A Resume of Sixteen Years of Sugar Beet Machinery Research

H. B. WALKER[1]

THE CALIFORNIA Agricultural Experiment Station in 1930 became interested in the opportunities to mechanize sugar beet production particularly those phases where labor demands created peaks such as for harvesting, and for spring thinning and hoeing. The labor demands, particularly for harvesting, are competitive with many other crops like grapes, walnuts, rice, beans and tomatoes, so it is natural for growers to be most interested in mechanical harvesters. However, the spring labor demand is not unrelated to the harvest labor problem, so in considering a project at the California Station both of these labor peaks received attention. In 1931, a cooperative agreement was made with the United States Department of Agriculture to conduct investigations at the California Station under the general title, "Sugar Beet Machinery Investigations," (Project No. 896). This cooperative agreement remained in force until 1943, but the California Station has continued its investigations until this date. The resume presented, therefore, includes research and experimental studies covering a period of 16 years. There were in fact, two periods of activity in this project, (a) the early investigational period extending from the project's inception until mid-1938, and (b), an accelerated research period extending from mid-1938 to date. The only real difference in the importance of these periods is related to the funds available to support the investigations.

The project was supported during the earlier period from State and Federal funds, while during the latter period it received grants-in-aid totaling $114,000 from the United States Beet Sugar Association. The California Station supplemented these funds over the 16-year period by expenditures equalling, or slightly exceeding, the total of the grant. Thus, these funds together with such funds as were supplied through the Federal government, represent a sizeable investment in this field of research. A list of the personnel working at some time or other at the California Station and contributing to this research project, together with their titles and connections, is appended to this paper. Each of these workers deserves credit for the achievements attained. The project was further aided in a consulting and advisory capacity by a committee of industry men representing the United States Beet Sugar Association.

The first period was inherently exploratory due to the limited personnel and funds available, but this should not detract from the importance of these earlier investigations. Mervine, Walker and McBirney explored the labor problems confronting growers during the period 1931-38 and some of the tests and studies of these earlier years formed the basis for the more

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concentrated efforts conducted later. Mervine made the first analytical studies of the blocking and thinning of sugar beets by hand and by mechanical aides. He used a John Deere No. 24 beet cultivator as early as 1931 for cross-blocking trials with various forms of sweeps, shovels, disks and shields. Early results were variable, depending upon the distribution of seedlings. Cross blocking in peat soils was unsuccessful and attempts were made to use chemical cross blocking. Mervine in 1932 made calculations based upon the laws of probability and chance for determining the proper blocker adjustment when the seedling stand had been measured. From these calculations he prepared curves for blocker adjustments when the germination stand is expressed in percentage of inches of row containing seedlings. These curves have been widely used in setting up cross-blocking equipment. They were published in 1933 by Mervine (2) and Skuderna.

During this early period, Mervine at the California Station and later at the Colorado Station, made studies of the relative emergence of seedlings when beet seedballs were planted with planters equipped with disk and shoe-furrow openers. The former gave the better results for whole-seed placement. The practice in California of bed planting and the inability to adapt cross blockers to such plantings led to field tests with "down the row" blockers of which two types were typical; the Uddenborg[2] and the Dixie[3]. Both used rotating members equipped with blades to chop out sections of the row and leave undisturbed blocks of beets as the machine traveled down the row. Where relatively uniform stands of seedlings were obtained, units of this type were satisfactory for thinning in sedimentary soils. Mervine worked with crust breakers, but he was unable to find a unit which had universal application, although many types proved beneficial. These early studies revealed the tendency for beet seedlings to emerge in clumps with frequent gaps in the row. This made thinning to singles difficult and likewise contributed to cross-blocking difficulties. These conditions were caused by the inherent weaknesses of beet drills to provide uniform seed distribution.

In 1932, McBirney considered the potential advantages of planting beet seed in hills, and Rassmann[4] had already designed and constructed planters of this type. The fluted feed drills then commonly used required heavy seeding rates to overcome long gaps in the row. Rates of 15 to 20 pounds per acre were common. The first tests with hill planters in California were made in 1933 with planters using horizontal and vertical plates. These tests, which were repeated the following 2 years, indicated seed-saving possibilities, but stands were imperfect; and in thinning, laborers sometimes pulled out all of the beets in a hill. Losses from this cause ranged up to 20 percent. McBirney investigated planter performance with respect to plate fill and found that plate fill decreased with plate speed and with decrease in box fill. In all of these studies, appreciable crushing or milling

[2]Uddenborg, R., Inventor, Fort Morgan, Colorado.
[3]Dixie Cotton Chopper Company, Dallas, Texas.
[4]Rassmann Manufacturing Co., Beaver Dam, Wisconsin.

of the seed was observed. However, he reported in 1936 that: "Planters can be devised to plant in close or scattered hills." He observed further that: "A high percentage of single seedlings in a germination stand was associated with a uniform distribution of seed in planting and that single seedlings contributed to good thinning and reduced time for doing this work." McBirney's objective was to place a single seedball per lineal inch of row. A planter developed by Palmer[5] seemed to offer potentially at least some of these advantages. However, it failed to produce good results under field tests because of variations in seed size, difficulties in seed flow, cell unloading, and the like. This planter was better than the hill-drop, but no improvement over the Planet Jr. No. 3, widely used in California at that time (1936). The results, however, encouraged McBirney to design, build, and test a chain-feed, single seedball planter whereby the chain with cups attached was pulled through the seed reservoir to pick up single seedballs and deliver these near the base of the planter furrow. This development initiated the idea of the single seedball planter and later led to the introduction of the term "precision planting." Walker[6] in September, 1938, reported: "Enough planter work has been completed already to forecast the successful development of a planter which will plant single seeds with controlled spacings."

The harvesting studies during this early period (1931-38), due to the limited funds, had to be confined to tests on machines currently under development, principally by inventors and smaller manufacturers. The problems of harvesting long had been recognized, and many efforts had been made to mechanize this part of sugar beet production. The background of this early development work was reported by Walker (3) to this Society in 1942. Such tests conducted previous to 1938 at the California Station were on such units as the Davis-Thompson, Great Western, and Scott-Viner harvesters. These tests did little more than bring into clearer definition the basic problems involved. Both ground and machine topping was attempted by early inventors with perhaps more attention to the former, but actually more careful engineering development with the latter as evidenced by the Scott-Viner machine. During this period, the standards for harvesting performance were set by hand labor which placed a rather high performance requirement on these early machines. No one during this period had made a really acceptable topper, when judged by the prevailing hand-labor standards, and what was more apparent, no machine had been developed which could successfully separate lifted beets from clods. No ground-topping unit could do an acceptable job of harvesting; and while machine-topping units like the Scott-Viner could do better, it failed to meet grower acceptance. Extensive tests covering a number of crop years were conducted in California with the latter machine, yet it failed to meet grower requirements in California, even though it was more successful elsewhere.

[5]Palmer, P. S., Spokane, Washington, Manufacturer, Cheney Weeder Co., Cheney, Washington.

[6]Walker, H. B., News Letter No. 1 to United States Beet Sugar Association, Sept. 12, 1938. Unpublished data.

In summarizing the studies made at the California Station for this period (1931-38), the following conclusions seem justified:

1.—Blocking by cross cultivation and by down-the-row machines was demonstrated to be practical.

2.—The need of planter development to distribute seeds in the soil regularly was a primary requisite for optimum benefits from mechanical thinning and blocking; and the general specifications for such a planter were conceived.

3.—The separation of beets from clods and a practical method of topping beets were the principal bottlenecks in successful mechanical harvesting with the former far the more important.

Thus, this early work brought into definition the more important of the problems to be solved in sugar beet mechanization. The United States Beet Sugar Association in 1937, largely through the initiative of its intermountain and far western members, became interested in these problems, and in the hope of accelerating their solution, made a grant to the California Station in 1938. The Association, likewise, supported research elsewhere, principally at the Colorado Station, but separate grants were made for these activities. With this added support, it was possible to undertake a much more vigorous program of research, which has been designated as the second period of investigations. In accepting support from industry, the Station realized fully that the research and development work required would present difficult problems. Walker[7] for example, revealed some of the difficulties to be met in defining general specifications for ground toppers in 1939. He stated: "The task (beet toppers) is not an easy one, since a unit of this type must adjust itself rather readily and accurately to (1) high and low yields—5 to 40 tons per arce; (2) high and low beets—that is, with crowns below the surface to 8 inches above; (3) beets of small diameter (1¼ inches) to as large as 10 inches in diameter and in some instances 20 pounds in weight; (4) wet and dry-field conditions; (5) clean and weedy fields; (6) high, brittle tops to low, frozen, dry and second-growth conditions; (7) flat and bed planting; (8) irregular spacings of beets; and (9) the machine must be simple and sufficiently rigid to stand up under rough field handling."

McBirney continued his work with single seedball planters in California, and Mervine in Colorado also developed a single seedball planter of some promise. The John Deere Company started its development work on single seedball planters using a horizontal plate. McBirney made comparative tests with the chain-feed cup, single seedball, experimental planter with 5 commercial types; and he concluded (1938) that while the chain-feed type was superior to ordinary commercial units. it was no better in performance than the improved, single seedball, plate planter. Interest in single seedball planting gained much momentum during this period, and the field results with improved types of plate planters were encouraging.

[7]Walker, H. B. A summary of progress and programs for sugar beet machinery investigations to advisory committee, U. S. Beet Sugar Assoc., Nov. 17, 1939. Unpublished data.

Mervine (1) and McBirney prepared a circular in October, 1938, which recorded developments in sugar beet mechanization up to that date.

During the winter of 1938-39, Bainer and associates in an effort to analyze the accuracy of planter performance introduced the grease-board method of studying seed distribution from sugar beet planters. This simple device was really an innovation which led, ultimately, to significant improvements in planters and seed processing. Many planters were tested, including the chain-feed, and horizontal- and vertical-plate types. The California Station in its August, 1939, report stated: "In addition to producing more uniform stands, the single-seed planters also produced from 20-30 percent more single seedlings than with conventional planters." McBirney further concluded in 1940 that: "The single seedball planter has demonstrated its ability to increase the number of single plants with the result that thinning is an easier operation. . . . Our tests have shown that elaborate planting equipment is not necessary."

As a result of these tests in the laboratory and field, the practice of modifying conventional plate planters to meet the requirements of single seedball planting was established, and by 1940, a number of companies were manufacturing such planters in limited numbers for the farm trade. The experiences with these and the modifications made on fluted feed drills developed troubles from seed grinding in the metering apparatus, and there was still a decided tendency toward bunching of the seeds with attendant skips.

During this period in planter development, harvester studies were also under way. The problems in harvester development were related to the occurrence of doubles and irregular spacings in the row. Bainer, who was interested in both planter and harvester investigations, decided to study further the factors influencing the accurate placement of seeds. Knowing seedballs usually contain more than one germ, he conceived the idea of breaking a multiple-germ seedball into segments in the hope that the segments so produced would provide a seed unit with greater singleness of germ. He had some success in accomplishing this by a "shearing" method, which produced seed units, in number, comparable to the number of original seedball units processed. These approached near unity in seed germs per seed unit, averaging 1.1 germs per unit as compared to 1.9 for the original seed. This method of seed processing, incorrectly termed "shearing" since the seedballs were broken into segments, introduced a radical departure from traditional practices. The method of shearing used by Bainer was first demonstrated at the California Station in May, 1941; and that year, he planted 1 acre with "sheared" seed. He planted plots at low seeding rates, as low as 3.25 pounds per acre. Some of these processed seeds were pelleted. The "sheared" seed germinated satisfactorily and contributed significantly to increased numbers of single seedlings. Pelleting in these early tests indicated no added advantages.

Encouraged by these results, Bainer developed machinery to process whole sugar beet seedballs into segments at a rate of 125 pounds of whole seed per hour. This product was cleaned by use of a fanning mill and graded on a gravity table. His recoveries were not high, and he advocated the up-grading of processed seed through the elimination of light ends. Leach, working with Bainer, successfully developed methods of seed treatment for this new form of seed.

This pioneer work by Bainer and Leach opened up new fields of attack for planter development. The farm-labor problem was acute at this time due to foreign wars and the threat of war in this Nation. The sugar industry immediately recognized the potentialities of using segmented seed. From the single acre planted in 1941, 10,000 acres were seeded in 1942; and this was extended to approximately 300,000 acres in 1943. By this time, all of the major beet-sugar processors in the United States had installed beet-seed processing equipment patterned after the original designs by Bainer. The demand for plate planters to plant these processed seeds exceeded the ability of manufacturers to supply during the war years, and many attempts were made to adapt old types of planters for using processed seed in the hope of obtaining the labor-saving benefits accruing from less difficult thinning. These savings were estimated to be approximately 10 man-hours per acre. Due to war conditions which aggravated the labor problems, acceptance was much more rapid than would be normally justified. However, results were generally favorable. Walker[8] warned in 1942 that: "We are still in the cautious phase of seed shearing;" but he also pointed out that "In the planting of seed segments, we are attempting to approach an ideal field stand, where even no subsequent thinning may be required. If this ideal is to be approached, it is essential to have seed of known viability approaching perfection in quality; planting equipment capable of distributing the seed in the soil as required for the perfect stand; and a seedbed favorable for the seed and seeding operation."

Lower seeding rates, down to 2 pounds per acre, were used experimentally. Planters of the plate type were designed for 2 sizes of seed: namely, 11/64 inch to 8/64 inch and 10/64 inch to 6/64 inch. Bainer stated in 1942, "that the greatest gain made through the use of 'sheared' seed is from light plantings." The use of seed of high viability and vitality is magnified by such light seeding rates. Armer and Bainer built an aspirator to separate seed segments on a weight basis. This machine, while simple, was effective in raising the percentage of viable seed recovered by approximately 8 percent.

During this time, Bainer observed continued evidence of planter skips. Some planters showed enough skips to make up as much as 25 percent of the row. Planter plates were restudied and improved, but skips persisted. It was decided that more analytical studies of seed distribution were needed. It was observed that even with hill-drop planting, seeds were scattered in the 34-inch drop down the tube. This led to a lowering of plates which tended to reduce cross trajectories in the seed path.

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[8]Walker, H. B. Report to Advisory Committee, U. S. Beet Sugar Assoc., Aug. 1942. Unpublished data.

By 1943, composite estimates made within the industry showed that 60 percent of the plantings that year were grown from segmented seed. The pre-season estimates for 1944 were 80 percent with estimated savings of 5,000,000 man-hours of labor due to less difficult thinning conditions.

Planter performance was generally recognized as a key factor in the successful use of processed seed. In July, 1943, a conference was called at Greeley, Colorado, to discuss the requirements of the ideal planter. It was at this meeting that Carsner[9] pointed out the injury to seed by the segmenting process, as well as seed damage from milling in plate planters. This was a significant critical contribution, since it led to a re-examination of seed processing and further attention to improvements in planters. This conference also emphasized the necessity of producing high-quality seed without excessive losses in the processing methods. Recovery heretofore had been low.

During the winter of 1943-44, Brooks[10] and others at the California Station made extensive statistical analyses of seed metering from plates which had been improved for seed-cell unloading with reduced seed injury and with uniformity of timing in unloading. These studies revealed such plates were capable of metering and unloading processed seeds accurately, thus indicating that seed placement contributing to skips and bunching of seedlings must take place beyond the point of plate unloading. These findings led to a study by Bainer of drop tubes in relation to final seed distribution. He found that uniformity of drop in relation to final position in the soil could be controlled best by small (½-inch diameter), smooth, metallic tubes. These, he found were effective for distances up to 32 inches in drop below the plate ejector. This, likewise, was a significant finding and provided the final element for a planter capable of near precision performance.

With planter elements determined, further attention was devoted to seed processing to reduce injuries as reported by Carsner and to produce uniformly sized and shaped seed units. Leach initiated the idea of using decorticated whole seed, and Bainer developed an experimental decorticating machine. When pregraded whole seed was decorticated and then regraded, the product was not unlike segmented seed. Leach made studies of field emergence with plantings of decorticated seeds, and his data confirmed his earlier observations that through decortication, a better shaped, more viable, more uniform and a more easily planted seed unit could be developed which would produce under actual field environments as many singles per unit of row length as the more roughly processed segmented seed, even though the latter may possess greater singleness of germ. Walker[11] the same year made measurements to determine size variations in segmented and decorticated seeds. He reported: "In sheared seed adhering, cork particles sometimes form more or less translucent knife-like edges to

[9]Carsner, Eubanks, U. S. Dept. of Agri., Riverside, California.

[10]Brooks, F. A., Baker, G. A., Lorenzen, Coby, Lewis, H. D. California Agri. Exp. Sta.

[11]Walker, H. B. Preliminary studies of sizes of processed sugar beet seed, Sept. 1945. Unpublished data.

make such units plate-like or flat in contrast to decorticated seed on which no cork adhered." These studies showed that the smoother, more spherical shape of the decorticated product was advantageous for precision planting.

Bainer then developed decorticating machinery suitable for commercial operations. Large-scale field plantings of these seeds confirmed the earlier conclusions of Leach. Bainer also built a machine in 1946 to reduce the size of whole seed through burr reduction. He concluded: "The quality of seed processed in either case (decorticated or burr reduction) is superior to segmented seed in every respect except the degree of singleness of germ." Seed recovery by these methods was considerably increased, being 50 to 60 percent for decorticated seed and varying from 60 to 70 percent for burred seed.

Thus, seed processing, now almost universally adopted by the industry, is a product of the research in planter development. Seed segmentation was the initial step in this search for a seed unit with singleness of germ. Injury to seed by this method, however, together with low recovery, led to methods less violent, and which provided a better shapefactor in the seed unit for precision planting. Thus, in this evolution of seed processing, the sized, decorticated seed unit has come to the forefront, and plate-type planters have been developed to provide uniform placement of any desired number of seeds per unit of linear travel. These planter improvements consist of properly cast and machined plates, improved "cut-off" and "knock-out" devices and the use of small-diameter, smooth, metallic tubes to carry the uniformly released seeds delivered by the plate, on a direct path at uniform velocities, to the soil.

Seed processed by burr reduction and decortication were planted in widely scattered sections in 1946, and three or more commercial processing plants are now in operation. Commercial precision plate planters are now generally available.

The harvester studies conducted during the second period of this project were limited to tests of such machines as were available; but with more funds for investigations, it was possible to conduct research and development on essential elements of machines. The machines which had been tested up to this time (1938) delivered much trash and dirt with the beets, and the topping quality was not satisfactory. In general, large beets were topped too high, and small beets were topped too low; and none of the machines had facilities to adjust the thickness of the crown cut to the diameter of the beet. Powers, in his research work in 1938, found there was a more or less linear relation between crown thickness and beet diameter. He, likewise, found there was a relationship between thickness of crown to be removed and elevation of crown above the soil surface. From these studies, he concluded: "There is the possibility of controlling the crown cut thickness through a gauging mechanism." The same year, field tests were run on the Liberty, Great Western, Zuckermann, and Scott-Viner topping units, as well as experimental tests on a rotary topper designed by Zimmerman.

The following season, Powers improved his experimental topper, and early tests showed the topping by number was 95 percent acceptable and by weight, 99 percent acceptable. The publicity given to harvester investigations through subsidized research attracted inventors and a few commercial companies to develop harvesters. In addition to those units mentioned earlier, were the Braden, the Alvos and Devey units, the Pueblo harvester, the Walz machine of Avondale, Colorado, which later became the foundation unit for the John Deere harvester, the Oliver digger built for American Crystal Sugar Company, and others.

Rimple at the California Station developed a finger pick-up unit with a special plow. Tramontini, at the same Station, worked on a unique vibrating lifter; and Armer made preliminary studies on beet pick-ups by spikes. Powers concentrated on his variable-cut topper, and he conceived the idea of a vibrating knife to sever crowns from beets, when topping in place. He also conceived a leaf and crown pick-up. Armer devised a variable-cut disk topper based upon the beet-size relationships determined by Powers. This topper was found to be effective in weedy fields. Out of all of this work, the topping problems were brought into clear focus for in-place operations, although much refinement work was still needed.

With harvesters, the clod problem remained unsolved. Rimple's claw-lifter was ineffective. The spiked wheel used by Armer showed little promise, although later a modification of this principle was used successfully by others. The Scott-Viner machine was unacceptable for California conditions. The Tramontini vibrator-lifter did not seem to possess reliable operating features which led to its eventual abandonment, perhaps prematurely. During this period, war clouds were forming and ready to break, and the pressure for some kind of labor-saving equipment for harvesting beets was acutely urgent. Loaders came into use; cross-conveyor harvesters and disk toppers were tried out with some satisfaction. Among those used were the Alvos, Rappetti, Hansen, Hunt Bros. and Zuckerman. Armer worked on the sorting-table principle, and Armer and Bainer together developed a two-row, topper-digger unit, with hand-sorting belts, and with ultimate delivery of beets direct to trucks. All of these units were cumbersome and relatively expensive to operate, even though some labor was saved. This pressure to do emergency work temporarily diverted the attention of most of the Station engineers from basic harvester research.

By 1942, the variable-cut topper developed by Powers was released for nonexclusive manufacture to three implement companies. Powers further perfected a leaf windrower to go with the topper and did preliminary work on a helical plow for lifting beets. He experimented with a chain-hook elevator to engage pretopped lifted beets in order to separate clods from the harvested beets. In spite of all of this pioneering, and basic work upon the part of Powers, the Station reports that year stated: "Our harvesting operations beyond topping have not reached a point of grower acceptance."

Industry was active during this period. The John Deere Company placed approximately 15 of its new harvesters in the field in 1942, and programmed 100 for the following year. The Allis-Chalmers Manufacturing Company did experimental work in California, as did also the Sawtooth Company. The International Harvester Company adopted the disk-type of topper as developed earlier by Armer, and the Blackwelder Company was building harvester units after designs by Schmidt, Jongeneal and others. This year (1943), perhaps, marked the beginning of the successful commercialization of sugar beet harvesters.

Powers in his designs at the California Station was successfully using flat, thin knives for topping, as was also the John Deere Company. Disk-toppers were used successfully by International Harvester Company, and Marbeet (Blackwelder) was successful with machine topping, as was also Scott-Urschel. In September, 1944, Walker reported to the Advisory Committee of the United States Beet Sugar Association, in part as follows: "The work on harvesting machinery has continued with varying degrees of success . . . Machines now commercially available are operating in the field with sufficient success to keep them going; but these are also sufficiently faulty to create a desire for improvements. Topping, top recovery, and removals of roots without excessive dirt and breakage, appear to be the bottlenecks for a satisfactory product at the dumps. The problems of these commercial units have caused us (California Station) to direct our studies toward obtaining a better harvested product."

Powers continued diligently his efforts during the 1945-47 seasons in perfecting a single-row, tractor-mounted unit, using his own design of variable-cut topper, helical plow, chain-lift conveyor, cleaning elevator, and overhead bin. With this unit, he has been able in 1947 to obtain 96 percent recovery of beets with excellent topping quality and relatively low dirt tare in soils ranging from dry-hard to moist and sticky. Under good operating conditions for harvesting in flat planted, 20-inch row spaced beets, yielding 20 tons and upwards per acre, the rate of recovery has been 6 to 8 tons per hour. This unit represents 9 years of intensive development work at the California Station upon the part of J. B. Powers and associates, and it closely approaches the broad objectives set up for a functional unit by the project statement.

Thus, 16 years of technological effort, 9 years of which were conducted intensively under the handicaps of World War II, have yielded commendable achievements of benefit to the sugar beet industry. One must remember, however, that during these years of research, a sympathetic and anxious industry, functioning through its Advisory Committee, and an eager implement industry stood by at all times to lend aid and assistance to carry into immediate practice the findings of this research. To these faithful and helpful cooperators, much credit is due. It is believed by your speaker, however, that the research investment has been fully justified.

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APPENDIX A

Names and Title of Research Workers California Agricultural Experiment Station Sugar Beet Machinery Investigations 1931-1947

Armer, Austin A. .... Assoc. in the Exp. Sta., Univ. of Calif., Asst. Agri. Engr., USDA
Bainer, Roy .... Agri. Engr. in the Exp. Sta., Univ. of Calif.
Baker, Geo. A. .... Asst. Statistician in the Exp. Sta., Univ. of Calif.
Barbee, C. E. .... Assoc. in the Exp. Sta., Univ. of Calif.
Bice, Richard A. .... Field Engineer (Colo.) Exp. Sta., Univ. of Calif.
Brooks, F. A. .... Agri. Engr. in the Exp. Sta., Univ of Calif.
Hall, F. G. .... Mechanician, Univ. of Calif.
Leach, Lyle .... Plant Pathologist in the Exp. Sta., Univ. of Calif.
Lewis, H. D. .... Assoc. in the Exp. Sta., Univ. of Calif.
Lorenzen, Coby, Jr. .... Asst. Agri. Engr. in the Exp. Sta , Univ. of Calif.
Lory, Fred, Jr. .... Mechanician, Univ. of Calif.
McBirney, S. W. .... Agri. Engr., U. S. Dept. of Agri.
Mervine, E. M. .... Agri. Engr., U. S. Dept. of Agri.
Powers, J. B. .... Assoc. Agri. Engr. in the Exp. Sta., Univ. of Calif.
Rimple, Ed. .... Development Engineer, Exp. Sta., Univ. of Calif.
Robbins, W. W. .... Botanist, Exp. Sta., Univ. of Calif.
Symens, P. .... Mechanician, Univ. of Calif.
Tramontini, Vernon N. .... Assoc. in the Exp. Sta., Univ. of Calif.
Walker, H. B. .... Agri. Engr. in the Exp. Sta., Univ. of Calif.
Zimmerman, O. B. .... Assoc. in the Exp. Sta., Univ. of Calif.