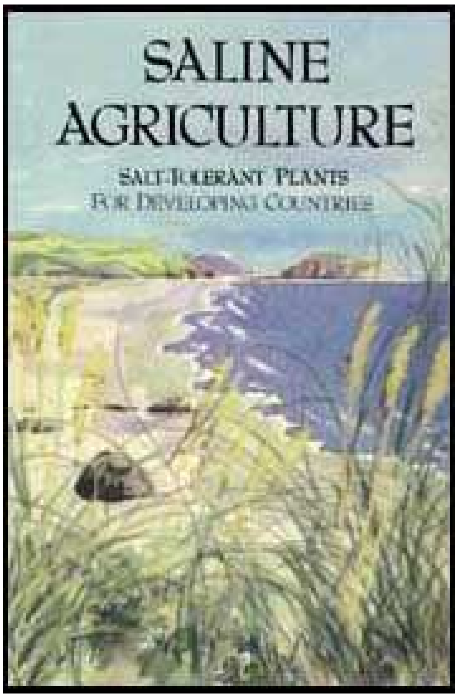

Introduction

Halophytes have been used as forage in arid and semiarid areas for millennia. The value of certain salt-tolerant shrub and grass species has been recognized by their incorporation in pasture improvement programs in many salt-affected regions throughout the world. There have been recent advances in selecting species with high biomass and protein levels in combination with their ability to survive a wide range of environmental conditions, including salinity.

Trees and shrubs can be valuable components of grazing lands and can also serve as shelter and complementary nutrient sources to grasses in arid and semiarid areas. Their deep roots serve as soil stabilizers and nutrient pumps and can lower saline water tables.

Trees can provide shade for livestock and shrubs can be used as living fences. Leguminous species improve soil quality by fixing nitrogen.

In arid and semiarid zones, trees and shrubs have several advantages over grasses as fodder. They are generally less susceptible to seasonal variation in moisture availability and temperature, and to fire. Usually less palatable than grasses, they can provide reserve or supplementary feed sources.

In Africa, about 60 percent of the meat production and about 70 percent of the milk production is from arid and semiarid environments. It is here that pastures are most severely degraded and where the planting of trees and shrubs may be most helpful. The use of salt-tolerant species in pasture improvement may allow the use of brackish water for irrigation.

In this section, salt-tolerant grasses, shrubs, and trees with potential for fodder use are described.

Grasses

Kallar Grass

Kallar grass (Leptochloa fusca) is a highly salt-tolerant perennial forage that grows well even in waterlogged conditions. Its deep roots help open hardened soils and harbor nitrogen-fixing bacteria. It recovers well from grazing and can also be cut for hay. Pastures can be established from seed, but the use of rooted slips or stem cuttings yields better results.

Kallar grass is widespread in tropical and southern Africa, the Middle East, and Southeast Asia. Although largely indifferent to rainfall levels, it does require almost constant moisture for its roots. It grows best in waterlogged soils, lake or river margins, and on seasonally flooded flats.

In Pakistan, March is the favored time for planting. A reasonable stand of grass develops in a month, with maximum yields during July and August, the monsoon season. Five cuttings can be obtained during the year with a total yield of about 40 tons of green fodder. Even during the winter months (November through February) when the growth of grass is retarded, a single cutting can yield 3 tons per hectare. Even this low yield is valuable in salt-affected areas where winter fodder is scarce. The grass appears palatable to sheep, goats, buffalo, and cattle.

The qualities that allow kallar grass to grow well under adverse conditions also contribute to its ability to compete well in rice fields and in irrigation canals as a weed.

Silt Grass

Silt grass (Paspalum vaginatum) occurs naturally on muddy seacoasts, in tidal marshes, and brackish sandy areas of tropical and subtropical regions. Either erect or prostrate, it has tough, creeping roots and forms dense mats. Once well established, it serves as a useful pasture grass, especially in bog and seepage areas that stay wet with salty water. Although quite suitable for grazing, it dries slowly and turns black when cut for hay. It has been grown with water containing 1.4 percent salts where ample water was applied for leaching to avoid salt accumulation.

This grass has been found in coastal areas of the West Indies, Belize, Costa Rica, Panama, Venezuela, Guyana, Brazil, Ecuador, Chile, and Argentina in the Western Hemisphere as well as in tidal swamps in Senegal, Sierra Leone, and Gabon. It is widely used for revegetation in saline seepage areas in Australia.

The best means of propagation is through roots, runners, or sod; seeding is not effective.

The grass is sensitive to herbicides. Since sheep crop the grass closely and prevent runners from colonizing, grazing protection must be provided until bare areas are covered.

Russian-Thistle

Russian-thistle (Salsola iberica) is a salt-tolerant annual common in the western United States. It is well adapted to survive under drought conditions, requiring only about half as much water per unit of dry matter produced as alfalfa. The crude protein content of Russian-thistle is in the 15-20 percent range and the amino acid composition of this protein is quite similar to that of alfalfa. In a study in New Mexico (USA), biomass yields of 10 tons per hectare were demonstrated.

Although salinity tolerance at germination is low, seedlings tolerate brackish water well, and this exposure seems to improve salinity tolerance in the later vegetative and reproductive stages. Moderate salinity levels resulted in improved yields. Table 11 shows some of these data.

Salsola may also find use as an energy crop. The energy content of field-dried Salsola is comparable to lignite. It has been successfully compressed into pellets for use as boiler fuel.

Saltgrasses

Distichlis spicata is used as forage for cattle near Mexico City. Grown on 20,000 hectares of salt flats, this may represent the world's largest area devoted to an introduced halophyte.

There are distinct seashore and inland ecotypes; the seashore ecotype has been grown with water twice as salty as seawater.

TABLE 11 Yield and Moisture Content of Salsola iberica at Five Salinity Levels. (Saline irogation was initiated six days after planting; harvest was 64 days after planting.)

Irrigation	**Fresh**	**Dry**	**Moisture**
Salinity (dS/m)	**Weight(g)**	**Weight(g)**	**Content(%)**
1.3	921.4	179.6	80.7
10.5	1,217.0	279.8	77.1
18.2	972.8	222.4	77.2
26.7	625.6	131.4	79.0
33.2	386.6	75.0	80.7

SOURCE: Fowler et al., 1985.

Another variety of Distichlis developed by NyPa, Inc. has growth rates and nutrient characteristics similar to those of alfalfa. Yields of 20 tons per hectare (dry matter) have been reported using irrigation water containing 1-2 percent salts. A perennial that can tolerate both waterlogging and long periods of drought, it appears suitable for use in many hot arid areas where saline water is available for irrigation.

Channel Millet

Channel millet (Echinochloa turnerana) is an uncultivated, wild Australian plant. Its most significant feature is that in its native habitat it requires only a single watering to develop from germination to harvest. It is always found in silty clay that cracks deeply when dry and is subjected to sporadic flooding. Sites may remain dry for years, but when flooding occurs growth is abundant. The seed will not germinate after light rains; deep flooding is required.

Channel millet grows almost exclusively in the so-called "Channel country" of Queensland in inland Australia, where it is recognized as a productive, palatable, and nutritious fodder grass. The grain is consumed by cattle, horses, and sheep. In addition, the leaves, calms, and seedheads are eaten by livestock and the whole plant makes excellent hay.

Little is known about the agronomy of channel millet; few attempts have been made to domesticate it and there is little documented information on its botany, germination, growth, environmental requirements, and yield. Laboratory salinity testing indicated that a 50-percent reduction in grain yield occurs at 24 dS/m. Some species of Echinochloa are ruinous weeds in rice fields. The weediness of channel millet is unknown, but quarantine measures should be used in its testing to prevent inadvertent release.

E. crus-galli is reported to be a good fodder for cattle, with its grain fed in time of scarcity. E. frumentacea is grown as a quickmaturing (six weeks) food crop in India. Both are grown in Egypt on lands too saline for other crops.

Cordgasses

Members of the Spartina genus are tough, long-leaved grasses found in tidal marshes in North America, Europe, and Africa. These grasses have hollow stems (culms) and rhizomes.

The hollow stems allow air transport from the leaves to the roots during tidal inundation to maintain aerobic conditions in the root zone. Most Spartina species propagate vegetatively by means of spreading underground rhizomes, which grow new roots and buds. Seeds are a less important means of propagation for most species. These grasses survive salt water and saline soils by excreting salt through special glands in their leaves.

Spartina alterniflora (smooth cordgrass) is a tall (1-3 m), robust species that grows closest to the water line. It transplants well and can be seeded under some conditions. S. folioso (California cordgrass) is shorter (1 m) and produces less seed. It grows along the western coast of North America from California to Mexico. S. patens (salt meadow cordgrass) grows densely in marshes in the area of mean high water. S. patens has historically been used for grazing or cut for hay.

S. alterniflora tidal salt marshes are important nursery grounds and sources of nutrients for aquatic organisms. These marshes also provide food and habitat for wildlife, reduce shoreline erosion, and assimilate excess nutrients from pollutants such as sewage and agricultural drainage. Because of this, studies have been made of establishment methods and long term stability of man-made marshes. In North Carolina (USA), it was shown that, after four growing seasons, there was no difference in growth between a transplanted S. alterniflora marsh and an adjacent natural marsh. Biomass production of the two marshes was similar during the remainder of the ten-year study.

Rhodes Grass

Rhodes grass (Chloris gayana) has been grown in the United Arab Emirates to supply fodder for a rapidly growing livestock population. When irrigation water with a salinity level of 6,000 ppm of dissolved salts was used, the survival of seedlings dropped to zero. However, when the grass was started in a nursery and tufts transplanted to the field, normal growth was obtained with water containing a salt load of up to 15,000 ppm. Success was attributed to good soil drainage. No difficulties were encountered in areas with deep sandy soils.

In laboratory work with C. gayana, five successive generations were grown on sand irrigated with NaCl solutions up to 0.7 M (about 4.2 percent). The most successful survivors were found to have not only greater salt tolerance but an improved ability to withstand multiple harvests even at salt levels of about 2 percent.

Tall Wheat Grass

Tall wheat grass (Elytrigia [Agropyron] elongata) is native to southern Russia and Asia Minor where it grows in seashore marshes. It was introduced in Australia more than 50 years ago, where it has since been used for revegetating salted areas. A perennial, it is well adapted to poorly drained saline soils. Although it grows moderately well on saline areas that are permanently wet, best growth occurs where the soil dries out in the summer. Tall wheat grass can be established from seed. It germinates well but is slow to establish. Once a crown of stems develops near ground level, it can withstand moderate grazing.

Other Species

Sporobolus airoides, S. helvolus, and S. maderaspatanus are all grown on sandy and saline soils in India as fodder for horses and cattle. In Pakistan, irrigation of S. arabicus with 17 dS/m water gave yields of 3.9 kg per m2 per year. In recent tests, S. stapfianus demonstrated salt tolerance comparable to kallar grass.

Puccinellia dietans (North Africa) and P. ciliata (Australia) are fodder grasses highly tolerant to salinity. Puccinellia has been widely used on saline areas in Australia. The plant is an outstanding pioneer species on bare salted land. Seedlings grow slowly and establishment is most successful on bare areas where there is no competition from other plants and where there is protection from grazing. Crude protein contents of 4 percent and digestibilities of about 50 percent are common.

Hedysarum carnosum is a biennial fodder legume that occurs in eastern Algeria and Tunisia on saline clay soils. Native stands in southern Tunisia may yield 2,000-3,000 kg dry matter per hectare per year. Data on H. carnosum and other salt-tolerant Mediterranean basin forage grasses are shown in Table 12.

Shrubs

Although shrubs such as the saltbush (Atriplex) and bluebush (Maireana) occur widely on saline soils, their salt tolerance at germination is poor. Atriplex species have relatively narrow temperature ranges under which germination will occur. As the external salt concentration increases, the temperature range for germination narrows. When saltbush and bluebush species are sown on saline soils under natural rainfall conditions, there is a delicate balance between temperature and salinity levels and the germination and establishment of the seedlings. Such salt-tolerant shrubs may be started in nurseries before being planted in potential grazing areas, but this increases the cost of establishment significantly since it is usually less expensive to plant seed than seedlings.

The use of the Mallen Niche Seeder overcomes some of these problems. In one pass, the seeder performs the following functions:

· Creates two furrows to collect water next to the seed planting site;

· Forms a central ridge to raise the seed above the level of the surrounding area to reduce waterlogging and aid salt leaching;

. Molds a niche on the top of the ridge to give a sheltered depression for the seed and mulch and to collect rain; and

· Deposits seed and mulch in the niche at approximately 2 m intervals and sprays the mulch and seed with a black coating to raise the soil temperature.

TABLE 12 Fodder Grasses Growing on Salt-Affected Land in the Mediterranean Basin.

Frost			**Salt**
Species	**Rainfall1**	**Tolerance2**	**Tolerance3**
			EC dS/m
Non-Legumes			
(Perennial)			
Festuca elatior	400	G	20

(subspecies arundinacea)			
Elylrigia elongatum	300	G	20
Agropyropsis lolium	300	G	20
Pucciniella distans	200	G	20
Sporobolus tourneuxii	50	F	20
S. helvolus	50	F	20
Legumes			
(Annual & Biannual)			
Medicago ciliaris	400	F	10
M. intertexta	400	F	10
M. hispada	200	F	10
Hedysarum carnosum	150	F	30
Melilotus indica	300	F	10
M. alba	300	G	10
(Perennial)			
Trifolium fragiferum	400	G	15
Lotus creticus	150	P	10
L. corniculatus	400	G	10
Teragonolobus siliquosus	400	G	15

1. Minimum rainfall requirement in rnm/yr.

2. Frost tolerance G = good, F = fair, P = poor.

3. Maximum salt tolerance = electrical conductivity of soil saturation extract at 25°C,

SOURCE: Adapted from Le Houerou, 1986.

The seedbed shape, ridge height, and plant spacing can be adjusted for different soil and climatic conditions. In arid areas, the niche is made lower and wider to capture more water; in high rainfall areas, it is made narrower and higher to reduce the danger of waterlogging.

Although newly planted fields can usually be protected from stock animals, the seedlings are attractive to insects, rodents, and other small animals that are more difficult to exclude.

Atriplex

Saltbushes grow throughout the world. They tolerate salinity in soil and water, and many are perennial shrubs that remain green all year. They are especially useful as forage in arid zones. Atriplex nummularia, for example, grows well with only 150-200 mm annual rainfall.

Native stands of Atriplex produce about 0.5-4 tons of dry matter per hectare per year. Under rain-fed cultivation, about twice that amount may be obtained. When grown with irrigation, yields equivalent to those of conventional irrigated forage crops can be obtained. And the

Atriplex can be irrigated with saline water.

Nutritive values for A. nummularia and A. halimus are high. Both have digestible protein contents averaging near 12 percent of dry matter, about the same as alfalfa. In a year with only 200 mm of rainfall, these two species supported 1,000-1,500 feed units per hectare, about eight times better than a good native pasture under the same conditions. They also survived a year with only 50 mm of rainfall. Although A. nummularia has poor palatability, a palatable type has been selected in South Africa. It has been successfully introduced in North and South Africa and several South American countries.

A. canescens (four wing saltbush) is native to semiarid areas of North America where spring and fall rainfall patterns are typical.

Its nutritive value is as high as A. nummularia and it can be seeded in saline soil. Pasture with a mixed population of A. canescens and native vegetation sustained three sheep per hectare with 250 mm annual rainfall. A. canescens is also palatable to cattle.

In Israel and North Africa, a Mediterranean species, A. halimus, has proven hardier than A. nummularia or A. canescens. Although less palatable, it will grow in shallow soil and on slopes where other plants cannot survive. It does well with a winter rainfall of 200 mm but should be interplanted with more palatable species.

A. patula grows on higher ground and does not tolerate prolonged flooding or immersion in salt water. It has grown well when irrigated with 2.5-3.2 percent saline water, yielding 1.2 tons per hectare of seed with 16 percent crude protein.

A. polycarpa reportedly produces vegetative yields equivalent to alfalfa even when irrigated with water containing 3-4 percent salt. The protein content of A. polycarpa is about the same as alfalfa.

A. amnicola (formerly A. rhagodioides) is a spreading bush that can reach 4 m in diameter and 1 m in height. Prostrate branches take root to expand coverage. Mulch-covered seeds can be used for introductions in new areas. Once established, it tolerates grazing well. It is particularly suited for waterlogged conditions.

A. amnicola grazed in autumn provided 1,588 sheep-grazing days per hectare (average over 6 years) in a 350-mm rainfall zone of Australia. Heavy grazing failed to damage the stand and many new plants were established. Establishment of A. amnicola in saline soils is improved by using genotypes selected for their tendency to produce volunteer plants.

A. undulate, from Argentina, is in widespread use on salt-affected land in Western Australia.

Seeds are harvested mechanically and the bushes are established by commercial contractors using direct seeding. A. undulata is palatable to sheep, and when used as an autumn reserve feed, provided about 900 sheep-grazing days per hectare in a 300 mm rainfall zone. A. lentiformis, from the southwest United States, is included with A. undulata sowings on salt-affected soil in southwest Australia.

A. halimus has been grown irrigated with a nutrient solution containing 3.0 percent sodium chloride. Propagation of A. halimus is straightforward. Seedlings or cuttings are grown in a nursery for 3-6 months and then planted in the field in early spring, preferably after rain. In Israel, washed seed planted directly into moist soil established well. Grazing should be deferred for two or three years until the plants are about 1.5 m high.

The importance of long-term adaptation studies has been demonstrated in Iran, where extensive plantings of A. halimus and A. lentiformis suffer from a disease not found in their native habitats. In northeastern Iran, A. lentiformis is unable to regenerate from seed, apparently because of the high temperatures required for germination.

As part of an extensive evaluation of halophytes in Israel, seven Atriplex species were grown using 100 percent seawater irrigation. Results of these experiments are shown in Table 13.

Of these seven species, A. barclayana is outstanding both in terms of salt tolerance and biomass production. This species has been multiplied from vegetative cuttings to develop plantings for animal feeding trials. A. lentiformis also produces large quantities of biomass but has a tendency to become woody. It therefore has the potential for both fodder and fuelwood. A. lentiformis and A. canescens (subsp. linearis) have also given high yields (1.7+ kg per m2 per year) when grown with hypersaline (about 4 percent total salts) seawater in Mexico's Sonora Desert.

Mairiena

In Australia, there are many Mairiena species that are useful for grazing. Mairiena are small to medium woody shrubs with succulent leaves and winged, wind-disseminated fruits. In general, they occur in less waterlogged areas than Atriplex. M. brevifolia is widely grown in Western Australia. It is palatable, recovers well from grazing, and colonizes readily. It has crude protein levels ranging from 15 to 26 percent (dry basis), and serves as a nutritious forage for sheep.

TABLE 13 Annual Yield and Feed Value of Atriplex Species Grown With 100 Percent

Seawater Irrigation.

	Fresh	**Dry**	**Crude**		
Atriplex Species	**Weight kg/m2**	**Weight kg/m2**	**Ash (%)**	**Fiber (%)**	**Protein (%)**
A. atacamensis	3.75	1.61	23-25	23.2-30.8	9.9-16.5
A. barclayana	8.70	2.09	23-28.5	15.5-22.4	11.9-17.9
A. "camarones"*	4.39	1.51	29.4-37	19.7-29.6	13.8-19.5
A. cinerea	3.90	1.46	28.4-33.5	24.1-30.6	12.6-17.7
A.	3.0	2.01	24.0	22.7-	17.6

lentiformis				27.3	
A. linearis	2.44	1.26	10.5-18.1	24.6-39.5	10.2-14.6
A. undulata	4.50	1.75	24.5-34.2	24.3-30.9	12.6-17.1

*Unidentified Atriplex species collected in the region of Camarones, Argentina.

SOURCE: Aronson et al., 1985.

Differences in salt resistance, salt content, drought resistance, leafiness, and palatability have been observed within populations of many of these shrub species. Selection and breeding could greatly improve these characteristics as well as growth habit (to allow easier grazing) and recovery after grazing.

Kochia

Prostrate kochia (Kochia prostrata) is a perennial shrub used for browse in Asiatic Russia, where it is consumed by domestic livestock and wildlife. It is well adapted to arid areas and does well on saline and even alkaline soils. Where it has been introduced in the western

United States, biomass yields have been good and oxalate levels, a concern with some members of this family, have been low (<2 percent). In a recent test, one accession of K. prostrata showed no reduction in dry matter yields at soil salinity levels of 17 dS/m.

Kochia indica and K scoparia have been field tested in Saudi Arabia to determine germination and vegetative yields on saltaffected land using saline water (0.53 percent total dissolved solids) for irrigation. Both K indica and K. scoparia germinated well when seeds were planted at <1 cm deep. Irrigated growth from March through August gave mean fresh weights of 8.5 kg per bush for K. indica and 5.6 kg per bush for K. scoparia.

Samphire

Samphires are succulent, highly salt-tolerant perennial shrubs that occur naturally on waterlogged saltland throughout agricultural areas in Western Australia. The most common species are blackseeded samphire (Halosarcia pergranulata), pale-seeded samphire (H. lepidosperma), and woody-seeded samphire (H. indica ssp. bidens).

Samphire plants do not have true leaves. The stem is thickened into a succulent cylinder with joints at the points where leaves or shoots would normally be. The black-seeded samphire contains about 14 percent crude protein on a dry basis. Pale-seeded samphire is generally lower in protein and higher in salt. Since all samphires contain high levels of salt, excessive salt intake by grazing animals is possible. Water with a low salt content and alternative feeds should be provided.

Trees

Trees can be used as forage in several ways. Trees with low branches can be grazed directly. Management of these stands can involve seasonal control of stocking rates to avoid periods when the plants are susceptible to grazing damage. Trees with branches out of the reach of livestock can provide fallen leaves and pods for fodder. Such taller trees can also be lopped for fodder. Trees of any size can be protected in their stands and fodder cut and carried to the livestock.

Acacia

Acacia species are widely used in arid and saline environments as supplementary sources of fodder. Although dry matter digestibility of Acacia leaves has not been determined for a large number of species, available data indicate it is relatively low. This is probably associated with the high lignin content of the cell wall and the presence of tannins, both of which inhibit digestibility.

Acacia pods provide food for livestock in large areas of the semiarid zone of Africa. Since most of the Acacia branches are above the reach of the livestock, overgrazing is not a problem.

A. cyclops and A. bivenosa tolerate salt spray and salinity. They grow on coastal dunes as small trees or bushy shrubs. Pods and leaves of both are consumed by goats. Although salt tolerance is likely in many Acacia species found in coastal areas, it is unmeasured or unconfirmed for most.

A. ampliceps grows in saline soils in northwestern Australia and appears to be a useful fodder species. Other Australian Acacias with potential for use as fodder include A. holosericea, A. saligna, A. salicina, and A. victoriae.

Leucaena

Leucaena leucocephala is a tree legume widely cultivated in tropical and subtropical countries. It is both salt and drought resistant. Leaves, pods, and seeds are browsed by cattle, sheep, and goats. In Pakistan, it has been grown on coastal sandy soil through irrigation with saline (14 dS/m) water. When seawater comprised 20 percent of the irrigation water, yields were reduced by 50 percent.

In the Ryukyu Islands, where monsoon winds carry seawater into windward pastures, salt- tolerant fodder sources are needed. Among nine tropical legumes tested in a forage- production project, Leucaena showed the highest salt tolerance.

Prosopis

The leaves and pods of mesquite (Prosopis spp.) have been used as forage for cattle, goats, sheep, and camels in countries throughout the world - P. juliflora and P. cineraria in India, P. chilensis in South America, P. glandulosa in the United States, and P. pallida in Australia.

In the Pampa del Tamarugal of northern Chile, the annual rainfall is less than 50 mm, the water table ranges from 2 to 20 m, and a crust of salt about 0.5 m thick covers much of the ground. About 20 years ago the Chilean government began to improve this area by growing tamarugo (P. tamarugo). In some cases, these trees were planted in pits dug through the salt into the soil. Although watering was required for the first year, after that the plants survived by capturing moisture from the ground and air.

About 23,000 hectares are now covered with tamarugo forest. The trees are 8-15 m in height with trunks up to 35 cm in diameter. After the trees reach about 10 m, further growth is very slow and the tree diverts more and more energy from photosynthesis to the production of leaves and fruits. The leaves are rich in carbohydrates and protein and have a feeding value similar to that of hay. The fruits have 37-61 percent digestibility and are an excellent feed for sheep and goats.

About 1.5 sheep per hectare can subsist on the tamarugo forest range and produce about 3-5 kg of wool per fleece. Supplemental feeding with alfalfa raises meat yields.

In addition, dense and durable tamarugo wood finds many uses. The heartwood is extremely resistant to weathering and has desirable timber qualities. It is used for heavy construction, railway ties, poles, furniture, tool handles, and, because of its hardness, for parquet floors. It also makes superior firewood and can be used to produce a high quality charcoal as well.

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