Traditional management of Agave used for mezcal and its associated knowledge: the case of Oaxaca and Aguascalientes, México

Manejo tradicional de los Agaves mezcaleros y su conocimiento asociado: el caso de Oaxaca y Aguascalientes, México.

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Abstract

Maybe the most known and diffused use of the Agave genus plants is the production of alcoholic beverages, being mezcal and tequila the most consumed. As a matter of fact, increased demand for these beverages has led to important pressures in the ecosystems from which the Agave is obtained. In the present article, we compare management practices carried out by mezcal producers in Oaxaca and Aguascalientes, comparing the state that produces the most volume of mezcal with a state that is new to that industry. We define management as "the interventions, transformations or decisions over natural or artificial systems, their elements and functional processes with explicit purposes", according with Casas et al (2014). We also explore the expressions of management, as ways to take advantage, preserve, restore or take back the vegetable elements of the ecosystem and the agroecosystem, finding important differences in terms of future sustainability for the alcoholic beverage industry.

Agave, Management, Cultivation

Resumen

Quizás el uso más conocido y difundido actualmente de los agaves es la producción de bebidas alcohólicas, siendo el tequila y el mezcal las más consumidas. De hecho, el incremento a nivel nacional y mundial de estas dos bebidas ha generado presiones importantes en los ecosistemas de los que se extrae el agave como materia prima, tanto para su uso directo, como para la obtención de semillas o plántulas. En el presente artículo, comparo las prácticas de manejo que llevan a cabo productores de mezcal en Oaxaca y Aguascalientes, contrastando al estado de mayor producción de la bebida, en donde existen incluso problemas para el abastecimiento de la planta, con un estado cuya producción de la bebida y aprovechamiento magueyero con tales fines, es incipiente. Defino como manejo a "las intervenciones, transformaciones o decisiones sobre los sistemas naturales o artificiales, sus elementos y procesos funcionales con fines explícitos" de acuerdo con Casas et al. (2014). Siguiendo a estos mismos autores, se exploran las expresiones de manejo del recurso agave, entendiendo a éstas como las formas de aprovechamiento, conservación, restauración o recuperación de los elementos vegetales de un ecosistema o agroecosistema, encontrando importantes diferencias en términos de sustentabilidad.

Agave, Manejo, Cultivo

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Introduction

Mexico is the point of origin and diversification of the genus *Agave*, belonging to the family *Agavaceae* or *Asparagaceae*, constituted, in national territory, by 159 species, of which 123 are endemic, being the eighth most diverse of the Mexican flora (García, 2007; García, Franco and Sandoval, 2019).

Agaves, or *magueyes*, are predominantly found in arid or semi-arid areas of the national territory, from 34° north latitude to 60° south latitude, being more abundant in the south of the republic, mainly in southern Puebla and northern Oaxaca (García, 2007), in terms of diversity of species and abundance of individuals.

The genetic diversification of the agaves is wide, since it is a species highly adaptable to different environmental conditions and, in addition, the management made by human populations of these plants, due to their socio-cultural importance, has contributed to the generation of varieties and cultivars (Lara-Ávila and Alpuche-Solís, 2016). Its use to obtain fibers, food and beverages, as well as agricultural uses aimed at retaining soils on steep slopes, has been widely documented (Castro and Guerrero, 2013; Félix-Valdez et al., 2016). The multiple uses of the species throughout the national territory have derived in an important knowledge about the growth cycle of each plant and its reproductive particularities, whether sexual or vegetative (Bautista and Smit, 2012). Depending on the species, Agaves can be propagated by seed, by vegetative stems, by propagules in inflorescence or by these three forms (Andrade and Martínez, 2017). Commonly, the separation of offshoots into nurseries or to the definitive growing ground is used directly. This is the fastest way to have an adult plant, since it avoids the risks of germination and the early stages of development (Félix-Valdéz, Vargas-Ponce, Cabrera-Toledo, Casas, Cibrian-Jaramillo and Cruz-Larios, 2016; Andrade y Martínez, 2017).

Perhaps the best known and widespread use of agaves today is the production of alcoholic beverages, with tequila and mezcal being the most consumed. In fact, the increased demand at national and global level of these two beverages has generated significant pressures in the ecosystems from which the *Agave* is extracted as raw material, both for direct use, and for the obtention of seeds or seedlings.

The Mezcal Regulatory Council reports that in 2016, the certified production of this beverage, that is, that with a guaranteed replacement of the plant, was 3 million liters, while the non-certified was greater than 6 million liters, generating significant pressures on plant populations and their ecosystem (CRM, 2016). On the other hand, García, Méndez and Talavera (2010) report that 18 species are now endangered, because they are extracted from their natural environment, which represents a threat to their habitat, since they are indispensable for the proliferation of pollinators such as bats.

In this paper, we compare the management practices carried out by mezcal producers in Oaxaca and Aguascalientes, contrasting the state that is the greatest producer of the beverage, where there are even supply problems due to constant shortage of the plant, with a state whose production and use of the agave for such purposes is recent. We define as management the “interventions, transformations or decisions about natural or artificial systems, their functional elements and processes for explicit purposes,” according to Casas et al. (2014). Following these authors, we explore the expressions of management of the agave resource, understanding these as the forms of use, conservation, restoration or recovery of the plant elements of an ecosystem or agroecosystem (Casas, et al. 2014) to obtain the same resources for human activity. Contextual elements are presented in the background, methodology and results classified by management categories.

Background

Unlike the tequila that is produced in Jalisco from a single species of *Agave* (*A. tequilana* Weber), mezcal is characterized by a great diversity of *magueyes* that can be used for its elaboration.

Some authors mention 53 species (Colunga-García Marín and Zizumbo-Villarreal, 2007; Torres, Casas, Delgado-Lemus and Rangel-Landa, 2015) but, regardless of certainty in numbers, the highest proportion of plants used to prepare mezcal, both in Oaxaca and Aguascalientes, are wild and are extracted -also in most cases- without proper planning to ensure the future conservation of wild populations through sexual reproduction.

Since the Agave is harvested just before flowering, when all carbohydrates are concentrated in the stem to start the reproductive stage (Delgado-Lemus, Casas and Tellez, 2014), which prevents the formation of flowers, fruits and subsequently seeds.

The agave used in Oaxaca to produce mezcal is *A. angustifolia* known locally as *maguey espadín*, this species gives rise to basal offshoot and propagules in the floral escape after cutting the apex, which facilitates *maguey* producers vegetative propagation, with a maturation period of five to six years for harvest, one of the shortest periods for maturation in *magueyes*. However, not all *magueyes* in Oaxaca have the ability to reproduce vegetatively and require flowering for seed production, as is the case with *A. marmorata*, used to prepare the tecaltate mezcal, which takes up to 25 years to mature (García, 2007), or *A. potatorum*, known as *papalometl* or *tobalá*. Agave maturation times are an important reason for mezcal producers to choose to remove the plant from the wild, instead of planting it on their land, either for family processing of mezcal, or to sell the plant to companies that produce the drink industrially, which offers them short-term gains, but it accentuates a problem of plant shortage in the medium and long term.

In Aguascalientes, the *Agave salmiana* is predominant, although *Agave angustifolia* var. *Samandoki*, native of the deciduous lowland forest, was disseminated by a Strategic Forestry for the State of Aguascalientes 2030 of CONAFOR for its ability to prevent soil erosion on steep slopes. Both have the possibility of spreading vegetatively. In Oaxaca, a state that produces 92% of the national total of mezcal (CRM, 2018), given the constant shortages of agave experienced annually and the growing demand, strategies to ensure availability of some species for the elaboration of mezcal are increasingly observed by producers, families, organizations and companies. In the state of Aguascalientes, with an approximate production of 1.15% of the national total of mezcal (personal communication from *maguey* producer), Agave is also used for its agronomic functions and for the elaboration of other products such as syrup and, despite that in the state a shortage of *maguey* cannot be foreseen in a short term, it is relevant to understand the management that is part of the *Agavero* landscape in times of population stability.

Understanding the management practices carried out by human populations that make use of significant amounts of plant (approximately 15 kilograms of *maguey* per final liter of mezcal) is important to recover the traditional knowledge of the region, as well as elucidate the future of the mezcal landscape in Mexico. So, this work aimed to document the management practices carried out by mezcal producers in Oaxaca, the main producer of the beverage nationwide, and in Aguascalientes, a state that only recently (2018) obtained the denomination of origin as producer state.

Methods

Field work was carried out during the months of July-November 2017. During this period, field research activities were conducted in the producing areas of mezcal Agave in Oaxaca (San Juan del Río and San Luis Amatlán) and Aguascalientes (Terrero de la labor).

In San Juan del Río, district of Tlacolula, region of Valle Centrales of Oaxaca, semi-structured interviews were applied (Díaz-Bravo, Torruco, Martínez and Varela, 2013) with seven mezcal producers who produce or extract the plant, while field trips (seven) were carried out for recognizing the routes and obtaining *magueyes* from each producer. During each tour, guiding questions were applied on practices related to the assurance of Agave's presence (or absence thereof).

In San Luis Amatlán, district of Miahuatlán, Sierra Sur region, Oaxaca, we worked with a group of eight *maguey* producers, with the focus group methodology and semi-structured interviews (Escobar and Bonilla, 2009) prior to field visits, as well as participatory mapping (Sletto et al., 2013) of the territory and its agaves. In this town, a three-kilometer route was made with participant observation with each of the five producers. During the collective activities, a survey was conducted on management practices used in agroecosystems as well as in the wild, to ensure the availability of Agave plants. With the information from the survey, the interviews and the participatory mapping, information was obtained on the main problems related to the wild and controlled reproduction of Agave plants, the management ways to guarantee their availability, as well as a mapping of geographic areas with abundance and shortage by species.

In Aguascalientes, we visited a polygon of 26 hectares of common use in the El Terrero de la Labor ejido, municipality of Calvillo. During the tour, conducted with five ejidatarios, the ejido commissioner and the president of the Agave-mezcal Product System of the state, who commented on management practices and questions of the semi-structured survey applied in Oaxaca.

The information obtained was poured into an Excel database to generate categories by management strategies mentioned, by location and state.

The management forms and practices were separated into categories based on the elements mentioned by producers and on the literature of Casas et al. (2007 and 2014). From this analysis, the results for both states are presented.

Results

Some of the actions for extracting *magüey*, including rhizome cutting, discarding the phenotypes considered less appropriate or encouraging those of greater size and shape, are *in situ* management actions (Casas, Otero-Arnaiz, Pérez-Negrón and Valiente-Banuet, 2007; Blancas et al., 2010), which involve artificial selection practices that change, in the landscape, the proportion of phenotypes and species in ecosystems, such as incipient domestication processes (Colunga-Garcíaamarín and Zizumbo-Villareal, 2007).

The cutting of offshoots and sometimes the selection of the “best” agaves (defined by criteria of size and thickness of the stem) to allow the obtention of seed, with the purpose of sexual reproduction in greenhouses, tend to modify the agave landscape, reducing the genetic diversity of the populations and the populations themselves in a physical and ecological way (Parker et al., 2010; Torres, Casas, Vega, Martínez-Ramos and Delgado-Lemus, 2014).

Therefore, this modifies the configuration of mezcales available, in sensory terms. In this sense, sexual reproduction predominates in wild populations, while vegetative propagation is the most common in those subjected to cultivation or some form of management.

Other authors have reported that some management strategies, such as the introduction of varieties from different regions, or the establishment of diversified nurseries, achieve significant levels of genetic diversity, even greater than in wild populations, by promoting cross-pollination between cultivars and varieties (Brush et al., 195, Pujol et al., 2005, Casas et al., 2007 and Vargas-Ponce et al., 2009).

These strategies combine varieties that in the wild do not reproduce or grow in the appropriate distances for pollination and can lead to gender diversification, that is, greater population genetic diversity but reduced in terms of species.

Forms of management and expressions of exploitation of Agaves in Oaxaca and Aguascalientes

We define as “management” the interventions, transformations or decisions on natural or artificial systems, their elements -or resources- and functional processes -or ecosystem services- for explicit purposes (Casas, et al. 2014). Management can adopt multiple expressions, such as forms of exploitation, conservation and restoration or recovery.

The information obtained allows the separation of management practices between those that are carried out in an uncontrolled natural environment and those conducted in planned or controlled environments in terms of environmental variables, such as nurseries, pieces of ground for cultivation or backyards.

We separate the analysis of management practices into two categories, according to the environment in which they are carried out, in accordance with the proposal of Casas et al. (2007) and Figueredo et al. (2015), as *ex-situ* (controlled sites in which the plant resource is extracted from its natural environment) and *in-situ* (management practices carried out in wild environment).

In this paper we do not intend to analyze the levels of domestication of populations, since agaves are distributed in a continuum of wild or uncontrolled environments to habitats planned and managed by human populations.

Understanding degrees of domestication usually involves comparative genetic analysis.

We are concerned with the difference between cultivated plants with total control of their phenological stages and their requirements to obtain the desired parts in the best possible state for human purposes and the polarity with wild plants, such as those that grow in environments without control of variables, understanding, with Harlan (1992), that to any degree of management of plants or the environment, there are ecological adaptations, usually associated with morphological differences that include intermediate states. According to this, it is possible to grow wild plants without them being, necessarily, domesticated.

In Oaxaca, but also in Aguascalientes, it is observed that wild plants are taken to gardens, nurseries or backyards and later returned to their natural environment, promoting a constant movement of the plants. In Aguascalientes, some forms of natural resource management were identified, such as the integration of mixed systems.

The areas of common use were distributed and assigned to the ejidatarios that make up the agrarian nucleus. Each of them used barbed wire fences to limit their assigned space. Each of these spaces is considered as "Productive Unit (PU)", with agroforestry systems with agaves, some wood for domestic use (bioenergetic), corn and grazing (cattle and goats).

The ejidatarios have varied the activities in their PU, so that their agricultural work generates a diversification of income. As a result, it has been observed that during an agricultural cycle, the activities are constant; taking care of the preparations of crops such as corn and *maguey*, while grazing goats or cattle, as well as the permanent extraction of firewood. In all these complex agricultural management systems, we distinguish the following common practices:

In-situ practices

Protection

It consists, as the name implies, in protecting seedlings in early stages of development, or *magueyes* that are considered exemplary or perfect to provide offspring and seedlings.

The possibility of protecting either seedlings in a wild or reforested area or adult specimens from being picked and subsequently harvested by another person to obtain seeds, rests in the form of land tenure where the ground is located. If it is a land owned by a private owner (either small property or own ejido portion), the possibility of achieving plant growth or protecting the specimen is greater than when it comes to community land, to which people introduce goat or cattle for grazing, or some mezcal producer chooses the adult maguey for their factory.

Normally, grazing is an activity that crosses the land of an owner, so that the protection of seedlings to be effective even on individual land, involves the enclosure of the land or even the posting of notices to inform neighbors or shepherds that it is an area with young plants that must be protected. However, in San Juan del Río, Oaxaca, the growing opening of cultivation areas for *maguey* in the last 3 years (2015-2016 to date) has implied community agreements not to cross individual lands and stick to common areas. This has implied a decrease in the use of communal ejido areas for reforestation and an expansion in the individual extensions of the producers. Although there were agreements for the use of *maguey* in communal areas, these have now lost their validity.

Palma (2000) reports protection of specimens of *A. Kerchovei* and *A. americana*, which grow isolated (not in colonies), by sprinkling their leaf apices with water and manure, to protect livestock intake. This practice was corroborated in Miahuatlán, although it is not assumed effective for young specimens. In the case of Aguascalientes, no protection practices have been identified.

Collection

It could also be called "assisted regeneration actions." It is not a proper management practice, but it is the most common way of obtaining the slowest-growing varieties through the collection and relocation of bulbs, either at the base of the agaves or in the floral escape, towards land of planting or in environments with a certain degree of protection to ensure the survival of the plants. Often, the plants are stacked in the yard of the houses, with periodic watering, to subsequently be transplanted in the rainy season.

At the time of planting, the tips of the *magueyes* are cut to stress them and encourage roots and development. In Oaxaca, the collection for young offshoots of *A. marmorata*, *A. americana* and *A. karwinskii* is practiced in terms of uncultivated *magueyes*. However, seed collection is also carried out for all *magueyes*, which germinate in seedlings for a year and a half or two, prior to transplantation. The collection of seeds depends on the protection of mature agaves to achieve the maturation of the floral escape in specimens that are selected in owned property by their size, with the aim of conserving their genetic potential for later planting. For subsequent sowing of the seeds, those with whitish coloration are discarded, carrying out a selection process.

In Aguascalientes, the collection is conducted in Calvillo, Tepezalá and Real de Asientos, where the seeds are harvested mainly from the *Agave angustifolia*, *A. salmiana* and *A. Americana*. They are stored in the courtyards of the ejidatarios and put to germination in seedlings, to be later transferred to the closest grounds of the ejidatarios. In the case of Tepezalá and Asientos, the Agave producers are organized around the Product System and the Association of Mezcal Women A.C., so they have been beneficiaries of the State Government's Productive Reconversion program for the planting of agaves. This activity has allowed the establishment of various plantations, vegetative material is granted to each of the beneficiaries, so seed collection is practically nil.

Tolerance

Tolerance is a practice that consists of conserving specimens of a plant species, the growth of which is not the final aim of a producer, in a predominantly agricultural space. Prior to the rise of mezcal and extensive agave cultivation, some seedlings were allowed to proliferate on agricultural land or adjacent to homes in urban areas; however, given the increased use of Agave for the elaboration of mezcal, the practice of tolerance does not apply, as it is currently promoted and protected; it is no longer seen as a species that is “allowed” to continue regardless of its usefulness.

In the Aguascalientes environment, it has been observed that this practice is scarce. Only some specimens have been left for seed and mostly as ornaments for landscape purposes.

Especially in the spaces where distillation workshops will be set up with small businesses selling food.

Induction

This practice includes strategies aimed at increasing the diversity of populations of useful species in a plant community (Casas et al., 2007).

It includes the burning of vegetation that favors the proliferation of some species or the planting of vegetative propagules of plants in wild areas. In Oaxaca, burning is not induced for the growth of *maguey*, however, producers are aware that when a property catches fire, the agave tends to mature faster “although with less flavor” (Hermogenes, producer of *maguey* and mezcal, 52 years, Amatlán, Oaxaca).

The reforestation in communal areas of propagules of wild agaves in Oaxaca takes place mainly in communal lands in San Juan del Río, mainly from the areas visited; however, due to the indiscriminate extraction of *maguey* in the last five years and the proliferation of plantations in owned properties it has decreased drastically.

Induction in Oaxaca is also carried out by irrigating seed or transplanting young plants of *A. potatorum* in rocky wild areas.

In the case of Tepezalá, Aguascalientes, there are agreements between the ejidatarios to conduct reforestation, through propagules, in the common areas, planting three agaves for each one that is extracted to obtain mead for pulque.

Ex-situ practices

It refers to the plantation or use of a species for commercial purposes. In the two municipalities of Oaxaca, this practice is the most common due to the increase in the demand for mezcal, displacing native vegetation (low forest) to land that is increasingly sold or rented to ejidatarios or community members and which were previously used for sowing cornfields or were in agricultural disuse.

The agave under agricultural management practices, although it is diversified in terms of supply and forms of management to incentivize productivity, is observed in two broad systems:

Monocultures

They are agricultural spaces in which a particular species is grown, either for commercial or subsistence purposes. It also seeks to prevent the growth of different plants such as temporary herbaceous.

In both San Juan del Río and San Luis Amatlán, the plantations of *A. angustifolia* or *maguey espadín* are becoming more common, both on flat terrain and on hillsides. The comuneros constantly acquire more land for the cultivation of this species of *maguey*, which is the fastest-growing species (5-6 years), and from which vegetative propagules are consistently obtained.

In San Luis Amatlán it is customary to plant wild agaves, such as *A. marmorata* or *A. karwinskii* on the boundaries of the *maguey espadín* plantations, or insert *maguey espadín* with *A. americana* (arroqueño) or *A. potatorum* (tobalá); the latter only in the case of rocky terrain. In San Juan del Río this practice is uncommon, as extensive crops of *A. angustifolia* predominate, however some owners cultivate *A. americana* in 2.0X2.5 grooves.

In Aguascalientes, producers started hastily their *maguey* plantations because the vegetative material was delivered by the National Forestry Commission without prior training in mid-2018. In this first stage, they were established under a monoculture model. Only the *Agave salmiana* was planted.

Polyculture

It is characterized by the cultivation of more than one plant species in the same agricultural space. In Oaxaca, both in San Luis Amatlán and in San Juan del Río, families have an average land of 3 hectares, in which the common sowing density of 1.50X2, 2X2 or 2.50X2 allows only 2000 to 3000 plants of *A. angustifolia* per hectare on land that can be shared, for the first three years, with the sowing of *milpa* (corn-bean system).

The growth of the *Agave* leaves subsequently hinders the planting and harvesting of other products from the third year, so the land is dedicated exclusively to the *maguey*, which, when extracted, generates a single gain until the next harvest cycle (3 to 4 years later).

In Amatlán, people manage stepped plantations. They are carried out in rows of agaves with different ages: plants of eight, six and two years. In the rainy season (May-October), beans, *milpa* and corn are interspersed. Also, the planting spaces with *higuerilla* are inserted or surrounded, an energy crop that has arrived in the region since 2016 from the installation of the oil extraction plant in Ejutla, which buys seeds per kilo from the producers.

This does not happen so commonly in San Juan del Río or Sola de Vega, where there is an important presence of mezcal brands. In this municipality, the producers have to decide to sell to brands vs. sell as a cooperative with their own brand. Mezcal brands rent fields in a 50-50 scheme, in which the producers provide the land and the brands send technicians to plant the *Agave*, mainly *espadín* and to a lesser extent *tobalá*. Since brands supervise and decide the ways of planting, there is no possibility of introducing other crops.

At least 30 producers in San Juan del Río are already working with brands, which invite their families to work in the same scheme: committing a stable amount of mezcal or renting land. Mezcal production by contract is becoming a problem, as producers often cannot meet volumes in established times and are forced to extract wild agaves or buy from other producers to comply and avoid suits.

In Aguascalientes, mezcal production is incipient. The agaves used to produce mezcal in this region are *Agave salmiana* also known as pulquero, *angustifolia*, in a wild variety known locally as “samandoque” or “samandoki,” extracted from the natural environment to produce an average of 2500 liters per year. In this region, there is no significant pressure on the ecosystem yet, but its product has the potential to grow in volume and quality over the next few years, given the current international demand for mezcal. In the ejido of the Terrero de la Labor, in the municipality of Calvillo, offshoots and seed of *Agave angustifolia* var. *Samandoki* were domesticated, which were distributed by the CONAFOR soil conservation program, although there are also *Salmian Agave* plantations for the production of mead and pulque. *Agave* plantations were implemented on private and ejido lands in order to restore soil and gather rainwater; contours were also made for the same purpose.

It is worth noting the actions carried out in Puerto de la Concepción, where there is significant progress in the restoration of soil through the sowing of Agaves in contour lines. In this sense, the presence of *Agave salmiana* constitutes the species with the highest population in the entire Aguascalientes territory. At the end of 2018 and the beginning of 2019, prior to the second stage of *maguey* crops, training on topics such as the establishment of agroforestry systems under the agroecological perspective, food systems and sustainable production was provided to communities. Producers from the municipalities of Asientos, Tepezalá, El Llano and Hacienda de Mirandillas undertook the training. After the sessions in Agroecology, agroecological systems were designed from the perspective of the producers, which integrated food crops such as corn, squash, legumes, *maguey* and *nopales*, as well as timber (oaks and mosques). In this second stage of planting, the species of *Agave salmiana* and *A. americana* were used.

Vegetative Propagation

It is the most commonly executed in nurseries, while it is the fastest way to grow a plant. Most agaves spread asexually, producing clones in different parts of the rosette or inflorescence.

The offspring develops at the base of the plant, or emerges by stolons at some distance from the mother plant, producing roots and, over time, growing independently. The intrafoliar offshoots grow between the leaves of the rosette and develop when they detach from the mother plant or it dies. Bulbs, on the other hand, originate in the inflorescence, next to the flowers.

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Conclusions

Recognizing the different agave management systems allows us to understand the strategies with which producers secure the material to supply a growing demand, as the distillate consumption increases worldwide.

The management strategies carried out to obtain agave, the traditional knowledge bases that these strategies entail, as well as the understanding of the consequences of each system, are key to any intervention strategy to be executed.

Likewise, the heritage of biocultural knowledge that underlies management decisions contributes to the identity of ancestral peoples related to the *maguey*, their environment and the different uses given to natural resources.

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Data sheet

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