A Preliminary Study of Rumple—A Serious Rind Disorder of Lemons in Turkey

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INTRODUCTION AND LITERATURE REVIEW

In Turkey, citrus fruit production grew from 41,368 tons in 1950 to 690,890 tons in 1970, an increase of 1696 per cent. Turkey has a big potential for citrus production and it should be possible to easily increase our citrus growing area from 35,000 hectares to 100,000 150,000 hectares. Now we also have an opportunity to increase the area and production of lemons, which are not being overproduced worldwide as are oranges and grapefruit. We believe that it should be possible to increase both the area and production of lemons by properly using our ecological conditions and by following good production practices. We must point out, however, that rumple, a serious rind disease, damages lemon fruits and needs to be effectively controlled.

Rumple was discovered by Knorr (1958) in 1956 in Florida. Later the same disease was reported by Russo and Klotz (1963) and Salerno *et al.* (1968) in Italy, Florida, Corsica, and Cyprus; by Chapot and Bahcecioglu (1969) and Chapot (1971) in Turkey, Lebanon, and Cyprus; and by Chapot (1971) in Ethiopia. Salerno (1963) indicated that rumple had been known in Sicily for many years and that various studies have been made on it during the past 30 years.

Chapot and Bahcecioglu (1969) stated that damage from rumple first appeared widespread during 1960-1961 in the Antalya, Mersin, Adana, and Arsus areas of Turkey. The per cent damage from rumple varies with the year and area; having been reported as 10 to 14 per cent (Knorr, 1963); 30 per cent (Salerno, 1963); and 38 per cent (Knorr and Koo, 1969). Extreme damage occurs in some orchards; up to 77 per cent in Florida (Knorr, 1963; Knorr and Koo, 1969; Klotz *et al.*, 1972); and 75 per cent in Turkey (Chapot and Bahcecioglu, 1969; Chapot, 1971; Klotz *et al.*, 1972). Rumple in different countries is called by various other names including, in Italy, *Raggrinzimento della Buccia* (Salerno, 1963), *Wrinklerind* (Russo and Klotz, 1963), and, in Turkey, *Cokuntu, Copur,* and *Benek*.

Rumple occurs mostly in lemons. Knorr and Koo (1969) noted damage in Florida to the lemon varieties Arizona, Cowgill, Des 4 Saisons, Mexica, Villafranca, Eureka, and Lisbon. Salerno (1963) and Knorr and Koo (1969) found the varieties Monachello and Do. So. Co. very sensitive to rumple. The general symptoms of rumple, including early and advanced stages are shown in figs. 1, 2, and 3.

Rumple causes rind damage similar to oleocellosis (fig. 4). Oil glands keep their normal shape, but tissues around them are abnormal (Knorr, 1963*a*). Damage is seen only in the flavedo and, although the oil glands in the damaged areas remain intact, they are filled with blackish gummy liquid (Knorr *et al.*, 1963) (fig. 5). Rumple shows symptoms similar to creasing at the first, or plesionecrotic, stage when the rind disorder seems to be on the surface, whereas at the second, holonecrotic stage, the disorder deepens and assumes a variola scar appearance (Knorr, 1963*a*).

Numerous field experiments have been conducted to find the causal factors of rumple and to determine how it damages fruits but until now these experiments have provided no definitive results. The first scientific studies were made on rumple in Florida in 1958 in connection with genetics (Knorr, 1958, 1963*a*, 1963*b*; Knorr *et al.*, 1963; Knorr and

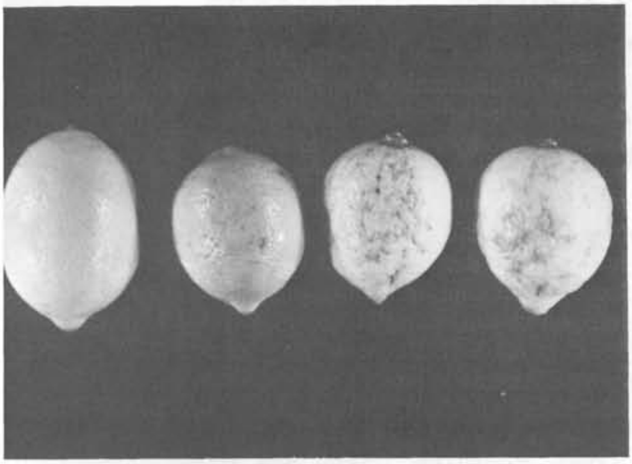

Fig. 1. Various stages of rumple in lemon fruits; healthy fruit (left) and diseased fruits (right).

Fig. 2. Primary stage of rumple disease in lemon fruit.

Fig. 3. Secondary state of rumple disease in lemon fruit.

Fig. 4. Rumple disease of lemons; oil glands remain intact.

Koo, 1969). Earlier research concentrated mainly on somatic mutations and genetic disorders but no positive results were obtained. The effects of fungi, bacteria, aphids and other insects, mites and insecticides were also studied. Isolation attempts from necrotic areas and various treatments gave negative results (Knorr, 1963*a*; Knorr *et al.*, 1963; Salerno and Koo, 1969). In addition, considering the possible relationship of virus disease or of *impietratura*, various studies of possible transmission were made. These studies were also negative (Knorr, 1963*a*; Chapot and Bahcecioglu, 1969; Knorr and Koo, 1969; Terranova and Scuderi, 1970; Chapot, 1971). On the other hand, studies related to irrigation and water balance seemed promising at first, but later proved unsatisfactory (Russo and Klotz, 1963; Salerno, 1963, 1965; Scaramuzzi, 1965; Knorr, 1965*a*, 1966, 1967; Salerno and Continella, 1967; Salerno *et al.*, 1968; Knorr and Koo, 1969).

On the chance that rumple might be a physiological disorder, gibberellic acid and antitranspirant applications were made by some workers to preserve the fruits on the tree and to prevent rind cracks, respectively. The results obtained were not as expected (Knorr, 1965*b*, Knorr and Koo, 1969). Mechanical effects were also studied without definitive results (Knorr *et al.,* 1963; Knorr and Oberbacher, 1964; Knorr and Koo, 1969).

Nutritional studies have concentrated on micronutrients. However, it was found that high rates of nitrogen caused a decrease in potassium content of the plants and that a deficiency of lime in the soil caused an increase of rind disorders, but these results were also considered unsatisfactory (Knorr, 1963; Salerno, 1963; Salerno, 1965; Scaramuzzi, 1965; Knorr, 1966; Salerno and Continella, 1967; Salerno *et al.,* 1968; Knorr and Koo, 1969; Klotz, 1973). The results of leaf and fruit analysis showed no differences between leaf and fruit samples from healthy and diseased trees (Salerno and Continella, 1967, Salerno *et al.,* 1968; Knorr and Koo, 1969). Experiments on lemons in Turkey have shown relationships between micronutrient deficiencies and rumple disease (Ozbek *et al.,* 1974).

Rumple symptoms appear mostly on large fruits (Knorr *et al.,* 1963; Knorr and Koo, 1969) and on the sun exposed south, southeast, and east parts of the crown (Knorr, 1963*a*; Salerno, 1965; Oberbacher and Knorr, 1965; Knorr and Koo, 1969). The disease affects mostly fruits formed from spring flowers (Salerno, 1963; Scaramuzzi, 1965). Symptoms start to appear near the end of

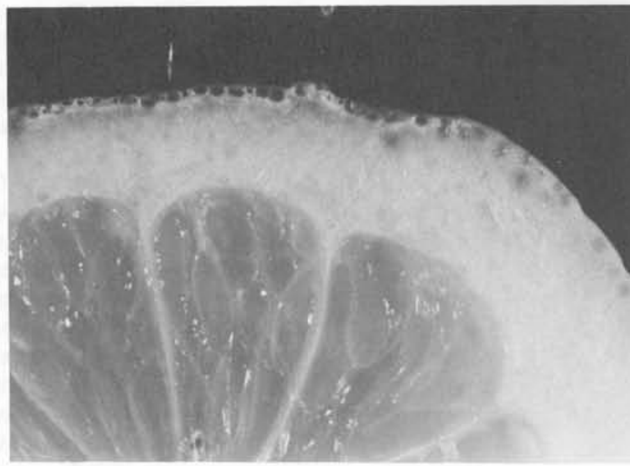

Fig. 5. Cross section of the peel of rumpled lemon fruit; oil glands are filled with a blackish gummy liquid.

autumn as the ripening fruits mature (Knorr, 1964; Salerno, 1963). Rumple generally has no harmful effect on internal fruit quality (Knorr, 1958, 1959; Reitz, 1958; Knorr *et al.,* 1963; Oberbacher and Knorr, 1965; Knorr and Koo, 1969).

Rumple shortens the storage life of the fruits but this effect can be largely eliminated by increasing humidity and decreasing temperature in storage (Oberbacher and Knorr, 1965; Knorr and Oberbacher, 1965). Various workers have insisted that rumple greatly reduces the market value of fruits by causing blemishes but this damage has no adverse effect on fruits used in the juice industry.

MATERIALS AND METHODS

This investigation was made to determine the relationships between nutritional problems of trees, particularly zinc and manganese deficiencies and rumple disease. Alàta and Lamas, two important lemon producing centers, were selected as experimental areas for work with the Kut Diken lemon variety. Representative sampling units of 4 to 8 decares were selected in these centers. We tried to obtain units as homogenous as possible for soil and plant characteristics.

Soil samples. Soil samples were collected from the sampling units according to the method of Chapman (1961) from depths of 0-15, 15-30, 30-60, 60-90, and 90-120 cm of each profile, except at Lamas soil samples could not be obtained from depths greater than 60 cm. Samples were dried, screened, and stored in polyethylene bags for analysis.

Soil analysis. For soil analysis the following methods were used: texture (Bouyoucos, 1951); cation exchange capacity (Richards, 1954); total nitrogen (Jackson, 1962); available phosphorus (Olsen *et al.,* 1954); potassium and sodium (Richards, 1954); calcium and magnesium (Chapman and Pratt, 1961);

zinc (Stewart and Berger, 1965); copper (Bould *et al.*, 1949); iron (Olson, 1948); boron (Silverman and Trego, 1953); manganese (Hoff and Mederski, 1958); molybdenum (Purvis and Peterson, 1956).

Leaf samples. Leaf samples were collected on May 15, 1974 (before treatment in Lamas, after treatment in Alata) from the same units used for soil sampling. Leaf samples were collected again after the treatments of August and November 1974). All collections were made from four different sides (east, west, north, south) of each tree. The leaves were cleaned carefully with detergent solution and deionized water, dried, screened, and stored in pyrex bottles for analysis.

Leaf Analysis. Analyses of total zinc and manganese in the leaves were done by the method of Jackson and Brown (1956).

Fruit samples. In December 1974, the yield of each tree was taken. Four hundred fruits were randomly collected from each tree; weights of these fruits and the numbers showing first and second stages of rumple were determined. From these samples, 50 fruits were taken randomly from each treatment to determine pomological properties. In determining the pomological properties of rumple-diseased and healthy fruits, 50 fruits were used from each of two groups (healthy and diseased) with six replications at Alata and at Lamas.

Fruit analyses. Pomological properties of the fruits and the procedures used were: weight of each fruit in grams; length, the distance between the calyx and the stylar end in millimeters; width, the greatest diameter in millimeters; index, width/length ratio; peel thickness, average of the median cross-section in millimeters; segments, the number in each fruit; seed, the number in each fruit; juice, the percentage from the average of each sample; acid, the percentage in juice, as water-bound citric acid ($C_6H_8O_7 . H_2O$); soluble solids, the percentage measured by a refractometer.

Field experiments. Field experiments to relate rumple disease with zinc and manganese deficiencies were conducted in May 1974 and later using a randomized complete block design on the same units from which soil, leaf, and fruit samples were taken. Various Zn and Mn treatments as shown in table 1 were applied to lemon trees of the Kut Diken variety.

Statistical analysis. Analysis of variance was made according to Duzgunes (1963), and Yazgan (1969).

TABLE 1
ZINC AND MANGANESE TREATMENTS APPLIED TO KUT DIKEN LEMON TREES IN ALATA AND LAMAS

Location	Amounts of chemicals in 1000 liters of water					
Alata	2.0kg $ZnSO_4$+ 1.0kg Na_2CO_3	5.0kg $ZnSO_4$+ 2.5Kg Na_2CO_3	2.0kg $ZnSO_4$+ 1.0kg $MnSO_4$+ 1.5kg Na_2CO_3	5.0kg $ZnSO_4$+ 3.0kg $MnSO_4$+ 4.0kg Na_2CO_3	1.0kg $MnSO_4$+ 0.5kg Na_2CO_3	3.0kg $MnSO_4$+ 1.5kg Na_2CO_3
Lamas	2.0kg $ZnSO_4$+ 1.0kg Na_2CO_3	5.0kg $ZnSO_4$+ 2.5kg Na_2CO_3	1.0kg $MnSO_4$+ 0.5kg Na_2CO_3	3.0kg $MnSO_4$+ 1.5kg Na_2CO_3		

RESULTS

Some physical and chemical characteristics of the soils from experimental areas are shown in table 2. The average values show that, with the exception of texture and cation exchange capacities, the soils did not have any significant variations. Variations in texture were between sandy clay loam (Alata) and sandy loam (Lamas); $CaCO_3$ content varied between 39.26 per cent (Alata) and 43.27 per cent (Lamas); cation exchange capacities varied between 27.60 meq/100 g (Alata) and 18.17 meq/100 g (Lamas).

Macro- and micronutrient contents of the Lamas and Alata soils are shown in table 3. The soils showed differences in some macro- and micro nutrient contents. However, the amount of available phos-

TABLE 2
PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS
IN THE ALATA AND LAMAS PLOTS

Region	Depth (cm)		pH (1 : 2.5)	$CaCO_3$ per cent	Organic matter per cent	Cation exchange capacity (meq/100 g)
Alata	0-15	Sandy clay loam	8.40	35.93	2.02	26.75
	15-30	Sandy clay loam	8.40	36.01	1.66	28.00
	30-60	Loam	8.40	37.18	1.45	29.50
	60-90	Loam	8.50	43.94	1.17	25.25
	90-120	Loam	8.45	43.22	1.27	28.50
	Average		8.43	39.26	1.51	27.60
Lamas	0-15	Sandy loam	8.50	35.50	1.30	15.70
	15-30	Sandy loam	8.40	43.72	1.44	18.25
	30-60	Sandy loam	8.40	50.60	1.20	20.25
	Average		8.43	43.27	1.31	18.17

TABLE 3
AMOUNTS OF MACRO- AND MICRONUTRIENTS IN ALATA AND LAMAS SOILS

Location	Depth (cm)	Ppm									Per cent		
		Zn	Fe	Cu	Mn	B	Mo	P	K	Na	N	Ca	Mg
Alata	0-15	0.33	0.37	0.46	11.50	0.22	0.38	6.86	180	31.50	0.12	0.79	0.80
	15-30	0.47	0.47	0.75	11.25	0.22	0.07	1.87	150	32.50	0.09	0.87	0.09
	30-60	0.05	0.37	0.36	10.50	0.48	0.03	0.73	120	40.00	0.10	0.87	0.10
	60-90	0.80	0.58	0.36	7.00	0.48	0.03	0.57	110	28.00	0.06	0.79	0.08
	90-120	0.11	0.56	0.32	6.00	0.44	0.01	0.36	80	36.00	0.06	0.78	0.10
	Average	0.17	0.47	0.45	9.25	0.37	0.10	2.08	128	33.60	0.09	0.82	0.09
Lamas	0-15	0.48	1.00	0.55	24.00	0.40	0.07	24.40	160	18.00	0.06	0.64	0.04
	15-30	0.56	0.91	0.45	20.50	0.46	0.06	20.45	140	38.00	0.07	0.87	0.06
	30-60	0.58	0.87	0.50	14.25	0.54	0.03	4.88	80	50.00	0.06	0.99	0.09
	Average	0.54	0.93	0.50	19.58	0.47	0.05	16.58	126.67	35.33	0.06	0.83	0.06

phorus in Lamas soils was high, whereas Alata soils except for the 0-15 cm samples, were deficient (Olsen *et al.*, 1954). The amounts of available K, Na, Ca, and Mg, in both Lamas and Alata soils were at the optimum level and the total zinc was in the normal range.

The soils also showed differences in their micronutrient contents. However, available Zn, as well as Fe, were deficient in Alata soils, whereas in Lamas soils both were adequate (Stewart and Berger, 1965; Olson and Carlson, 1950). Available Cu, Mn, and Mo were deficient and B was at an optimum level in both Alata and Lamas soils.

The effects of various Zn and Mn treatments on Zn and Mn content of the leaves are given in tables 4 and 5.

In Alata, Zn content of the leaves was increased significantly by the effect of various Zn and Mn treatments at all three periods (May, August, November); the highest increase was obtained by application of 5 kg $ZnSO_4$ + 3 kg $MnSO_4$, followed in decreasing order by 5 kg $ZnSO_4$, 2 kg $ZnSO_4$ + 1 kg $MnSO_4$, and 2 kg $ZnSO_4$. In Alata various Zn and Mn treatments also affected the Mn content of the leaves significantly at all three periods, the highest increase being obtained from 5 kg $ZnSO_4$ + 3 kg $MnSO_4$, then by 3 kg $MnSO_4$, 2 kg $ZnSO_4$ + 1 kg $MnSO_4$, respectively. $ZnSO_4$ alone had no significant effect on the Mn content of leaves.

TABLE 4
EFFECTS OF VARIOUS ZN AND MN TREATMENTS ON ZN AND MN CONTENTS OF LEMON LEAVES (ALATA)

Treatments	Zn (ppm)			Mn (ppm)		
	May	August	November	May	August	November
Control	13.20a*	11.60a	11.00a	12.75a	12.10a	12.52a
2 kg $ZnSO_4$	12.50a	13.56a	16.40b	11.60a	12.40a	14.05a
5 kg $ZnSO_4$	16.70b	20.12c	23.10c	13.49a	12.70a	13.72a
2 kg $ZnSO_4$+ 1 kg $MnSO_4$	15.10b	15.90b	16.95b	15.60b	16.20b	16.90b
5 kg $ZnSO_4$+ 3 kg $MnSO_4$	18.30c	22.20c	27.50d	16.50b	17.90c	19.36b
1 kg $MnSO_4$	12.40a	11.70a	12.00a	14.40a	15.40b	15.90b
3 kg $MnSO_4$	13.30a	12.40a	12.30a	15.10b	16.30b	17.71b
Significance	†	†	†	†	†	†

*Differences are significant at the 99 per cent level if there are no subscript letters in common.
†Significant at the 95 per cent level.

TABLE 5
EFFECTS OF VARIOUS ZN AND MN TREATMENTS ON ZN AND MN CONTENTS OF LEMON LEAVES (LAMAS)

Treatments	Zn(ppm)			Mn (ppm)		
	May	August	November	May*	August	November
Control	12.30	12.96a†	11.50a	10.46	10.08a	9.15a
2 kg $ZnSO_4$	16.80	20.77b	19.40b	11.02	10.88a	9.86a
5 kg $ZnSO_4$	12.16	32.71c	30.42c	9.98	10.06a	9.30a
1 kg $MnSO_4$	12.30	12.62a	11.30a	10.70	20.86b	18.70b
3 kg $MnSO_4$	12.56	11.97a	11.06a	10.50	38.79c	34.36c
Significance	NS	‡	‡	NS	‡	‡

*May leaf samples taken before applications.
†Differences are significant at the 99 per cent level if there are no subscript letters in common.
‡Significant at 95 per cent level.
NS = not significant at 95 per cent level.

In Lamas also, the various Zn and Mn treatments increased the Mn content of leaves significantly in two periods (August and November), the highest increases being obtained by the application of 3 kg $MnSO_4$ and the next highest by 1 kg $MnSO_4$. Both the 5 kg $ZnSO_4$ and the 2 kg $ZnSO_4$ treatments were ineffective. In Lamas the effects of various Zn and Mn treatments in May were not determined. The leaf samples having been taken prior to application.

The effects of various Zn and Mn treatments applied in Alata and Lamas on the development of rumpled fruits are summarized in tables 6 and 7, respectively. There was a close relationship between Mn application and the number as well as weight of rumpled fruits. However, in Alata rumpled fruits were reduced from 11.47 to 0.02 per cent and in Lamas from 18.43 to 0.51 per cent by the application of 3 kg $MnSO_4$. These results show that under our experimental conditions Mn deficiency especially was responsible for the development of rumple, and that application of 3 kg $MnSO_4$/1000 liters H_2O was the most

TABLE 6
EFFECTS OF VARIOUS ZN AND MN TREATMENTS ON THE DEVELOPMENT OF RUMPLE IN LEMON FRUITS (ALATA)

Treatment	Yield (kg/tree)	Per cent of rumpled fruit	Weight of rumpled fruit (kg)	Per cent of total rumpled fruits showing second stage symptoms
Control	146.29	11.47c*	12.78b	10.56
2 kg $ZnSO_4$	124.87	2.13b	1.45a	2.68
5 kg $ZnSO_4$	125.71	2.67b	1.82a	6.43
2 kg $ZnSO_4$+ 1 kg $MnSO_4$	142.86	2.06ab	2.41a	6.25
5 kg $ZnSO_4$+ 3 kg $MnSO_4$	126.00	2.74b	2.85a	2.34
1 kg $MnSO_4$	140.63	1.74ab	0.81a	2.08
3 kg $MnSO_4$	142.00	0.02a	0.00a	0.00
Significance	NS	†	‡	NS

*Differences are significant at the 99 per cent level if there are no subscript letters in common.
†Significant at the 99 per cent level.
‡Significant at the 95 per cent level.
NS = not significant.

TABLE 7
EFFECTS OF VARIOUS ZN AND MN TREATMENTS ON THE DEVELOPMENT OF RUMPLE IN LEMON FRUITS (LAMAS)

Treatment	Yield (kg/tree)	Per cent rumpled fruit	Weight rumpled fruit (kg)	Per cent of rumpled fruits showing second stage symptoms
Control	54.00ab*	18.43b	20.56b	34.20b
2 kg $ZnSO_4$	35.80a	13.43ab	2.82ab	11.59ab
5 kg $ZnSO_4$	87.00b	13.27ab	14.98ab	23.25ab
1 kg $MnSO_4$	53.80ab	13.84ab	9.13ab	23.18ab
3 kg $MnSO_4$	46.80ab	0.51a	0.00a	0.00a
Significance	†	†	‡	‡

*Differences are significant at the 99 per cent level if there are no subscript letters in common.
†Significant at the 99 per cent level.
‡Significant at the 95 per cent level.

effective treatment. Application of 3 kg $MnSO_4$ both in Alata and Lamas reduced the number of rumpled fruits to a minimum. In contrast, no satisfactory results were obtained from low-level manganese or low-level zinc plus manganese applications.

Close relationships existed between Mn applications and the percentage and weight of rumpled fruits. At Alata and at Lamas, very high correlations, ($r = 0.713 \pm 0.150$**) and ($r = 0.657 \pm 0.209$**), respectively, were found between the amount of Mn applied and the percentage of rumpled fruits. With respect to weight, correlations were also high, being (r=0.702 $\pm$0.152**)and(r=0.741$\pm$0.186**),respectively. Fig. 6 shows similar results when Zn was added to Mn applications. The same rate of Mn (3 kg $MnSO_4$) was more effective in Alata than in Lamas, there being 0.02 per cent rumple in Alata and 0.51 per cent in Lamas. This difference could be related to the physiological balance of the trees. In Alata, because of better growth conditions, the physiological balance of the trees may have been better than in Lamas.

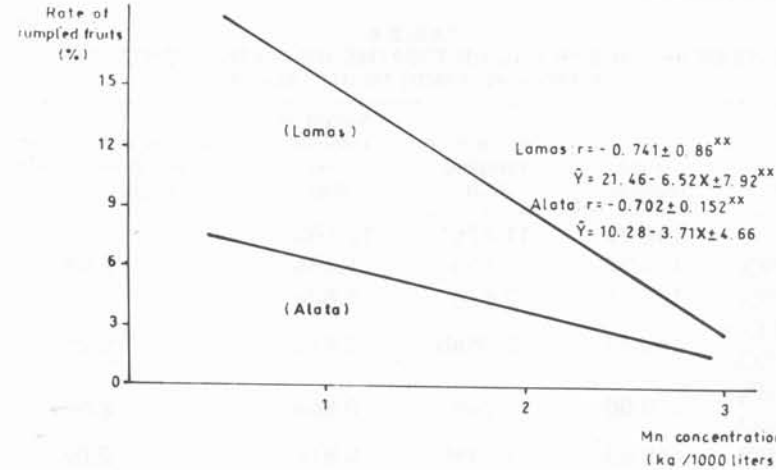

Fig. 6. The effect of various Mn (plus Zn) applications on the percentage of rumpled fruit in two regions.

TABLE 8
EFFECTS OF RUMPLE DISEASE ON THE POMOLOGICAL PROPERTIES OF LEMON FRUIT

Characters	Healthy fruit	Rumpled fruit	Significance
General fruit quality (per individual unit)	– 5.04	+ 5.04	NS
Weight (g)	100.19	107.60	NS
Size (mm)	54.41	56.23	NS
Length (mm)	71.29	70.23	NS
Index	0.766	0.800	NS
Peel Thickness (mm)	4.95	4.87	NS
Seeds (number)	5.43	6.42	NS
Juice (per cent)	24.86	25.16	NS
Acid (per cent)	8.62b*	7.71a	†
Soluble solids (per cent)	10.47b	9.27a	†

*Differences are significant at the 99 per cent level if there are no subscript letters in common.
†Significant at the 95 per cent level.
NS = not significant.

The effects of rumple on the pomological characteristics of the fruits are shown in table 8. With the exception of soluble solids and acid, pomological characteristics were not significantly affected by rumple.

DISCUSSION

Comparatively few investigations have been conducted on the causal factors of rumple disease or its effective control and the results obtained earlier were inadequate to solve the problem. For instance, Russo and Klotz (1963) and Salerno (1963) suggested that soil and climatic conditions may cause rumple, Scaramuzzi (1965), Salerno (1965), Salerno and Continella (1967), Salerno *et al.* (1968), and Klotz (1973) suggested that various macronutrient imbalances might be responsible for this disease.

The results of our investigations in two important lemon producing centers in Turkey show clearly that under our experimental conditions manganese deficiency was especially responsible for development of rumple and that 3 kg $MnSO_4$ per 1000 liters H_2O was the most effective treatment. Statistical data showed high correlations between high rates of Mn application and the percentage as well as the weight of rumpled fruits of the Kut Diken lemon variety. The results of previous investigations by Ozbek *et al.* (1974) on diagnosis and correction of micronutrient deficiencies in important lemon varieties in the Mediterranean region of Turkey were confirmed.

We must point out that these results are preliminary and that these investigations will continue until more information leading to the effective control of rumple is obtained.

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