

This field was located in the Chandler-Higley area, about 2 miles south and 8 miles east of Chandler. This area

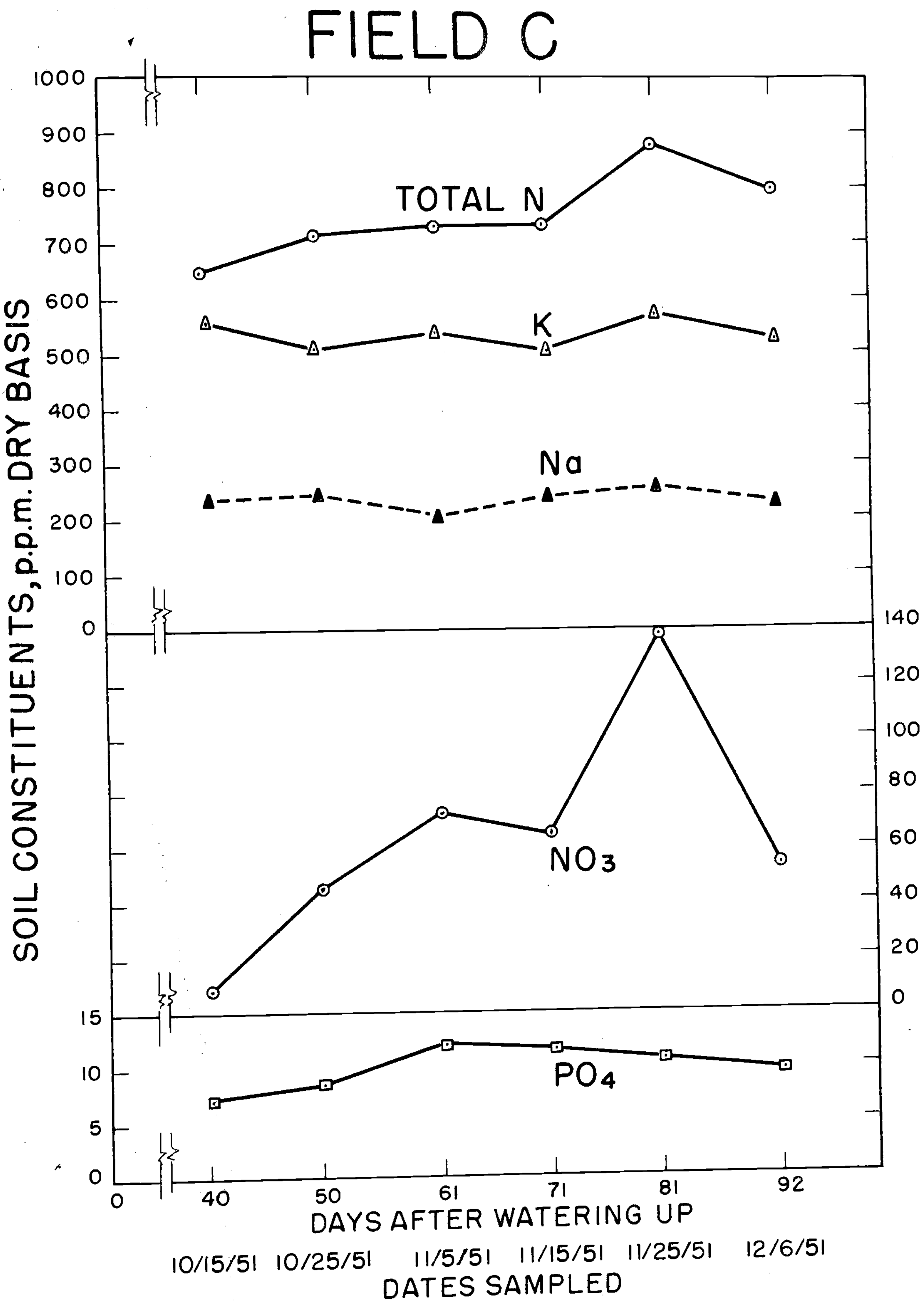

Figure 6.- Changes in Total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field C.

has not been under cultivation very long and all the irrigation water is pumped. The soil appeared to be well suited to vegetable production, and mechanical analysis showed it to be a loam. In 1950 this field was planted to cotton. Liquid fertilizers were used, consisting of 50 pounds of NH_4NO_3, and 50 pounds of H_3PO_4 per acre applied in the irrigation water. In the summer of 1951 honeydew melons were grown and manure was applied at the rate of 4 tons per acre, preceding the crop. Imperial 44 was planted and watered up on September 10th. Four hundred pounds of single super phosphate was applied before planting, with 300 pounds broadcast and 100 pounds banded. The field was irrigated again on the 29th of September prior to thinning. Thirty pounds of nitrogen as ammonia gas was applied per acre in the water during this irrigation. The later irrigation dates were October 20, November 8, November 21 and December 11. The irrigation of December 11 included application of 40 pounds per acre of nitrogen as NH_3 gas in the water. Two hundred pounds of $Ca(NO_3)_2$ were side dressed in bands between October 10th and November 7th. Harvest was begun December 17th, thus the entire growing period was 98 days. Differences in planting date of 1 or 2 days in the early fall may make a difference of a week or more in the time of harvest.

Plant analyses are shown in Table 4 and Figure 7. An examination of results shows a marked reduction of potassium in both tops and roots during the growth period, the

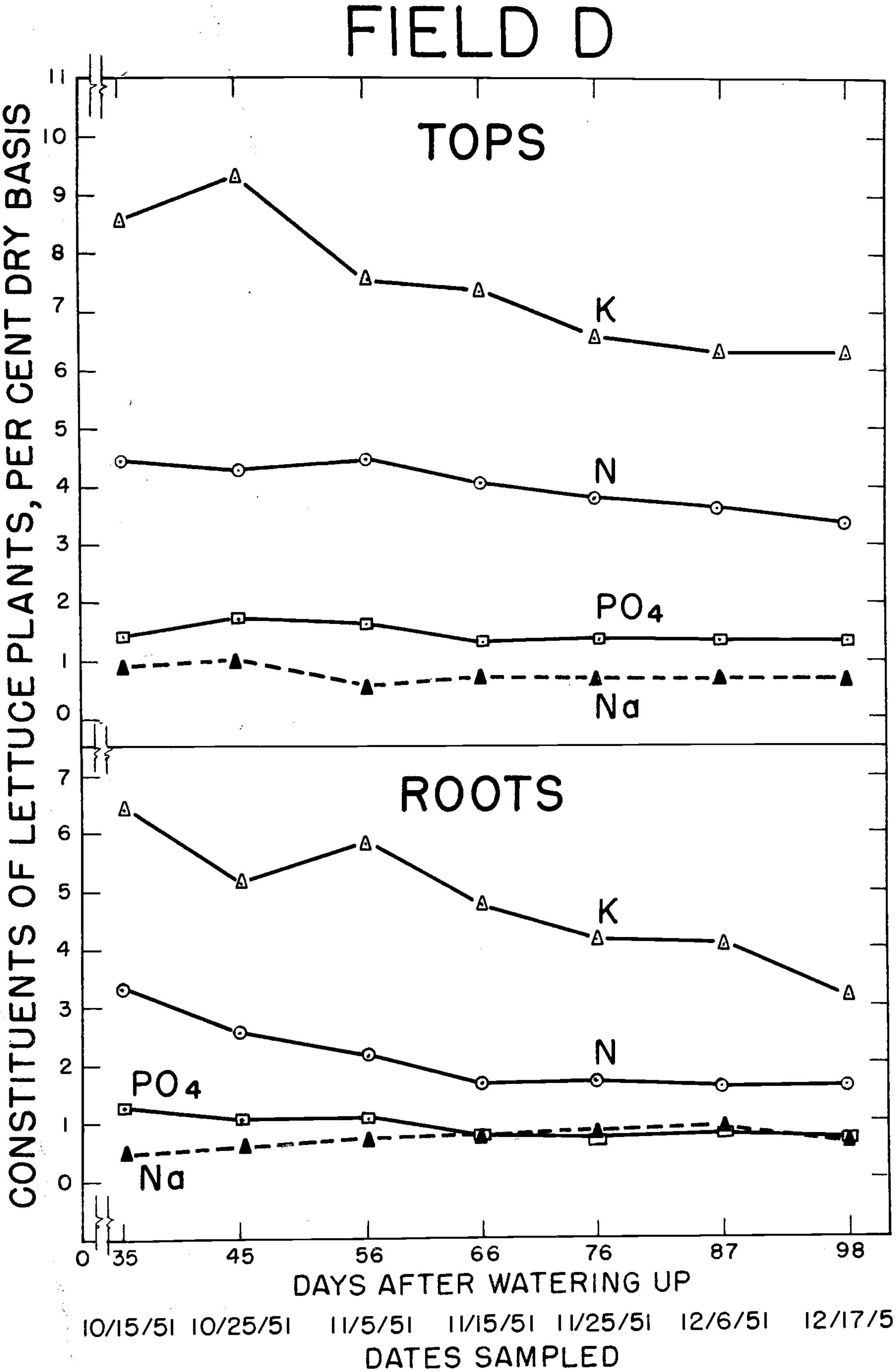

Figure 7.- Changes in N, PO4, K and Na in Lettuce plants during growth, Field D.

TABLE IV

COMPOSITION OF LETTUCE PLANTS FROM FIELD D, VARIETY: NO. 44

		Tops					Roots				
Date sampled	Days after watering up	Dry wt. gms./plant	Per cent dry basis N	PO_4	K	Na	Dry wt. gms./plant	Per cent dry basis N	PO_4	K	Na
10/15/51	35	.69	4.46	1.42	8.56	.89	.07	3.34	1.28	6.46	.45
10/25/51	45	2.30	4.31	1.75	9.79	1.01	.31	2.58	1.05	5.16	.59
11/5/51	56	7.79	4.48	1.63	7.56	.58	.56	2.15	1.07	5.83	.71
11/15/51	66	15.06	4.06	1.30	7.39	.70	1.40	1.66	.74	4.76	.76
11/25/51	76	19.00	3.81	1.35	6.58	.66	1.61	1.70	.74	4.15	.81
12/6/51	87	30.88	3.65	1.33	6.31	.66	3.08	1.61	.73	4.05	.89
12/17/51	98	22.93	3.37	1.32	6.31	.66	3.42	1.61	.68	3.15	.64

SOIL ANALYSES FROM FIELD D (p.p.m. dry soil)

Date sampled	pH	TSS	Total N	CO_2-soluble NO_3	CO_2-soluble PO_4	Exchangeable--H_2O soluble K	Exchangeable--H_2O soluble Na
10/15/51	7.58	1170	581	16.1	9.4	623	390
10/25/51	7.45	1265	609	28.8	9.2	801	394
11/5/51	7.58	1190	610	11.8	10.2	803	387
11/15/51	7.57	1255	515	11.5	5.8	794	422
11/25/51	7.59	1670	617	22.5	7.9	857	499
12/6/51	7.52	1280	635	12.5	6.7	729	459
12/17/51	7.58	1420	604	26.8	7.3	750	417

differences varying over a range of two per cent. Nitrogen also shows a decline on the percentage dry basis, but the drop in the roots is more significant than in the tops. The phosphate level in the tops remained almost constant, but dropped slightly in the roots. Sodium decreased slightly in the tops and increased slightly in the roots.

Soil analyses in Table 4 and Figure 8 show a very high amount of exchangeable-plus-water-soluble potassium was present. This was the only case where potassium exceeded total nitrogen. The sodium values were also fairly high. Both the sodium and potassium levels as determined increased, reaching a peak at the fifth sampling. Total nitrogen values remained reasonably constant with the exception of a rather sharp decline at the fourth sampling. The nitrate nitrogen level fluctuated considerably, but was in all cases above the amount thought to be necessary for plant growth. Phosphate values dropped slightly and even at the highest point only meet the minimum requirement needed for plant growth. Total soluble salts were fairly high with the values reaching peak concentrations at the fifth and seventh samplings. pH values were fairly constant throughout the growing period.

Field E

Field E was located approximately one mile west of the point where Baseline road intersects State Highway 87. This

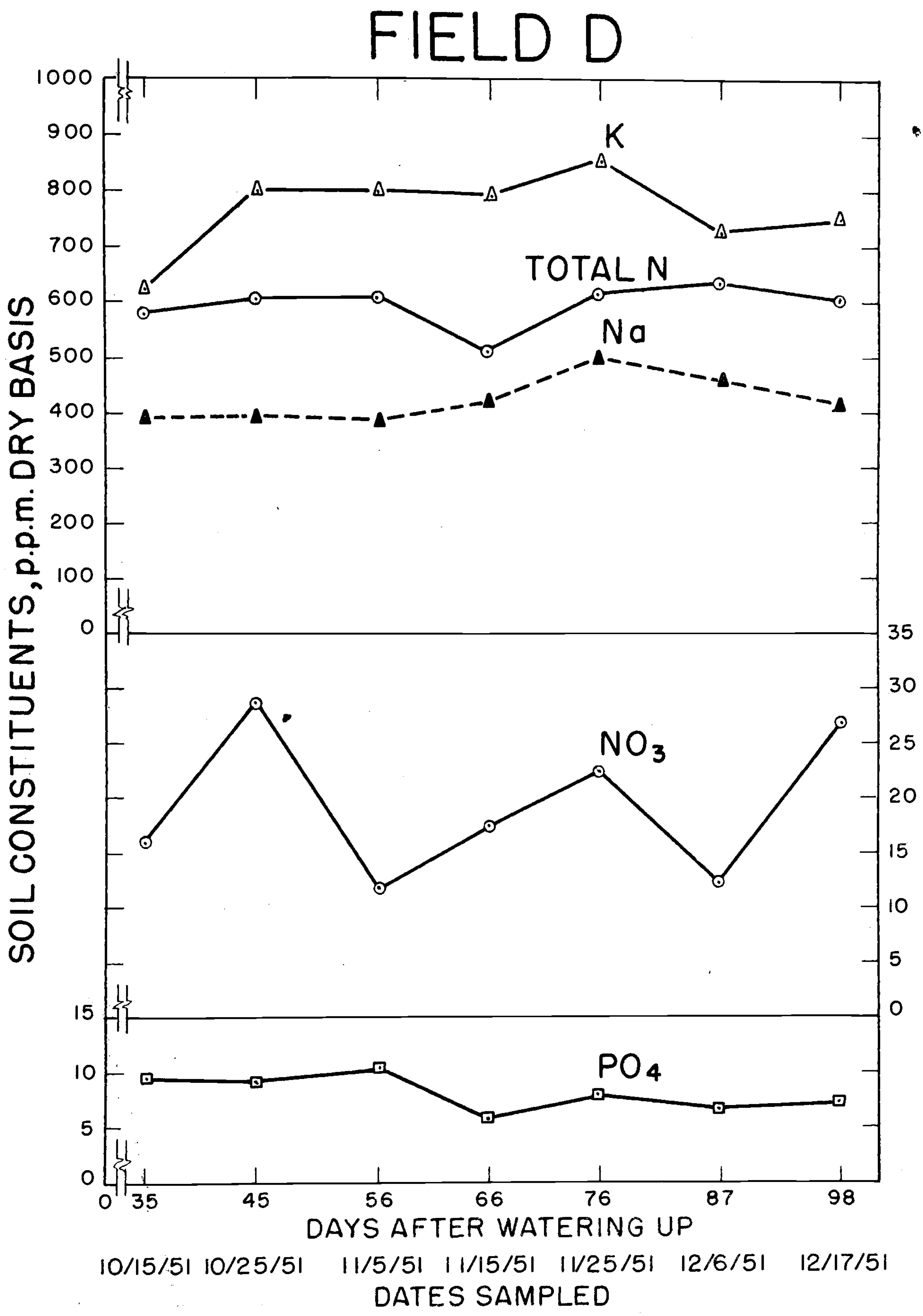

Figure 8.– Changes in Total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field D.

soil was very heavy in texture, mechanical analysis indicating it to be a clay loam. The field had been planted to Sesbania as a green manure crop the preceding summer and a high amount of organic matter was in evidence. The crop to be discussed was a winter lettuce crop, variety Imperial 615. It was planted and watered up on October the 29th. Three hundred and fifty pounds of 10-20-0 per acre was banded at planting time. Other irrigation dates were November 29th, prior to thinning, February 18-20th and March 7th. There was sufficient rainfall to provide water during December, January and half of February. One hundred and twenty-five pounds of NH_4NO_3 per acre was applied in the irrigation water on February 18-20th, 350 pounds per acre of calcium nitrate was applied in bands January 19th, and 200 pounds more calcium nitrate per acre was applied in the water of the March 7th irrigation. Harvesting was begun March 18th, thus extending the growing period to 141 days. This growing period was longer than usual, due probably to low temperatures and unsuitable growth conditions during December and January. Winter lettuce crops are usually planted on light textured soils which drain quickly and warm up sooner.

The results of plant analyses shown in Table 5 and Figure 9 show a marked increase in percentage of potassium in both tops and roots, reaching a peak at the 5th sampling.

TABLE V

COMPOSITION OF LETTUCE PLANTS FROM FIELD E, VARIETY: NO. 615

		Tops					Roots				
Date sampled	Days after watering up	Dry wt. gms./plant	Per cent dry basis				Dry wt. gms./plant	Per cent dry basis			
			N	PO_4	K	Na		N	PO_4	K	Na
12/27/51	59	.72	4.28	1.56	4.95	1.28	.07	2.65	1.30	3.66	.42
1/6/52	69	1.10	4.06	1.59	5.20	1.22	.09	2.53	1.27	3.88	.42
1/17/52	80	2.17	4.00	1.51	5.00	1.25	.24	2.31	1.16	3.69	.45
1/28/52	91	3.12	4.16	1.49	5.76	1.32	.26	2.33	1.12	4.44	.61
2/5/52	99	5.53	4.18	1.46	6.44	1.34	.45	2.21	1.09	4.69	.61
2/16/52	110	7.58	3.94	1.44	5.66	1.19	.75	2.24	1.10	4.24	.64
2/26/52	120	12.87	4.00	1.57	5.54	1.27	1.14	2.29	1.25	4.14	.73
3/8/52	131	13.66	3.79	1.49	5.26	1.32	1.16	2.18	1.16	4.24	.79
3/18/52	141	29.47	3.61	1.69	5.34	1.17	2.30	2.46	1.27	4.28	.94

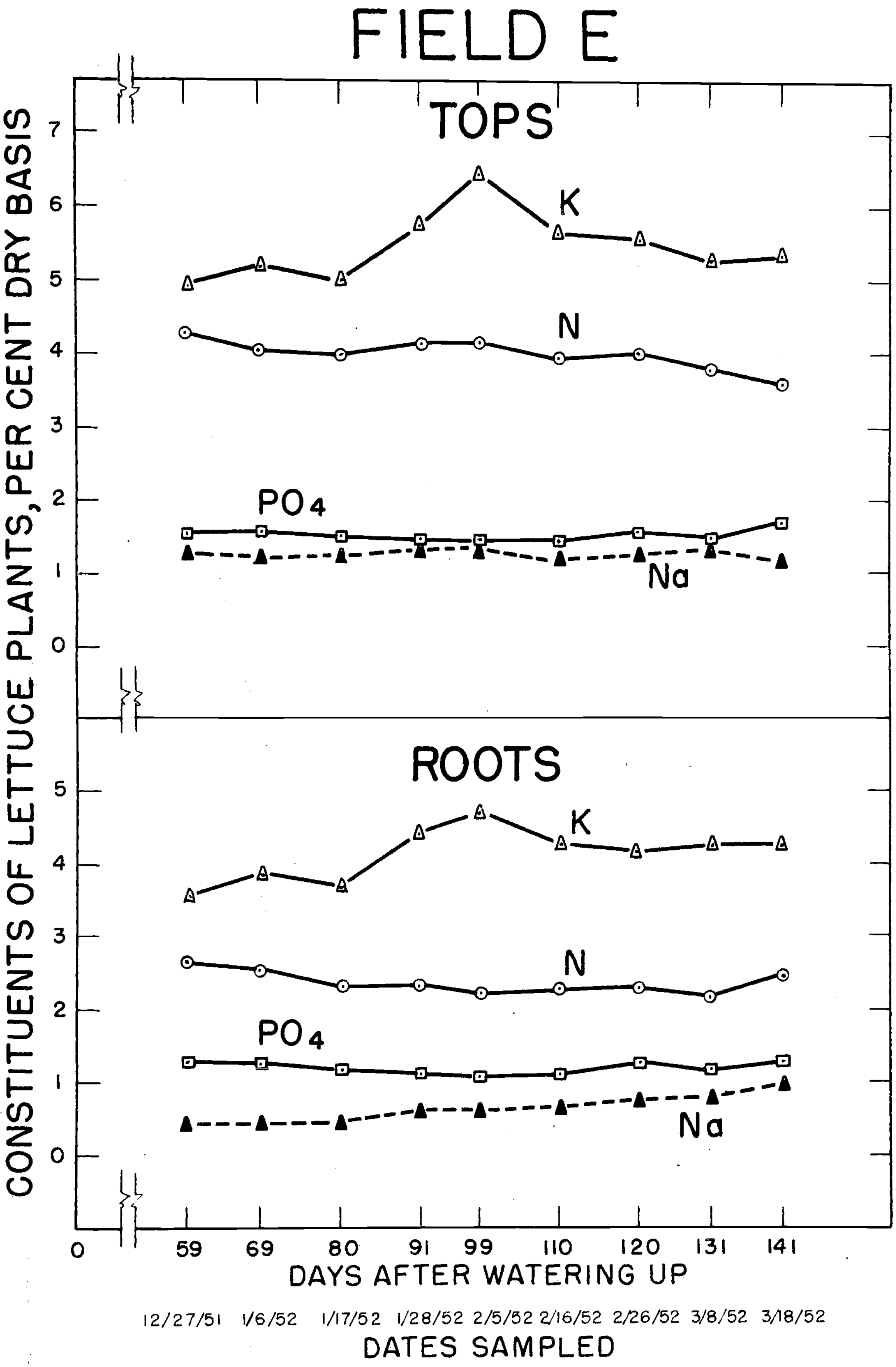

Figure 9.-Changes in N, PO4, K and Na in Lettuce plants during growth, Field E.

Nitrogen contents varied only slightly, with a slight decrease as maturity was reached. Phosphate values remained fairly constant in both roots and tops throughout the growing period. Sodium concentrations in the tops were high in relation to samples from other fields and fluctuated only slightly from thinning time to harvest. The sodium values of the roots, however, underwent a gradual increase of fair significance.

The soil analyses are shown in Table 6 and Figure 10. There were high amounts of both potassium and total nitrogen, and fluctuations were observed in the levels of each. Exchangeable-plus-water-soluble sodium was high and variable also. Nitrate nitrogen started high and increased toward a maximum at the 5th and 8th samplings. Phosphate levels were high and showed considerable fluctuation, varying between 40 and 60 ppm. The maximum was reached at the 6th sampling. The fertility level of this field according to soil analyses was higher than any other field included in this study. The amount of nutrients found were over and above the minimum amount required at every sampling period.

Field F

Field F was located in the Tolleson area at Lateral 24 and 1/2 and Yuma Road. This soil was very light and sandy. Mechanical analyses showed it to be a sandy loam. Winter lettuce was grown with Imperial 615 variety being planted

TABLE VI

SOIL ANALYSES FROM FIELD E (p.p.m. dry soil)

Date sampled	pH	TSS	Total N	CO_2- soluble NO_3	CO_2- soluble PO_4	Exchangeable--H_2O soluble K	Exchangeable--H_2O soluble Na
12/27/51	7.59	2125	917	56.8	43.9	901	530
1/6/52	7.41	2745	1006	57.2	42.9	959	589
1/17/52	7.42	2780	897	66.5	48.4	948	625
1/28/52	7.45	2385	943	72.7	42.9	974	574
2/5/52	7.42	2275	938	116.6	52.7	1001	526
2/16/52	7.44	2690	1025	63.6	59.3	963	533
2/26/52	7.47	2070	940	106.0	44.5	1000	531
3/8/52	7.56	2915	1003	116.1	39.2	943	612
3/18/52	7.47	2125	950	109.2	53.0	951	479

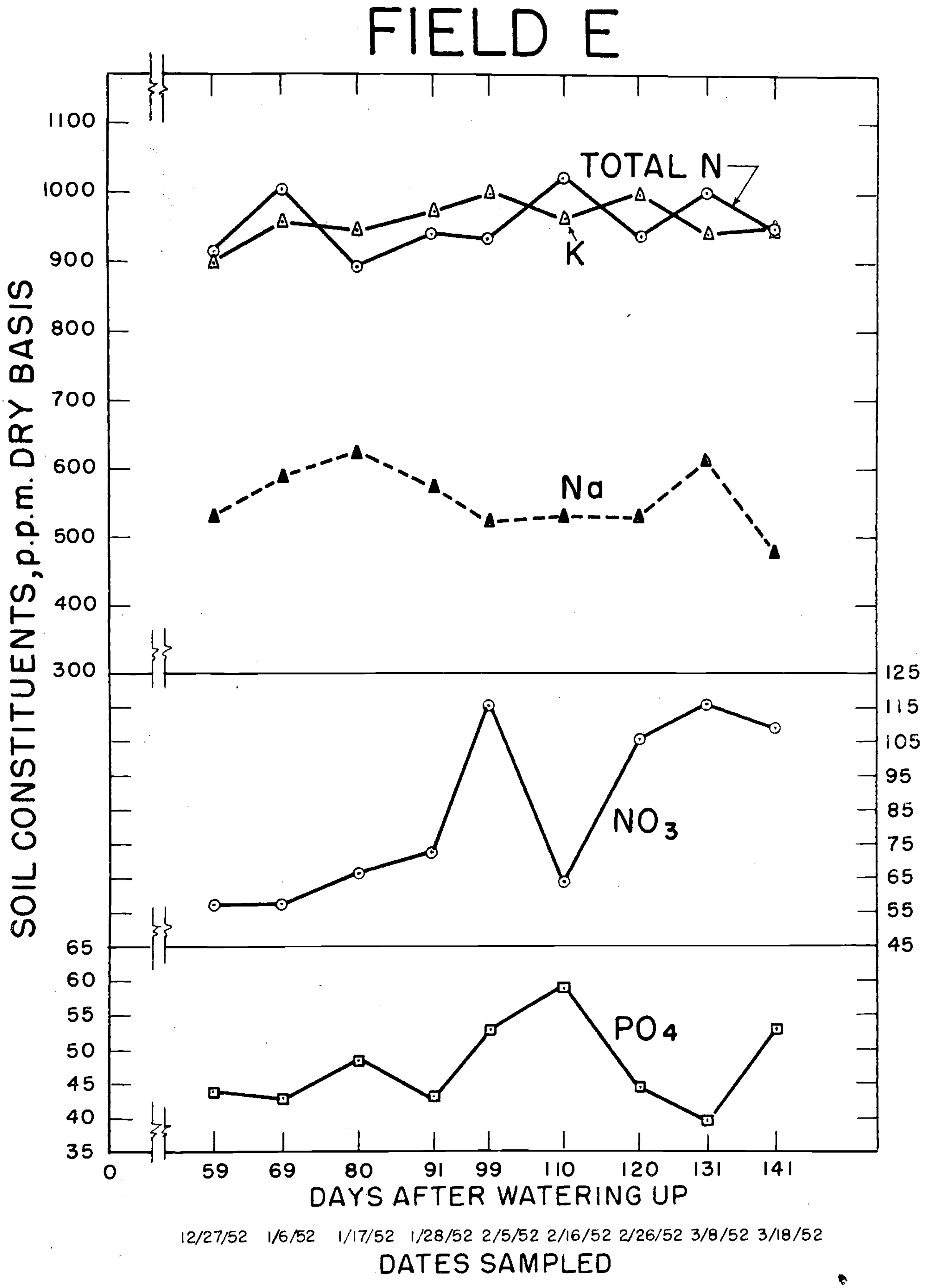

Figure 10.– Changes in Total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field E.

and watered up on November 10-11th. Four hundred pounds per acre of 10-20-0 was broadcast prior to planting. The crop was irrigated again December 20th and sufficient rain fell so that no irrigation was required during January and February. Other irrigation dates were March 1st, 10th, and 22nd. During these three irrigations a total of 500 pounds of calcium nitrate per acre was applied in the irrigation water. During the winter months extended periods of low temperature caused the growing period to be slightly longer than usual. Harvest was begun March 28th with a 139-day period having elapsed from watering up.

Plant analyses for Field F are shown in Table 7 and Figure 11. The amounts of potassium shown in the tops were fairly constant at different samplings excluding the rise between the first two samplings. Potassium concentrations in the roots increased rather markedly as maturity was approached. The nitrogen level showed a decline in the tops, but in general remained rather constant in the roots. Phosphate values with the exception of minor fluctuations remained constant throughout the growing period. Sodium values were constant in the tops, but increased slightly in the roots.

Soil analyses are shown for Field F in Table 7 and Figure 12. The amounts of total nitrogen are fairly high and remain practically constant. Exchangeable-plus-water-soluble potassium and sodium were quite low in relation to

TABLE VII

COMPOSITION OF LETTUCE PLANTS FROM FIELD F, VARIETY: NO. 615

		Tops					Roots				
Date sampled	Days after watering up	Dry wt. gms./plant	Per cent dry basis N	PO_4	K	Na	Dry wt. gms./plant	Per cent dry basis N	PO_4	K	Na
1/28/52	79	.97	4.04	1.10	5.65	.39	.12	2.02	.77	3.01	.21
2/5/52	87	2.23	4.22	1.30	6.88	.46	.29	1.93	.78	3.58	.27
2/16/52	98	3.25	3.98	1.26	6.61	.45	.44	1.89	.82	3.40	.24
2/26/52	108	6.90	3.88	1.29	6.31	.47	.84	1.68	.86	3.41	.38
3/8/52	119	9.63	3.71	1.21	6.28	.42	1.33	1.70	.64	3.43	.44
3/18/52	129	17.28	3.60	1.30	6.26	.43	1.44	1.85	.87	4.41	.52
3/28/52	139	27.34	3.72	1.36	6.61	.45	1.93	1.77	.78	4.73	.55

SOIL ANALYSES FROM FIELD F (p.p.m. dry soil)

Date sampled	pH	TSS	Total N	CO_2-soluble NO_3	CO_2-soluble PO_4	Exchangeable--H_2O soluble K	Exchangeable--H_2O soluble Na
1/28/52	7.69	860	571	11.0	14.4	191	141
2/5/52	7.66	865	566	27.4	16.3	208	141
2/16/52	7.66	885	561	20.0	15.0	188	140
2/26/52	7.84	830	568	24.3	17.0	208	152
3/8/52	7.72	1080	566	48.3	16.5	197	151
3/18/52	7.80	517	577	18.3	14.9	213	151
3/28/52	7.87	755	553	45.5	15.7	219	143

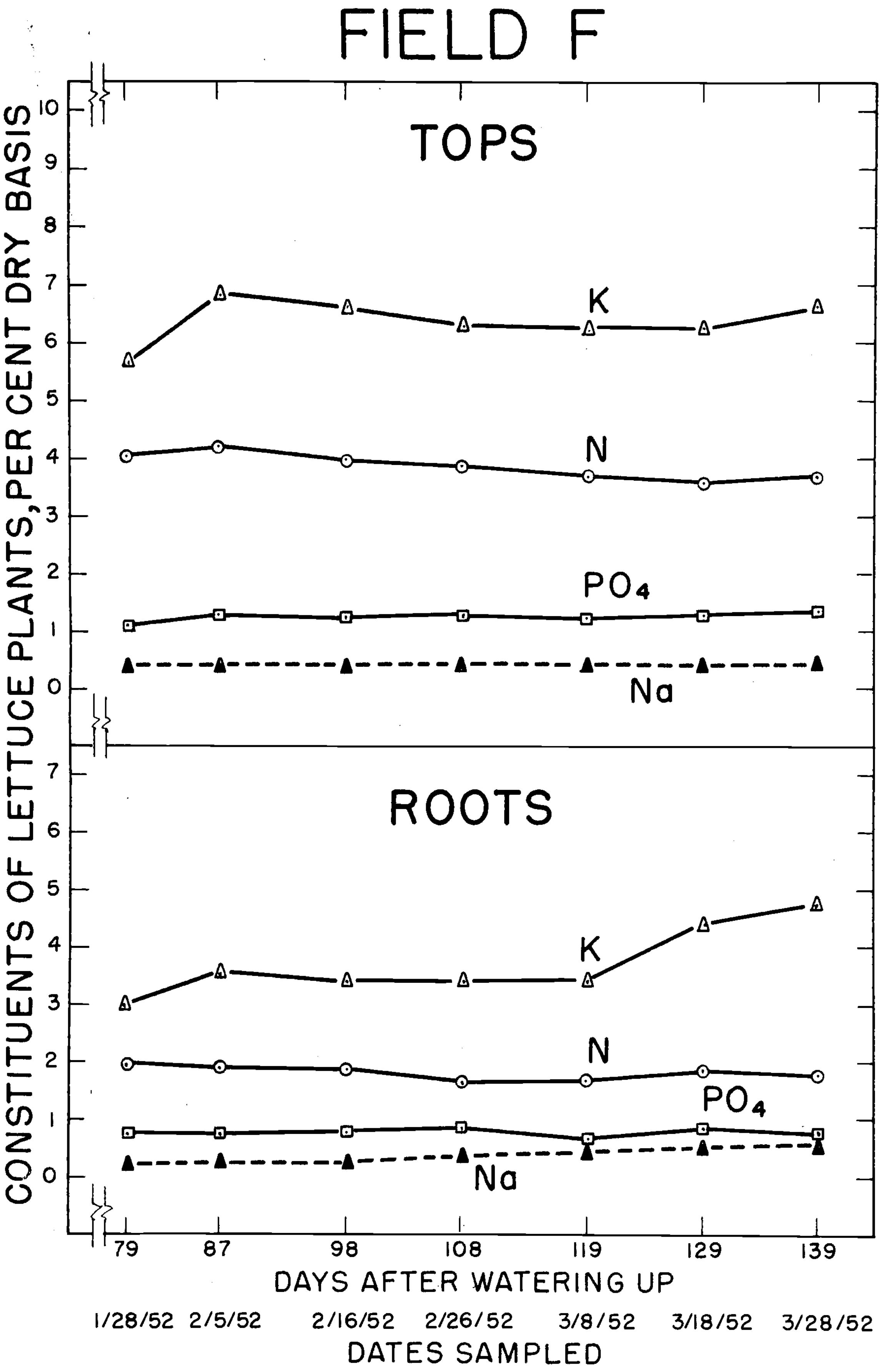

Figure 11.- Changes in N, PO4, K and Na in Lettuce plants during growth, Field F.

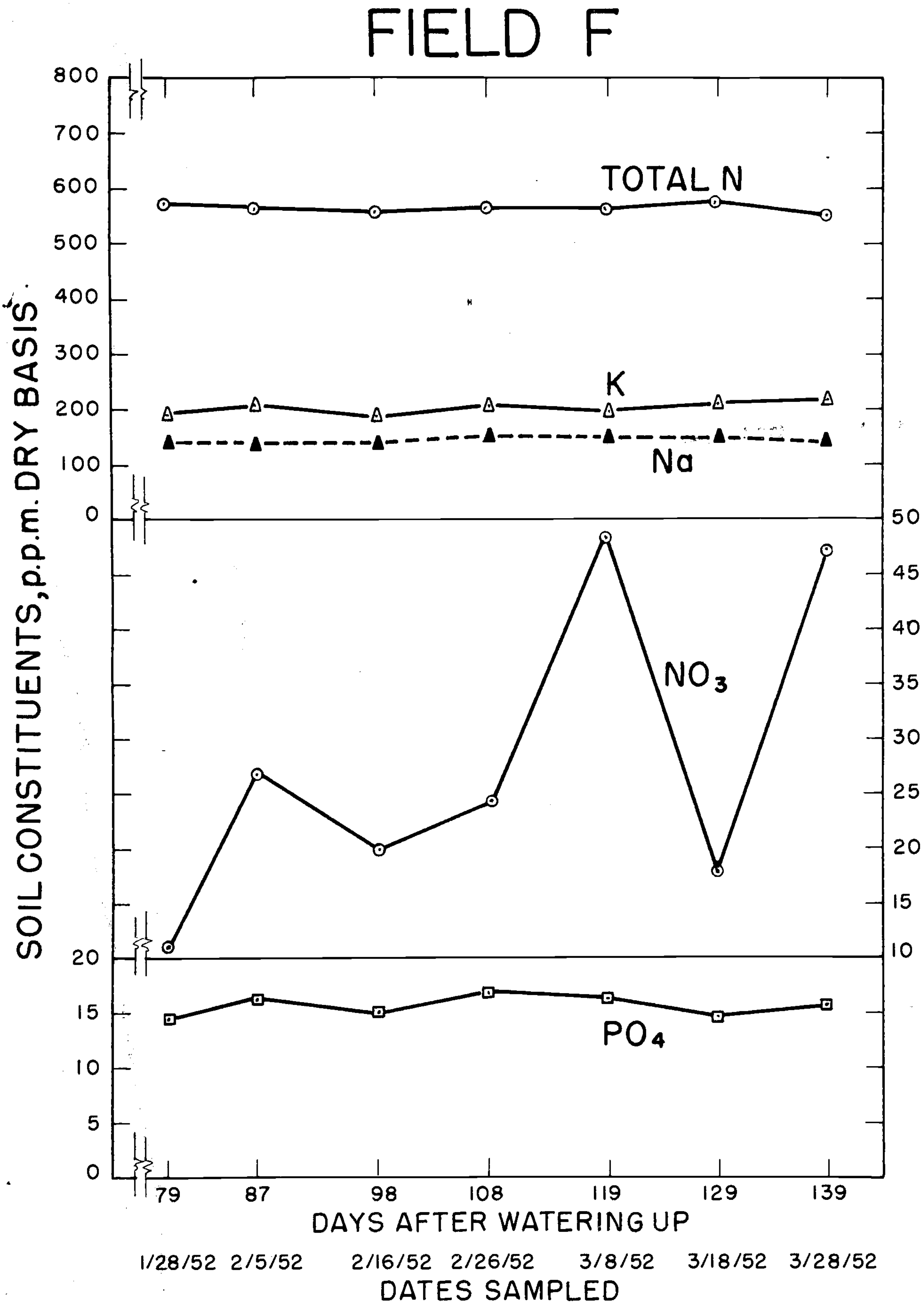

Figure 12.- Changes in Total N, NO_3, PO_4, K and Na in soil during growth of Lettuce, Field F.

amounts found in other fields in this study, and remained fairly constant throughout the sampling period. Nitrate nitrogen values were extremely variable, fluctuating from the minimum amount required for plant growth to almost 50 ppm. The effect of the application of 500 pounds per acre of calcium nitrate during the month of March upon nitrate values is quite evident in the graph. Phosphate was present in sufficient amounts and remained fairly constant throughout the growing season. This soil contained ample amounts of all the nutrients tested for. Soluble salt content was not very high and remained fairly constant, excluding a rise followed by a decrease between the 5th and 6th samplings. pH values showed no significant change.

DISCUSSION

The investigation which forms the basis of this thesis has brought out a number of interesting facts concerning the field practices in use in Arizona at the present time which have to do with the production of lettuce, especially in regard to the manner in which the plant responds to various treatments. It was found that there is little uniformity among the growers regarding the kind, amount, placement or time of application of fertilizers. Lettuce production involves very intensive farming practices and requires the maintenance of optimum fertility and conditions at all times, in order to insure good yield, quality and maturity.

Considerable information on lettuce production in Arizona has been contributed by McGeorge, Wharton and Frazier (17), Griffiths and Finch (11), Griffiths (12), McGeorge and Wharton (16) and Crider (6). McGeorge, Wharton and Frazier (17) made a somewhat similar study to that reported in this thesis, doing their work in cooperation with commercial growers, and following the growth of lettuce by plant and soil analyses. However, they applied the fertilizer themselves, determining the kinds, amounts, method of placement, etc. In addition yield data were determined and reported. The present study differed in that the tests were made on soils and lettuce crops under the grower's own system of fertilization and management, and samples were taken at shorter intervals of time from thinning through harvest. This study is not a fertilizer study based upon replicated plot tests. It was planned with the idea of determining, if possible, the response of the lettuce plant to the treatments applied during the course of production, as not being followed, and in that sense constitutes a test of various production procedures now in use in the Salt River Valley.

The nutrient requirements of lettuce, like those of any other crop, vary with climatic and soil conditions of each region. In Arizona the nutrient requirement of lettuce per acre of the average crop is 75 lbs. of nitrogen, 24 lbs. of phosphoric acid and 120 lbs. of potash. The results of the present study show that these primary nutrients are taken up by the crop in this same order. Differences in composition at maturity are in general influenced by variety, location, soil type and other factors, hence limits of uptake should be considered rather than mean values. The uptake of nutrients found in this study varied in magnitude in each case, but the order of uptake was the same in all cases, with potassium taken up in greatest amount, followed by nitrogen and lastly, phosphorus. This relationship is brought out in Figure 14, in which the nutrient uptake of

N, P and K in the whole plant is plotted against time, for two fields. The order is shown to be that mentioned above, with phosphate taken up in comparatively small amounts. The nutrient uptake by the plant as a whole increases gradually with time and tends toward a maximum as maturity is approached.

Growth in the lettuce plant can be measured best in terms of dry matter produced. When the results for dry weight per plant are plotted against time, as shown in Figure 13, the curve turns out to be a typical sigmoid growth curve. An interesting observation was that different varieties of lettuce apparently have their own characteristic growth curves. Three curves for Imperial 44 were so closely identical that they almost coincided, even though the crops were grown on widely separated fields of different soil types, and under different systems of fertilization and cultivation. In addition, the two curves for Imperial 615 were practically identical. The curves have slopes which correlate closely with the maturation and general growth characteristics of these varieties. Imperial 615 is better adapted to low temperature conditions and is usually planted in the winter. For this reason the growing season is longer. On the other hand, the Great Lakes variety, of which one curve is shown on the graph in Figure 13, is more heat resistant and can be planted in late August or very early September. The curve extends much higher than

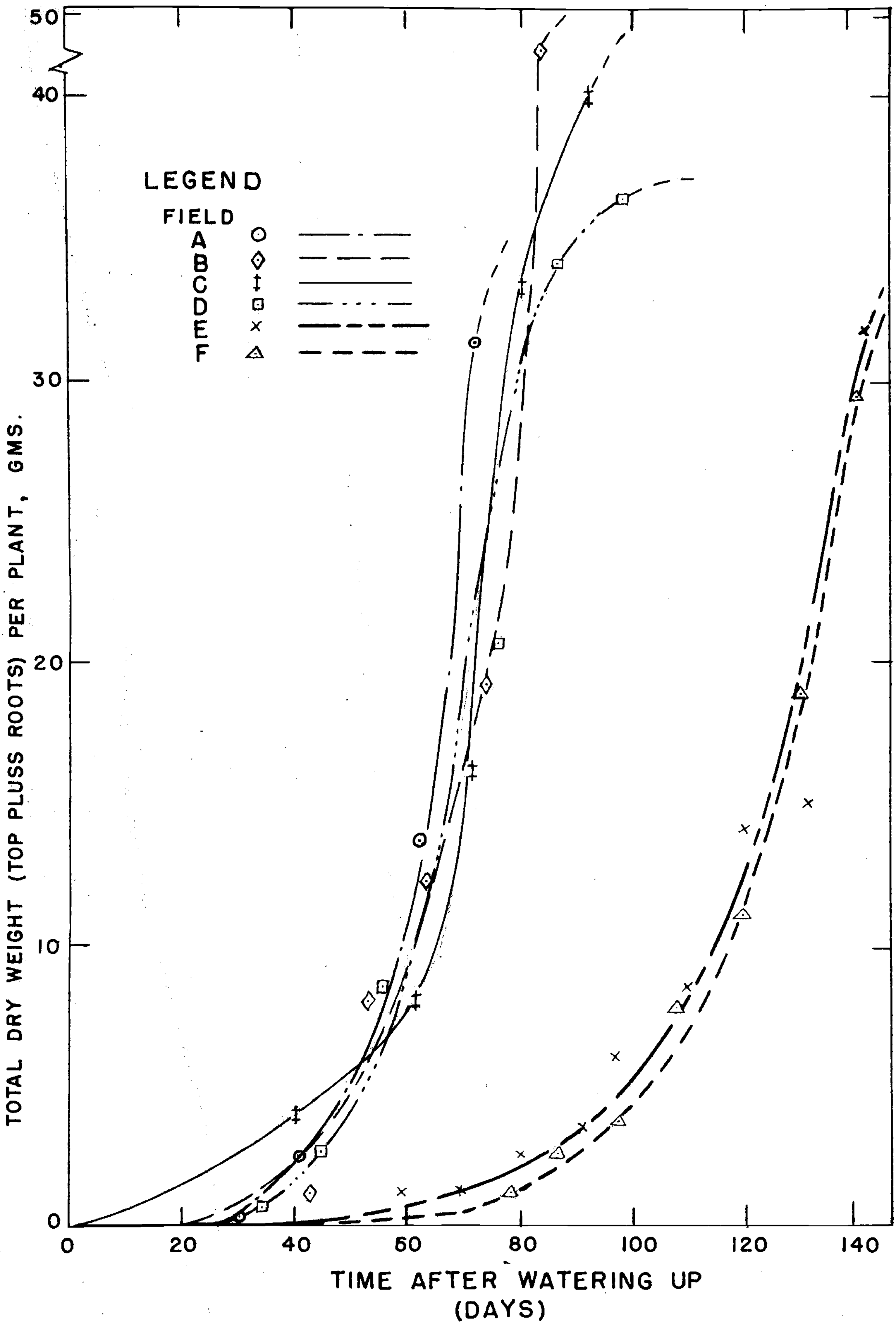

FIGURE 13. VARIATION OF TOTAL DRY WEIGHT OF LETTUCE PLANTS WITH TIME. (LETTERS IN FIGURE DENOTE FIELDS STUDIED)

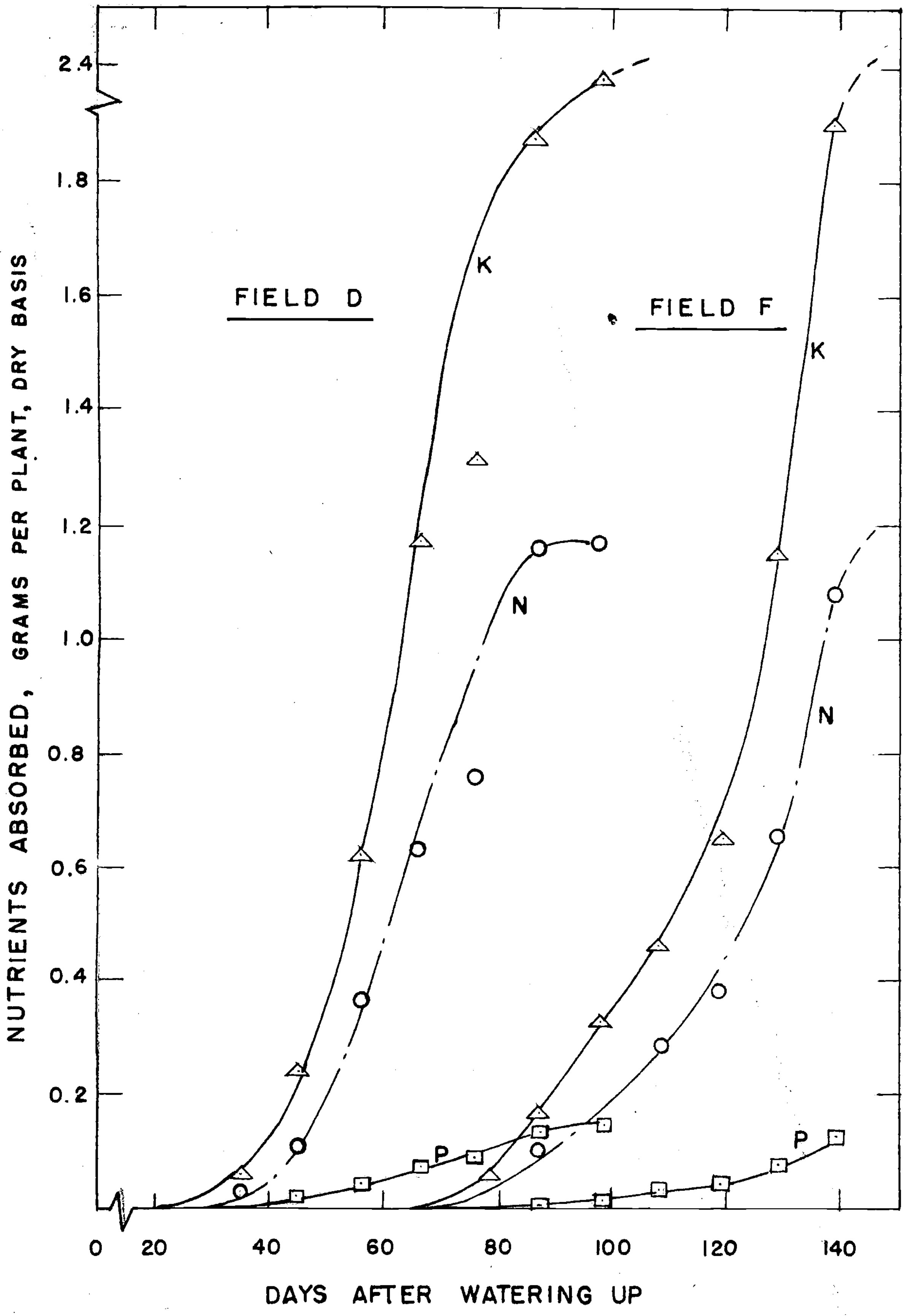

FIGURE 14. NUTRIENT ABSORPTION BY LETTUCE AT DIFFERENT STAGES OF GROWTH.

those of Imperial 44 variety, indicating that it forms larger heads, but otherwise has much the same growth characteristics as Imperial 44, and a growing season of similar length.

On the basis of the present study, the limits of constituents as taken up by mature lettuce grown in the Salt River Valley, expressed as per cent on the dry plant basis, was found to be as follows:

	Nitrogen	Phosphate	Potassium	Sodium
Tops	3.28-4.31	1.32-1.67	5.34-7.68	0.30-1.17
Roots	1.61-2.46	0.64-1.27	3.15-4.73	0.35-0.96

Analysis of lettuce grown in the Salinas Valley of California (14) showed that it contained 6.51% potassium which compares favorably with the results found in this study. They also found a phosphorus content of 1.12% and nitrogen 2.65% which were less than those reported above. Data by Beeson (3) on lettuce grown in the East showed maximum and minimum values as follows: For potassium, between 3.69 and 7.91%; for phosphate, 1.73 to 3.22. These results compare favorably with those found in this study with the exception that phosphate was slightly higher. Lettuce grown in Colorado showed potassium 4.85%, sodium 0.04%, and phosphate, 0.97% (2). Lettuce grown in the eastern coastal states contained 3.55% potassium, 0.17% sodium, and 1.08% phosphate (2).

The results of McGeorge, Wharton and Frazier (17) showed that lettuce plants contained about the same phosphate content as those here found, but were higher in potassium and nitrogen. These differences may be due in part, however, to differences in analytical methods used, and not actually related to either cultural practices or weather conditions, which may have prevailed at the different periods when the studies were carried out.

In connection with this study the question of bolting of lettuce was also given slight consideration. Bolting is often attributed to an unusually warm period prevailing during the fall of the year which causes the plant to put out a seed stalk without first forming a head. Others attribute the condition to excessive phosphate fertilization. Some attention was given to this phase of the problem by being constantly on the watch for bolting plants. In general there was very little bolting during the period covered by this study. Rare instances were noticed, and samples of bolting plants were taken and analyzed along with normal heads from the same field. The results are shown in Tables 1 and 3. No appreciable difference was found in the N, P and K contents of the bolting and normal plants, except that the nitrogen and phosphate contents were slightly higher in the bolting plants analyzed.

In Table 8 are shown some data relating to a computation

TABLE 8

RELATION BETWEEN FERTILIZER APPLICATIONS AND LETTUCE CROP AT MATURITY

Field Cropped	Variety	Growth period - days	Actual nutrients in soil at start - lbs./A.ft.		Actual nutrients added ** lbs./A.	Dry wt. per plant		Yield Crates/A.
						Tops Gms.	Roots Gms.	
A Mohave loam	Imperial 44	82	N(T)	1920	N 30	22.3	1.77	251 *
			$N(NO_3)$	39	P None			
			P	29	K None			
			K	608				
B Cajon clay loam	Great Lakes	84	N(T)	2880	N 25	46.7	2.57	272 @
			$N(NO_3)$	160	P None			
			P	13	K None			
			K	1870				
C McLellan clay loam	Imperial 44	92	N(T)	2600	N 9.6	37.5	2.55	---
			$N(NO_3)$	33	P 3.7			
			P	9	K none			
			K	2286				
D Cajon loam	Imperial 44	98	N(T)	2324	N 65	32.9	3.42	---
			$N(NO_3)$	64	P None			
			P	12	K None			
			K	2490				
E Mohave clay loam	Imperial 615	141	N(T)	3670	N 130	29.5	2.30	---
			$N(NO_3)$	228	P None			
			P	57	K None			
			K	2120				
F McLellan sandy loam	Imperial 615	139	N(T)	2284	N 80	27.3	1.93	#
			$N(NO_3)$	44	P None			
			P	19	K None			
			K	764				

* 4 and 5 dozen size.
** After first sampling date.
@ Dry packed.
# No yield data available due to hail damage.

of nutrients in the soils of the six fields, and the fertilizers added by the grower. It can be seen from these results that the soils contained unusually high amounts of total nitrogen and potassium, and in two cases extremely high amounts of nitrate nitrogen. Phosphate was ample in most cases for good plant growth. The high amounts of available potassium (water-soluble and exchangeable) make it unnecessary to fertilize lettuce with potash, in spite of the high potassium requirement of this crop. Phosphate fertilizer, it was noted, is frequently applied by broadcasting, often prior to planting, and the analyses of the soils showed that much of the phosphate applied in such a manner must have become unavailable by reversion or fixation. Much of the nitrogen is applied as ammonia gas in the irrigation water, and many growers apply other nutrients in liquid form by the same means.

In general it was observed that the fertility level of the soils was maintained high, far above the recognized deficiency limits. It is evident that the present practice in growing lettuce is to maintain a high nutrient level and an ample supply of water, to help provide optimum growing conditions for the crop throughout the season. By doing so the crop is never put under stress of any kind and high yield and quality of crop can be achieved.

SUMMARY

1. A study has been made of the uptake of nutrients by lettuce under field conditions and under various systems of fertilization.

2. Arrangements were made with six successful lettuce growers of the Salt River Valley to sample certain fields. These growers also supplied data concerning the kinds and amounts of fertilizer applied, dates of irrigation, yields, and other information.

3. Three varieties of lettuce were included in this study. Six commercial fields, representing three different soil series of various surface textures, were the source of the soil and plant samples. Sampling was randomized as far as possible to provide representative samples.

4. Samples of both crop and soil were taken for analysis from watering up until harvest, at approximately ten-day intervals. Analyses were made for the primary nutrients and sodium on the plant and soil samples, and in the case of the latter, pH, soluble salts, and texture were determined. Results of the analyses were calculated as per cent on the dry plant basis, as well as dry weight per plant. Thus the results could be interpreted quantitatively.

5. The soil analyses showed that high nutrient levels are being maintained for the optimum growth of lettuce,

considerably above the deficiency limits.

6. The plant analyses indicate that potassium is absorbed by lettuce in greatest proportion, then nitrogen, phosphate, and sodium, in that order. No deficiency symptoms were observed at any time during the growth period of the crops studied.

7. The growth cruves obtained by plotting dry weight of the whole plant against time after watering up, were found to be sigmoid, and proved to be almost identical for the individual varieties growing under widely different conditions.

8. It was evident from the analyses that the lettuce plant takes up the major nutrients within certain limits regardless of the amounts available in the soil. Undoubtedly the plant indulges in luxury consumption to some extent, but excessive applications of fertilizer over and above the amount required by the crop does not result in a corresponding increase in yield.

9. Sodium was determined in addition to the primary nutrients in the plant material and soils, although it is not generally regarded as a nutrient. It was found on the per cent dry basis in the dry plant, that sodium appears to increase in the roots while all other elements decrease with time after watering up. It is taken up by lettuce approximately in proportion to the amount of soluble or exchangeable sodium in the soil.

10. This study bears out the fact that commercially grown lettuce is being produced under conditions of unusually high fertilization and irrigation. Such favorable conditions are maintained that the plant is never put under stress of any kind, hence as far as soil fertility is concerned, providing conditions are favorable, the maximum yield and quality of crop should be attained under the existing fertilization practices.

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