The revival of land

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"...It was a prosperous region with fertile fields and flowering gardens, deep, teeming with fish rivers and forests abound in game. But a terrible calamity befell upon the country. It was bewitched by a wicked magician who neither annihilated the people nor deprived them of their riches, but turned the land into a desert. Over the years, people forgot how grass grows, trees blossom and forests rustle. Children did not know the smell of flowers, singing of birds and murmuring of streams.

Once upon a time an old man came to the tzar. He was also a magician but a good one. He said: "I shall save the country from this calamity!"

Then, as the legend goes, the magician climbed up a high mountain, bowed to the four sides of the world, whispered the words of invocation and... trees blossomed out in the desert, tender grass shot in the meadows, a green haze of vineyards curled on the mountain slopes, streams began to murmur and birds started their songs"

About which mysterious lands does this legend narrate? Perhaps, about Mesopotamia — one of the flourishing states of the Ancient East which mysteriously rapidly fell into decline. There are evidences that growing soil salinity played an important part in the breakup of this state. However, salinization and especially soda salinization of soils is still a great calamity for the agriculture of many countries of the world. According to the FAO data, no less than 50% of the world's irrigated soils are affected by salinization.

Soda solonetzes-solonchaks occupy vast areas in India, Pakistan, Iran, almost in all countries of Africa, and especially in Egypt, in North and West China and in Mongolia. Such soils are spread in Australia, Canada and the USA (particularly, near the Great Lakes and in Central California), in Mexico, Brazil, Venezuela, Chile, Uruguay and Argentina. Solonetz and solonchak soils are not infrequent in Hungary, Rumania, Bulgaria, Yugoslavia, Czechoslovakia and Spain.

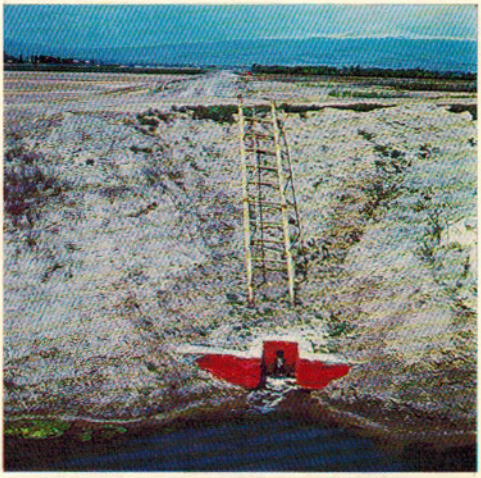
In the Soviet Union, soda-saline soils are spread on the alluvial plains of Eastern and Western Siberia, in Yakutia, Transbaikal area, in the Urals area, in Moldavia, Ukraine, Georgia, Azerbaidjan and Armenia.

The Armenian Upland... Magnificent scenery: snow-clad mountains with peaks towering in the clouds, fast-flowing silvery rivers and streams winding their way through deep canyons and flumes, small lakes of unbelievable beauty amid mountain sides.

Mountain topography makes Armenia short of agricultural lands accounting for only 46% of its territory and comprising 18.3% of arable lands, 26% of haylands and pastures and 1.7% of vineyards and orchards. About two-thirds of arable lands are situated on stony slopes and occur in small patches.

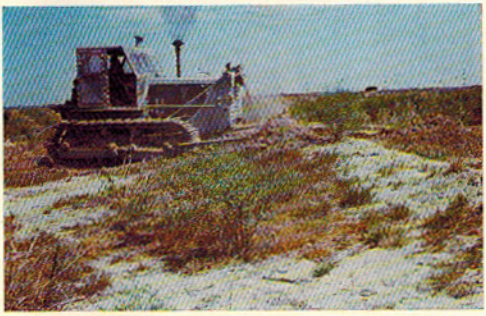
How hard working, patient and skilled should the Armenian peasant be in order to till these lands and to raise crops! Only on the left bank of the Arax River abundant yields of fruit, grapes, vegetables, as well as guard, cereal and industrial crops are obtained in large land areas due to favourable natural conditions. But even here nature could not but play insidious tricks: the cultivated fields are wedged by considerable areas of barren lands affected by the most malicious soda salinization and, therefore, extremely difficult to reclaim.

Soda solonetzes-solonchaks in the Ararat Plain



Closed horizontal drainage

Vertical drainage providing pumped water for irrigation



Cutting knolls and shrubs by C-100 bulldozer

Primary soil levelling by Д-20Б grader

Salt accumulation and solonetz soil formation in the Ararat Plain are caused by a number of historically shaped natural, social economic and technological factors. Infiltration waters from the tremendous catchment area of various vertical bioclimatic belts, whose salinity increases on their way from the area of formation to the zone of discharge, discharge in the Ararat Plain. The chemical composition of these waters changes depending on the geologic structures and substance composition of rocks. Waters circulating through andesite-basalt rocks of bicarbonate-sodium composition get enriched in these salts and acquire an alkaline character of salinity.

In the conditions characterized by shallow groundwater, an impeded groundwater outflow and exudational water regime the capillary rise of salts and evaporation result in the salinization of soils and formation of solonchaks. In the aeration zone, sodium bicarbonate transforms into sodium carbonate and soils, enriched with sulphates and chlorides, acquire soda salinity with a high content of absorbed sodium and pH 9.0—11.0.

The above-stated peculiar features of soil salinization in the Arax River basin are responsible for the specific geochemical characteristics of these soils and domination of soda-salinization processes. Saline soil loses its productive capacity, flora and fauna grow scanty, moisture evaporates intensively from the unprotected by vegetation surface of soil, groundwater reserves are spent unproductively, the air gets dry and the green apparel of the plain is changed by witish-dirty spots as if it has been affected by tetter.

"Soil-pox or ailment that requires treatment" — thus solonchaks were figuratively described by V. V. Dokuchaev, the founder of home soil science. And this problem of solonchaks treatment has become one of the most urgent in the modern agriculture.

But it is not an easy task to cure them. From the reclamative view point alkaline

soils are known to be difficult to develop. Even though such soils occupy vast areas they are insignificantly reclaimed and used in agriculture. Natural peculiarities of such soils hamper their reclamation.

The strongly alkaline reaction of these soils caused by the presence of soda and domination of exchangeable sodium in the composition of absorbed cations is responsible for their alkalinity, hydrophility, swelling of colloids and rather negative water-physical properties. By inactivating calcium and magnesium bicarbonates contained in the soil solution, the alkaline reaction of the medium reduces their reclamative effect. The soils become practically impermeable which excludes their desalinization by leaching without preliminary chemical amelioration.

Depending on the soil-hydrogeological conditions and the technologic-economic potential of each country, the following specific methods for reclaiming soda-saline soils have been developed and applied, viz. agrotechnical, biological, phytotechnical, electrotechnical, chemical. The first two are employed mainly for the improvement of solonetz soils under dry farming conditions and involve various tillage techniques ensuring the utilization of intrasoil calcium compounds for the self-reclamation of soils with a subsequent sowing of relatively salt-tolerant crops-ameliorants. In some countries such soils are improved through the application of manure, straw, ploughing in of greenmanure crops, sanding and earthing.

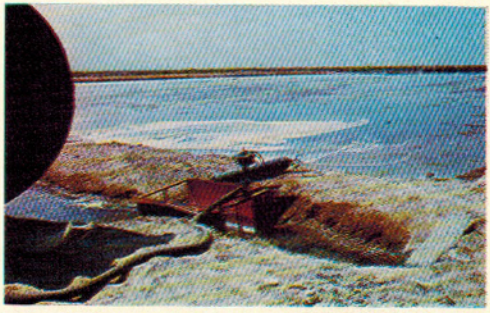
The method of electric reclamation as well as application of synthetic soil conditioners have not yet found practical employment and are still being investigated.

The following substances are extensively applied for the chemical reclamation of saline soils: gypsum, gaja, chalk, industrial wastes containing phosphogypsum, calcium chloride, defecate, etc.

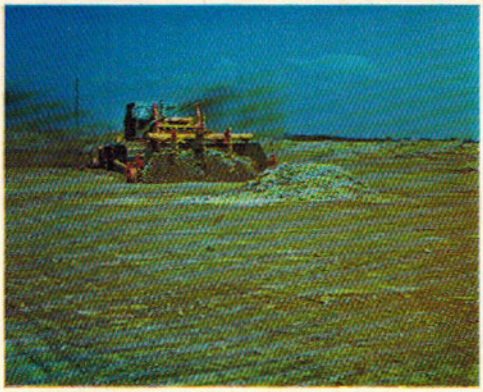
Gypsuming in combination with various biological and agrotechnical practices is most extensively used in the Soviet Union

Soil levelling by П-4 leveller

Making protective mounds by ВУ-0,7 mound-making machine



Waste sulphuric acid supply to the field through an automatic metering device securing its concentration



Broadcasting green vitriol over the soil surface by a rotor broadcaster

Green vitriol ploughing into soil

Soil leaching following an ameliorant application

and in the majority of foreign countries for reclaiming the salt-affected soils. Practically all methods have been tested in Armenia, but without success.

Even though application of gypsum to alkaline solonetzes-solonchaks with a high content of absorbed sodium gives some positive results, due to low solubility of gypsum its influence is extremely slow and often ineffective. Moreover, gypsuming increases the leaching requirement.

In Armenia positive results have been obtained through the application of waste sulphuric acid as an ameliorant for soda-saline soils which brings about the neutralization of soda and formation of sodium sulphate. While interacting with the soil absorbing complex, the sulphuric acid hydrogen replaces sodium which also results in the formation of secondary sodium sulphate. The coagulation of hydrophilic colloids sharply reduces soil dispersity thus increasing the filtrational capacity and water permeability of soils.

Apart from the neutralization of the alkaline medium, acid solutions in the zone of their penetration decompose magnesium and calcium carbonate compounds and contribute to the formation of easier soluble calcium compounds (in the form of finely dispersed gypsum differing from soil (natural) gypsum by high dispersity and activity) and, partly, calcium bicarbonates which also replace exchangeable sodium from the absorbing complex of soil. An increase in the content of calcium cations changes the ionic composition of soil solutions which improves both the physical properties of soil and the nutritive regime of plants.

The decomposition of calcium and magnesium carbonate compounds is accompanied by the release of carbon dioxide which partly volatalizes in the air and is partly absorbed by leaching water thus increasing solubility of calcium and magnesium carbonates. The formed ions also participate in soil reclamation. Combining with the replaced exchangeable sodium, part of the bi-

carbonate ions form soda which is easily removed from the soil in the course of leaching.

In comparison with other chemical reagents applied in practice, the positive reclamative effect of sulphuric acid is achieved over extremely short periods of time.

The sulphuric acid application for soil reclamation is called "acidification".

Green vitriol — a by-product of mining industry is also extensively used for developing the solonetzes-solonchaks in the Ararat Plain. The reclamative effect of green vitriol is based on its ability to form sulphuric acid and ferrous hydroxide in the course of acid hydrolysis. When interacting with sodium, calcium and magnesium carbonates and bicarbonates, the free sulphuric acid neutralizes the alkaline reaction of solution; calcium of the newly formed gypsum replaces sodium from the soil absorbing complex thus ensuring the dehydratation of soil colloids.

Ferrous hydroxide and carbon dioxide form ferrous oxide hydrocarbonate whose cation replaces sodium from the soil absorbing complex. Moreover, green vitriol participates directly in the chemical reactions with sodium, calcium and magnesium carbonates and bicarbonates which results in the formation of iron carbonates and bicarbonates and sulphates including gypsum. Sodium sulphates and part of calcium are removed from the soil during subsequent leaching operations, whereas the newly-formed gypsum and magnesium sulphate participate in the exchange reactions with soil and contribute to its dealkalinization. The soil aggregation increases due to the coagulating influence of iron ions. The reclamative effect of green vitriol, like that of sulphuric acid, manifests itself over short periods of time.

The process of green vitriol application is conditionally called "ironing".

The method for developing soda solonetzes-solonchaks by the application of by-products of chemical and mining industries which has been developed by the Research

Winter wheat

Alfalfa

Watermelons

Rose pelargonium

Harvesting of early potatoes

Tomatoes

Pepper

Institute of Soil Science and Agricultural Chemistry, Ministry of Agricultural of the Armenian SSR has been applied on the production scale since 1963. The reclamation of solonetzes-solonchaks in the Ararat Plain is effected by a specialized Reclamation Trust. The technology of soil development envisages a combined implementation of the following measures:

— Construction of drainage-irrigation system.

— Capital levelling of lands and their preparation for the application of ameliorants.

— Ridging of leaching checks.

— Chemical reclamation and leaching.

— Agricultural development.

Chemical reclamation is preceded by the construction of a drainage-collector and irrigation system.

Closed horizontal or vertical drainage is employed depending on the hydrogeological conditions and degree of water permeability of rocks.

In the conditions of head groundwater most advantageous is the construction of a combined horizontal and vertical drainage. This combination of different types of drainage provides for maintaining the precalculated lowering of the groundwater table and rational utilization of water resources. Vertical drainage fails to remove the leached salts beyond the territory under development in a short space of time. This is successfully done by horizontal drainage laid at a depth of 3.0—3.5 m. The role of drainage is not limited to lowering of the groundwater table and creating the conditions needed for leaching operations. It must also provide for the desalinization of the lower layers of subsoils and freshing of groundwater.

To achieve a rational utilization of the pumped groundwater all vertical drainage wells are connected by a network of closed pipelines with the irrigation systems thus making it possible to use drainage water for leaching and irrigation during the en-

tire growing period. Upon the termination of the leaching and irrigation season, the operation of vertical drainage wells is suspended and the closed horizontal drainage successfully maintains the groundwater table at a given depth.

Capital levelling of the reclaimed territory is very significant for developing saline lands. A qualitative levelling creates favourable conditions for a uniform distribution of acid solutions and dry ameliorants on the soil surface and for their subsequent uniform absorption by the soil thickness in the course of leachings.

To promote a more rapid penetration of acid solutions, the soil, prior to the application of sulphuric acid, is "slitted" or deeply mellowed and the checks are banked with protective mounds.

When applying green vitriol, it is uniformly broadcast on the field surface and then plowed in the top layer of soil which is subsequently leached.

The required amounts of chemical ameliorants needed to neutralize the alkaline medium and to replace the absorbed sodium are calculated from a special formula devised by the Institute on the basis of experimental data.

The necessary concentration of sulphuric acid (0.8—1.0%) is achieved by diluting it with irrigation water with the aid of an especially designed automatic metering device.

The leaching requirement is determined taking into account the particle-size distribution of soil and character of salinity; the depth, salinity and head of groundwater as well as the amounts of ameliorants to be applied to the soil. It is calculated from the well-known V. A. Kovda's formula partly modified in accordance with the salt distribution in the soil profile.

Chemical reclamation results in a complete neutralization of soda. The total amount of salts in the one-meter-thick layer of soil decreases to 0.2—0.3% and the con-

Keeping soil fallow in the inter-row spacings of fruit-tree plantings

Slag mulching of inter-row spacings in fruit-tree plantings

Inter-rows of fruit-tree plantings shaded by alfalfa

Furrow irrigation of fruit-tree plantings

Flooding irrigation of fruit-tree plantings

tent of water-soluble sodium drops to 3—4 meq.

The land allocation for agricultural development can be withheld until a complete freshing of soil to bring it to the condition of old-irrigated soils of this zone. However, leaching is known to have an attenuating character: the removal of every new tonn of salts requires greater volumes of water which is not profitable under an acute water deficit.

During the first stage of agricultural development of soil it is sufficient to decrease the salt concentration below the threshold of toxicity to plants and to accomplish further soil improvement on the background of crop cultivation by applying a complex of measures preventing the capillary rise of salty groundwater, moisture evaporation from the soil surface and salt accumulation in the root zone. This is achieved by growing winter wheat in the first year of agricultural development of soil followed by 3—4 years of alfalfa cultivation.

The application of an ameliorant starts in spring and soil leaching terminates by autumn. Winter wheat, serving as edificator, is sown the same year. The status of crop is indicative of the quality of reclamation. If necessary, the detected reclamation blemishes are eliminated upon harvesting.

Establishment of the optimum irrigation regime and practices is one of the major components in the complex of agrotechnical measures ensuring further improvement of the reclamative status of soil.

Application of irrigation norms exceeding the water-retaining capacity of the soil cropped to winter wheat and then to alfalfa makes it possible to achieve further desalinization of the soil profile and to remove salts which remained after the radical reclamation. The downward movement of water ensures the salt discharge with drainage waters beyond the territory being reclaimed. In the conditions of good shading of soil (sown to the above-mentioned crops) the

leaching regime is preserved requiring by far smaller amount of water.

Depending on the salt content of soils, waterings during the first years of agricultural development are applied when moisture of soil equals 80% of the total moisture capacity which by 25—30% and in certain conditions by up to 50% exceeds the calculated irrigation norm.

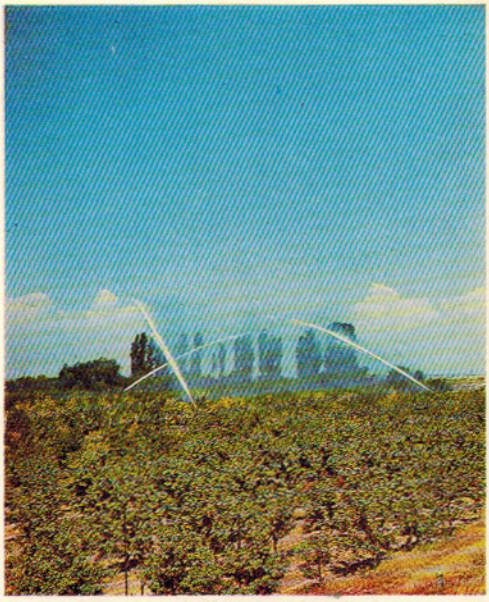
The irrigation practices applied are of great significance. During the first years of agricultural development furrow irrigation of reclaimed soils does not ensure a uniform leaching of the remaining salts from the irrigated territory due to the redistribution of salts on the bottoms and crests of furrows. Even though sprinkling irrigation provides for a uniform distribution of water over the soil profile, it is not economically advantageous owing to the sharply increased irrigation norms and intensive evaporation.

The most uniform freshing of soil is achieved by flooding irrigation of bands 5—6 m wide and 150—200 m long.

Sprinkling and furrow irrigation is employed after a complete desalinization of soil.

With a view to increasing the efficiency of the irrigation system preventing an unproductive expenditure of water on infiltration and uplifting the groundwater table, a modern irrigation system has been constructed on 200 ha of the reclaimed soils at the Institute's experimental station. Fruit tree plantings and vineyards in an area of 26 ha are irrigated by a stationary sprinkling system equipped with DD-30 hydraulic sprinklers. 62 ha of alfalfa and winter wheat are irrigated by "Volzhanka" sprinkling machine.

The rose pelargonium plantations are irrigated by sprinklers using the head water from a vertical drainage well. To the rest of the territory water is supplied through reinforced concrete chutes. The seepage of water from the irrigation systems and subsequent overloading of drains are practically excluded.



Sprinkling irrigation of fruit-tree plantings

Irrigation of rose pelargonium by a sprinkler using head groundwater from a vertical drainage well

Alfalfa irrigation by „Volzhanka" sprinkling machine

Fruiting apple-tree with palmetta training

Thus, the correct alternation of crops combined with the optimum regime and method of irrigation on the background of appropriate agricultural practices provide for a complete desalinization of soil during 4—5 years since the beginning of agricultural utilization of the reclaimed soils.

Upon the achievement of the predetermined level of freshing, the soils are sown to vegetable-guard, rose pelargonium and fruit-grape crops.

The success of chemical reclamation is stipulated by the improvement of the main physical and water-physical properties of soil by increasing the number of water-stable aggregates and especially microaggregates.

The water permeability of solonchaks being equal practically to zero, amounts, upon the application of an ameliorant, to 0.28—0.40 mm/min and this parameter approaches that of old-irrigated soils.

The root zone of the reclaimed soils is characterized by a decreased apparent density and specific weight of soil, a reduced maximum hygroscopic humidity and an increased field moisture capacity. These favourable changes evidence a higher degree of cultivation of the reclaimed soils.

Chemical reclamation sharply changes the content and availability of nutrients. The sulphuric acid applied to the soil promotes the transfer of hardly available phosphorous compounds into the easily soluble ones.

The reclaimed soils of the Ararat Plain are well supplied with mobile forms of phosphorus, potassium and trace elements: the crops being raised over 10—15 years after reclamation of these soils do not respond to their additional application.

After reclamation the content of available nitrogen is extremely low and the reclaimed soils require an annual application of nitrogen fertilizers.

The quantitative and qualitative composition of microorganisms and the intensity of microbiological and enzymatic processes undergo significant changes during the pro-

cess of solonchaks reclamation and their agricultural development. The microbiological and enzymatic activity increases with the desalinization of soils which reflects vividly the degree of soil freshing and cultivation.

Our experience shows that high economic efficiency of the development of solonchacks is ensured only by a complex reclamation. A solonchak gets reclaimed and retreats as a result of a frontal offensive involving a complete complex of hydrotechnical, soil and chemical-reclamative, agrotechnical and biological measures. Only this approach guarantees effective reclamation of soils and high yields of the cultivated crops.

The revived soils produce 300—350 metric centners of rose pelargonium, watermelons, tomatoes, apples and pears, 150—160 metric centners of early potatoes, 100—120 metric centners of alfalfa and grapes and 45—50 metric centners of winter wheat per hectare. Depending on the intensity of crop cultivation, all investments on the reclamation of soda solonetzes-solonchaks and their agricultural development are repaid during 3—6 years.

High-quality sweet wines distinguished by their intensive colour, pleasant taste and flavour are produced from the grape grown on the reclaimed soils.

Chemical reclamation promotes the revival of soils and restoration of their favourable properties which condition the soil fertility. Land again gives agricultural produce.

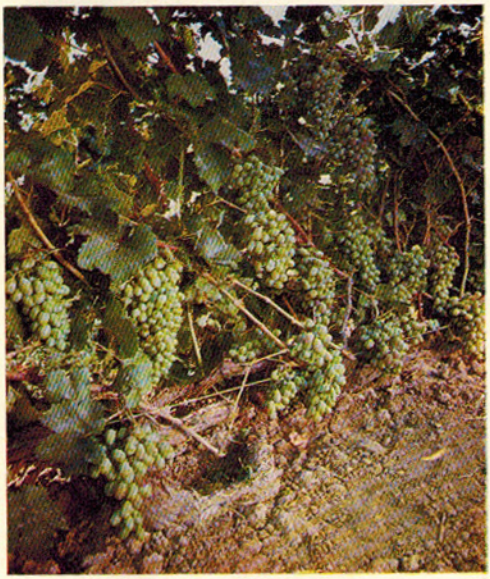
Some investigations are carried out in collaboration with the Research Institute of Water Management and Hydraulic Engineering, Research Institute of Mechanization and Electrification of Agriculture, and other research establishments.

The method of development of soda solonetzes-solonchaks elaborated and proposed by the Armenian scientists has won wide recognition among scientists in many countries of the world.

Fruiting pear-tree with palmetta training

Plum-tree

Vineyard



Fruiting grapevines

The scientific consultant of this problem is Corresponding Member of the USSR Academy of Sciences, Prof. V. A. Kovda.

Sweet wines produced from the grapes grown on the reclaimed soils

Photographs by G. Shakarian

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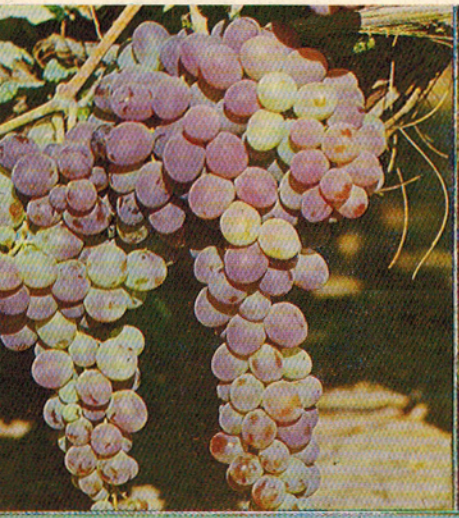

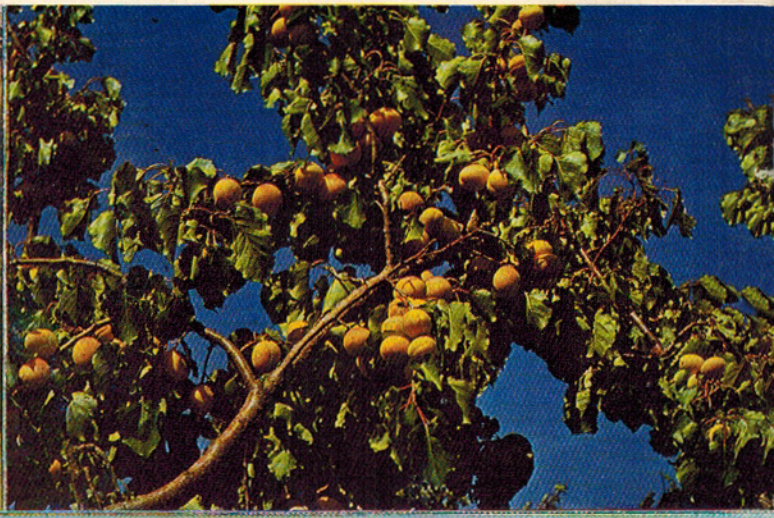

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