Irrigating Vegetables with Brackish Water

F. L. Long, J. M. Daniels, and J. R. Carreker
Fellow ASAE

SUPPLEMENTAL irrigation is used widely in production of high-value crops throughout the humid eastern states. This is especially true for vegetables along the Atlantic seaboard. Sources of water for irrigation in this area and at selected locations elsewhere often are brackish; *i.e.*, there is some degree of salt in the water. Examples of such sources are tidal marshes, rivers and other streams that are affected by tides, wells and storage ponds, seepage ponds, and bays or sounds (1)*. The concentration of salt can be determined by the electrical conductivity (EC) of the water, expressed in millimhos per centimeter (mmho/cm). Gallatin *et al* (1) found that salt concentration varied widely between locations and with time or depth of sampling at a given location. For example, the EC in a pond on the eastern shore of Virginia varied from 0.33 mmho/cm in August 1958 to 8.90 mmho/cm in August 1959. Differences in rainfall probably caused this variation.

Irrigation with saline water adds salts to the upper horizon of the soil where fertilizer salts also are concentrated. The normal upward movement of water with dissolved salts by capillary action during dry periods and the addition of salts from brackish irrigation water would tend to cause a salt problem in soils otherwise considered as nonsaline. These salts can be removed only by leaching (2). Heavy rainfall during the growing season and over winter tends to leach out such accumulations of salt in soils of the humid area.

Crops generally are more susceptible to salt damage during the seedling stage than when more mature. Also, some crops are more sensitive to salt than others (3). These factors might affect the extent to which a given supply of brackish water could be used for irrigation.

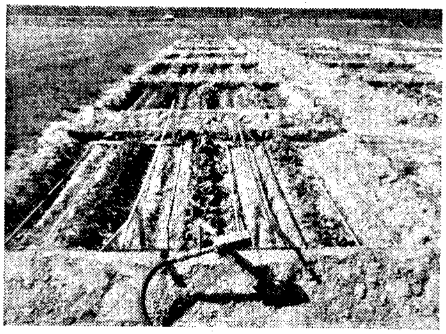

FIG. 1 Apparatus used for irrigating plots.

Gallatin et al (4), in a study with spring crops of potatoes, beans, onions and tomatoes and fall crops of beans, turnips, peas and cabbage at Norfolk, Va., found that salinity effects varied with the saline status of the soil throughout the growing season and with the sensitivity of the crop.

Lunin *et al* (5), in a greenhouse study at Norfolk, Va., showed there was considerable difference in salinity effects when the soil was salinized at different stages of growth of broccoli, tomatoes, spinach, beets, onions and peppers.

The time of application of irrigation water cannot be preselected in the humid area since water is applied as needed during erratic periods of limited rainfall. Information is needed on the response of different crops to irrigation, and especially irrigation with brackish water at various places along the Eastern Seaboard with different climatic patterns and soil types.

This paper presents results from a study of no irrigation versus irrigation with and without brackish water at Fleming, Ga., in partial fulfillment of this need†.

Experimental Procedure

The field study reported in this paper was initiated in 1962 at the Southeastern Tidewater Experiment Station, Fleming, Ga., on a Fairhope very fine sandy loam soil (Table 1). The study was primarily designed to determine the tolerance of some vegetable crops to irrigation water with different levels of salt concentration, the relative value of no irrigation versus 1-in. and 2-in. irrigations of brackish vs. salt-free water, and the effectiveness of rainfall in leaching out accumulated salts. The experiment was a split-plot design with twelve irrigation treatments as whole plots and varieties or crops as subplots. All treatments were replicated three times. The whole plots were 10 by 10 ft with a 6-in. earthen dam around each plot. In the spring, the split plots consisted of three varieties of snapbeans, namely, Extender, Contender, and Black Valentine. In the fall, the split plots consisted of three crops: collards, kale and turnips. These crops were planted in rows 2½ ft apart. The snapbeans and fall crops received an application of 6-12-12 fertilizer at the rate of 1,000 lb per acre at time of planting. This initial fertilizer was mixed with the soil beneath the row. Approximately six wks after planting the crops were sidedressed with 100 lb of N per acre as ammonium nitrate.

The beans were planted at a rate sufficient to allow thinning to approximately 36 plants per row at the seedling stage. The greens were seeded at the rate of about two g per row.

The irrigation treatments consisted of no irrigation (rainfall only) and irrigations of 1 in. and 2 in. of salt-free water, and water having different salt contents. Concentrations of the brackish water used were 640, 1280, 2560, and 3480 ppm total salts, giving electrical conductivities (EC) of 1, 2, 4, and 6 millimhos per cm. This gave 12 treatments of 0/0‡, 1/0§, 1/1, 1/2, 1/4, 1/6, 0/0‡, 2/0§, 2/1, 2/2, 2/4, and 2/6 in. water/ mmho per cm. The irrigations were applied to the plots through the apparatus shown in Fig. 1. This apparatus was designed so that the water passed through a meter for accurately measuring the amount applied to each plot, and also so as to give uniform distribution over the entire plot. The pipes extending along each alley had 1/16-in.-diameter holes spaced 6 in. apart on the underside. The plots were irrigated when soil moisture in the 0- to 6-in. depth of the plots receiving tap water had dropped to 5 percent or about 1 bar, where 50 percent or more of the available water was depleted.

The snapbeans were harvested as the pods reached marketable size. The edible portions of the collards, kale, and turnips were harvested when they reached the marketable state of maturity.

Soil samples were taken at depths of 0 to 6 and 6 to 12 in. from each plot

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The authors—F. L. LONG, J. M. DANIELS and J. R. CARREKER—are research soil scientist, ARS, USDA, Florence, S.C., civil engineering technician, and research agricultural engineer and investigations leader for water management research, ARS, USDA.

* Numbers in parentheses refer to the appended references.

† This was part of a joint study conducted at Fleming, Ga.; Norfolk, Va.; and New Brunswick, N. J. The authors participated only in the work at Fleming, and this paper reports only the results from that location.

‡ Rainwater only. No irrigation, no salt.

§ Inches irrigated with tap water/EC of the tap water. (Note: The EC of the tap water was actually 0.24 mmho/cm.)

TABLE 1. SOME PROPERTIES OF FAIRHOPE VERY FINE SANDY LOAM

Horizon	Depth, in	Mechanical analysis Percent			Sand					Textural class	Organic matter percent	CEC, per me/100g
		Sand	Silt	Clay	2.0-1.0 mm dia.	1.0-0.5 mm dia.	0.5-0.25 mm dia.	0.25-0.10 mm dia.	0.10-0.05 mm dia.			
					Percent of total sand							
AP	0-8	68	26	6	0.03	0.53	1.53	55.47	42.43	vfsl	0.30	4.52
A_2	8-11	66	26	8	0.09	0.56	1.41	48.64	49.29	vfsl	0.13	2.90
B_1	11-14	57	23	20	0.00	0.44	1.36	42.94	55.26	scl	0.09	5.40
B_{21}	14-23	43	13	44	0.00	0.35	0.91	49.45	49.28	c	0.12	14.35
B_{22}	23-35	45	13	42	0.00	0.22	0.51	52.01	47.27	sc	0.064	14.55
B_3	35-40+	55	9	36	0.16	0.21	0.40	68.63	30.60	sc	0.042	13.51

prior to planting the crop and one or two days after each irrigation treatment. Approximately 10 samples were taken in each plot and composited to give a plot sample. The samples were airdried and the pH of the saturated paste and the electrical conductivity (EC) of the saturation extract were determined.

Results and Discussion

The effect of saline water irrigations on the electrical conductivity (EC) of the saturated soil extract is shown in Figs. 2 and 3 for five of the twelve treatments. These five treatments ranged from the minimum to the maximum levels of salinity.

The average initial EC of all plots on January 23, 1962, was less than 0.3 mmho per cm in both the 0 to 6-in. and 6 to 12-in. depth. Irrigation treatments applied on May 9 and May 23, 1962, had very little effect on the EC of the 0 to 6 in. depth as measured on June 20 because 13.47 in. of rainfall occurred between May 9 and the June 20 sampling. There was some accumulation of salts in the 6 to 12-in. depths, however (Fig. 3). No irrigation treatments were applied between June 20 and August 29, at which time the EC was still low in the 0 to 6-in. depth but slightly higher in the 6 to 12-in. depth. Irrigation treatments applied on October 18 resulted in high soil EC values as measured on October 19, 1962. The increased soil EC values for the no-irrigation and tap-water irrigation plots were unaccounted for, except for possible fertilizer salts in the sample because the 1962 soil samples were taken from the row while subsequent soil samples were taken from the middles. Only 1.90 in. of rainfall occurred between October 19 and November 29, 1962, and the EC of the 0 to 6-in. depth (Fig. 2) decreased very little during this period. In fact, the EC for the two highest rates of application (2/4 and 2/6) showed some increase. All EC values were less than 1 on March 29, 1963, except for the 6 to 12-in. depth of the 2/6 treatment, where the value was 1.11. During 1963, the EC of the 0 to 6-in. depth (Fig. 2) generally increased with increasing amounts of applied salts. The irrigation on May 13 was followed next day by 0.72 in. of rain, which caused moderately low EC values. The 16.72 in. of rainfall that occurred between June 12 and August 15 effectively lowered the soil salinity throughout the 12-in. depth. The October 17 irrigation raised the soil salinity of the 0 to 6-in. depth considerably but had little effect on the 6 to 12-in. depth (Fig. 3).

In 1964, irrigation treatments were applied on May 21 to the beans and on October 1 and November 12 to the fall crops. The May 21 irrigation resulted in increases in soil salinity of the 0 to 6-in. depth (Fig. 2) in relation to the amount of salt applied, but there was relatively little alteration in the salinity of the 6 to 12-in. depth (Fig. 3). The 22.35 in. of rainfall between the May 22 and August 13 samplings was sufficient to leach the salts from the 0 to 6-in. depth, so that the EC level was essentially the same as at the beginning of the year. Conversely, during the same period there was an increase in the EC level of the 6 to 12-in. depth. The irrigation of October 1 resulted in increases in the soil EC

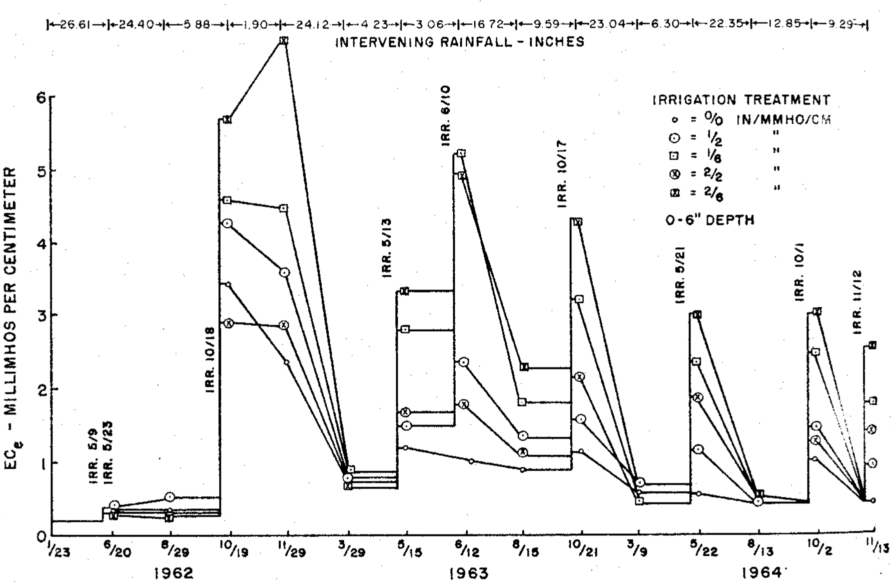

FIG. 2 Electrical conductivity of saturated soil extract 6 in. deep on specific dates before and after irrigation with saline water.

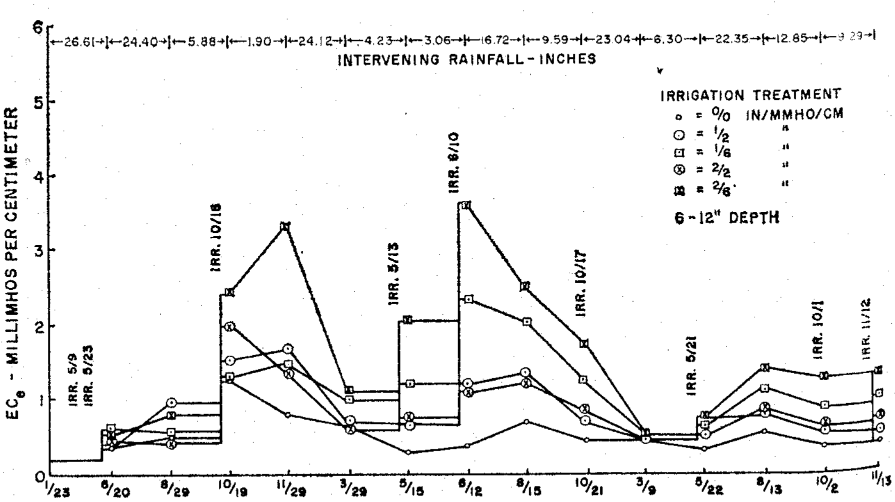

FIG. 3 Electrical conductivity of saturated soil extract 6 to 12 in. deep on specific dates before and after irrigation with saline water.

values of the 0 to 6-in. depth the following day comparable to those resulting from the May 21 irrigation, but in the 6 to 12-in. depth the EC values averaged lower than on August 13. Even though only 0.29 in. of rain fell before the November 12 irrigation, measurements made the following day showed generally lower EC values in the 0 to 6-in. depth than on October 2, and the EC values of the 6 to 12-in. depth remained fairly constant.

At the time of spring planting, soil EC values were usually less than 1 mmho per cm in both the 0 to 6-in. and 6 to 12-in. depths. At fall planting EC values averaged somewhat higher, but were less than 2 mmho per cm. Rainfall occurring between the last irrigation of the fall crop and the planting of the spring crop was very effective in reducing soil salinity.

The adverse effect of soil salinity on the yield of three varieties of snapbeans is shown in Table 2. The three varieties reacted similarly to the saline treatments over the 3-yr period. In practically every case the yield was reduced, relative to the tap-water irrigations, when even a small amount of salt was present in the irrigation water. The low salinity treatments (1/1, 1/2, and 2/1) tended to give higher yields than the no-irrigation treatments (0/0), but the differences were not statistically significant at the 5-percent level. Treatments 1/4, 1/6, 2/4, and 2/6 rather consistently gave yields lower than the no-irrigation checks, but due to the high coefficient of variation rather large yield differences were necessary for significance at the 5-percent level. Considering the 3-yr average yield of the Extender and Valentine varieties, the 2-in. tap-water irrigation treatment (2/0) resulted in a yield significantly higher than all other treatments except the 1/0 treatment. The results showing the average effect of treatment on soil salinity and yield of the Contender variety are shown in Fig. 4. Soil salinity (EC values) increased with each increment of added salt, both in the 0 to 6-in. and 6 to 12-in. depth. The EC in the 0 to 6-in. depth was consistently higher than in the 6 to 12-in. depth. Yields decreased with each increase in soil salinity; however, treatments 1/1, 1/2, 2/1, and 2/2 gave yields higher than the no irrigation check (0/0).

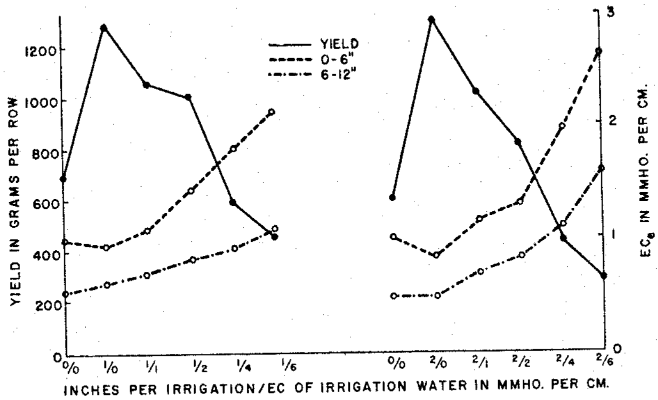

FIG. 4 Three-year average EC values of saturated soil extract and yield of Contender snapbeans with different irrigation and saline water treatments.

The fall crops (turnips, collards and kale) were considerably more tolerant of soil salinity than were snapbeans (Table 3). During the growth of the fall crops in 1963, when there was very little rainfall, the 2-in. irrigations tended to increase yield more than the 1-in. treatments regardless of the fact that more salts were applied in the 2-in. treatments. During the growth of the 1964 fall crops the reverse was true; *i.e.*, more rainfall occurred and yields were lower with the 2-in. treatments. This may be partially accounted for by the fact that the first irrigation was followed by five consecutive days of rainfall, one in which there was 4.93 in. The excess moisture apparently had an adverse effect on yield. During 1962 there did not appear to be any consistent relationship between the yield of the fall crops and the amount of water or salts applied. There were no significant differences between treatments in the three-year average yield of any of the fall crops.

TABLE 2. YIELD OF THREE VARIETIES OF SNAPBEANS WITH DIFFERENT IRRIGATION AND SALINE WATER TREATMENTS

Treatment*	1962 gm per row	1963 gm per row	1964 gm per row	3-year average, gm per row
	Contender variety			
2/0	935 ab†	2088 a†	905 a	1309 a†
1/0	1048 a	1918 a	880 a	1282 a
1/1	903 ab	1547 ab	742 ab	1064 ab
2/1	658 bcd	1558 ab	862 a	1026 abc
1/2	828 ab	1395 ab	805 ab	1009 abc
2/2	350 de	1552 ab	588 bc	830 bcd
0/0	708 abc	998 bc	445 cd	687 bcde
0/0	702 abc	645 c	362 cd	599 cde
1/4	418 cde	852 bc	482 c	584 cde
1/6	352 de	550 c	430 cd	444 de
2/4	260 e	620 c	430 cd	437 de
2/6	162 e	428 c	228 d	273 e
	Extender variety			
2/0	913 ab	2808 a	945 a	1556 a
1/0	1033 a	1985 b	825 a	1281 ab
1/1	712 abc	1383 bc	598 b	898 bc
1/2	672 abc	1445 bc	553 bc	890 bc
2/1	380 cd	1513 bc	510 bc	801 bcd
0/0	637 abc	1013 cd	395 cd	676 cde
0/0	583 bc	950 cd	378 cd	642 cde
1/4	138 d	832 cd	455 bc	475 cde
2/2	175 d	792 cd	458 bc	475 cde
2/4	143 d	533 d	393 cd	357 de
1/6	130 d	477 d	278 d	295 de
2/6	75 d	315 d	272 d	221 e
	Valentine variety			
2/0	872 a	1330 a	1032 a	1078 a
1/0	812 a	1057 abc	755 b	874 ab
1/2	367 bcd	1052 abc	678 bc	699 bc
2/1	338 bcde	1142 ab	508 cdef	663 bcd
1/1	605 ab	655 bcde	637 bcd	632 bcd
2/2	142 def	987 abc	585 bcde	571 cde
0/0	483 bc	743 bcd	462 def	513 cde
0/0	338 bcde	595 cde	352 fg	478 cde
2/4	30 f	740 bcd	415 efg	395 cdef
1/4	283 cdef	347 de	478 cdef	369 def
1/6	175 def	378 de	430 defg	328 ef
2/6	62 ef	198 e	242 g	167 f

* Inches of irrigation water/EC of water applied.
† Duncan's multiple range test at 5 percent level.

SUMMARY AND CONCLUSIONS

The use of brackish water for supplemental irrigation of vegetable crops was studied on replicated field plots for 3 yrs. The treatments consisted of no irrigation, irrigations with 1 in. and 2 in. of tap water (0.24 mmho per cm), and 1 and 2 in. of saline water having electrical conductivities of 1, 2, 4, and 6 millimhos per cm. Three varieties of snapbeans were planted each spring and turnips, collards, and kale each fall. Irrigation treatments were applied when soil moisture was about 5 percent, or 1 bar in the top 6 in. Soil samples were collected from the 0 to 6-in. and 6 to 12-in. depths prior to planting each crop and soon after each irrigation. Electrical conductivity of the saturated soil extract was measured to determine the soil salinity resulting from

TABLE 3. YIELD OF THREE FALL CROPS WITH DIFFERENT IRRIGATION AND SALINE WATER TREATMENTS

Treatment*	1962 kg per row	1963 kg per row	1964 kg per row	3-year average, kg per row
Turnips:				
2/0	8.91 a†	5.97 a	2.02 bc	5.63 a
1/2	9.09 a	3.70 cde	3.68 a	5.49 a
2/2	9.90 a	4.33 bcd	1.44 bc	5.29 a
1/4	9.59 a	3.62 cde	2.40 abc	5.20 a
2/1	8.77 a	5.18 ab	1.31 c	5.09 a
1/6	9.28 a	3.18 de	2.72 ab	5.06 a
1/1	8.21 a	3.94 cde	2.73 ab	4.96 a
1/0	8.43 a	3.72 cde	2.69 ab	4.95 a
0/0	9.59 a	2.91 e	2.26 bc	4.85 a
2/6	8.82 a	3.86 cde	1.58 bc	4.75 a
0/0	7.76 a	2.69 e	2.24 bc	4.31 a
2/4	9.11 a	4.68 bc	1.10 c	4.07 a
Collards:				
2/0	5.46 a	3.85 a	2.95 bcd	4.09 a
1/2	5.40 ab	2.59 cde	4.24 ab	4.08 a
2/4	4.99 abc	3.05 bc	3.08 bcd	3.70 a
1/4	3.75 c	2.61 cde	4.65 a	3.67 a
1/1	3.99 bc	2.73 cd	3.89 abc	3.54 a
2/1	4.48 abc	3.45 ab	2.34 d	3.42 a
1/0	4.42 abc	2.55 cde	3.05 bcd	3.34 a
1/6	3.97 bc	2.23 def	3.70 abcd	3.30 a
2/6	4.05 abc	2.94 bc	2.79 bcd	3.26 a
2/2	4.10 abc	3.08 bc	2.37 cd	3.18 a
0/0	4.32 abc	2.08 ef	3.10 bcd	3.09 a
0/0	4.08 abc	1.81 f	2.87 bcd	3.00 a
Kale:				
1/1	3.02 a	2.20 bcd	2.81 a	2.68 a
2/4	3.41 a	2.57 b	2.01 ab	2.67 a
1/0	3.16 a	2.27 bcd	2.34 ab	2.59 a
2/0	2.97 a	3.14 a	1.59 ab	2.57 a
1/2	3.38 a	2.02 cd	2.18 ab	2.53 a
1/6	3.09 a	1.88 cd	2.26 ab	2.41 a
2/2	2.69 a	2.56 b	1.70 ab	2.32 a
2/1	2.80 a	2.64 b	1.30 ab	2.24 a
2/6	2.69 a	2.30 bc	1.71 ab	2.23 a
1/4	2.26 a	1.82 de	2.43 ab	2.17 a
0/0	3.28 a	1.40 ef	2.16 ab	2.15 a
0/0	2.58 a	1.28 f	1.77 ab	2.00 a

* Inches of irrigation water/EC of water applied.
† Duncan's multiple range test at 5 percent level.

the applied salts and the effectiv[e]... of rainfall in leaching out the salts.

The study showed that snapbeans ... very sensitive to saline conditions ... turnips, collards, and kale are toler[ant]. Irrigating snapbeans with 1 or 2 in. ... fresh water gave yields consider[ably] higher than any other treatment. [Irri]gating with either 1 or 2 in. of sal[ine] water having electrical conductivit[y] of 1 and 2 gave yields higher than [the] no-irrigation treatment. The saline [ir]rigation treatments had no signific[ant] effect on the 3-yr average yield of [tur]nips, collards, and kale. Normal rai[n]fall was very effective in leaching th[e] applied salts.

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PROPERTIES OF SWEET POTATOES

(Continued from page 170)

to which a sweet potato is subject in a handling operation, since some knowledge now exists concerning the shear stress, and the determination of contact area is a geometrical problem. If such forces can be determined, then it can be predicted to what extent damage will occur and steps can be taken to reduce these applied forces to a level at which only insignificant damage will occur.

The magnitude of tangential forces generated between a root and any surface material is dependent upon the coefficient of friction between the two. A root sliding down an inclined plane of rubber is much more likely to be skinned than one sliding down the same inclined plane of galvanized sheet metal due to the larger friction coefficient. However, if the root were falling into a surface, rubber would obviously be more desirable in that the cushioning effect of the rubber would reduce bruising. This points out the necessity of knowing the exact manner in which the root and the handling system interact in order that the proper steps be taken to reduce damage. For instance, according to the data presented, drying rollers of aluminum in a grading line may cause less skinning than wooden rollers and yet not increase bruising. Even so, this approach should be moderated by practical experience which has shown that aluminum rollers pick up soil particles and latex from the roots whereas wooden rollers become smooth and polished.

Summary

A series of compression plunger tests was run at 0.2 in. per min on an Instron tester with a 3/16-in. plunger to measure certain mechanical properties of Centennial, Goldrush and Nugget varieties of sweet potatoes during a normal harvest-curing-storage sequence. Roots were cured at approximately 85 F for five days, cooled to 55 to 60 F, and stored until late spring at which time the temperature varied near average ambient temperature. The five variables measured from force-deformation curves and their resulting ranges of value were: (a) proportional limit force, 10 to 17 lb, (b) slope, 100 to 200 lb per in., (c) energy to proportional limit, 0.4 to 0.8 in. lbs, (d) percent elasticity, 55 to 70 percent, and (e) percent energy return, 32 to 46 percent. There were significant mechanical changes with curing, cooling, and storage as well as among varieties.

Special instrumentation was designed and built to measure skin shear stress and friction coefficients. Measured skin-shear stresses ranged from 100 to 130 psi. Static and kinetic coefficients of friction were dependent on the surface material and ranged from 0.2 to 0.7.

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