SOME ASPECTS OF THE NITROGEN AND PHOSPHORUS NUTRITION OF TOMATOES IN A RED LOAM

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SUMMARY

The effect of nitrogen and phosphorus as basal and side-dressing fertilizers on the growth and yield of tomatoes has been investigated at the Redlands Horticultural Research Station in south-eastern Queensland.

Tomatoes gave a consistent yield response to basal applications of both nitrogen and phosphorus, while side-dressings of these elements were without effect.

A study of movement of nitrogen and phosphorus revealed that nitrate was rapidly leached to a depth of 4-6 ft under the existing cultural practices, while little movement of phosphorus was evident.

Evidence is presented suggesting that poor fruit set in colder months is associated with a higher phosphorus requirement during that period.

The results emphasize the need to examine further the methods for assessing available phosphorus in red loams.

I. INTRODUCTION

The Redlands district, approximately 20 miles east of Brisbane, accounts for a high proportion of the vegetable production of southern Queensland. The dominant soil type is a red loam of low inherent chemical fertility but with desirable physical characteristics for crop growth. Irrigation is used to supplement rainfall. If water is adequate and plant diseases can be controlled, the major limiting factor to high crop production is the nutrient status of the soil. To meet this need, heavy applications of mixed NPK fertilizers are recommended by the Department of Agriculture and Stock, based on the results of extensive field experimentation.

The current recommendation for tomatoes (Officers of the Department of Agriculture and Stock 1961) is a preplanting application of mixed NPK fertilizers of approximate composition 5:13:5 at the rate of about 8 cwt per acre (referred to as the basal dressing), followed by a second application, at flowering, of the same mixture at the rate of 3-4 cwt per acre (referred to as the side-dressing). This recommendation is based on a row spacing of approximately 5 ft.

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When this practice is followed, many growers express concern about excessive plant vigour in the early stages of growth. The early flush of growth favours vegetative growth at the expense of the reproductive phase and as a result early fruit set is delayed or unsatisfactory. In spite of this, many commercial growers use even heavier applications than those recommended and symptoms attributable to fertilizer injury have been observed, particularly during dry years.

It is important that fertilizer recommendations for small-crop production be based on crop responses in order to avoid over-use of fertilizer and its consequent problems. Perhaps the most serious of these is nutrient imbalance, a condition which is known to be responsible for certain nutritional disorders such as blossom end rot and pith rot and abnormal vegetative and reproductive behaviour.

At the recommended rate of fertilization, accumulation of nutrients in the profile would be expected. For example, some 250 lb P_2O_5 per acre is applied to each tomato crop; loss in marketable fruit is of the order of 30 lb P_2O_5 per acre, and crop residues are returned to the soil. Assuming no leaching loss occurs, considerable increases in soil total phosphorus must take place. Accumulation of nitrogen, in particular, and potassium in surface layers will be very much less, due to greater crop removal and leaching.

Soil analysis demonstrates that an accumulation of all three nutrients does take place under this fertilizer regimen. Nevertheless, satisfactory yields cannot be obtained without applications of ammonium sulphate and superphosphate, so the adequacy of the residual nutrient supply is doubtful.

In the Redlands district there are three tomato cropping periods each year—one each in autumn, spring and winter. The autumn crop, which is by far the most extensive, is field-planted in early February. As land preparation for this crop often coincides with heavy rains, it is not always possible to open furrows for the basal fertilizer. During one particularly wet year many growers were not able to apply the usual basal fertilizer, but applied the 5:13:5 mixture as a side-dressing after transplanting. All such plantings exhibited symptoms of phosphorus deficiency. This observation throws doubt on the value of side-dressing fertilizers as a source of phosphorus.

The water requirement during the summer months is approximately 1 in. per week, and under such high water applications it might be expected that nutrients would leach very rapidly. Since nitrogen is particularly susceptible to leaching, the possibility exists that light, frequent applications of this nutrient might be preferable to the heavier, less frequent applications which are part of the current recommendation.

The production of at least two vegetable crops in the same ground each year is not an uncommon practice. Under these conditions, if leaching has not been too severe the follow-on crops might be expected to receive some beneficial effects from the excess fertilizer applied to previous crops.

The series of experiments reported here demonstrates the nature of the response by the tomato plant to basal and side applications of fertilizer and examines the movement of nitrogen and phosphorus under the existing cultural practices. The short-term residual effect of these fertilizers is also investigated. As the dependence of nutrient responses on enviromental conditions is well established, the fertilizer requirement of the tomato crop at the three commercial cropping periods is examined.

This paper deals with the results of three field trials performed during the autumn, spring and winter cropping periods in the years 1956, 1957 and 1958.

II. MATERIALS AND METHODS

Location, Soil Type and Climate.—Field experiments were performed at Redlands Horticultural Research Station at Ormiston. The land had been under grass for about 18 years up to 1948, since when the cropping programme for vegetable research has been one cover crop and two vegetable crops per year. The soil is a typical red loam, and analytical data for a representative profile from the experimental area prior to cropping are given in Table 1. The climate is subtropical, with predominantly summer rainfall but a significant winter component. Mean annual rainfall for the preceding 29-year period was 49 in. Climatic and irrigation data for each of the three cropping periods are given in Table 2.

TABLE 1

ANALYSIS OF RED LOAM, 1948

Depth (in.)	pH	Available P_2O_5 (p.p.m.)	Total P_2O_5 (p.p.m.)	Exchangeable K^+ (m-equiv. %)	Total N (%)
0–10	5·7	28	730	0·47	0·14
10–17	5·7	15	210	0·06	—
17–26	5·7	11	220	0·02	—
26–48	5·8	16	215	0·15	—

TABLE 2

MEAN MONTHLY TEMPERATURES, RAINFALL AND IRRIGATION FOR THE THREE CROPPING PERIODS

Month	Trial 1, 1956				Trial 2, 1957				Trial 3, 1958			
	Min. Temp* (°F)	Max. Temp.† (°F)	Rain-fall (in.)	Irriga-tion (in.)	Min. Temp.† (°F)	Max. Temp.† (°F)	Rain-fall (in.)	Irriga-tion (in.)	Min. Temp.* (°F)	Max. Temp.† (°F)	Rain-fall (in.)	Irriga-tion (in.)
March ..					62·2	81·1	·29	2·20				
April ..	60·5	79·2	5·73	1·50	59·6	79·5	·90	2·50				
May ..	53·7	71·9	7·66	·20	50·0	74·1	·18	2·00				
June ..	48·8	66·3	4·78	1·70	51·8	71·3	1·31	1·10				
July ..	45·7	66·0	·93	·90	46·6	64·5	4·16	—				
August ..	43·9	68·7	·38	1·70	48·5	69·0	2·66	—				
September	47·1	71·1	·79	2·00					52·2	71·7	2·38	3·20
October									57·0	79·9	1·01	4·96
November									63·6	80·4	1·75	4·80
December									67·0	83·1	5·69	—

* Terrestrial minimum † Screen maximum

Design of Trials and Cultural Practices.—Treatment details of the three trials are given in Table 3.

TABLE 3

TREATMENT SCHEDULE

Trial 1

Type of Application	Type of Fertilizer	Code No.	Time of Application	Level (cwt/ac)
Basal.. ..	Ammonium sulphate, superphosphate and potassium chloride in ratio 5 : 13 : 5	B1 B2	Preplant .. .. .. Preplant	8 16
Side	Ammonium sulphate ..	N0 N1 N2	— Every 2 weeks .. .. Every 2 weeks	Nil 1 2
	Ammonium sulphate, superphosphate and potassium chloride in ratio 5 : 13 : 5	C1 C2	Every 4 weeks .. .. Every 8 weeks	4 8

Trial 2

Type of	Type of Fertilizer	Code No.	Time of Application	Level (cwt/ac)
Basal.. ..	Ammonium sulphate ..	N0 N1 N2	Preplant .. .. .. Preplant .. .. .. Preplant	Nil 1 2
	Superphosphate	P0 P1 P2	Preplant .. .. .. Preplant .. .. .. Preplant	Nil 2·7 5·3
Side	Ammonium sulphate ..	N0 N1 N2	8 weeks after transplanting .. 8 weeks after transplanting .. 8 weeks after transplanting ..	Nil 0·5 1
	Superphosphate	P0 P1 P2	8 weeks after transplanting .. 8 weeks after transplanting .. 8 weeks after transplanting ..	Nil 1·4 2·7

Trial 3

Type of Application	Type of Fertilizer	Code No. Fertilizer	Code No. Time	Time of Application	Levels (cwt/ac)	No. of Applications
Basal ..	Ammonium sulphate	N		Preplanting	2	1
	Superphosphate ..	P0 P1		Preplanting .. .. Preplanting	Nil 4	 1
	Potassium chloride	K		Preplanting	0·58	1
Side.. ..	Ammonium sulphate	N N N	T1 T2 T3	1st & 3rd hand set .. Every 2 weeks .. Every week	1·65 0·66 0·33	2 5 10
	Superphosphate and potassium chloride in ratio 17 : 9	PK PK PK	T1 T2 T3	1st & 3rd hand set .. Every 2 weeks .. Every week	1·42 0·57 0·28	2 5 10
	Ammonium sulphate, superphosphate and potassium chloride in ratio 5 : 13 : 5	NPK NPK NPK	T1 T2 T3	1st & 3rd hand set .. Every 2 weeks .. Every week	3·07 1·23 0·61	2 5 10

In all cases basal fertilizer was applied in a band approximately 4 in. wide in mouldboard furrows 5 ft 6 in. apart and subsequently covered with minimum disturbance of the fertilizer. Side-dressing fertilizer was applied to the surface in a band 6 in. wide on each side of the plant row and chipped in by hand. In all experiments, sources of nitrogen, phosphorus and potassium were ammonium sulphate, superphosphate and potassium chloride respectively. Calcium carbonate at the rate of 1 ton per acre was broadcast over the trial areas and ploughed in prior to the commencement of each trial. Molybdenum was applied to all plants as a routine spray, and diseases were suitably controlled.

Tomatoes were grown on parallel-wire trellises and all laterals below the first hand were pruned; fruit were harvested at the mature green stage. Plant height measurements were made by the method of Ross (1946).

Irrigation was applied when the surface soil (0-12 in.) showed signs of drying. Soil cores were removed with a soil auger to a depth of 12 in. and approximate soil moisture was determined. Irrometers installed for trial 1 indicated that soil moisture was maintained close to field capacity to a depth of 3 ft.

Soil Sampling.—At the completion of Trial 1, the soil was sampled to 12 in. for nitrate nitrogen and available phosphorus determinations.

In Trial 2, a more detailed sampling of selected plots was carried out to determine the movement of nitrogen and phosphorus. Sampling depths were 0-1 in., 1-2 in., 2-3 in., 3-6 in., 6-9 in. and 9-12 in. For depths of less than one foot, samples were taken from the sides of the sampling hole so that depths could be accurately measured. Deeper samples were obtained with an auger. In all cases the samples were taken from the plant row. There were four sampling dates, viz. 2 weeks after basal fertilizer application, 7 weeks after basal, 5 weeks after side-dressing application and 9 weeks after side-dressing.

Chemical Analyses.—The soils were analysed for nitrate nitrogen, available phosphorus and pH. Nitrate nitrogen was determined by the phenol-disulphonic acid method (Prince 1945). The method of Kerr and von Stieglitz (1938) was used for available phosphorus. pH was determined according to the method of International Society of Soil Science, Soil Reaction Committee (1930).

III. RESULTS

(a) Response to Basal Fertilizer

Yield.—Fresh fruit weights recorded for Trials 1, 2 and 3 are given in Tables 4, 5 and 6. There was a consistent response to applications of basal fertilizer in all three trials. A mixed NPK fertilizer was used for the basal dressing in Trial 1, but Trial 2 showed that both ammonium sulphate and superphosphate were involved in the yield responses, the former giving a 14 per cent. increase while the latter was responsible for an increase of 6 per cent. Trial 3 confirmed the response to basal superphosphate by demonstrating that an 80 per cent. yield increase could be obtained by using 4 cwt. of superphosphate. At this stage there was no information as to whether this response was wholly attributable to phosphorus. Accordingly, a trial was conducted to clarify this point; details are set out in the appendix. The results established that the response to superphosphate was due to phosphorus.

TABLE 4

Fresh Fruit Weight (lb/7 Plant Plot), Trial 1

Basal \ Side	Nil	N1	N2	C1	C2	Mean
B1	22·0	31·6	21·1	24·6	35·8	27·0
B2	37·9	34·8	43·9	28·1	38·9	36·7
Mean ..	30·0	33·2	32·5	26·4	37·4	

B2>>B1

Treatment Schedule

Code	Rate of Fertilizer
B1 (N : P : K, 5: 13 : 5) ..	8 cwt/ac
B2 (N : P : K, 5 : 13 : 5) ..	16 cwt/ac
N1	1 cwt every 2 weeks
N2	2 cwt every 2 weeks
C1 (N : P : K, 5 : 13 : 5) ..	4 cwt every 4 weeks
C2 (N : P : K, 5 : 13 : 5) ..	8 cwt every 8 weeks

TABLE 5

FRESH FRUIT WEIGHT (LB/16 PLANT PLOT), TRIAL 2

Basal \ Side	N0	N1	N2	P0	P1	P2	Mean
N0	118·7	125·3	121·8	119·6	121·4	124·8	121·9
N1	143·7	134·9	145·4	145·0	140·8	138·2	141·3
N2	138·1	133·0	139·2	143·3	131·3	135·7	136·8
P0	130·9	125·9	127·6	126·5	123·4	134·5	128·1
P1	142·9	125·8	136·5	137·1	135·7	132·6	135·1
P2	126·6	141·5	142·3	144·3	134·5	131·7	136·8
Mean ..	133·5	131·0	135·5	136·0	131·2	132·9	

Basal N1, N2,>> Basal N0
Basal P1, P2> Basal P0
Basal P x Side significantly different at 5% level

TREATMENT SCHEDULE

Basal Dressings

Code	Rate of Fertilizer
N0	Nil
N1	1cwt/ac
N2	2 cwt/ac
P0	Nil
P1	2·7 cwt/ac
P2	5·3 cwt/ac

Side-dressings

Code	Rate of Fertilizer
N0	Nil
N1	0·5 cwt/ac
N2	1 cwt/ac
P0	Nil
P1	1·4 cwt/ac
P2	2·7 cwt/ac

TABLE 6

FRESH FRUIT WEIGHT (LB/7 PLANT PLOT), TRIAL 3

Basal \ Basal	P0	P1	Mean
Nil N	22·6	38·4	30·5
N	24·4	43·5	34·0
Nil PK	22·9	38·8	30·8
PK	24·2	43·2	33·7
Mean	23·5	41·0	..

P1>> P0

TREATMENT SCHEDULE

Code	Rate of Fertilizer
P0	Nil
P1	4 cwt/ac
N	2 cwt/ac
PK (17 : 9)	4·5 cwt/ac

Fruit Size.—Relevant data are given in Table 7. In trial 2, smaller fruit were produced at the higher level of basal superphosphate; as total weight of fruit was increased, the response took the form of increased fruit set.

TABLE 7

AVERAGE WEIGHT OF FRUIT (LB), TRIAL 2

Basal \ Side	N0	N1	N2	P0	P1	P2	Mean
N0	·340	·349	·335	·340	·350	·335	·341
N1	·369	·365	·355	·364	·372	·354	·363
N2	·365	·353	·352	·361	·360	·349	·357
P0	·359	·357	·356	·348	·364	·360	·357
P1	·376	·356	·346	·364	·364	·349	·359
P2	·338	·354	·341	·351	·353	·329	·345
Mean	·358	·356	·348	·355	·360	·346	

Basal N1, N2>> Basal N0
Basal P0, P1> Basal P2

TREATMENT SCHEDULE

Basal Dressings

Code	Rate of Fertilizer
N0	Nil
N1	1 cwt/ac
N2	2 cwt /ac
P0	Nil
P1	2·7 cwt/ac
P2	5·3 cwt/ac

Side-dressings

Code	Rate of Fertilizer
N0	Nil
N1	0·5 cwt/ac
N2	1 cwt/ac
P0	Nil
P1	1·4 cwt/ac
P2	2·7 cwt/ac

Plant Height.—Measurements are set out in Table 8. In Trial 3, four weeks after field planting, plants which received basal superphosphate were six times as high as those which did not receive this fertilizer. This growth difference had disappeared at the conclusion of the trial.

TABLE 8

CUBE OF HEIGHT OF STEM (CM) x 10^{-3} FOUR WEEKS AFTER TRANSPLANTING, TRIAL 3

Side \ Time	T1	T2	T3	Means
N	7·4	9·0	7·6	8·0
PK	6·7	10·4	7·3	8·1
NPK	7·0	8·5	7·5	7·7
Basal P0	2·3	2·9	2·5	2·6
P1	11·8	15·7	12·4	13·3
Means	7·0	9·3	7·5	

P1>>P0

TREATMENT SCHEDULE

Code		Rate of Fertilizer
N	T1	1st & 3rd hand set at 1·65 cwt/ac
N	T2	Every 2 weeks at 0·66 cwt/ac
N	T3	Every week at 0·33 cwt/ac
PK (17 : 9)	T1	1st & 3rd hand set @ 1·42 cwt/ac
PK (17 : 9)	T2	Every 2 weeks @ 0·57 cwt/ac
PK (17 : 9)	T3	Every week @ 0·28 cwt/ac
NPK (5 : 13 : 5)	T1	1st & 3rd hand set @ 3·07 cwt/ac
NPK (5 : 13 : 5)	T2	Every 2 weeks @ 1·23 cwt/ac
NPK (5 : 13 : 5)	T3	Every week @ 0·61 cwt/ac
P0	..	Nil
P2	..	4 cwt/ac

(b) Response to Side-dressings

There was no response by tomatoes to side-dressings of ammonium sulphate and superphosphate in any of the three trials (Tables 4, 5 and 9).

TABLE 9

FRESH FRUIT WEIGHT (LB/7 PLANT PLOT), TRIAL 3

Side \ Time	T1	T2	T3	Mean
N	30·4	35·2	28·8	31·5
PK	29·3	32·9	30·3	30·8
NPK ..	35·9	36·9	36·6	36·5
Mean ..	31·9	35·0	31·9	—

No significant differences

TREATMENT SCHEDULE

Code		Rate of Fertilizer
N	T1	1st & 3rd hand set at 1·65 cwt/ac
N	T2	Every 2 weeks at 0·66 cwt/ac
N	T3	Every week at 0·33 cwt/ac
PK (17 : 9)	T1	1st & 3rd hand set @ 1·42 cwt/ac
PK (17 : 9)	T2	Every 2 weeks at 0·57 cwt/ac
PK (17 : 9)	T3	Every week at 0·28 cwt/ac
NPK (5 : 13 : 5)	T1	1st and 3rd hand set @ 3·07 cwt/ac
NPK (5 : 13 : 5)	T2	Every 2 weeks at 1·23 cwt/ac
NPK (5 : 13 : 5)	T3	Every week at 0·61 cwt/ac

In Trial 2, side-dressings of ammonium sulphate and superphosphate were applied 8 weeks after field planting, which gave sufficient time for any response to become apparent. A greater range of rates and times of application of side-dressings were tested in Trial 3, again without effect.

Although side-dressing nitrogen did not produce a significant yield response in Trial 2, there was positive interaction between side nitrogen and basal phosphorus (Table 5). In the absence of basal phosphorus there was no effect due to side nitrogen. At the higher level of basal phosphorus the presence of side nitrogen increased yield by approximately 10 per cent. However, at the lower level of basal phosphorus, side nitrogen resulted in a depression in yield.

(c) Residual Effects

At the completion of Trials 1 and 2, a follow-up crop of beans was planted on the rows previously occupied by tomatoes. No additional fertilizer was added. The results are given in Tables 10 and 11. Following Trial 1 there was a 25 per cent. increase in yield as a result of previous side-dressings of both ammonium sulphate and a 5:13:5 mixture. This established ammonium sulphate as the effective component in the mixture. In contrast, however, beans grown subsequent to Trial 3 did not exhibit any responses to residual fertilizer.

TABLE 10

GREEN POD WEIGHT (lb/PLOT) OF BEAN CROP FOLLOWING TRIAL 1

Basal \ Side	N0	N1	N2	C1	C2	Mean
B1	6·8	10·1	8·4	10·1	8·8	8·8
B2	8·9	10·2	8·3	9·0	9·4	9·2
Mean ..	7·9	10·2	8·4	9·6	9·1	

N1, C1>>O
N2, C2>O

TREATMENT SCHEDULE

Code	Rate of Fertilizer
B1 (N : P : K, 5 : 13 : 5)	8 cwt/ac
B2 (N : P : K, 5 : 13 : 5)	16 cwt/ac
N1	1 cwt every 2 weeks
N2	2 cwt every 2 weeks
C1 (N : P : K, 5 : 13 : 5)	4 cwt every 4 weeks
C2 (N : P : K, 5 : 13 : 5)	8 cwt every 8 weeks

TABLE 11

GREEN POD WEIGHT (lb/PLOT) OF BEAN CROP FOLLOWING TRIAL 3

Time	T1	T2	T3	Mean
Side N ..	7·85	8·97	10·80	9·21
PK ..	9·20	9·32	9·03	9·18
NPK ..	9·83	8·53	9·90	9·42
Basal NK ..	8·87	8·32	9·66	9·07
NPK ..	9·06	9·56	10·17	9·31
Mean ..	8·96	8·94	9·91	

No significant differences

TREATMENT SCHEDULE

Code	Rate of Fertilizer
NK (4 : 3)	2·58 cwt/ac
NPK (5 : 13 : 5)	6·58 cwt/ac

(d) Movement of Applied Fertilizer

The results of chemical analyses of soil samples relating to Trials 1 and 2 are given in Table 12 and Figures 1-4. Rainfall and irrigation data are included in Table 2 because of their significance in leaching.

TABLE 12

NUTRIENT LEVELS ADJACENT TO TOMATO PLANTS AT THE CONCLUSION OF TRIAL 1

Depth (in.)	Nitrate N (p.p.m.)			Available P_2O_5 (p.p.m.)		
	Inter-row Space	B2	B2 C2	Inter-row Space	B2	B2 C2
0–1	2·3	6·3	55·8	216	540	3,120
1–2	5·1	6·3	56·7	176	900	1,380
2–3	0·9	—	—	248	1,140	1,000
3–6	0·3	0·45	59·1	196	640	540
6–9	0·6	—	—	106	620	500
9–12 ..	1·5	1·8	49·5	22	340	500

TREATMENT SCHEDULE

Code	Rate and Type of Fertilizer
B2 (5 : 13 : 5)	16 cwt/ac, basal
C2 (5 : 13 : 5)	8 cwt/ac every 8 weeks

Nitrogen.—The results of soil analyses from Trial 1 show a reasonably high level of nitrate, evenly distributed to 12 in., in those plots receiving side-dressing fertilizer. Crop removal and leaching failed to completely remove nitrate from this layer, presumably because of the frequency of side-dressing applications.

In Trial 2 the distribution of nitrate is considered under two fertilizer regimens.

Figure 1 shows the distribution with no basal nitrogen but side-dressings of ammonium sulphate. The accumulation of nitrate due to fallow, apparent at the first sampling, was rapidly depleted as a result of crop removal and leaching. Despite the application of side-dressing, nitrate levels in the surface foot at the third and fourth sampling times were approximately 5 and 10 p.p.m. nitrogen respectively. Presumably, leaching was the major factor influencing the distribution, but as sampling was not carried out below 12 in., no information was available regarding the location of nitrate at depth.

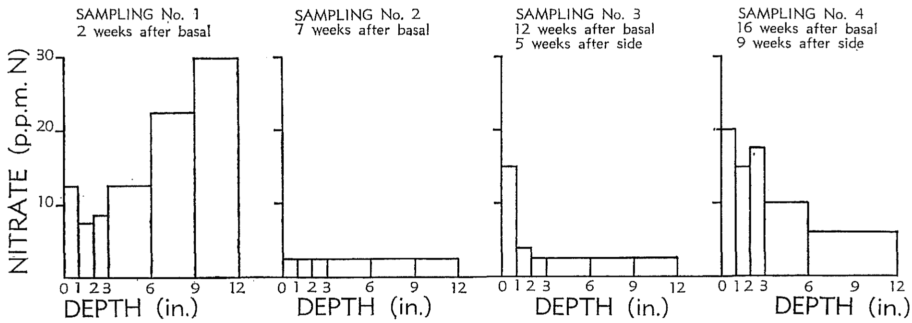

Fig. 1.—Distribution of nitrate in Trail 2 with no ammonium sulphate in the basal fertilizer but 0·5 cwt per acre as a side-dressing applied before the third sampling.

Figure 2 shows the distribution of nitrate with basal and side-dressings of ammonium sulphate. Applications of basal nitrogen produced an even distribution of nitrate to a depth of 12 in. at the first sampling. At the second sampling there was a change in distribution, influenced by accumulation due to nitrification on the one hand and depletion due to leaching and crop removal on the other. At this stage, nitrification was dominant, leading to a considerable accumulation in the 3-12 in. zone. Almost complete removal from the 0-3 in. layer was apparent. Although a side-dressing was applied prior to the third and fourth sampling dates, there is no evidence of its presence in the surface foot of soil.

Subsequent to Trial 2, samples were taken at various locations within the experimental area to investigate the distribution of nitrate below 12 in. These results, given in Table 13, show an accumulation of nitrate at a depth of 4-6 ft. Applications of fertilizer over a period of years have led to this accumulation in the profile at a depth still within the root zone of tomato plants.

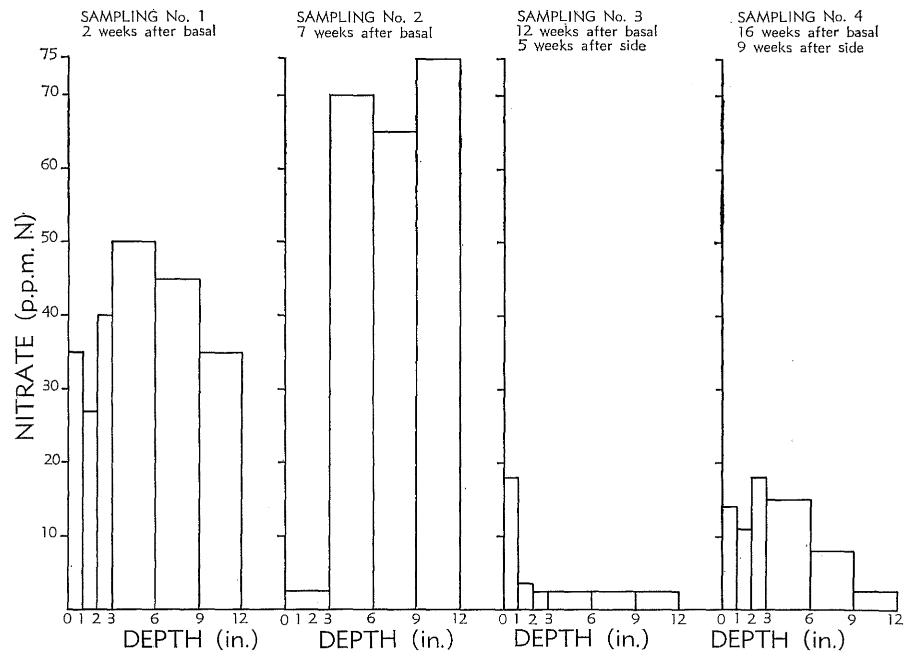

Fig. 2.—Distribution of nitrate in Trial 2 with nitrogen in the basal fertilizer at 1 cwt per acre and ammonium sulphate at 0·5 cwt per acre as a side-dressing applied before the third sampling.

Phosphorus.—Table 12 shows the accumulation of phosphorus in the 0-3 in. layer as a result of side-dressing of superphosphate in Trial 1.

For Trial 2, phosphate distribution can be considered for two fertilizer regimens. Figure 3 presents analytical data to show the distribution of phosphorus with side-dressings of superphosphate but no basal fertilizer. Small accumulations due to side-dressings are evident in the 0-1 in. layer.

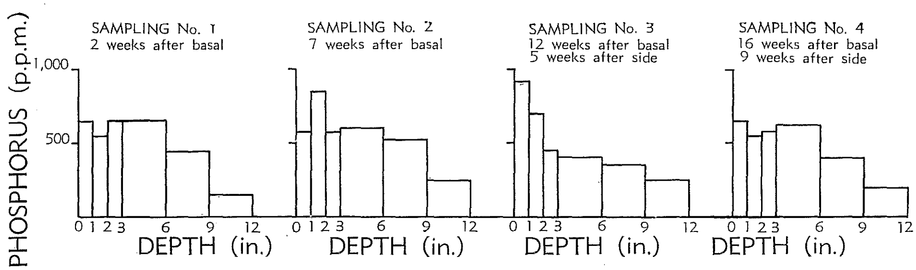

Fig. 3.—Distribution of phosphorus in Trial 2 with no basal fertilizer but with superphosphate at 2·7 cwt per acre as a side-dressing applied before the third sampling.

Figure 4 illustrates the effect with both basal and side-dressings of superphosphate. Accumulations due to basal phosphorus are illustrated by a peak initially located at 2–3 in., and subsequently at 3–6 in. The effects of side-dressings are again apparent in the 0–1 in. layer at the third sampling.

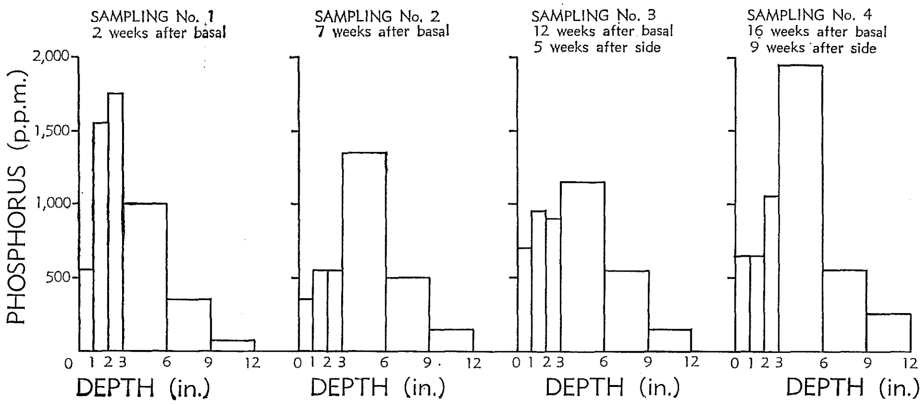

Fig. 4.—Distribution of phosphorus in Trial 2 with superphosphate as basal fertilizer at 5·3 cwt per acre and as a side-dressing at 2·7 cwt per acre applied before the third sampling.

IV. DISCUSSION

(a) Nutrient Responses

Clear evidence for a response to basal nitrogen was provided in Trial 2, in the form of increased plant height and increased size and weight of fruit.

In all three trials where basal nitrogen was used, there was no benefit from subsequent applications of nitrogen in the form of side-dressings, regardless of whether the crop was grown in autumn, winter or spring. A possible explanation is that sufficient nitrogen was applied in the basal fertilizer. However, even in the absence of basal nitrogen, side-dressing nitrogen applied 8 weeks after transplanting had no effect. This explanation is, therefore, not valid.

A second possibility is that time of application is an important factor governing responses to side-dressing nitrogen. When this was examined in Trial 3 it was found that weekly or fortnightly dressings, commencing 2 weeks after transplanting, were ineffective. In this trial, however, all plots received basal nitrogen, so that no information concerning the importance of time of application of side-dressings in the absence of basal nitrogen was obtained.

A subsequent observation trial demonstrated that in the absence of basal nitrogen no responses to side-dressings of this element 2 weeks after planting were obtained. The lack of response is surprising in view of the fact that soil analyses showed a very low nitrate content in the top foot of soil. An even earlier application, perhaps within 2 weeks of transplanting, might prove effective.

A third possibility is that tomatoes have a high nitrogen requirement in the very early stages of growth and a much lower one when reproduction commences. If this were the case one would not expect responses to late side-dressings. As the fertilizer trials reported by Vallance (1945) did show responses to side nitrogen applied after first fruit set, it is unlikely that the nitrogen requirements of tomatoes can be satisfied by basal fertilizer alone.

Table 13 shows an accumulation of nitrate nitrogen at 4–6 ft. This could be expected from a consideration of rainfall and irrigation data, which show that the wetting front in this soil would rarely reach a depth of more than 6 ft. Some indication of the size of the nitrate reservoir is given by a calculation, based on a bulk density of 1·4, that 12 p.p.m. nitrogen corresponds to approximately 50 lb nitrogen per acre-foot.

TABLE 13

NITRATE (p.p.m. N) DISTRIBUTION AT DEPTH, MEANS OF SIX SITES

Depth (ft)	Area		
	1	2	3
2–3	1·0	2·8	0·5
3–4	1·3	9·6	—
4–5	4·5	12·1	27·4
5–6	16·8	10·1	14·4
6–7	—	—	6·2

Tomato roots have been shown to occur at a depth of 5 ft. It is suggested therefore that the behaviour of plants towards side-dressing nitrogen depends on the extent to which the reservoir of nitrate at depth is exploited. With deep-rooting tomatoes sufficient was obtained from the reservoir to satisfy the plant's requirements.

While this reservoir of nitrate exists, no responses would be expected with deep-rooted plants to side-dressings applied subsequent to the basal application. However, as the accumulation is the result of heavy fertilizer regimens, elimination of side-dressings would result in a rapid depletion of the nitrate reservoir. In this event, a careful check would be necessary to ensure that side-dressings were resumed if and when they were needed.

Clear evidence for a yield response to basal phosphorus was provided by these trials, and confirmed observations in the district that tomatoes could not be successfully grown without preplanting applications of superphosphate.

Poor fruit set is always encountered with the commercial winter crop of variety Q2 in the Redlands district. At this time of year tomatoes frequently exhibit visual symptoms of phosphorus deficiency. The results of Trial 2 show that fruit set is related to phosphorus nutrition. Figures for fruit size which are presented in Table 5 show that smaller fruit were produced at the higher level of basal phosphorus, and as total weight of fruit was increased the response took the form of increased fruit set. The fruit size data for Trial 1 have not been presented, but there is similar evidence to suggest that high-phosphate fertilizer increased fruit set.

There was a yield response to the highest level of basal nitrogen and phosphorus in the winter trial which was not duplicated in the autumn trial. This points to a higher requirement in the colder months, which is probably a phosphorus requirement in view of the observed relationship between phosphorus nutrition and fruit set. Thus heavier basal applications of this nutrient in the winter months may be necessary to overcome the problem of poor fruit set.

Considerable fixation of phosphorus would be anticipated in this soil type, and it appears that the high amounts of superphosphate which have been applied over a period of years have not yet satisfied the capacity of the soil to sorb phosphorus.

However, on the basis of soil analytical data, which showed generally high levels of available phosphorus, no response to phosphorus would be expected. A critical value of 40 p.p.m. P_2O_5 for sugar-cane grown on red loams was suggested by Kerr and von Stieglitz (1938). Available P_2O_5 values for representative samples taken prior to each of the present trials were:

Trial No.	Available P_2O_5
1	122
2	400
3	168

The poor response to basal superphosphate which was obtained in Trial 2 may be explained on the basis that this trial area had more available phosphate.

These figures given above, along with previous evidence of yield responses, indicate that the critical level of 40 p.p.m. P_2O_5 for the tomato crop in this soil type is not valid.

In view of the very restricted movement of phosphorus shown by soil anlysis in Table 12 and Figures 3 and 4, the consistent lack of response by tomatoes to side-dressing superphosphate appears due to positional unavailability.

However, if mulching were practised, thus ensuring adequate moisture in the surface soil and enabling the roots to exploit this layer, tomatoes may show a yield response to side applications of superphosphate. Similarly, if the side application was placed in a band 4–6 in. below the soil surface and within the root zone there may also be some yield response. The value of side-dressing superphosphate may therefore depend largely on surface soil moisture and other cultural practices used.

(b) Residual Effect and Accumulations in Profile

Rapid movement of soil nitrates *pari passu* with water movement under suitable conditions is well established, and is further illustrated by the results of the present trials. Nitrate levels in plots which did not receive applied nitrogen were consistently low, but the effects of leaching are quite apparent in nitrogen-treated plots.

Leaching of nitrogen from the top foot of soil in Trial 2, as shown in Figures 1 and 2, occurred rapidly when adequate moisture levels were maintained, and resulted in considerable losses from this zone. It has been shown that nitrate accumulates at a depth of 5–6 ft, and because soil sampling in Trial 2 was restricted to a depth of 12 in., no information was available as to how rapidly the nitrate moved to this depth. It is obvious, however, that incomplete use of basal nitrogen fertilizer resulted from the downward movement of nitrogen. No measurement of accumulation of this nutrient in the ammonium form has been made. However, conditions are suitable for nitrification of ammonium ion so that nitrate levels can be used as an index of residual effect. The results suggest that the long-term accumulation will be low, except in deeper horizons. Here some benefit to deep-rooted crops can be anticipated. Over a short period, if leaching losses are low, some residual effect due to more recent application of nitrogen may be obtained. This is instanced by the response of a follow-up crop of beans grown after Trial 1. In this case, there was an accumulation of 60 p.p.m. N as nitrate to a depth of 12 in. after the final tomato harvest. The residual effect, however, is likely to vary considerably with seasonal conditions and is therefore unreliable.

The consistent response to basal phosphorus indicated that the residual effect of previous applications is insufficient to meet current crop needs. As no leaching of phosphorus occurs on this soil, it is apparent that fixation is responsible for the unavailability of the large accumulation of this element in the surface 12 in.

V. CONCLUSIONS

(1) Autumn, winter and spring tomato crops give a consistent response to basal applications of both nitrogen and phosphorus. The response to nitrogen is in the form of increased plant height, fruit size and total fruit weight, while phosphorus increases fruit numbers and total fruit weight.

(2) No responses to side-dressings of either nitrogen or phosphorus can be expected. In the case of nitrogen, this is due in these experiments to the exploitation of an accumulation of nitrate at depth, while the lack of response to phosphorus is due to positional unavailability.

(3) The residual effects of nitrogen fertilizers are uncertain and are likely to vary with seasonal conditions and deposits in lower root zones. As a result of fixation the residual effect of previous applications of phosphorus fertilizer is insufficient to meet crop needs.

(4) Poor fruit set in colder months is associated with a higher phosphorus requirement during this period.

(5) Rapid movement of nitrogen to a depth of 4–6 ft occurred under the existing cultural practices, while little movement of phosphorus was evident.

(6) The results emphasize the need to examine methods for assessing available phosphorus in red loams, and to consider cultural practices with respect to side-dressings.

(7) Side-dressings of phosphorus are not justified for tomatoes in this soil type.

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APPENDIX

Tomato Responses to Basal Applications of Calcium Phosphate

In order to establish conclusively that superphosphate responses were in fact due to phosphorus, a field trial was conducted to compare plant responses to superphosphate and calcium phosphate. The results are given in Table 14.

The yield data established that the response to superphosphate was due to phosphorus. In Trials 1, 2 and 3, calcium carbonate at 1 ton per acre was applied prior to their commencement. This eliminated the possibility that the superphosphate response was due to calcium.

TABLE 14

FRESH FRUIT WEIGHT PER PLANT (lb)

Basal	P0	P1	P2	Mean
S0	9·90	12·38	11·40	11·22
S1	9·75	12·15	12·08	11·32
S2	10·35	11·25	12·60	11·40
Mean ..	10·00	11·92	12·02	11·32

P1, P2>>O

TREATMENT SCHEDULE

Code	Time of Application	Levels	Type of Fertilizer
P0 ..		Nil	Nil
P1 ..	Preplanting	3 cwt/ac	Superphosphate
P2 ..	Preplanting	Equiv. to 3 cwt/ac of superphosphate	Calcium phosphate (monobasic)
S0 ..	Preplanting	Nil	Sulphur
S1 ..	Preplanting	0·1 cwt/ac	
S2 ..	Preplanting	0·3 cwt/ac	