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COMPARATIVE BEHAVIOR OF AMMONIA AND AMMONIUM SALTS IN SOILS

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UTILIZATION OF AMMONIA SUPPLIED TO PEACHES AND PRUNES AT DIFFERENT SEASONS[1]

HAROLD I. FORDE[2] AND E. L. PROEBSTING[3]

NITROGEN fertilization of peaches and prunes in the fruit-growing area of Sutter County, California, has become a well-established practice. Earlier trials and commercial experience have fairly well defined the profitable rates of application for peaches. Responses by prunes are common but not universal in the area. There has been some doubt concerning the relative effectiveness of equal amounts of nitrogen applied at different seasons. This question has now assumed more prominence because of the practice of applying ammonia in the irrigation water as either a summer or a fall treatment. To obtain information on this point, experimental plots of peach and of prune trees were established in 1938.

PEACH EXPERIMENT

A series of plots was laid out in a Paloro peach orchard on Gridley loam, the prevailing soil type in the orchards of the county. The soil is shallower than the best of this series. The orchard was planted in 1924.

Ten plots of 60 trees each were arranged as shown in figure 1. The form of the plots, 4 trees by 15, was adapted to the orchard practices. Trees were planted 20 feet apart each way. Irrigation was by rectangular basins, and all treatments received the same amount of water. Orchard practices were typical of the district. The outside trees—that is, 4 at each end of each plot—served as guards.

METHODS

Nitrogen was applied to all plots except checks at the rate of 1 pound annually per tree. Ammonium sulfate, $(NH_4)_2SO_4$, was put on plots 5 and 10 during the first week in January each year. Anhydrous ammonia, NH_3, was distributed in the first irrigation to plots 1 and 9; in the last irrigation to plots 4 and 6; and half in the first and half in the last irrigation to plots 2 and 7. Plots 3 and 8 were checks. Nitrogen deficiency was so acute in plots 3 and 8 that one application was given them in 1939. The dates of the first irrigation varied from year to year—from May 29 in 1939 to June 25 in 1942. Those of the last irrigation varied from September 8 in 1940 to October 25 in 1939.

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Leaf, shoot, and soil samples were taken at intervals. Leaf samples were composites of 10 leaves per tree, the first basal leaf of full size on shoots of average vigor being selected. Leaves were dried at 60° C. This procedure has been found to give reproducible results, which random sampling of leaves of various ages does not. A somewhat lower variability is obtained if sampling is done early in the morning than if time of day is not considered, but the hour is of less importance than the age of the leaves.

Dormant shoot samples were likewise composites of 10 per tree. One-year wood of moderate vigor was selected. The wood and bark were separated, and each was analyzed. Total nitrogen was determined on the plant samples by

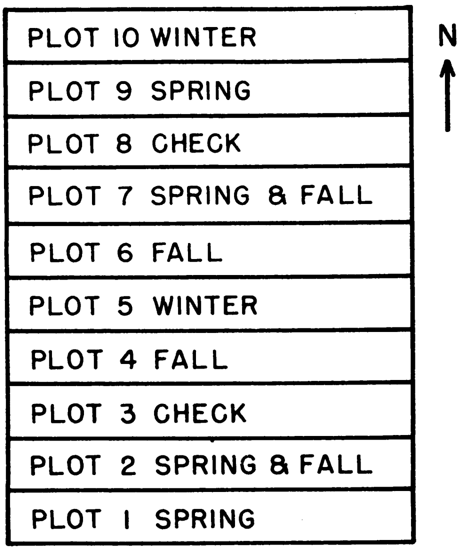

Fig. 1.—Arrangement of peach plots. Each plot is 15 trees long and 4 trees wide.

the official Kjeldahl method. Nitrate in the soil was estimated in 1:1 water extracts by the Devarda alloy method. Ammonia analyses were made by the Olsen procedure outlined in Russell (1932).[4] This method proved to be inaccurate for the soils used, and a satisfactory correction has not yet been found. The ammonia data, therefore, are not reported.

Examination of root distribution by plotting permanent roots in trench faces disclosed few roots in the surface foot. The greatest concentration occurred in the second and third feet. Hardpan at about 4 feet limited root penetration to that depth.

Application of NH_3 in the irrigation water was the commercial method of the district. The gas, supplied as a liquid under pressure in steel cylinders, was allowed to bubble through a spreader lying in the irrigation ditch. The rate was controlled by using suitable orifices to give the desired concentration for a known head of water. Samples of the resulting solution were secured at different points to follow distribution. Before the addition of material, analysis

[4] See "Literature Cited" for complete data on citations, referred to in the text by author and date of publication.

showed the irrigation water to contain no ammonia. On May 29, 1939, it had a pH of 7.8, containing 4.30 m.e. of HCO_3^- per liter. After the addition of NH_3 at full rate, the pH increased to 8.4, and the concentration of ammonia below the spreader became 5.50 m.e. per liter. The ammonia concentration at the lower end of the ditch was 5.00; at the head of the basin, plot 9, 5.20; and at the lower end of the same plot, 5.20 m.e. per liter. Where the rate was reduced one half, in plot 7, the concentrations in the same positions were 2.10, 2.70, 2.65, and 2.70 m.e. per liter respectively. These figures indicate lack of completely uniform mixing in the ditch, but an even distribution over the basins, with no appreciable loss by vaporization. Later determinations for the six plots receiving this material showed similar characteristics. The range in concentration was plus or minus 10 per cent between the sample in the ditch and that at the lower end of the basin. Other samples secured from the prune plots likewise showed very good agreement between the samples in the basin, with some deviation from those taken in the ditch.

Preliminary soil sampling to determine the nitrate level, done in June, 1938, showed a mean of 31 $\pm$ 2.8 p.p.m. of NO_3^- on a dry-soil basis in the 0 to 2 foot section, and 13 $\pm$ 1.4 in the 2 to 4 foot. Thereafter, composite samples from six locations in each plot were used; and all the figures in the tables represent such composites.

PRESENTATION OF DATA

The nitrates found in the soil samples are recorded in table 1. As might be expected, the lowest concentration is usually found in the check plots. Evidence of nitrification between the time of application and the next date of sampling is clear, except for the winter application, where leaching into deeper soil has reduced the concentration in the surface foot. Although ammonia analyses are not considered satisfactory, the data secured confirm other experience that NH_4^+ is fixed in the surface soil.

This experiment covered a series of years of more than average rainfall, four of the five being wet, and two having severe floods. The orchard suffered some damage, especially in plot 7. The degree to which root damage following these floods has influenced nitrate concentration by affecting absorbing surface is impossible to evaluate. It may, however, be one reason for the variability shown in these data.

The total nitrogen content of the leaves is reported in table 2. The seasonal curves are typical of those found generally in the literature—namely, a high initial concentration in the spring, which decreases sharply as the leaves mature; a slowly declining percentage through most of the summer; and another drop in the fall. There is a good agreement between duplicate plots, except for plots 2 and 7. The latter is consistently and significantly lower than plot 2. This difference appeared at the outset of the experiment and continued throughout the period of sampling except for a period in 1941. The check plots are significantly lower than any treatment, except the aberrant plot 7. Differences between treated plots, with the same exception, are not significant over the whole period. Absorption following application of NH_3 in the irrigation water has not been demonstrated in less than 3 weeks, and not before the next irrigation following the application. This tends to substantiate the earlier work reported (Proebsting, 1937) and checks with the soil analyses. Although

TABLE 1

NITRATE CONTENT OF SOIL IN PEACH PLOTS FERTILIZED AT DIFFERENT SEASONS, 1938 THROUGH 1942

Date of sampling	0 to 1 foot depth									
	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1938:										
June 24	102	94	60	..	..	...	60	40	99	..
July 4	107	84	67	..	..	..	92	84	117	..
July 17	69	87	45	..	..	..	22	37	71	..
Aug. 12	30	24	22	..	..	..	17	21	43	..
Aug. 31	19	32	19	..	..	..	30	26	34	..
Nov. 12	17	55	24	41	16	41	19	16	34	16
Dec. 17	19	22	16	20	15	26	15	11	19	10
1939:										
Mar. 21	14	14	10	32	29	17	15	9	9	20
May 6	17	19	16	31	29	27	27	26	29	30
June 6	61	74	27	15	30	42	27	15	201	25
June 19	68	27	12	6	15	14	16	11	51	16
July 14	47	26	22	29	24	34	22	12	51	21
Aug. 8	15	14	27	20	14	15	15	12	32	10
Sept. 9	17	16	15	16	34	25	12	11	22	11
Nov. 2	16	43	24	24	19	30	20	19	34	21
Dec. 16	30	29	20	30	15	22	17	12	27	29
1940:										
Apr. 13	11	6	10	9	12	16	5	3	5	3
May 11	27	31	25	31	38	58	26	22	22	38
June 18	92	47	17	17	25	32	40	22	65	32
July 29	21	14	11	16	16	17	17	17	35	27
Aug. 12	12	6	5	4	5	11	6	1	9	4
Sept. 21	26	60	22	71	27	77	37	11	38	14
1941:										
May 6	11	37	17	47	57	41	10	7	11	24
May 20	14	22	14	26	26	17	22	17	22	12
June 16	15	16	10	15	61	24	24	26	12	30
June 30	52	38	9	15	15	15	24	15	52	22
July 23	61	12	9	17	10	24	10	9	37	30
Aug. 20	11	7	1	5	4	4	3	3	6	7
Sept. 14	24	22	5	79	39	25	68	22	19	59
Oct. 23	26	196	42	192	140	91	150	47	79	92
1942:										
Apr. 20	17	9	5	7	10	..	..	..	..	..
May 7	27	17	17	21	25	17	12	11	19	19
June 3	40	37	37	33	40	42	22	17	26	37
July 7	88	58	20	25	24	14	67	17	55	15
Aug. 12	21	35	44	39	40	38	21	23	20	35

(Continued on opposite page)

seasonal variations occur as a result of differential timing of applications, the level in all fertilized plots tends to be higher than the level in the checks. With a supply of the order given these trees, greater tissue concentration is maintained until the next annual application. Occasional abèrrant samples were found, and these have been reanalyzed to insure that the sample and not the analysis was the variant.

TABLE 1 (*Continued*)

NITRATE CONTENT OF SOIL IN PEACH PLOTS FERTILIZED AT DIFFERENT SEASONS, 1938 THROUGH 1942

Date of sampling	1 to 2 foot depth (1938) or 1 to 3 foot depth (1939 through 1942)									
	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1938:										
June 24	17	15	17	..	..	..	12	15	22	..
July 4	62	37	52	..	..	..	42	47	52	..
July 17	20	10	7	..	..	..	6	7	19	..
Aug. 12	22	19	10	..	..	..	8	9	37	..
Aug. 31	26	12	7	..	..	..	9	7	17	..
Nov. 12	12	14	9	9	7	7	9	15	7	7
Dec. 17	12	17	6	9	6	7	7	15	7	6
1939:										
Mar. 21	10	9	10	10	30	7	9	9	7	6
May 6	16	24	24	15	15	12	15	21	14	12
June 6	7	12	12	7	10	12	7	12	15	15
June 19	16	19	5	4	9	6	6	9	10	3
July 14	18	18	6	7	7	5	9	6	9	7
Aug. 8	12	7	10	5	7	12	12	7	11	6
Sept. 9	10	9	4	5	5	3	5	7	10	5
Nov. 2	10	6	5	5	5	3	5	5	5	5
Dec. 16	7	5	5	4	4	3	4	5	5	4
1940:										
Apr. 13	3	3	4	5	6	3	4	3	4	6
May 11	5	6	4	6	6	7	6	6	3	6
June 18	10	17	15	10	17	7	10	7	17	10
July 29	7	6	1	1	3	1	4	3	10	4
Aug. 12	5	9	3	3	4	3	4	5	5	4
Sept. 21	7	6	6	5	7	5	5	3	9	4
1941:										
May 6	11	15	11	5	6	4	5	6	5	4
May 20	6	7	5	6	4	5	4	1	4	5
June 16	12	11	5	5	9	4	6	6	3	4
June 30	6	7	1	5	5	7	6	5	5	9
July 23	17	12	6	3	4	6	5	7	11	5
Aug. 20	3	3	1	3	5	1	1	1	3	3
Sept. 14	4	12	9	9	4	16	14	6	0	4
Oct. 23	35	12	12	14	20	14	20	7	9	12
1942:										
Apr. 20	3	0	1	4	4	..	..	..	..	..
May 7	7	5	3	3	4	1	5	5	5	3
June 3	7	7	9	7	7	5	5	6	5	10
July 7	19	15	16	7	5	6	6	6	10	12
Aug. 12	13	6	20	25	18	20	24	19	16	13

The nitrogen content of dormant wood (table 3) is low. After the first year, the checks tend to run somewhat lower than the fertilized samples; but the differences that develop are not great. Bark samples have a higher nitrogen content and tend to reflect treatment better than wood. There is no evidence of increase in nitrogen content until very shortly before blossoming. This confirms the findings of Aldrich (1931), Batjer, Magness, and Regeimbal (1943), and others that translocation is negligible while the trees are dormant. The increase just before blossoming noted in table 3 in 1938–39 and, in the prune, in table 8 for March 11, 1942, with no corresponding increase in the wood,

TABLE 2

TOTAL NITROGEN CONTENT OF PEACH LEAVES, 1938 THROUGH 1942
(Dry-weight basis)

Date of sampling	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1938:										
June 6	2.45	2.57	2.52	2.57	2.43	2.48	2.47	2.59	2.53	2.47
June 24	2.66	2.66	2.56	....	....	....	2.35	2.52	2.64	....
July 9	2.98	3.02	2.62	....	....	....	2.36	2.52	2.95	....
July 19	2.97	2.87	2.66	....	....	....	2.43	2.57	2.93	....
Aug. 12	2.74	2.41	2.37	....	....	....	2.07	2.30	2.35	....
Aug. 31	2.14	2.07	1.87	....	....	....	1.95	2.03	2.24	....
1939:										
Apr. 13	3.47	3.24	2.71	3.08	2.98	3.01	2.86	2.63	3.07	3.00
May 7	2.82	2.65	2.49	2.64	2.54	2.66	2.50	2.48	2.80	2.56
June 6	2.65	2.66	2.38	2.63	2.52	2.61	2.30	2.32	2.52	2.57
June 19	2.89	2.68	2.30	2.67	2.38	2.66	2.35	2.32	2.66	2.66
July 14	3.06	2.94	2.26	2.85	2.76	2.96	2.66	2.57	3.07	2.80
Aug. 8	3.01	2.84	2.38	2.77	2.79	2.80	2.49	2.62	3.07	2.71
Sept. 9	2.79	2.65	2.36	2.47	2.46	2.56	2.39	2.50	2.67	2.47
1940:										
Apr. 13	3.76	3.60	3.46	3.76	3.94	3.86	3.54	3.45	3.62	3.82
May 11	2.86	3.10	2.94	3.17	3.27	3.24	2.82	2.88	3.14	3.30
June 18	2.68	2.62	2.32	2.38	2.64	2.60	2.38	2.23	2.22	2.46
July 29	2.79	2.76	2.19	2.62	2.68	2.56	2.26	2.18	2.78	2.73
Aug. 12	2.58	2.66	2.26	2.56	2.43	2.31	2.26	2.01	2.60	2.50
Sept. 21	2.34	2.40	2.00	2.14	2.03	2.18	1.88	1.79	2.20	2.22
1941:										
Apr. 19	3.19	2.94	2.88	2.76	3.36	3.32	3.28	2.78	3.42	3.45
May 5	3.08	2.96	2.82	3.17	3.62	3.34	3.23	3.28	3.34	3.76
May 20	3.02	3.23	2.90	3.47	3.51	3.40	3.29	3.07	3.22	3.40
June 16	2.62	2.54	2.32	2.78	2.99	2.78	2.61	2.61	2.56	2.39
June 30	2.45	2.67	2.40	2.54	3.10	2.49	2.46	2.71	2.78	3.15
July 23	2.99	2.69	2.49	2.28	2.86	2.48	2.60	2.39	3.13	2.87
Aug. 20	2.68	2.59	2.14	2.24	2.49	2.27	2.59	2.20	2.65	2.79
Sept. 15	2.12	2.36	1.85	1.92	2.13	1.98	1.98	1.93	2.05	2.43
1942:										
May 7	3.24	3.26	3.06	3.31	3.51	3.63	3.15	2.90	3.30	3.72
June 3	2.51	3.16	2.67	3.23	2.73	3.18	2.84	3.07	2.70	3.07
July 7	2.28	2.48	2.16	2.36	2.36	2.56	2.41	2.18	2.46	2.71
Aug. 12	2.14	2.15	1.85	1.89	2.26	1.84	1.91	1.86	2.20	2.26

suggests some translocation in the bark before the beginning of an appreciable transpiration stream in the spring.

The yields are given in table 4. The 1938 season can be considered as preliminary, since only four plots received any nitrogen before harvest, and two of those only half of their seasonal total. The sole influence possible from such an application as was given would be on the size of individual fruits. Nothing in the data suggests that there was any such effect.

TABLE 3

TOTAL NITROGEN IN BARK AND WOOD OF ONE-YEAR-OLD PEACH SHOOTS, 1938–39 THROUGH 1941–42

(Dry-weight basis)

Date of sampling	Nitrogen in bark									
	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1938–39:										
Nov. 12	1.89	1.67	1.54	1.64	1.38	1.48	1.68	1.65	1.77	1.56
Dec. 17	2.07	1.96	1.93	2.10	1.86	2.08	1.96	1.87	2.05	1.98
Jan. 9	1.86	1.62	1.47	1.58	1.48	1.59	1.70	1.75	1.84	1.70
Feb. 17	1.90	1.77	1.52	1.70	1.60	1.62	1.64	1.66	1.83	1.66
Mar. 21	2.50	2.35	2.12	2.26	2.27	2.26	2.28	2.25	2.45	2.32
1939–40:										
Nov. 2	1.99	1.94	1.96	1.88	1.77	1.84	1.77	1.89	1.88	1.86
Dec. 16	2.12	1.96	2.01	1.87	1.90	1.92	1.85	1.78	2.08	1.88
Jan. 12	2.18	2.03	1.95	1.92	1.98	1.94	1.94	2.03	2.04	2.10
Feb. 22	2.23	2.25	2.19	2.16	2.04	2.10	2.04	2.14	2.16	2.14
1940–41:										
Nov. 9	1.82	1.76	1.70	1.93	1.82	1.84	1.80	1.74	1.82	1.98
Feb. 22	1.84	1.91	1.70	1.78	1.75	1.78	1.75	1.78	1.94	1.93
1941–42:										
Oct. 28	1.56	1.45	1.55	1.45	1.35	1.54	1.53	1.34	1.72	1.49
Dec. 8	1.52	1.70	1.47	1.66	1.57	1.79	1.84	1.58	1.86	1.82
Feb. 13	1.70	1.62	1.34	1.51	1.57	1.35	1.75	1.43	1.85	1.53

Date of sampling	Nitrogen in wood									
	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1938–39:										
Nov. 12	0.47	0.42	0.38	0.46	0.35	0.39	0.46	0.47	0.47	0.43
Dec. 17	0.53	0.53	0.49	0.48	0.47	0.51	0.56	0.45	0.55	0.47
Jan. 9	0.55	0.52	0.45	0.48	0.44	0.47	0.51	0.50	0.52	0.46
Feb. 17	0.48	0.48	0.43	0.46	0.43	0.48	0.48	0.52	0.53	0.47
Mar. 21	0.48	0.48	0.44	0.45	0.46	0.48	0.48	0.43	0.52	0.48
1939–40:										
Nov. 2	0.76	0.67	0.54	0.63	0.54	0.68	0.66	0.68	0.75	0.60
Dec. 16	0.45	0.42	0.48	0.42	0.40	0.45	0.42	0.43	0.45	0.44
Jan. 12	0.52	0.54	0.48	0.50	0.50	0.52	0.50	0.52	0.50	0.52
Feb. 22	0.43	0.49	0.43	0.42	0.42	0.47	0.45	0.48	0.48	0.46
1940–41:										
Nov. 9	0.42	0.44	0.42	0.46	0.45	0.44	0.42	0.42	0.51	0.50
Feb. 22	0.34	0.36	0.32	0.36	0.36	0.37	0.38	0.36	0.41	0.41
1941–42:										
Oct. 28	0.50	0.48	0.44	0.53	0.52	0.52	0.47	0.46	0.59	0.63
Dec. 8	....	....	....	....	....	....	....	....	....	....
Feb. 13	0.53	0.48	0.38	0.48	0.48	0.45	0.51	0.45	0.53	0.49

The plots that received $(NH_4)_2SO_4$ in the winter (nos. 5 and 10), those that had NH_3 in the spring (nos. 1 and 9) and no. 2, which had split applications, clearly outyielded the checks, and showed no significant differences among them. The fall plots (nos. 4 and 6) take an intermediate position. Plot 4 is not significantly better than its adjacent check, plot 3; but plot 6 is better than plot 8. Excluding 1938, when neither had been treated, the combination of plots 4 and 6 shows odds of 40:1 that it outyields the checks. Although inherent differences are suggested in the 1938 data, plot 7 being low and 10 high, only plot 7 proved to be seriously aberrant. This plot (no. 7) outyielded the check plot each year after 1938, but not significantly, and was lower than the other fertilized plots on the average. Taken in conjunction with the low nitrogen content of the leaves, noted above, these facts would suggest caution

TABLE 4

YIELD OF MARKETABLE PEACHES PER TREE, 1938 THROUGH 1942

Year	Plot 1, spring	Plot 2, spring and fall	Plot 3, check	Plot 4, fall	Plot 5, winter	Plot 6, fall	Plot 7, spring and fall	Plot 8, check	Plot 9, spring	Plot 10, winter
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
1938	194±5.9	184±6.6	193±6.5	178±6.0	171±9.4	162±8.1	139±8.9	169±8.7	201±7.9	236±8.7
1939	270±8.2	292±6.9	239±6.9	265±6.7	275±5.6	245±6.4	179±6.8	152±6.4	245±9.2	296±5.4
1940	198±5.2	190±6.2	163±5.0	181±3.7	203±4.5	186±6.1	148±4.8	122±3.8	180±5.8	193±4.7
1941	159±4.4	122±3.7	101±3.6	96±3.4	133±4.4	106±3.7	116±3.1	103±4.1	131±4.3	117±3.6
1942	164±5.5	180±5.4	150±3.1	146±3.7	185±5.7	151±5.4	120±3.5	105±3.8	185±3.9	205±4.8

in the use of data from this plot. Since there was no delay in maturity in any plot, apparently the rate of application was not excessive.

The phosphorus content of the plant samples was also determined. The wood and bark samples showed no regular relation. The leaves, with few exceptions, gave the usual inverse relation reported earlier by Proebsting and Kinman (1933) and substantiated by others. Plot 7, which had a low nitrogen content even though fertilized, had a high phosphorus content.

PRUNE EXPERIMENT

A series of plots of prune trees was established in October, 1938, following the same general plan described for peaches. The trees were planted in 1918 on Gridley clay loam 20 feet apart each way. Ten plots of 20 trees each were arranged as shown in figure 2. A guard row surrounded the block, and two guard rows separated the two sets of replications. Irrigation was by rectangular basins, and all received the same irrigation treatment. The time and rate of application of nitrogen followed the same scheme outlined for peaches. The first irrigation varied in time from May in 1939 to July in 1942; the last from late July to August. Winter applications of $(NH_4)_2SO_4$ were made early in January each year except 1943, when it was delayed until March 3.

Data were collected for three years on the percentage set of the blossoms in the various plots. These figures are the averages of 10 branches in each plot, each branch being taken from a different tree. The blossoms were counted, and the fruits reaching maturity on the same branches were counted just before harvest. Variability was high; and the results are not considered significant, although the winter plots average the highest throughout and may approach significance. The behavior of these trees in this respect differs from general experience with trees in low nitrogen status. Obviously, percentage set is only one factor concerned; the same number of fruits might be secured by a high percentage set with light bloom and a low percentage set with heavy bloom.

Drying ratios were secured for the 1940 and 1941 crops. Samples of about 500 pounds fresh weight were taken from each plot and dehydrated in the University dehydrater. Drying ratios varied from 2.05 : 1 to 2.36 : 1 in 1940 and from 1.87 : 1 to 2.53 : 1 in 1941. This variation was random. For example, both of the extremes came from winter-fertilized plots in 1941. Factors other than the fertilization treatment have dominated this relation.

Each lot of fruit was graded after drying; and the size distribution, percentage of culls, and specific gravity for each lot are reported in table 5. Size

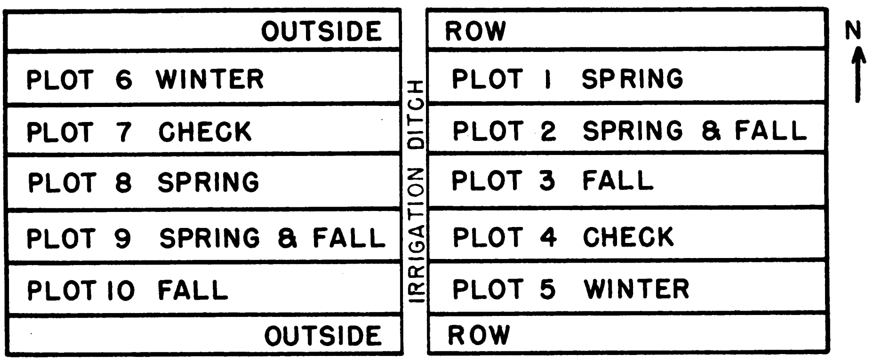

Fig. 2.—Arrangement of prune plots. Each plot is 10 trees long and 2 trees wide.

distribution seems to be principally a matter of number of fruits per tree, according to the data of Hendrickson and Veihmeyer (1942). These data fall in line with such an interpretation. The culls in 1940 consisted largely of split fruit, a condition general in the district in that year. Those in 1941 were largely fruits damaged by brown rot. Treatment has not affected the size of fruit significantly in this experiment.

The specific gravity was determined by weighing samples in air and in xylene, in an effort to find a short method of estimating quality. This method has been explored over a period of ten years by Hendrickson,[5] who has recently dismissed it except as a measure indicating the texture of the flesh.

Yield records (table 6) were secured for each of the five years. Thus far there was little evidence of response, despite the better tree condition produced by the nitrogen. There was a pronounced difference in the color of foliage and the amount of new growth between fertilized and check trees. Other factors have dominated the development of fruit; and even in 1943, the year of maximum crop, when the greatest response would be expected, differences are neither great nor consistent. Evidently, despite a relatively low supply of nitrogen, this material is not limiting in this orchard. The difference in behavior between prunes and peaches in this soil and district confirms the gen-

[5] Hendrickson, A. H. Unpublished data.

TABLE 5

PER CENT OF DRY WEIGHT IN EACH SIZE, NUMBER OF DRIED PRUNES PER POUND, PER CENT CULLS, AND SPECIFIC GRAVITY OF DRIED PRUNES

Plot no., treatment, and screen no.	Size of fruit		Percentage in each size		Culls		Specific gravity	
	1940	1941	1940	1941	1940	1941	1940	1941
	number per pound	*number per pound*	*per cent*	*per cent*	*per cent*	*per cent*		
No. 1, spring:								
28	103	102	1.7	3.8	....	38.6	....	1.27
30	79	78	5.6	9.5	....	28.9	....	1.30
32	56	65	15.1	16.0	21.5	27.0	1.27	1.28
34	49	55	22.4	25.2	19.7	23.0	1.31	1.30
36	44	50	25.0	26.5	19.2	16.5	1.28	1.23
38	41	45	19.8	16.5	11.4	23.4	1.27	1.23
End	37	42	10.3	2.4	16.1	42.4	1.27	1.20
No. 2, spring and fall:								
28	104	103	0.8	2.5	....	38.5	....	1.25
30	81	81	3.7	6.9	....	28.8	....	1.29
32	56	66	12.4	15.3	20.7	26.1	1.30	1.28
34	49	56	21.8	24.6	23.0	24.7	1.31	1.29
36	45	48	26.9	27.0	23.8	9.5	1.28	1.23
38	40	45	21.1	19.9	22.6	27.6	1.27	1.26
End	36	38	13.2	3.6	15.4	31.8	1.29	1.23
No. 3, fall:								
28	99	97	0.4	2.7	....	29.9	....	1.29
30	82	81	1.6	4.8	....	23.4	....	1.31
32	58	65	7.1	8.7	16.4	14.2	1.30	1.31
34	48	54	14.6	15.9	14.7	17.5	1.28	1.32
36	44	45	26.5	26.9	13.8	11.4	1.28	1.31
38	38	43	26.9	33.0	11.7	32.4	1.29	1.33
End	33	34	22.9	8.0	13.8	20.3	1.29	1.31
No. 4, check:								
28	103	106	0.8	2.5	....	20.1	....	1.28
30	79	77	3.3	5.6	....	21.8	....	1.31
32	56	62	9.4	10.7	12.8	26.0	1.30	1.34
34	48	54	18.9	20.2	8.8	24.5	1.30	1.32
36	42	47	27.0	29.4	9.5	18.5	1.28	1.32
38	38	41	24.2	26.2	12.7	13.6	1.31	1.32
End	35	37	16.4	5.4	9.7	24.1	1.29	1.32
No. 5, winter:								
28	109	111	1.7	13.0	....	13.7	....	1.20
30	90	91	6.1	20.7	....	22.0	....	1.24
32	56	75	12.6	23.9	18.4	22.8	1.29	1.21
34	48	64	22.2	21.0	12.3	23.6	1.29	1.20
36	45	59	24.4	13.6	7.8	36.4	1.27	1.21
38	40	49	20.4	6.7	6.8	38.9	1.29	1.15
End	37	45	12.6	1.1	4.9	41.1	1.28	1.00
No. 6, winter:								
28	112	117	0.8	3.1	....	43.1	....	1.20
30	82	82	1.2	6.3	....	26.6	....	1.19
32	60	68	6.2	15.1	15.8	45.5	1.29	1.23
34	52	57	12.9	22.2	22.2	22.5	1.29	1.26
36	45	49	21.6	26.6	14.8	25.9	1.26	1.17
38	40	46	25.7	24.3	14.5	27.1	1.26	1.22
End	35	40	31.5	2.5	17.2	31.6	1.28	1.19

(Continued on opposite page)

TABLE 5 (*Continued*)

PER CENT OF DRY WEIGHT IN EACH SIZE, NUMBER OF DRIED PRUNES PER POUND, PER CENT CULLS, AND SPECIFIC GRAVITY OF DRIED PRUNES

Plot no., treatment, and screen no.	Size of fruit		Percentage in each size		Culls		Specific gravity	
	1940	1941	1940	1941	1940	1941	1940	1941
	number per pound	*number per pound*	*per cent*	*per cent*	*per cent*	*per cent*		
No. 7, check:								
28	..	99	0	0.6	....	....	....	1.18
30	76	76	1.3	1.5	....	33.6	....	1.21
32	55	64	3.8	4.0	10.8	23.8	1.31	1.21
34	49	54	9.3	12.9	10.8	19.9	1.33	1.26
36	42	46	20.4	26.0	8.4	19.7	1.31	1.22
38	38	41	29.0	38.8	9.7	15.3	1.30	1.24
End	32	35	36.0	16.1	13.2	17.9	1.31	1.24
No. 8, spring:								
28	..	99	0	0.7	....	....	....	1.27
30	78	77	1.1	2.2	....	27.3	....	1.29
32	57	61	4.3	5.3	18.5	26.5	1.26	1.28
34	49	53	12.0	12.2	16.8	28.2	1.28	1.28
36	43	46	23.9	28.0	17.2	22.5	1.29	1.30
38	38	40	28.3	38.7	14.4	19.2	1.28	1.30
End	34	34	30.4	12.9	10.0	18.6	1.29	1.28
No. 9, spring and fall:								
28	100	102	1.6	2.1	....	15.9	....	1.24
30	78	76	4.3	5.7	....	19.4	....	1.28
32	61	67	11.8	13.3	30.2	24.7	1.28	1.31
34	50	58	20.1	22.9	36.5	19.4	1.30	1.30
36	43	47	28.4	29.9	26.4	13.9	1.29	1.23
38	40	42	19.7	22.5	25.7	9.3	1.31	1.28
End	35	35	14.2	3.5	20.7	18.8	1.29	1.22
No. 10, fall:								
28	102	105	1.1	1.4	....	20.9	....	1.27
30	77	76	2.5	4.3	....	18.4	....	1.32
32	55	64	7.4	19.1	27.9	9.6	1.32	1.30
34	49	50	15.1	19.2	32.9	9.4	1.31	1.31
36	45	47	27.0	27.9	26.6	10.8	1.28	1.31
38	40	42	27.7	23.0	22.5	15.6	1.27	1.31
End	35	35	19.3	5.1	25.5	23.3	1.27	1.31

TABLE 6

YIELDS OF PRUNES IN FRESH WEIGHT, PER TREE, 1939 THROUGH 1943

Year	Plot 1, spring	Plot 2, spring and fall	Plot 3, fall	Plot 4, check	Plot 5, winter	Plot 6, winter	Plot 7, check	Plot 8, spring	Plot 9, spring and fall	Plot 10, fall
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
1939	24±3.4	28±3.6	19±4.5	36±4.5	33±4.6	60±5.6	54±5.2	53±5.4	53±5.9	51±4.2
1940	167±7.8	120±9.4	113±8.7	112±9.9	164±10.4	151±6.7	80±4.6	108±6.1	110±6.3	105±6.1
1941	182±10.6	155±8.7	156±11.4	161±9.3	212±10.4	138±7.5	115±9.6	112±5.9	127±9.6	134±8.5
1942	75±6.7	68±7.6	89±7.8	65±5.3	59±6.9	66±4.3	58±4.6	54±4.2	72±7.2	86±5.1
1943	271±15.5	224±16.9	216±12.8	221±11.4	244±15.5	320±16.8	262±21.0	229±10.1	194±11.4	252±12.8

TABLE 7

TOTAL NITROGEN CONTENT OF PRUNE LEAVES, 1939 THROUGH 1943
(Dry-weight basis)

Date of sampling	Plot 1, spring	Plot 2, spring and fall	Plot 3, fall	Plot 4, check	Plot 5, winter	Plot 6, winter	Plot 7, check	Plot 8, spring	Plot 9, spring and fall	Plot 10, fall
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1939:										
May 6	2.31	2.24	2.29	2.28	2.45	2.39	2.22	2.25	2.27	2.20
June 2	2.04	2.01	1.98	2.02	2.29	2.34	2.02	2.00	2.01	1.98
June 19	1.93	1.86	1.77	1.73	2.16	2.16	1.79	1.89	1.86	1.80
July 5	1.83	1.80	1.69	1.69	2.02	2.06	1.72	1.86	1.92	1.69
Aug. 8	1.96	1.87	1.58	1.53	1.93	1.96	1.61	1.79	1.91	1.52
Sept. 9	1.83	1.61	1.45	1.39	1.79	1.88	1.57	1.72	1.73	1.47
1940:										
June 24	2.12	2.00	2.04	1.69	2.41	2.63	1.78	1.97	1.99	1.92
July 17	2.13	1.71	1.66	1.57	2.10	2.18	1.56	1.84	1.88	1.64
Aug. 1	1.92	1.86	1.66	1.49	2.00	2.08	1.54	1.91	1.88	1.88
Sept. 21	1.72	1.64	1.52	1.29	1.71	1.78	1.46	1.70	1.48	1.50
1941:										
May 6	2.14	2.18	2.23	1.95	2.44	2.42	2.01	2.15	2.18	2.26
May 20	2.26	2.35	2.34	2.02	2.60	2.58	2.08	2.22	2.24	2.22
June 25	1.97	1.78	1.78	1.69	2.11	2.12	1.83	1.82	1.90	1.81
July 15	1.89	1.84	1.84	1.67	2.14	2.12	1.78	1.94	1.78	1.70
July 23	2.02	1.98	1.94	1.79	2.12	2.17	1.76	2.10	1.99	1.87
Aug. 20	1.86	1.78	1.72	1.58	1.92	1.82	1.50	1.88	1.73	1.70
Sept. 15	1.54	1.46	1.48	1.47	1.60	1.60	1.37	1.38	1.53	1.47
1942:										
May 7	2.80	2.65	2.49	2.35	3.02	2.52	2.61	2.65	2.60	2.56
June 3	2.08	1.96	1.95	1.87	2.23	2.35	2.01	2.27	2.16	1.95
July 7	1.57	1.60	1.75	1.66	1.90	1.89	1.60	1.65	1.69	1.58
Aug. 12	1.67	1.68	1.63	1.55	1.73	1.78	1.53	1.69	1.76	1.74
1943:										
May 5	2.38	2.34	2.34	2.27	2.48	2.68	2.20	2.28	2.49	2.38
June 18	2.10	2.14	2.10	1.88	2.13	2.23	1.98	2.20	2.14	2.17

TABLE 8

TOTAL NITROGEN CONTENT OF BARK FROM PRUNE SHOOTS, 1939 THROUGH 1942
(Dry-weight basis)

Date of sampling	Plot 1, spring	Plot 2, spring and fall	Plot 3, fall	Plot 4, check	Plot 5, winter	Plot 6. winter	Plot 7, check	Plot 8, spring	Plot 9, spring and fall	Plot 10, fall
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1939:										
Jan. 4	1.42	1.47	1.40	1.51	1.54	1.56	1.60	1.56	1.47	1.44
Feb. 14	1.34	1.27	1.30	1.31	1.33	1.41	1.47	1.53	1.33	1.35
1939–40:										
Nov. 24	1.64	1.63	1.38	1.39	1.56	1.63	1.41	1.65	1.57	1.44
Jan. 12	1.68	1.60	1.40	1.40	1.60	1.79	1.49	1.66	1.66	1.48
1940–41:										
Nov. 9	1.55	1.55	1.48	1.37	1.51	1.67	1.44	1.55	1.43	1.47
Feb. 1	1.80	1.71	1.64	1.68	1.68	1.63	1.56	1.68	1.70	1.57
1941–42:										
Oct. 28	1.45	1.40	1.34	1.35	1.48	1.52	1.35	1.46	1.29	1.19
Dec. 3	1.42	1.33	1.31	1.31	1.48	1.44	1.30	1.39	1.39	1.36
Mar. 11	1.68	1.58	1.61	1.58	1.60	1.74	1.44	1.67	1.65	1.65

TABLE 9

NITRATE CONTENT OF SOIL IN PRUNE PLOTS FERTILIZED AT DIFFERENT SEASONS, 1939 THROUGH 1942

(Dry-soil basis)

Date of sampling	Plot 1, spring	Plot 2, spring and fall	Plot 3, fall	Plot 4, check	Plot 5, winter	Plot 6, winter	Plot 7, check	Plot 8, spring	Plot 9, spring and fall	Plot 10, fall
	0 to 1 foot depth									
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1939:										
Apr. 1	16	21	17	16	27	44	12	11	12	10
May 6	17	16	16	12	19	22	15	16	16	15
June 2	50	40	20	15	17	20	22	35	35	17
July 5	42	26	16	15	19	35	15	25	24	11
Aug. 8	65	27	63	25	40	47	25	66	41	43
Sept. 9	45	74	47	36	36	32	21	50	40	60
Nov. 24	46	69	34	21	43	47	24	74	12	27
1940:										
Apr. 19	11	10	11	7	11	7	9	6	9	6
May 14	11	10	11	10	15	17	12	7	11	10
June 24	22	16	7	7	9	10	6	24	19	5
July 17	72	35	9	5	14	16	11	43	20	6
Aug. 6	35	27	14	3	10	11	6	6	9	15
1941:										
May 5	9	10	7	12	15	11	10	12	11	14
May 20	17	12	10	11	16	14	12	10	14	10
June 16	9	12	22	15	16	26	10	19	15	12
July 7	47	37	20	10	32	22	17	52	42	12
July 23	52	32	25	10	27	25	17	20	22	27
Aug. 20	35	29	20	14	38	27	12	46	27	47
Oct. 23	46	29	41	19	27	27	15	62	61	67
1942:										
June 3	24	11	7	16	12	26	12	16	11	17
July 7	29	24	21	30	29	19	15	14	19	26
	1 to 3 foot depth									
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1939:										
Apr. 1	10	15	10	9	10	12	6	14	11	7
May 6	6	5	4	4	10	7	5	4	4	4
June 2	12	15	12	12	22	20	10	10	10	7
July 5	11	15	7	5	14	26	6	11	10	4
Aug. 8	4	7	14	6	10	9	6	6	10	12
Sept. 9	21	9	7	9	14	9	7	26	14	12
Nov. 24	30	9	9	6	9	9	11	15	14	7
1940:										
Apr. 19	5	5	4	5	5	4	4	6	3	3
May 14	5	4	5	3	4	5	3	1	4	3
June 24	6	4	6	3	6	3	4	3	4	3
July 17	7	3	5	3	4	4	4	4	5	1
Aug. 6	9	14	3	1	6	3	1	9	9	7
1941:										
May 5	5	3	4	4	4	5	1	3	9	4
May 20	6	6	4	5	6	4	1	6	1	3
June 16	5	6	5	7	7	4	5	5	6	4
July 7	7	7	10	3	15	5	10	7	7	7
July 23	17	27	7	5	7	7	10	15	12	5
Aug. 20	7	0	1	1	7	7	4	6	1	1
Oct. 23	6	9	6	4	10	5	14	9	9	26
1942:										
June 3	2	5	7	6	7	4	2	5	4	4
July 7	6	2	2	1	2	5	5	2	2	4

eral experience that the peach will respond to additions of nitrogen where prunes obtain an adequate supply.

Perhaps the most interesting data from this trial were obtained from the nitrogen analyses. These analyses were made on samples of leaves, twigs, and soil taken in the same manner as for peaches. The data are presented in tables 7, 8, and 9. The seasonal curves for soil nitrate (table 9) tend to follow the usual pattern of a spring minimum and a fall maximum as reported earlier by Proebsting (1933), modified in those plots receiving summer applications of ammonia. The check plots tend to be low throughout the period.

The twig samples (table 8) show the same tendency exhibited by the peach to reflect no increase in nitrogen until shortly before blossoming. In the prune material (as compared with the peach) there is less difference between fertilized and check trees, and the difference is less consistent. The increase noted just before blossoming in the peach in 1939 and in the prune in 1942 suggests translocation of nitrogen to the twigs before movement in the transpiration stream is possible.

The leaf samples reflect treatment fairly well (table 7). The check plots are lower than the fertilized plots in nearly all cases, and the differences tend to be at the maximum shortly after an application has been made.

SUMMARY AND CONCLUSIONS

Data are presented for a five-year period for peach and prune plots fertilized with nitrogen in the form of NH_3 and $(NH_4)_2SO_4$ at different seasons. Yield records and nitrogen analyses of soil and plant parts are included, together with some supplementary data. Peaches gave increased yields irrespective of time of application, with an indication that fall was a slightly less favorable season than spring or winter and that no advantage inheres in a split application. Prunes in the same soil type and district failed after five years to produce increased yields. Nitrogen applied as NH_3 in the irrigation water behaved essentially the same as $(NH_4)_2SO_4$. Nitrogen levels in the tissues analyzed reflected the treatments, and after an application they remained higher than in the check during the year until the next application. That is, at the rate used and for the conditions of the experiment, the time of applying nitrogen was a matter of minor importance.

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