Frost Injury to Range Annuals

nitrogen fertilization applied in fall found to reduce frost burn and extend growing season of annuals on foothill ranges

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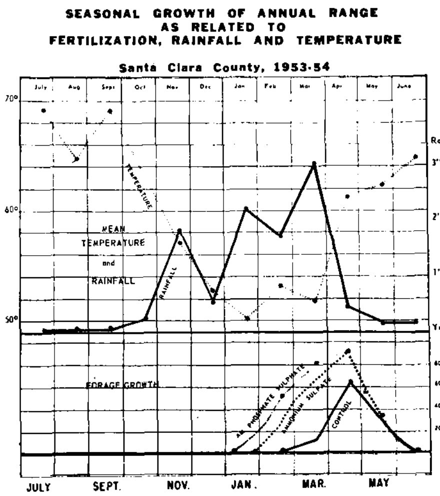
Late fall applications of nitrogenous fertilizers to California foothill ranges have consistently hastened the growth of native forage plants both in fall and spring, resulting in a winter forage production which may be advanced as much as two months. Also, the herbage produced by fertilized plants is not subject to frost damage to the same extent as that produced by unfertilized plants.

Moisture, temperature, and nutrient supply primarily govern the production of range plants, but in California—on the foothill areas under 1,000′ in elevation and adjacent to the central valleys—the climate is such that favorable temperature, moisture, and nutrient supply do not necessarily occur together.

Soil moisture is usually highest during the winter months when temperatures are at their lowest. The more favorable growing conditions occur in the autumn soon after the first rain and again in the spring when the likelihood of rain is declining.

Nutrient supplies also reflect the seasonal effect. In the case of nitrogen, the amount naturally available increases as the soils warm in the spring. Such conditions combine to produce the usual flush of spring growth.

This seasonal aspect of range growth and climatic conditions for Santa Clara County is depicted in the graph. The increased earliness in winter growth re-



lated to fertilization is also illustrated.

Because the most favorable growing temperatures occur when there is little rain and the most favorable moisture conditions exist when the temperatures are too low for rapid natural growth, fertilization stands out as an exceedingly important management tool. Fertilization provides a means of better utilizing features of the prevailing climate, for if adequate nutrients are provided, the temperature conditions which exist during the most favorable moisture periods are seldom too low to prevent growth.

The minimum winter temperatures seldom fall much below 25° F and then for relatively short periods of time. Above-freezing temperatures, often quite mild, prevail for most of the daylight hours. These aspects of the California winter undoubtedly influence the responses in relation to fertilization.

The growth hazards of early range forage appear to be periodic frost injury to new vegetative growth and drying by cold winds which may accompany the periods of frosty nights.

The succulent growth stimulated by nitrogen applications would appear particularly subject to both injuries. Yet field observations reveal that the fertilized feed is less susceptible to damage by both frost and spring droughts than adjacent unfertilized feed. Even when the conditions are severe enough to interrupt growth, recovery is more rapid in the fertilized areas.

Studies of winter injury on fertilized forage plants are few and more attention has been given to winter small grains, but they—being annuals—are somewhat similar to the winter annuals on California foothill ranges. Although the results are variable, it is apparent in regions of relatively severe winter that nitrogen exerts a more striking influence on cold resistance than the other mineral

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Six-weeks-old soft chess plants. ***Left fertilized, right unfertilized, two days after a single night of frost.***

LEAF BURN

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total dissolved solids are 768 ppm—parts per million—with 95 ppm sodium and 75 ppm chloride. The percentage of sodium to total bases is 37.

The water used on a Valencia orange orchard at La Sierra has 903 ppm of total dissolved solids including 131 ppm chloride and 190 ppm sodium. Its sodium percentage of 64 is fairly high. The use of this water in citrus production would usually require careful management practices with the occasional use of gypsum.

The water used on a navel orange orchard at Corona has 824 ppm of dissolved solids including 117 ppm chloride and 69 ppm sodium. The percentage of sodium to total bases is 30. This water is also of medium salinity and with good soil drainage and occasional leaching, good citrus production has been maintained in the past.

These three irrigation waters are representative of the quality of waters used in sprinkled orchards where leaf burn on tree skirts has been found.

Soluble salts in the soil of the sprinkled section of the Hemet grapefruit orchard are slightly higher than the furrow-irrigated area. However, in both sections the total water soluble salts are quite low and the leaf burn and excessive amounts of sodium and chloride in the leaf of the sprinkled section cannot be associated with excessive sodium and chloride in the soil. Many excellent citrus orchards with no leaf symptoms and excellent production have similar amounts of soluble salts in the soil.

The sprinkling practices of the three locations have varied somewhat. At the Hemet orchard, alternate middles were irrigated every seven days during the summer period. In this way a given location received water every two weeks. The duration for each irrigation was nine hours, with an estimated three acre-inches applied.

The La Sierra Valencia orchard was irrigated more or less on demand, as indicated by the condition of a cover crop. Usually the sprinkling interval was every two to three weeks. In the summer the shorter interval was usually used. Sprinklers were run for about two hours with an estimated two acre-inches of water.

The navel orchard at Corona maintains a 10-day irrigation schedule during most of the summer period. Sprinklers were usually run about five hours although on occasion the period extended to eight hours. Lowered water pressures sometimes resulted in longer runs. It was estimated that about one and one-half acre-inches of water were applied at each irrigation.

The information obtained in this study is of a preliminary nature but it does show that citrus leaves wetted by sprinkler-applied water can absorb sodium and chloride in sufficient quantities to cause severe leaf burn and defoliation.

At the time of this report, absorption of sodium and chloride had been found in orchards of interior citrus districts of Riverside County. In all cases the waters used were of medium salinity with dissolved solids in the range of 700 to 900 ppm. The amounts of sodium in the irrigation waters have ranged between 70 and 190 ppm, while chloride ranged between 75 and 120 ppm. There is no indication that other elements such as calcium or sulfur from sulfates have been absorbed.

It is established that such materials as zinc and nitrogen are absorbed by citrus leaves from sprays, so it is not surprising to find that sodium and chloride can also be absorbed.

There was no evidence obtained in this study that sodium or chloride absorbed on the lower sprinkled leaves was translocated to the leaves of the upper tree which received no spray. It was found, however, that small twigs behind burned leaves had larger amounts of sodium and chloride than twigs from the upper part of the tree where leaf burn did not occur.

It is reasonable to conclude that water quality is one very important factor in the problem of leaf burn, but local climatic influences must be considered. At present, leaf burn in citrus due to sodium and chloride absorption from sprinkler-applied water has been found in interior, warmer districts where humidities are lower than in costal areas. Observations also indicate that trees directly exposed to prevailing winds show more severe burn than interior trees of the same orchard. The windward side of trees in some cases shows greater damage than the lee side of the same tree. The effect of the type of sprinkler and the frequency of sprinkling are not known.

It appears that any factor which increases the rate of evaporation is likely to be important. However, additional study is needed on this problem of sodium and chloride absorption by citrus leaves.

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elements. Furthermore, an appreciable increase in nitrogen has generally resulted in an increase in frost damage.

Against this background, the present practice in California of autumn fertilization of annual range with nitrogen raises questions as to the hazard from frost injury following such application.

To study the frost hazard to range annuals under known conditions, controlled freezing tests were conducted at Davis on soft chess and annual ryegrass during the winter of 1955–56. The grass was seeded thickly in 4″ clay pots and permitted to grow in the greenhouse four to six weeks before it was moved outdoors. Difference in nitrogen level was obtained by watering half of each planting weekly—after the two-leaf stage was reached—with a dilute solution of urea nitrogen. The effect of this differential treatment was shown clearly before the freezing trials. Response to this nitrogen was evidenced by a deep green leaf coloration, this differing markedly from the paler control plants receiving no supplemental nitrogen. The high density of planting hastened the symptoms of low nitrogen supply.

At ages between six and 14 weeks after planting, 30 pots—15 controls and 15 treated—were embedded in dry sand to the pot rim to delay the freezing of soil at depth, and were subjected to one hour at 28° F air temperature followed by 16 to 24 hours at 20° F. The younger plants required the longer freezes to develop differential response. After each freeze, thawing was permitted before returning the plants outdoors. Such exposure killed leaf tissue, evidenced by a severe frost burn, and resulted in some plant mortality.

Survival—as well as the amount of regrowth made by living plants—was determined two weeks after a freeze. The soft chess and the annual ryegrass responded in like manner.

Following a freeze, reduced mortality and greater regrowth were evidenced by plants receiving nitrogen compared to the controls. Under the conditions of the tests, the added nitrogen did not result in increased frost injury. Survival of such plants was as much as 32% greater than in the controls and averaged 15% higher for all tests.

Vigorous regrowth of the plants receiving nitrogen was visible within a week following the freeze. Little regrowth occurred on the control plants. Quantitative measurement of this growth was made by clipping and drying the green tissue produced during the 14 days subsequent to freezing. Up to four times as

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DECLINING YIELDS

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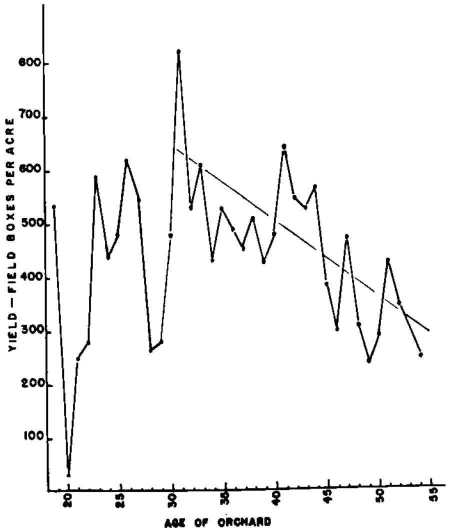
can continue to advance into virgin soil—young orchards remain in good health and increase in production. A leveling off of production characterizes the period of maturity. Roots now occupy the entire mass of the orchard soil. When root parasitic organisms begin to in-

A 35-year production record of a navel orchard planted in 1898. Note how yields increased to 31 years of age, then started into a period of gradually declining production. The extremely low yield when the orchard was 20 years old was due to the destruction of the crops by the June 1917 heat wave.

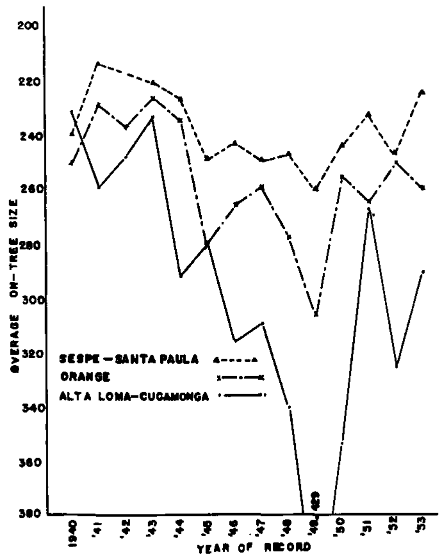


crease and toxins—both organic and inorganic—accumulate to damaging levels, root systems begin to deteriorate and the orchard enters a period of declining vigor. Crowding and shading out of lower limbs and sides may also contribute to the condition of decline. Senility may be another contributing factor inasmuch as—with old age—the renewal rate of bearing wood diminishes and the nonproductive wood—which the tree must support and which competes with fruiting wood for energy and nutrients—accumulates.

In order to determine if declining production was due either to decreasing size or diminishing numbers of fruit, both yield and size data were obtained from 42 Valencia orange districts and 23 navel districts, comprising all the citrus producing areas of southern California. The data—covering a 10-year period for navels and a 14-year period for Valencias—show that 37 out of 42 Valencia districts experienced a decrease in fruit size while only five maintained a continuing normal size trend.

In the Santa Clara Valley of Ventura County, fruit sizes showed the least reduction, dropping from a four-year average of 230 to a low—over another four-year period—of 250 fruit per box. Areas most seriously affected were the foothill

Comparison of fruit size trends in three southern California orange districts showing typical patterns of areas experiencing severe, moderate, and slight size reduction during the 14-year period 1940–1953.



districts of western San Bernardino County where fruit sizes dropped from an average of about 250 to a low—for one year—of 429 fruit per box. In Escondido and the Rancho Santa Fe districts—both in San Diego County—which in most years have grown the largest Valencias in southern California—sizes decreased from about 205 fruit per box to about 250.

Of the 23 navel districts studied, sizes showed a decreasing trend in 21 districts, remained nearly normal in one district, and increased in one district.

During the same period that Valencia sizes were decreasing, 24 districts had an increase in number of fruit per acre, while 16 showed a steady trend, and only two districts experienced a decline. However—throughout the 14-year period—only 18 districts showed declining production trends, as measured in field boxes per tree, while 18 other districts maintained the same production level, and six districts actually increased production.

Southern California navels fared worse than Valencias. Along with the decline in fruit sizes, numbers of fruit per acre diminished in nine districts, remained fairly constant in 11, and increased in only three. Yields, expressed as field boxes per acre, dwindled in 19 districts, remained steady in four, and increased in no district.

The problem of diminishing yield for Valencias, therefore, is primarily one of decreasing size. For navels, diminishing production has been due first of all to small sizes, but also—in certain areas—dwindling numbers of fruit per acre have accentuated the downward trend.

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much growth was obtained as in the controls. Many of the control plants were still living when survival counts were made but they were weak and produced little or no new tissue. Growth clearly revealed the difference in cold injury and indicated the increased forage production.

These freezing tests confirm observations made on the range. Whereas frost may kill back leaf tissue of fertilized plants, it results in nearly complete growth cessation in the unfertilized.

The photograph on page 5 illustrates the effect of nitrogen fertilizer on frost burn in six-weeks-old soft chess plants two days after being subjected to a single night when the temperature dropped to 30° F. The pot on the left had received four applications of supplemental nitrogen while the control on the right received none. The twisted, curled leaf tips—from the tip to 1″ down the leaf—of the control are brown and dead. The plants with added nitrogen show no frost burn.

In the field, density of ground cover and height of growth are increased by nitrogen applications. This may provide an insulating effect against frost injury to the plant bases. However, in the small pots used in the freezing studies, such insulation is negligible.

Increased root development is likely a factor in the better tolerance of fertilized field plants to drought. However, such root development in the pots is restricted and would not seem capable of producing the improved growth and recovery from injury. The physiology of these responses will be investigated further.

It is probable that the improved frost tolerance observed in these experiments can be found only in areas of mild winters where night freezing alternates with day temperatures warm enough to promote growth. Such conditions in California apparently permit the stimulation of winter forage production by fertilization without increasing the hazard of frost damage.

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The above progress report is based on Research Project No. 1194A.