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LETTUCE RESEARCH IN ARIZONA

Summary for 1960

Agricultural Experiment Station
The University of Arizona
Tucson, Arizona

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LETTUCE IMPROVEMENT PROGRAM

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The lettuce program of the U. S. Department of Agriculture is designed primarily to improve the horticultural qualities of the crop, and in addition we aim to counteract or control the serious diseases that menace crop production. Nearly all of our efforts are devoted to the production problems of Arizona and California, where about 85-90 per cent of the head lettuce crop is produced. Generally, we have used plant breeding procedures to achieve our goals, but we are not averse to using other approaches if it appears they will provide relief more quickly and more effectively than plant breeding methods.

HORTICULTURAL CHARACTERISTICS

The list of horticultural characteristics we are striving to improve is no doubt similar to those considered important by other lettuce breeders. Color is high on our list. A dark, rich green color of the exterior leaves is considered a "must" for present day varieties of head lettuce. If the green pigment is carried into the interior of the head, so much the better. The recently released variety, Vanguard, offers the possibility of bringing a richer, darker green color into some of our present day varieties. While not a satisfactory variety itself, because it is slow to mature, and lacks firmness under most conditions, nevertheless, it has some good characteristics such as color and edibility which should be useful for breeding purposes.

Moderately firm heads of uniform maturity, good butt shape and lack of prominent ribs are other horticultural characteristics regarded as important, and which we are attempting to improve through selection. Unfortunately these characters are apt to be unusually sensitive to slight differences in the environment, and consequently they are difficult to stabilize under the varied conditions where lettuce is grown in the West.

DISEASES

The two diseases with which we are most concerned at the present time are downy mildew and lettuce mosaic.

Downy Mildew

Except for lettuce mosaic and possibly tipburn, downy mildew is probably the most important disease of lettuce in the states of Arizona and California. Its importance is not generally recognized or realized by the industry because the damage it causes is not immediately visible.

With moderate to severe infection the disease will damage the outer leaves of the head to the extent that it is usually necessary to trim such heads drastically before they can be packed in the carton. Undamaged but infected leaves may serve as the site for the entry of secondary organisms during transit. These organisms cause rots, slime and decay. As a result the produce arrives at the terminal markets in unsalable condition. If not actually unsalable, the shelf-life of such produce is greatly curtailed.

In some areas downy mildew is chronic to the extent that it is present and does considerable damage every year. In most of the desert valleys of Arizona and California damage from the disease varies from year to year depending upon temperature and humidity, but mostly upon humidity, since the spores are splashed around by rain, and this serves as one of the principal means of dissemination of the fungus. The disease while sporadic occurs frequently enough and does enough damage to justify control measures in almost every lettuce producing district in Arizona and California. Certainly a cheap and easy method of controlling this disease would decrease one of the hazards to profitable crop production.

It is our good fortune to have at hand a dominant gene for resistance to downy mildew which confers immunity on the individual bearing this gene in both the heterozygous and homozygous state. The problem is to transfer the gene to a phenotype adapted to culture in the Southwest, and with the requisite horticultural characteristics. This appears to be a relatively simple task in backcrossing but it does take time and skill in selecting resistant individuals with the horticultural qualities necessary for successful varieties.

We have our greenhouses equipped for the control of humidity and we have enough control over temperature so that we can screen material for resistance during the entire year at La Jolla. With adequate facilities for testing resistance to downy mildew, an enormous amount of material can be screened and scored rather easily and quickly.

Lettuce Mosaic

The control of lettuce mosaic is the prime concern of those of us interested in lettuce production in the West. A heavy infection drastically reduces yields, and causes a corresponding decrease in quality of the produce. Plants infected when young are usually severely stunted and almost never develop into marketable heads. Those infected in later stages have a droopy or wilted appearance that contributes to a loss in quality of the product.

The virus causing this disease is introduced into the fields by the seed and is spread to adjacent plants by aphids, chiefly the green peach aphid, a most efficient vector of the disease.

The only successful method for controlling this important disease of lettuce was devised by Grogan and Welch of the University of California. Their method depends primarily upon two assumptions. First, that it is possible to obtain disease free or practically disease free seed for planting the commercial crop, and secondly that there are no important cultivated or weed host species of the virus in the areas where the head lettuce crop is to be grown. Theoretically, this scheme looks good, but in practice it has proven to be very troublesome for the seedsmen to reduce the amount of virus infected seed below 0.1 per cent needed to meet the requirements of mosaic tested seed and for the effective control of the disease in the field. An added hurdle has been the difficulty of locating virgin areas in which to produce the seed crop. This has forced seed producers into out-of-the-way areas in this country and Mexico, where production problems take on a nightmarish quality and are not easily solved by conventional methods.

By now it is abundantly clear that the "clean seed" program is not working as well as we could wish. Historically, it was never intended to be more than a stop-gap solution, devised to give plant breeders time to locate and make use of sources of resistance to the virus. Up to the present a great quantity of material has been screened for resistance to mosaic with no indication of success. Our screening program has been particularly unrewarding. Nevertheless, I believe it should be continued, and we are testing all the material we can get our hands on. In my opinion, however, the time is now ripe to consider fresh approaches to cope with the disease.

Accordingly we are commencing some new lines of work at our La Jolla and Salinas Field Stations. Dr. E. J. Ryder at our Salinas Station has started an extensive series of experiments attempting to create resistance in his material by inducing favorable mutations through the use of X-rays. He has perfected techniques that will permit him to score an enormous amount of radiated material for resistance over a relatively short period of time.

Another approach that should be investigated is heat treatment of the seed. Grogan and Welch report some evidence suggesting that seed produced in the Imperial Valley transmitted the virus to a lesser extent than seed produced in the Sacramento Valley. This differential in virus transmission was attributed to temperature at the time the seed matured. Dr. Pollock of our Seed Investigations Laboratory in Beltsville has agreed to set-up a pilot experiment that will give us more precise data concerning this suggestion.

There is some indication that older seed transmits less virus than freshly harvested seed. This idea should be vigorously explored, and if substantiated, every effort should be made to find means for aging seed rapidly. It should not be impossible to discover chemicals or certain combinations of chemicals and physical treatments that will do this job.

Another approach that is being explored by investigators at the University of California is based upon the common observation that wild lettuce, along with certain varieties and breeding lines of cultivated lettuce transmit the virus through the seed to a lesser extent than the expected 2-3%, characteristic for most varieties. Dr. Grogan and Dr. Welch have uncovered an English variety, Sutton's Giant, that transmits the virus in a low or perhaps negligible extent through the seed. These investigators assume that inability to transmit the virus is heritable and they have commenced a breeding program to transfer this character to Great Lakes types of head lettuce adaptable to production in the Western States. As one could anticipate, this job is proving to be a long, and arduous task, and up to the moment has not been successful.

Virologists informed me that there are chemicals which will greatly reduce the infectivity of certain viruses in the host tissue without damaging the host itself. This might be another approach meriting attention.

It is evident from the foregoing remarks about lettuce mosaic that much more must be known concerning the virus before we can develop a completely satisfactory method of controlling this important disease of the lettuce crop in the Western states.

ARIZONA LETTUCE BREEDING PROGRAM

R. E. Foster
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The primary goal in the Department of Horticulture lettuce breeding program is still the development of varieties or strains suitable for Arizona production and superior to existing types in horticultural characteristics and/or disease resistance. Three main approaches have been used to reach objectives. These are (1) variety testing of existing material, (2) selection within established strains or breeding material, and (3) hybridization for combining desirable characteristics. Progress has been noted in all three phases; examples are mentioned below.

Variety Testing: Long-range plans call for thorough testing of commercial strains at three to five year intervals. Extensive tests were completed in 1959 and described fully in University of Arizona Report No. 189 (1960). In this work newly released varieties were tested and recommendations given regarding the best Arizona location and season for their use. Interesting data were obtained on older strains revealing such things as relative susceptibility to common disorders, shipping ability, and unrecognized seasonal adaptability.

Selection: It is very unusual to find a completely uniform lettuce stock. Because variation exists in virtually all strains regardless of pedigree, it is possible to utilize this fact in making repeated selections for any given characteristic. This technique is most useful to intensify characters controlled by complex genetic factors in stocks where differences between individuals are not great.

Such a program, involving a number of years' field selections, was used in developing Arizona Sunbright, a late spring Great Lakes type lettuce resistant to tip burn. This strain showed the least amount of tip burn of all the high producing stocks in the extensive variety trials. In a subsequent test of fourteen strains in Cochise County, Arizona Sunbright was the only one free of the disease. Stock seed of this strain has been released to seven seed companies. "Low mosaic" lots of seed could be available commercially in 1962, possibly sooner.

Repeated selection is being used to produce new lettuce strains carrying characteristics adapted to Arizona conditions. It is too early to publicize these selections but gratifying results have been recorded in the programs.

Hybridization: In cases where desirable characters are controlled by simple genetic factors and where differences between individuals can be recognized easily, hybridization can be used effectively in the breeding program.

An example of this is the work in progress to develop downy mildew-resistant strains of all the important Arizona lettuce varieties. Two resistant varieties or strains have been released in other states. Since Arizona growers use thirty or more lettuce strains and varieties for many reasons including geographical and seasonal adaptability, it is apparent that additional downy mildew-resistant types are needed.

Using resistant parental stock furnished by the U. S. Department of Agriculture (Whittaker and Bohn, La Jolla) an extensive hybridization program is in progress to transfer the disease resistance to many lettuce strains popular in Arizona. A new plastic greenhouse has been built on the Mesa Experiment Station expressly for this work.

POSTHARVEST LETTUCE RESEARCH

Paul M. Bessey
Department of Horticulture

Studies on Aging in Harvested Lettuce

More than a dozen tests were made during 1960 at the Vegetable Research Laboratory in Mesa to better establish the typical pattern of senescence of harvested lettuce and to determine factors which may extend its storage and market life.

The typical pattern of aging begins with a partial loss of chlorophyll in the outer leaves. This results in a progressive yellowing usually extending inward from leaf margins to midribs and from outer to inner leaves. Tissues change from yellow-green to straw color then to brown and black as disease organisms invade and destroy tissue organization thus completing the senescence pattern. Conditions which speed this process include injuries received in packing, preharvest frost damage, high transit and storage temperatures (e.g., above 40° F.), and probably a low reserve food supply in the individual leaves and stem.

The commercial practice in packing is to retain as many wrapper leaves as possible but not exceeding the current legal maximum in Arizona of six. This is used to help maintain consistent and competitive carton weights, despite varying size and solidity of heads between fields and seasons.

Another value of wrapper leaves which is a little more realistic in the quality sense, is that they take the brunt of senescence breakdown during transit. Since deterioration generally progresses inward from the outermost leaves, the more wrapper leaves remaining, the greater the flexibility in transit and holding conditions and in holding time.

One important limiting factor is that aging symptoms and diseases also spread from injuries. In packing commercially desirable lettuce, most, if not all, of the wrapper leaves are crushed or at least bruised, and the more wrapper leaves there are, the more serious are the injuries, thus defeating the objective of head protection.

Several of the experiments on improvement of lettuce quality during the year included sprays with N^6 benzyladenine* which were found to slow the senescence or aging process rather remarkably. Results were most dramatic at high storage temperatures (e.g., 55 to 60° F.) wherein untreated lettuce was unmarketable within three days due to loss of chlorophyll, yellowing, and disease induced breakdown. Treated heads remained in salable condition for more than seven days. This of course is not a practical storage or transit temperature. However at 35 to 38° F. which closely approximates commercial conditions of transit, the N^6 benzyladenine treatment extended potential market life by as much as 10 days.

One large apparent advantage is that fewer wrapper leaves, if treated with N^6 benzyladenine, would likely be as effective in head protection as the large number used at present. This would help lower carton weights without reducing the net quantity of retailable lettuce.

Heads trimmed to the retail condition (all wrappers plus the cap leaf removed) then sprayed with N^6 benzyladenine also held up longer than checks sprayed with water. The color difference was not so easily distinguished since inner head leaves

*Product code SD 4901 from Shell Development Company, Modesto, California.

are always much lighter and yellower than the wrapper leaves, but treated heads again stayed free from slime and other breakdown for a much longer period, as much as a month in some cases.

Further tests are under way with lettuce to reduce market waste and maintain the garden-fresh eating quality.

Pink Rib and Russet Spotting Relations

Pink rib and russet spotting continue to be among the more serious quality defects of Arizona lettuce.

Winter-grown lettuce, in contrast to late spring and early fall lettuce, has a greater susceptibility to development of pink rib while in transit. In several winter tests some pink rib has been found as lettuce was packed. However, even though not often found in the field, pink rib usually appears within two or three days of cold storage. The less coarse inner wrapper leaves show it first, then the cap leaf and progressively inward through the head leaves to the core.

The speed of pink rib development is highly conditioned by temperature. Postharvest temperatures of 32 to 33° F. result in a slower rate than higher temperatures up to about 48 to 50° F. At this point spoilage and aging reactions proceed so rapidly that pink rib evaluations are meaningless.

Late spring and early fall lettuce could be made to develop pink rib if sufficient time in cold storage was allowed but this was far in excess of the usual transit and market periods.

Russet spotting, the defect often described by housewives as rust has been regularly induced experimentally by treatment with ethylene gas. As with most ethylene reactions, the speed of symptom development goes up with increases in holding temperature.

Symptoms of russet spotting were also fairly common in several of the lettuce storage tests in 1960 even without deliberate exposure to ethylene gas. It was noted that subsequent cuttings in the same field resulted in more russet spotting. This may be related to repeated handling as the cutters tend to feel each head to assess its maturity.

Senescence control treatments with N^6 benzyladenine did not affect the incidence of russet spotting which suggests that the russet spotting defect is independent from senescence in lettuce.

ENZYME ACTIVITY AND POLYPHENOL CONTENT OF LETTUCE IN RELATION TO PINK RIB AND RIB DISCOLORATION

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The presence of both polyphenol oxidase and peroxidase has been demonstrated in lettuce leaves. Laboratory tests have also shown the presence of unidentified polyphenols or tannin products which serve as substrates for these enzymes. In the presence of polyphenol oxidase, certain polyphenols, such as pyrogallol and catechol are oxidized by atmospheric oxygen to produce red or brown water soluble pigments called quinones. Through the action of peroxidase or by direct polymerization quinones can be converted to insoluble and inert red or brown colored substances called melanins, which may be absorbed into the nuclei or walls of cells. It is theorized that such reactions take place in lettuce leaves and lead to the conditions known as pink rib and rib discoloration.

The purpose of current studies has been twofold: (1) to establish the presence of such enzymes and measure their activity; (2) isolate and identify the polyphenolic constituents upon which they act. The latter is necessary so that quantitative measurements of their concentration and distribution within the leaves may be studied.

Polyphenol Oxidase and Peroxidase Activity in Lettuce Leaves of Different Ages

In 1960, a study was made of the relationship of polyphenol oxidase and peroxidase activity in lettuce leaves to their age. This is necessary to provide information for intelligent sampling of leaves in future studies. Several heads each of Imperial 101 from Yuma and Great Lakes 660 from Mesa were used. Starting with the outermost, leaves were removed from the head and counted, making allowance for those which were previously dead or senescent. Every third leaf was retained for enzyme analysis so that an acropetal series of 10 or 11 leaves was obtained. Leaves smaller than the 35th leaf were usually too small to provide sufficient tissue for analysis. The method of measuring enzyme activity depends upon the rate of oxidation of an indophenol dye from a colorless (reduced) state to the colored (oxidized) state. The color change is measured in a colorimeter and results are expressed as micrograms of dye oxidized per minute per gram of fresh tissue.

In Figure 1 the results are plotted to show the variation in enzyme activity from the outermost leaves through increasingly younger leaves toward the meristem or growing tip. The lowest activities were found in the 18th to 23rd leaves. Wrapper leaves and those just under the cap leaf tended to be slightly higher. Beginning at approximately the 23rd leaf enzyme activity increased very rapidly with decreasing age. Extrapolation of the data suggests that enzyme activity near the growing point is in the order of 100 times as great as in outer leaves.

Peroxidase activity in leaves follows a pattern similar to polyphenol oxidase, but at levels one-half to one-fifth as great.

Seasonal Changes in Polyphenol Oxidase and Peroxidase Activity in Different Varieties

Although this portion of the study is incomplete, the data in Table 1 serve to illustrate some differences between varieties and perhaps a seasonal variation. Three types of lettuce and endive, planted and harvested at three different dates are being studied. Great Lakes 659 (head type) showed a decrease in polyphenol oxidase activity and a marked increase in peroxidase activity during the 37 day period preceding harvest (about January 10). Enzyme activity in leaf types of lettuce does not seem to be

Table 1
Polyphenol Oxidase and Peroxidase Activity
in Lettuce Leaves, 1960-61

Date	Variety	Micrograms Dye Oxidized/ Min./gm. Fresh Tissue		Remarks
		Polyphenol Oxidase	Peroxidase	
11/15	G. L. 659	7.15	0.95	Immature
12/15	G. L. 659	6.45	1.46	Beginning to head
1/6	G. L. 659	3.21	3.86	Harvest
12/15	Grand Rapids	7.15	1.36	Near mature
	B. S. Simpson	4.42	0.75	Near mature
	Endive	13.0	4.18	Mature

much different than in head types. Conclusion of the study should clarify some of these facts and show whether climatic factors influence enzyme activity.

Occurrence and Identification of Polyphenols in Lettuce Leaves

The problem of isolating and identifying any unknown organic substance, particularly as a constituent of plant tissue, can be complex and difficult. Preliminary tests using the techniques of paper chromatography indicate at least one, possibly two, unidentified polyphenols are present which may be involved in tissue discoloration reactions. It appears that a large proportion of the polyphenolic compounds is present in the latex, the white viscous emulsion which exudes from broken or cut midrib or stem sections. The ducts in which the latex is contained are always found in close association with vascular or conducting tubes of leaf and stem tissues, a large number of which are concentrated in the midrib. Previous studies indicate that mechanical bruising can initiate pink rib symptoms and that elevated storage temperatures speed its formation. This suggests why pink rib is confined to the midrib and veins. Bruising of the tissues in the area of the midrib possibly releases the contents of the latex ducts into air spaces surrounding adjacent cells where oxidation of the polyphenols can occur in the presence of enzymes released simultaneously from ruptured cells. Like all chemical reactions, these enzymic reactions are accelerated by increasing the temperature. Diffusion of the solution of colored pigments through intercellular spaces explains the diffuse appearance of the pink rib coloration.

The brown pigments characteristic of rib discoloration are thought to be the result of similar reactions, but the lesions are usually more discrete and appear closer to the epidermal layers of cells. No causal agent has yet been discovered for this condition.

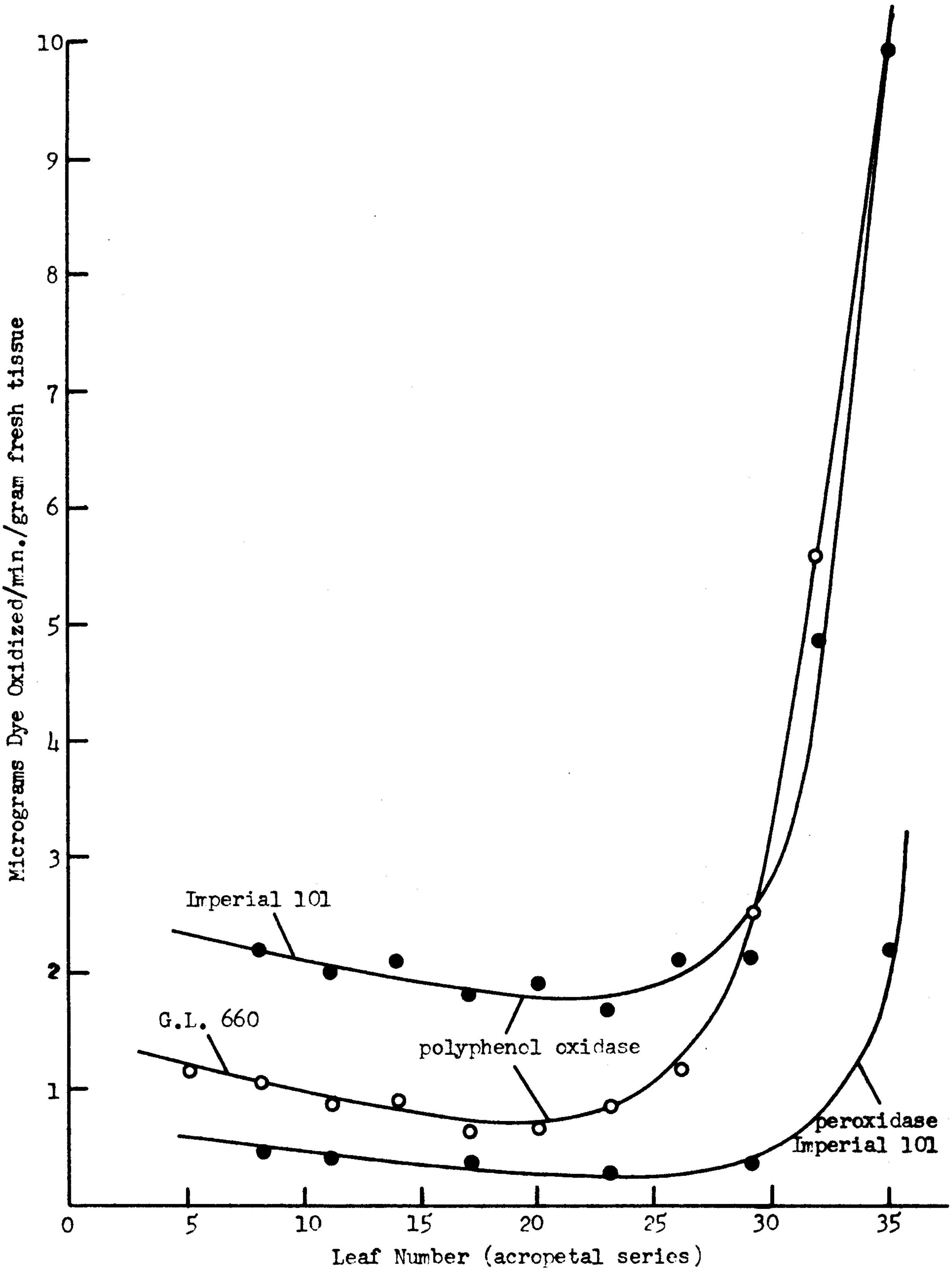

FIGURE 1. Polyphenol oxidase and peroxidase activity in lettuce leaves of different ages.

THE UPTAKE OF NUTRIENTS BY LETTUCE

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Department of Agricultural Chemistry and Soils

In the past few years the Sulphur Springs Valley in southeastern Arizona has become an important lettuce-producing area. Many problems beset the growers concerning the nutrient-supplying powers of the soils for this crop and for its fertilizer requirements. Fundamental studies of these problems are needed.

A controlled, greenhouse experiment was conducted to help determine the effects of differential fertilization, particularly at high rates, with nitrogen and potassium on the uptake by head lettuce plants of nitrogen, phosphorus and potassium. Two soils typical of the area were selected for this study. One was the Elfrida clay loam from newly-cleared land in the Kansas Settlement area. The other was a McAllister sandy clay loam from the Stewart area which had been in cotton for most of its 20-year cultivated history. Some analyses of these soils are shown in Table 2.

Table 2. Some Chemical Analysis of the upper one-foot of two Sulphur Springs Valley soils.

Analysis for	Elfrida c.l.	McAllister s.c.l.
pH	7.1	7.8
Total Soluble Salts (ppm)	854	560
Total Nitrogen (%)	.108	.078
CO_2 - extractable phosphorus (ppm)	7.5	8.5
Available Potassium (%)	.095	.090

The lettuce was grown until the frame leaves were developed and heads started to form in some of the treatments. The analyses of the harvested tops are reported in the elemental form in Table 3 as percentages of the dry matter.

Soil applications to the Elfrida soil of phosphorus alone slightly lowered the uptake of N and K but increased the uptake of P. Additional soil potassium lowered the N and K uptake. The first two increments of nitrogen increased uptake of N, P and K - At the highest rate of nitrogen there was little further increase in N uptake, and there was a decrease in both plant P and K. With additional soil potassium, the tissue N, P and K contents varied slightly at the N_1 and N_3 levels, but all were lowered at the N_2 level.

Soil applications to the McAllister soil of phosphorus alone slightly decreased N and K uptake. Additional potassium plus soil P increased plant P and raised K and N levels in the plants back to levels in the check. The nitrogen applications N_1 and N_2 increased N, P and K uptake, whereas N_3 decreased their uptake, particularly that of N. Soil potassium with N_1 had inconclusive effects on uptake of N, P and K, but with N_2 it reduced uptake of these nutrients. Potassium added with the N_3 treatment had little effect on P and K uptake but greatly increased the uptake of N.

These investigations are continuing.

Table 3. Analyses of lettuce tops from a greenhouse investigation of two soils from lettuce-producing areas in the Sulphur Springs Valley.

Soil Treatment[a]	Elfrida c.l.			McAllister s.c.l.		
	N	P	K	N	P	K
	%	%	%	%	%	%
1. Check	1.68	0.27	6.56	1.18	0.23	5.12
2. N_0K_0	1.53	0.32	6.38	0.94	0.23	4.23
3. N_0K_1	1.37	0.33	5.43	1.13	0.28	5.37
4. N_0K_2	1.33	0.32	5.52	1.06	0.27	4.96
5. N_1K_0	2.54	0.38	6.81	2.72	0.30	7.79
6. N_1K_1	2.50	0.38	7.48	2.53	0.25	7.46
7. N_1K_2	2.72	0.39	7.43	2.44	0.34	7.85
8. N_2K_0	3.48	0.41	8.67	3.27	0.32	9.17
9. N_2K_1	3.09	0.34	7.26	3.12	0.27	8.67
10. N_2K_2	3.22	0.38	8.06	1.91	0.25	8.25
11. N_3K_3	3.42	0.36	8.26	2.02	0.26	8.29
12. N_3K_1	3.49	0.34	8.14	3.27	0.25	8.33
13. N_3K_2	3.69	0.40	8.65	3.34	0.26	8.70

[a] 400 lbs./A. P_2O_5 added to all soil treatments except the check.

N_0 =	0 lbs./A. N	K_0 =	0 lbs./A. K_2O
N_1 =	200 lbs./A. N	K_1 =	100 lbs./A. K_2O
N_2 =	400 lbs./A. N	K_2 =	200 lbs./A. K_2O
N_3 =	800 lbs./A. N		

N, P and K were applied as NH_4NO_3, T.S.P., and K_2SO_4, respectively

LETTUCE WEED CONTROL IN THE SALT RIVER VALLEY

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Considerable experimentation has been done to combine types of herbicides to improve weed-killing activity and to provide control for a wider group of weeds. Many times such combinations have been wholly unsatisfactory, yet in other cases they have given outstanding results. In the test reported herein, the combination of certain herbicides was more effective against both broad and grassy weeds than either of the materials applied separately. All chemicals were applied after seeding the crop and before the germination irrigation.

Several interesting and important comparisons can be made with the data in Table 4. Most noticeable is the fact that yields from all the treatments, except 7 and 8, were excellent.

Table 4. Effects of Certain Herbicides on Earliness and Yields of Fall Crop Head Lettuce.

TREATMENT	Yield by Cuttings in Cartons/Acre 1st	2nd	3rd	Total
1. Check	100	272	262	634
2. CDEC 5#/Acre	140	225	276	641
3. CDEC 5#/Acre + Sprinkle	126	279	232	587
4. CIPC 5#/Acre	121	241	254	616
5. CDEC 2#/Acre + CIPC 2#/Acre	182	269	250	701
6. CDEC 2#/Acre + CIPC 1#/Acre	151	258	271	680
7. CDEC 2#/Acre + F734 2#/Acre	41	200	232	473
8. Zytron 15#/Acre	10	87	16	113

From the data presented in Table 4, it is obvious that the outstanding treatment was number 5 which involved a combination of CDEC (Vegadex) and CIPC. The yield was 701 cartons per acre. This treatment was followed closely in yield by treatment 6 in which the same materials were used, but the CIPC was reduced from 2 to 1 pound per acre. Not only did these treatments effectively control broadleaf weeds, but also many of the grasses. This control of weeds early in the crop growth period, along with a reduced dosage of each material, undoubtedly were important factors in the excellent yields obtained. No apparent adverse effects on the lettuce crop were noted. Much of the value of combining CDEC and CIPC is its total weed control effectiveness and a minimum adverse effect on the crop plants. Both of these treatments appear very promising for commercial lettuce production.

Treatments 2 and 4 where CDEC and CIPC were used separately were less effective than for the combination-type treatments but were very similar to the hand-weeded, untreated plots. The check plots were hand weeded shortly after the crop was thinned so some competition did exist early in these plots.

From a comparison and evaluation of treatments 2, 3 and 4 with the check areas, it appears that any adverse effects caused by the herbicide were offset by one or more advantages of each material. CDEC applied alone gave some broadleaf weed control but was relatively ineffective against grasses and the competition from these weeds plus some slight depressing effect on the crop early in the season accounted for the slight reduction in yield.

Sprinkling to simulate rainfall after CDEC was applied produced slightly better weed control than where sprinkling was not used. This advantage was offset by early but temporary retardation of the crop plants resulting in lower yields.

CIPC provided excellent control of grassy weeds and some broadleaf weeds but caused some crop-plant retardation and noticeable burning of the leaf margin. Yields were reduced where CIPC was used alone.

Treatment number 7, using F-734 in combination with CDEC, caused a marked retardation of the lettuce plants and a reduction in yield. Zytron (treatment 8) drastically reduced the crop-plant population and the few plants that emerged were severely retarded and stunted. Both treatments 7 and 8 gave excellent weed control throughout the season.

From earlier experience, it is felt that the amount of material used in treatment 8 was the chief cause for the plant-crop damage. To properly evaluate this material it will be used at lower rates per acre in subsequent testing.

CHEMICAL CONTROL OF DOWNY MILDEW OF LETTUCE

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All fungicides were applied with hand operated equipment; the sprays with a Hudson knapsack sprayer and the dusts with a Hudson roto-power duster. There were 6 replicates of each treatment, each of which consisted of 40 feet of a standard lettuce bed. Downy mildew incidence was moderate but general when treatments were started on December 28, 1959. Data, which were recorded on February 10, 1960, were taken as the total number of leaves affected per plant. See table for results of treatments.

Table 5. List of fungicides tested and their relative effectiveness. All applications were made bi-weekly, unless otherwise indicated. Variety: Great Lakes 749

		Rate	Mean Number of Leaves Affected Per Plot	1%
*	Zinc Coposil-Captan	2# ea. per acre	41.17	A
*	Copper Sulfate	4# per acre	42.17	A
*	Zinc Sulfate	4# per acre	43.17	A
*	Phaltan	2# per acre	43.83	A
*	Phaltan Zinc Coposil	6# per acre	44.50	A
	Zineb 6 percent dust	30-40# per acre	44.67	A
*	Zinc Coposil	4# per acre	45.00	A
	Phaltan	4# per acre	45.67	A
	Karathane .75 percent dust	30-40# per acre	47.33	AB
	Phaltan	2# per acre	47.33	AB
**	Phaltan	2# per acre	47.33	AB
	Captan	2# per acre	49.50	ABC
	Phaltan	1# per acre	51.00	ABC
	Phaltan 5 percent dust	30-40# per acre	55.83	BC
	Control		59.00	C

Duncan's multiple range test: Any two means not followed by the same letter are significantly different.

* With spreader sticker added.
** Weekly application.

LETTUCE VIRUS STUDIES

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Strains of cucumber mosaics as well as viruses of the ringspot groups were consistently isolated from lettuce from commercial plantings in the Salt River and Sulphur Springs Valleys. In many instances, infected plants showed few or no external symptoms, although in some areas, plants showing well-defined mottling were found. Mottling is usually associated with infections by cucumber mosaic virus 1 (*Marmor cucumeris*) or strains of western cucumber mosaic. In many plants from which successful isolations of cucumber mosaic and ringspot viruses were made, common lettuce mosaic (*Marmor lactucae*) was not detected. Perhaps the latter virus was present, but in such small amounts as to render detection difficult or impossible.

The complexes formed by the simultaneous presence of cucumber mosaics and ringspot viruses in individual plants have consistently given symptoms simulating those from complexes in cantaloups and other cucurbits affected by so-called "crown-blight", when extracts have been inoculated into indicator plants under controlled conditions in the greenhouse. The same phenomena have been associated with extracts from watermelons infected with "rind-rot" as well as "yellow-streak". In addition, the same virus complexes (cucumber and other mosaics and ringspot types) have been isolated from watermelons and honeydew melons showing symptoms known as "pimples".

It is known that in certain crops other than lettuce, cucumber mosaic viruses may be seed-borne to a certain extent. Common lettuce mosaic virus may also be seed-borne. The lettuce grower is thus faced with the possibility of two seed-borne viruses, rather than just one. Additional studies will be essential in order to check the possible significance of isolation of cucumber mosaic viruses from lettuce.

A virus causing yellow ringspots in indicator plants (Fig. 2, C) as well as typical cucumber-mosaic-like mottling and blister-like leaf surface roughenings (Fig. 2, E at a) was isolated from extracts from lettuce showing marked symptoms of "rib-discoloration" (Fig. 2, A, a and b, B). Also, necrotic lesions of irregular shapes resulted in indicator plants as a result of inoculations with extracts from "rib-discolored" lettuce (Fig. 2, D: 2, B). An unusual ringspot-type virus was obtained from a Great Lakes lettuce plant showing intense green and yellow leaf mottling, from a commercial planting near Mesa (Fig. 2, F: 2, A). When examined in reflected light inoculated leaves of *Chenopodium amaranticolor* showed small chlorotic dot-like areas which did not appear to be typical of a ringspot virus. In transmitted light, the same symptoms appeared as very faint, chlorotic ringspots (Fig. 3, A).

The appearance of necrotic spots, streaks and veins in indicator plants inoculated with crude or partially purified sap extracts from field-infected lettuce showing symptoms of "rib-discoloration", and from cucurbits affected by so-called "crown-blight", "pimples", "rind-rot" and "yellow-streak" indicates the need for further studies as to possible common or related causes for these disorders.

Studies relating to the comparative histology of the necrotic areas in both leaves and fruits are being conducted in the hope that some clues may result as to the nature of the impairment of functions which multiple viruses may cause in a plant.

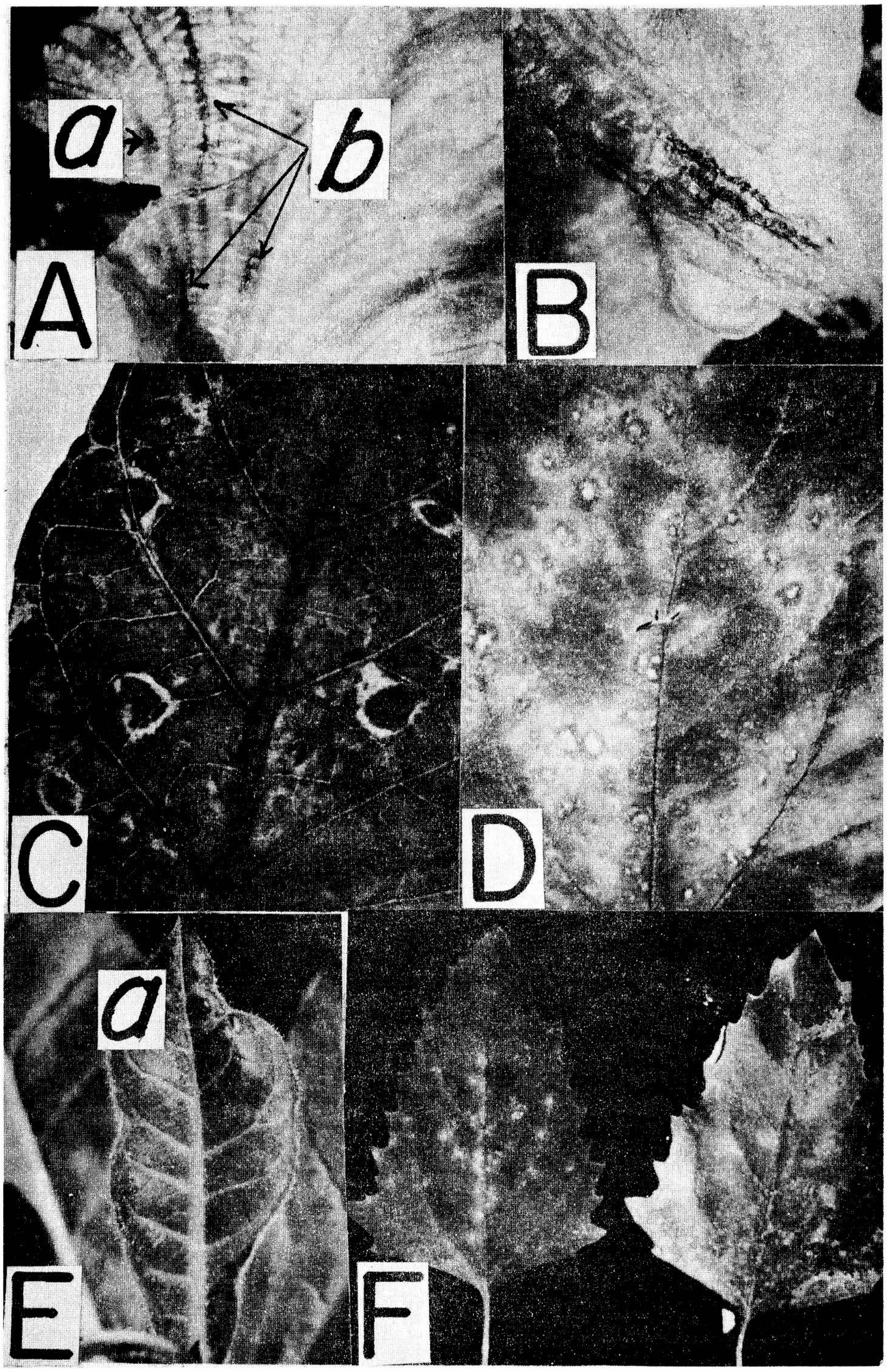

FIGURE 2.

FIGURE 2. Symptoms caused in field-infected and artificially-inoculated plants, by viruses associated with lettuce in Arizona.

A. Narrow band-like necrotic areas (b and arrows) in a leaf of field-infected lettuce, showing symptoms of "rib-discoloration." Note the discoloration indicating necrosis in single veins. At "a" there is a necrotic dot-like region (at tip of arrow), also part of the rib-discoloration picture.

B. A main rib of a field-infected lettuce plant showing symptoms of "rib-discoloration," a portion of which has become necrotic.

C. Yellow ringspot-like symptoms in a leaf of Nicotiana sylvestris resulting from inoculation with field-infected lettuce plants showing symptoms of "rib-discoloration."

D. Necrotic ringspots sometimes result from inoculation of extracts from lettuce plants in the field having discolored mid-veins. These lesions are on a leaf of Chenopodium amaranticolor, and result from necrotic strains of ringspot viruses or severe mottle strains of cucumber mosaics.

E. Typical cucumber mosaic virus symptoms in Nicotiana tabacum var. Havana 38, caused by inoculation of extracts from Great Lakes field-grown lettuce in which the outer head leaves had an intense yellow and green mottle.

F. What appear to be typical cucumber mosaic virus symptoms on leaves of Chenopodium amaranticolor, after inoculation with juice extracted from a field-grown lettuce plant having typical "rib-discoloration." Compare the leaf on the left with the one in Figure 3, A.

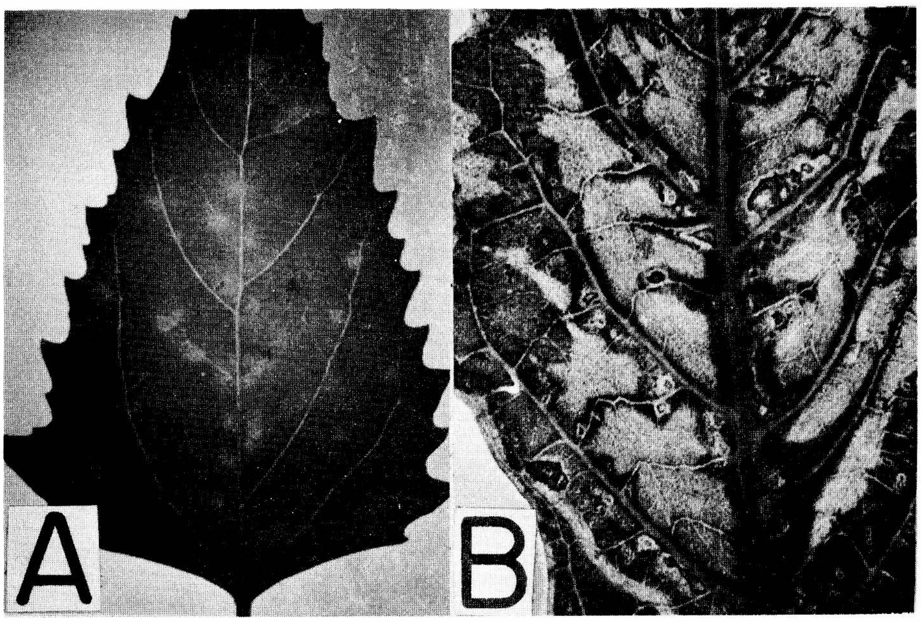

FIGURE 3. Symptoms appearing in indicator plants after mechanical inoculations with juices extracted from virus-infected field-grown lettuce plants showing symptoms of "rib-discoloration."

A. Mild chlorotic ringspots on a leaf of Chenopodium amaranticolor. Ringspots were made visible only after placement of leaf in transmitted light path. Compare the character of these symptoms with those from the same leaf illustrated in Figure 2, E, in which the "ringspots" here appear as ordinary chlorotic dots, without rings.

B. Green and yellow mottle with vein-banding and necrotic spotting, indications of a mixture of more than one virus in a leaf of Nicotiana sylvestris.

CABBAGE LOOPER CONTROL ON LETTUCE

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Investigations were conducted during 1960 on the fall planting of lettuce because the greatest number of cabbage loopers can be expected to appear during this period.

One experiment conducted in the Willcox area was on lettuce planted during July. Looper populations were high during the early part of the growing season requiring frequent treatments.

Sprays of the following materials were made at 50 gallons per acre, beginning shortly after thinning: Endrin E. C. (Emulsion Concentrate), Sevin Sprayable, American Cyanamid Compound 24053 W. P. (Wettable Powder), and Dibrom + Toxaphene E. C.

In Table 6 the results of these materials are given.

Table 6. Spray Applications for Looper Control on Lettuce.

Treatments 1/		Number per 40 Plant Sample on							
		August 25		August 31		September 8		September 15	
Material	Lbs. Actual/ Acre	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant
Endrin E. C. (1.6 lbs./gal.)	0.5	1	1.0	0	0	7	1.4	1	1.0
Sevin 85% Sprayable	2.0	3	1.3	2	1	30	2.0	10	1.3
Comp 24055 25% W. P.	2.0	1	1.0	5	1.2	24	2.0	4	1.0
Dibrom E. C.+ Toxaphene E. C.	1.0+ 3.0	4	1.3	3	1.0	22	1.7	4	1.0
Check	-	8	2.6	13	1.4	32	1.9	15	1.1

1/ All treatments applied 3 times, August 17, August 25 and September 8.

Of the four materials used only the endrin gave the most effective control during the period of heaviest looper population.

In two other trials Bacillus thuringiensis 3-D dust (having a count of 3 billion spores per gram) was compared with applications of phosphate dusts or sprays. Results of a trial conducted in the Willcox area are given in Table 7 below.

Table 7. Results of Looper Control with B. thuringiensis.

Treatments		Number per 40 Plant Sample on					
		September 11		Semtember 22		September 28	
Materials	Amt./ Acre	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant
Thuricide 3-D dust	35 lbs.	1.5	0.67	1	0	1	0
Parathion 2% + Perthane 10% dust	30 lbs.	0	0	0	0	0	0

The Parathion + Perthane dust effectively controlled the looper larvae occurring during September while the Thuricide dust did not completely control the looper larvae.

The other trial with B. thuringiensis was conducted in the Salt River Valley. The Thuricide 3-D dust was applied at 35 pounds per acre with a tractor-mounted ground duster and the Phosphate spray with a commercial ground sprayer at 35 gallons of spray mixture.

Results of this test are given in Table 8.

Table 8. Results of Looper Control with Bacillus dust and Phosphate mixture Spray.

Treatments 1/		Number Per 40 Plant Sample on							
		September 17		September 21		September 26		October 3	
Materials	Amt./ Acre	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant	Inf. Plants	Larv/ Inf. Plant
Thuricide 3-D	35 lbs.	6	1.3	18	1.8	5	1	1	1
Phosphate-Hydrocarbon Spray Mixture 2/	30 gals.	5	1	4	1.0	0	0	0	0

1/ Four treatments had been made at time of last count.
2/ Contained Methyl Parathion 0.4 lb. + Phosdrin 0.4 lb. + Toxaphene 2 lbs. + DDT 1 lb. per acre, applied at the rate of 35 gallons spray mixture per acre.

The population of small looper larvae was heavy early in the season in this field with continuous egg deposition taking place. The September 17 counts indicated little difference in looper control between the two plots. But succeeding weeks show almost complete control with the spray while the thuricide dust allowed a certain buildup with a few loopers still persisting at the October 3 count.

Results thus far indicate that B. thuringiensis dust will not control a heavy looper population early in the growing season of a crop of lettuce. But later as the lettuce begins to mature it appears to be more effective. B. thuringiensis can be used close to harvest when the more toxic insecticides can not be used because of the residue hazard.

LETTUCE INSECT CONTROL STUDIES

By Ross W. Brubaker, Entomology Research Division,
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In a farmer-cooperative experiment on spring lettuce to control the cabbage aphid (Brevicoryne brassicae (L.)) and the cabbage looper (Trichoplusia ni (Hbn.)), insecticide sprays and dusts were applied by means of an experimental sprayer-duster mounted on a tractor and equipped with a trailing-boom. Four replicates were made on plots 8 rows wide by 137 feet long. Population counts 7 days after application, given in table 1, show that Thiodan spray gave outstanding results against both the aphid and the looper. Results with Dibrom spray were also good against loopers and fair against aphids, but the results with Dibrom dust were poor. There was very little difference in effectiveness of the parathion dust and spray against aphids, but against the looper the dust was superior.

In an experiment on fall lettuce at the Mesa Experiment Farm against the cabbage looper there were four replicates in plots 6 rows wide and 25 feet long. Insecticides were applied with hand equipment on October 27, soon after the plants had been thinned. The numbers of loopers surviving per 40 plants (Table 10) remained rather static in the check plots for 4 weeks after application. Thiodan and Dibrom gave excellent results, equal to those from the recommended toxaphene-DDT mixture. Bacillus thuringiensis (Berliner) from two sources was tested. Lot A, prepared by Nutrilite Products, Inc., had 5 billion spores per gram and was more effective than Lot B, prepared by Bioferm Corporation, which had only 3 billion spores per gram. A 7 1/2-percent Sevin dust was almost as effective as the best treatments immediately after application but became ineffective after 3 weeks. A commercial allethrin dust containing diatomaceous earth fortified with 0.16-percent allethrin and 0.06-percent pyrethrins was not effective at the dosage used. An antifeeding compound, American Cyanamid 24055, was about on a par with Sevin for 2 weeks after treatment, then became ineffective.

In a second fall experiment, also replicated 4 times, each plot contained 10 plants in a 10-foot section of lettuce bed enclosed by an aluminum-foil barrier. The natural population of cabbage loopers was removed from the plants. Each plant was then reinfested with two medium-sized larvae just prior to the application of the test insecticides with a rotary-type hand duster or a knapsack sprayer. As shown in Table 11, the allethrin dust showed outstanding effectiveness in contrast to the poor results in the earlier experiment. The increased effectiveness may have been because of the higher dosage. The antifeeding compound was much more effective in a dust than in a wettable-powder spray. Bacillus Lot A gave a quicker kill than Lot B, but by 12 days after treatment they were about equal. The combination of 4-percent malathion and the Lot B material increased the effectiveness but was still no better than Lot A without malathion. Not all the larvae placed in the plots were found, even in the untreated checks. Some mortality resulted from handling, polyhedrosis, and parasitism by Tachinid flies even though larvae showing evidence of parasitism were discarded when collected for this test.

The chemical formulations for the proprietary products included in this paper for which there are no common names are listed as follows:

American Cyanamid 24055 (4'-dimethyltriazenoacetanilide)
Dibrom (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate)
Phosdrin (1-methoxycarbonyl-1-propen-2yl dimethyl phosphate)
Sevin (1-naphthyl methylcarbamate)
Thiodan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide)

Table 9. Number of aphids and cabbage loopers surviving on 40 lettuce plants 7 days after insecticide application. April 20, 1960.

Insecticide	Pounds of Active Ingredient per Acre	Number of Aphids	Number of Loopers
Thiodan spray	1.0	0	4
Parathion dust (2%)	0.6	13	9
Phosdrin spray	.5	14	14
Parathion spray	.5	17	24
Phosphamidon spray	1.0	36	23
Dibrom spray	1.0	61	5
Dibrom dust (4%)	1.2	222	18
Untreated check	-	372	45
LSD 5%		61	14

Table 10. Number of cabbage loopers per 40 lettuce plants on various days after insecticide application. Mesa, Arizona. October and November 1960.

Materials	Pounds of Active Ingredient or Number of Spores per Acre	Number of Loopers after			
		5 Days	13 Days	20 Days	27 Days
SPRAYS					
Thiodan	1.0	0	1	1	1
Toxaphene + DDT	3.3 + 1.1	1	0	2	10
Amer. Cyan. 24055	1.9	7	6	18	16
Dibrom	1.2	2	3	7	7
DUSTS					
7 1/2% Sevin	2.0	4	5	13	20
<u>Bacillus thuringiensis</u> Lot A	51,711 billion	17	14	10	15
<u>Baccillus thuringiensis</u> Lot B	40,824 billion	6	7	11	6
Allethrin 0.16% + pyrethrin 0.06%	4.3 + 1.6	11	13	21	14
Untreated check	--	18	20	21	25
LSD at 5% level		7	8	13	a/

a/ Not significant by the F test.

Table 11. Number of cabbage loopers surviving where two were placed on each plant prior to application of insecticides. Mesa, Arizona. November 1960.

Insecticide	Pounds of Active Ingredient or Number of Spores per Acre	Larvae Surviving on 40 Plants after 5 Days	12 Days
Amer. Cyan. 24055 (Spray)	1.5	71	55
Amer. Cyan. 24055 (5% dust)	1.5	46	3
Bacillus thuringiensis Lot A	40,824 billion	30	11
Bacillus thuringiensis Lot B	40,824 billion	48	12
Bacillus thuringiensis Lot B + 4% malathion	40,824 billion + 1.2	24	7
Allethrins .16% + pyrethrins .06% dust	0.064 + 0.024	0	0
Untreated check	---	66	65
LSD at 5% level		15	7.8

NATURE AND CONTROL OF BIG VEIN AND CONTROL OF DOWNY MILDEW IN LETTUCE

by R. B. Marlatt and R. T. McKittrick
Department of Plant Pathology

BIG VEIN

Four fungicides were applied to infested soil in an attempt to control big vein in Great Lakes 66 lettuce: calcium cyanamide, 1,000 pounds, chloropicrin 35 and 70 gallons, dichloropropenes-dichloropropanes (D-D) 20 and 40 gallons, and PCNB (75 percent) 200 pounds per acre. Part of each chloropicrin and D-D plot was tarped with plastic immediately after injection. Treatments were randomized and replicated 4 times. Tarped chloropicrin (70 gallons) and PCNB (200 lbs.) provided significant control of big vein; however, PCNB stunted the lettuce and the high rate of chloropicrin is too expensive for commercial lettuce production.

Testing irrigation water for the fungus that probably causes big vein failed to reveal its presence. Water was collected from the University Farm pipeline and from plot ditches and used for irrigating plants in the greenhouse.

Plant size was estimated by measuring plant diameters, top weights and counting leaves on 80 diseased and 80 normal plants shortly before harvest. Comparisons showed that all 3 size measurements were decreased significantly by big-vein infection.

Maturity of lettuce, as estimated by head size and firmness, was observed in 868 plants, half of them normal and half showing severe big-vein symptoms. By the time the majority of big-vein and normal heads had matured, 94% of normal and only 68% of big-vein affected plants had formed mature heads. This difference was statistically significant (5% level).

Seed yields were obtained from 430 plants, half of which had severe big vein before heading and half appeared normal. Seed from each plant was harvested separately, cleaned and weighed to the nearest hundredth gram. Group comparison of seed weights revealed that there was no significant difference in yields from big-vein vs. normal plants.

DOWNY MILDEW

Oversummering of the mildew fungus may occur in Arizona since the disease invariably appears in winter-grown lettuce if weather is favorable for it. Wild lettuce (prickly lettuce) and a Great Lakes variety were infected in the greenhouse and then transplanted to the field into cotton, sorghum, and fallow plots for the summer. Only 29 of 210 head lettuce plants survived the summer and 208 of 230 prickly lettuce plants survived. These survivors were transplanted to the greenhouse and subjected to conditions favorable for mildew sporulation. After 3 weeks they were examined for mildew; 1 head lettuce and 163 prickly plants were alive when examined. No mildew was found on living or dead plants.

The potential lettuce reservoirs of the disease lasted through the summer in fallow plots as well as in the shade of cotton or sorghum. It remains to be proved whether or not they are the annual source of mildew.

Inoculations with root-stem tissues were made in the greenhouse. Tap roots and attached stems were obtained from severely mildewed heads, leaves removed, surfaces disinfected and the macerated root and/or stem tissues poured over 10 young healthy plants. None of the inoculated plants became infected even though conditions were shown to be favorable for downy mildew by severe infections in spore-inoculated controls.

Effects of temperature on stem invasion by the downy-mildew fungus were studied by storing 48 root-stem pieces from severely mildewed plants at 38, 43, 48, and 60° F for at least one month. No mildew fungus was found after storage. The effect of rising storage temperatures on 24 similar root-stem pieces were noted by moving them at weekly intervals from the lower to the higher temperatures. Again no signs of the fungus were found by microscopic examination. Five mildew-inoculated plants were grown under infra-red lamps in the greenhouse until they approached head maturity and four controls were inoculated and grown at normal greenhouse temperatures. None of them showed stem invasion by the mildew fungus.

Soil transmission of mildew was attempted by partially burying root-stem pieces from severely mildewed heads in sterile soil which was then planted to lettuce. Plants in 24 of such pots failed to develop mildew.

A search for oospores was made to determine if this dormant stage of the mildew fungus occurs in Arizona. Fifty severely infected heads and attached roots were stored at 34, 43, 48, 60 and 80° F. Mildew lesions were removed from the heads at weekly intervals, cleared, stained and examined for oospores. No oospores were found over a 2-month period. In a similar test, 30 large infected leaves were obtained from a severely diseased field, stored at the 5 temperatures and examined for oospores without finding any.

Inoculation with dried leaves which were severely mildewed was tried in the greenhouse. Young plants were sprinkled with a coarse powder consisting of mildewed leaf lesions which were air-dried at room temperature for over a month. None of the 24 potted plants thus inoculated developed mildew.

LETTUCE MECHANIZATION

by Kenneth K. Barnes
Agricultural Engineering Department

Developments in the agricultural labor picture in California during 1960 and 61 indicate that Arizona lettuce growers will soon face increased costs for field labor. Increased unit costs for labor will make substitution of capital for labor profitable if labor replacing techniques and devices are available.

The two peak hand-labor jobs in lettuce production are stand establishment and harvest. Little or no progress has been made in mechanization of lettuce harvest. Stand establishment is well mechanized from the standpoint of seedbed preparation and planting, but present planting practice leaves high-labor hand thinning for establishment of final stand.

Stand establishment development must be directed toward systems which will either plant to a final stand or plant to a stand which can be mechanically thinned to a final stand. Pest control, seed treatment, control of seedbed physical conditions, pelleted seed, and strip mulches are among practices which may ultimately contribute to completely mechanized stand establishment.

Two possibilities exist in approaching mechanized harvesting. The first involves development of a machine system which will harvest lettuce selectively in a manner similar to present hand-harvest practice. A selective harvest machine requires two basic functional elements. The first a sensing device which determines if a given head is ready for harvest, and the second, a cutting device which removes the selected head without disturbing adjacent heads.

A second approach to mechanized harvest is development of a non-selective harvest system. This is a simpler approach from the standpoint of the harvesting machine, but for success requires progress in breeding and culture of lettuce for uniform maturity. Undoubtedly progress in mechanized precision stand establishment will be progress toward mechanized non-selective harvest.

To date lettuce mechanization has consisted of adoption of machines developed for a wide range of crops, and effort directed toward the unique requirements of lettuce has been limited. Current labor cost trends force attention to specific mechanization problems in lettuce.