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Post-Harvest Management of Sorghum Bicolor (Sorghum) in Balimba Canton, Moyen-Chari Province, Chad

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Abstract: ***This study assessed post harvest management practices of sorghum producers in Balimba Canton, Chad, using structured surveys of 175 respondents. Descriptive statistical analysis revealed that field drying predominates at 83.75 percent, while grain storage in huts or rooms accounts for 67 percent of practices. Chemical preservatives are used by 53.75 percent of farmers despite reported pest and fungal losses across processing stages. The findings indicate significant storage inefficiencies and health risks associated with pesticide misuse. Strengthening training and promoting improved storage technologies could reduce post harvest losses and enhance food security outcomes.***

Keywords: Post-harvest loss, Chad, grain storage systems, food security and agroecological practices

1. Introduction

Sorghum is a widely consumed staple food in the world's poorest regions, where food security is most at risk (Dempewolf, 2014; Peerzada *et al*., 2017). It is the primary source of energy, protein, vitamins, and minerals for more than 500 million people in developing countries in Africa, Asia, and the Middle East (Liu *et al*., 2019) and of carbohydrates (Anonymous, 2024). It is also used in the formulation of poultry feed. Its straw is used to make brooms, house fences, and as livestock feed (Fall *et al*., 2016). Beyond its nutritional and energy values, sorghum offers significant agroecological benefits and environmental services, such as soil improvement and conservation, pesticide reduction and remediation, and the detoxification of contaminated soils (Balole *et al.,* 2006; Kéita, 2019). Added to this is the use of its allelopathic properties (Kouakou *et al*., 2024). Mature sorghum contains a number of water-soluble chemicals that can be used as herbicides (Hamadou *et al*., 2017).

Post-harvest losses of grains begin once they have reached physiological maturity in the field. This is followed by a chain of post-harvest activities, from the field to the consumer. At each stage, there are generally losses in dry matter weight when the grain is scattered or spilled, or due to grain rot or consumption by pests. To ensure food availability throughout the year, certain traditional methods have been developed to extend the storage life of products (Gandaho *et al*., 2017). The objective of this study was to characterize the post-harvest management practices of sorghum producers in the Balimba canton, Moyen-Chari province, Chad.

2. Materials and Methods

2.1 Description of the Study Area

The study was conducted in southern Chad, in the Moyen-Chari Province, Barh-Kôh Department, Balimba Subprefecture, and Balimba Canton. Figure 1 shows the study map extracted from the map of Chad. It currently comprises 76 villages and has an estimated population of 65,104 inhabitants living over an area of 1,378 km² (Anonymous, 2022). The Balimba Canton is located west of the city of Sarh, in the Moyen-Chari Province. It is bordered to the south by the cantons of Koumogo and Bekamba, to the west by the cantons of Bedaya and Djoli, to the north by the canton of Kokaga, and to the northwest by Manda National Park. It is one of the largest cantons in the Barh-Koh Department, after those of Koumogo and Moussafoyo. The Barh-Koh River forms a natural border with the town of Sarh and Koumogo Canton. To the west, the Barh Sara River separates it from the cantons of Djoli, Bedaya, and Békamba-Moïssala. The climate is of the Sudano-Sahelian type. Balimba Canton has a flat terrain across its entire area. According to the Balimba Canton Development Plan (Anonymous, 2008), there are two types of soil: white sandy-clay and silty clay throughout the canton's plains. These soils are undergoing severe degradation due to population pressure. Bushfires and slash-and-burn agriculture are also contributing factors. Balimba Township used to be a forested area, fairly dense, with a wide variety of tree species and tall trees, sometimes reaching heights of 15 to 35 meters. Today, the vegetation is not what it used to be, with tall trees and thick grass

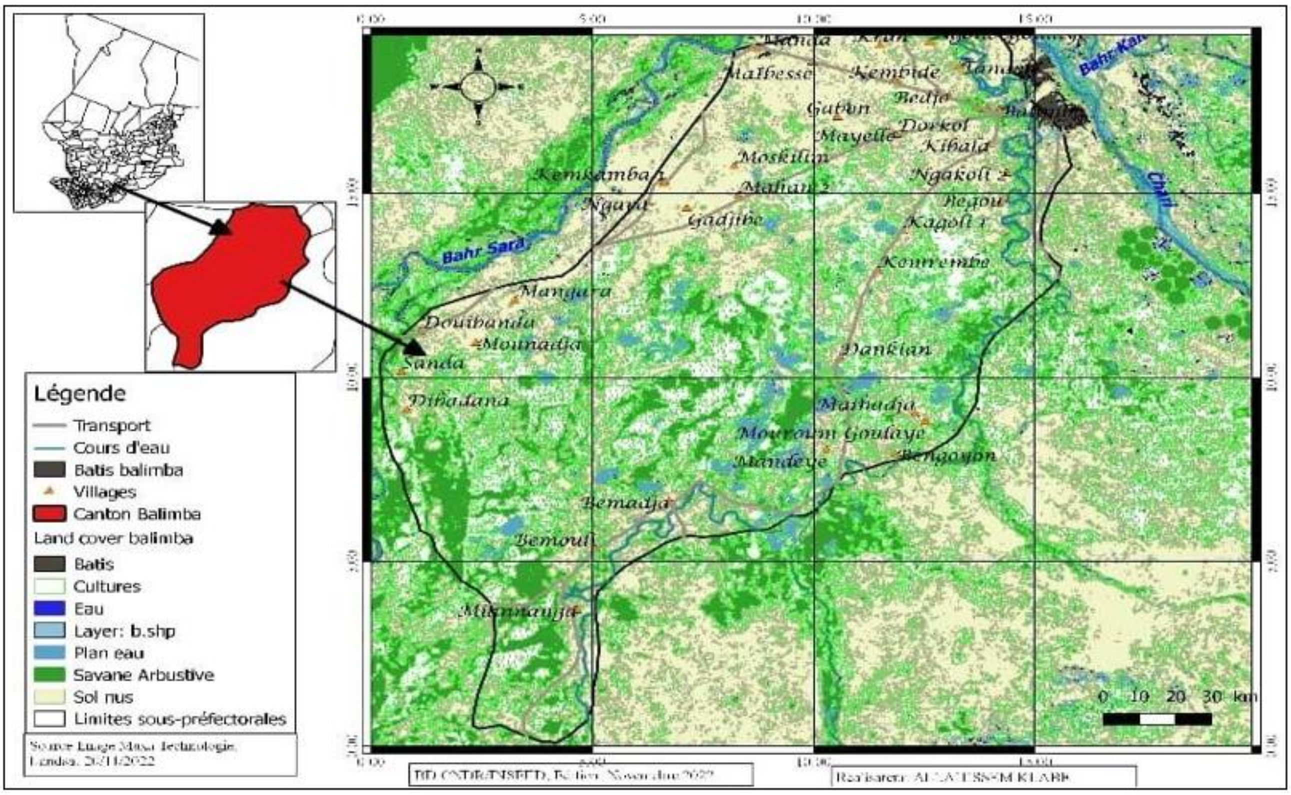

Figure 1: Location of the study area

2.2 Data Collection Methods

2.2.1 Field Survey

The survey was conducted among government technical services (Sarh Agriculture Delegation and ANDER/Sarh), NGOs (RAPS, CARITAS, RESAP/MC), traditional authorities, farmers, and sorghum producers in the Balimba canton. This canton was selected as representative of local sorghum production agroecology. A random sample of 175 respondents (sorghum producers and non-producers) was selected, resulting in a total of 160 producers who were interviewed using a guided questionnaire on post-harvest management of sorghum. These interviews yielded data that were then used to characterize the post-harvest management practices of sorghum producers based on the following parameters: Drying and transport of harvested crops, sorghum storage location, storage method, use of preservatives, grain losses, individuals responsible for sorghum grain management, and grain utilization. The data collection methods used were interviews, individual interviews, and focus groups. The questionnaire included closed-ended questions (answered with “yes” or “no”), open-ended questions (answered based on the respondent’s own perspective), and guided questions (where respondents are provided with a few suggested answers). Individual interviews were chosen, specifically face-to-face interviews, as they yield the highest response rates to the greatest number of questions (Arouna, 2012; Waya, 2023). Finally, direct observation was used to supplement the field data.

2.2.2. Selection of Villages for the Survey

The survey was conducted in eight villages selected based on the following criteria: high sorghum production. The total population of the eight surveyed villages is 10,370. In each village, 20 farmers were surveyed. The surveyed villages are: Balimba Centre, Bendouma I, Bendouma II, Bedouada, Kembide, Maibessé, Manda I, and Benama.

2.2.3. Data Analysis

Data analysis was conducted in two stages: the tabulation and computerized processing of the data collected in the field. The first stage, focused on the tabulation of quantitative and qualitative data, involved verifying that the questionnaires had been completed and checking for consistency in the respondents’ answers. Generally speaking, this involved carefully reviewing the survey forms to extract the information. The second stage involved the processing of the collected data. This phase required the use of computer software. After data collection, Microsoft Office Excel 2010 was used to calculate histograms, averages, and percentages for the various post-harvest management characteristics.

3. Results

3.1 Drying and Transport of Harvested Crops

There are two methods of drying sorghum used in Balimba District: field drying and home drying. However, 83.75% of households dry their harvest in the field, while 16.25% dry it at home (Figure 2). Most farmers reported threshing within two to three weeks after drying, whether in the field or at home. The primary means of transport used by producers in Balimba Canton is the cart (75%); some producers transport their post-harvest produce by motorcycle or bicycle (21.87%) and by carrying it on a carrier or on their heads (3.12%) (Figure 3).

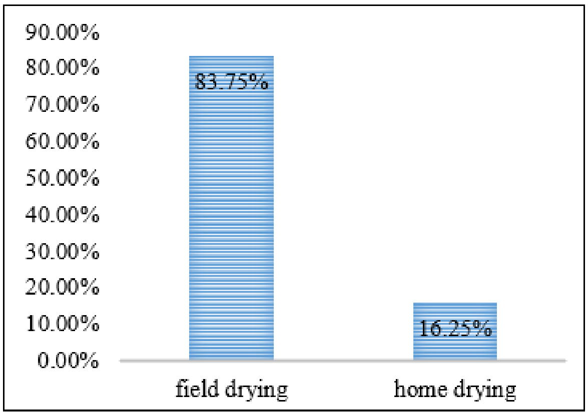

Figure 2: Sorghum drying sites

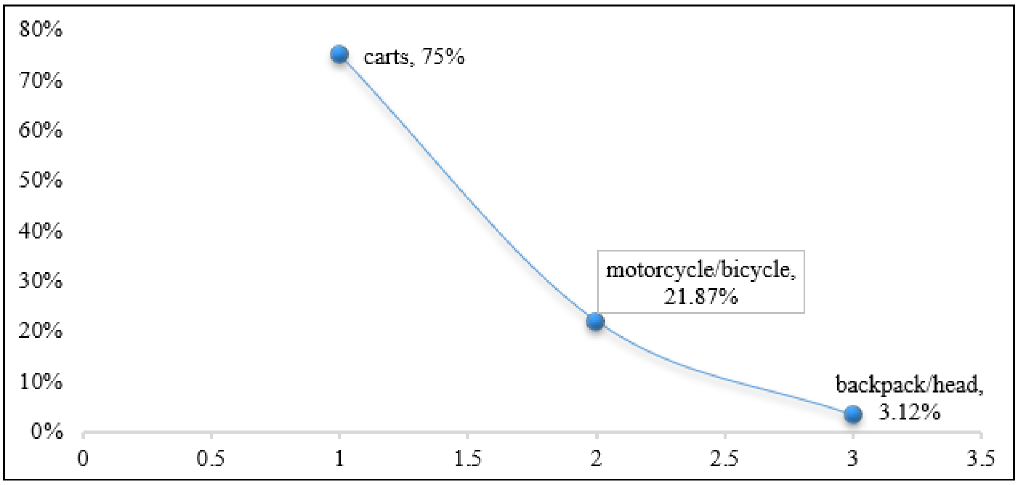

Figure 3: Transportation equipment

3.2. Sorghum Storage Locations

In the study area, sorghum is stored in huts, rooms, individual granaries, sheds, and community storage facilities. Sixty-seven percent of all surveyed producers store their harvest in huts and/or rooms; 14% of producers store the panicles in sheds; 8% store the grains in individual granaries, and 11% in community warehouses.

3.3. Storage Methods

There are two methods of storing sorghum (in grains or in panicles) in the Balimba canton (Figure 4), which are influenced by local factors (theft, damage by livestock) and environmental conditions (humidity, mold, wind, etc.) and could be improved by combining them with other, more modern methods that have proven effective. This is because producers say that grains stored in panicles offer some protection against insect and mold attacks. According to the survey, the majority of the surveyed population stores their sorghum as grains (83.13%) rather than in panicles (16.88%) (Figure 4).

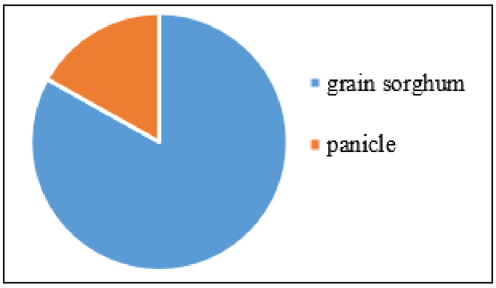

Figure 4: Storage methods observed among producers

3.4 Use of Preservation Products

The preservation products used in the study area are local and chemical products (Figure 5). Of the 160 farmers surveyed, 86 (53.75%) use chemical products such as powdered pesticides (Mancozeb), and 24 (15%) use local products, namely neem seeds; soda ash; salt; and pigments, while the remaining 50 (31.25%) use neither chemical nor local products. Powdered pesticides are often applied by hand without respiratory protection. Given the presence of pests in storage areas, farmers adopt multiple preservation strategies their harvest.

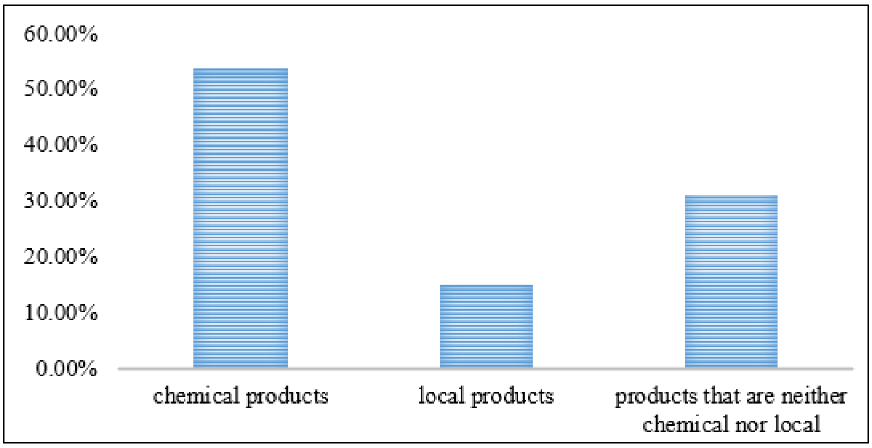

Figure 5: Use of preservatives

3.5 Grain Losses

Farmers report grain losses during the following operations: threshing, drying, transport, grain processing, etc. 30.62% of farmers experience grain losses during threshing, winnowing, and bagging, 28.12% of producers report losses during grain processing at the mill, 25% due to insect and fungal infestations, and 16.25% say grain losses occur during drying, transport, and storage (Figure 6).

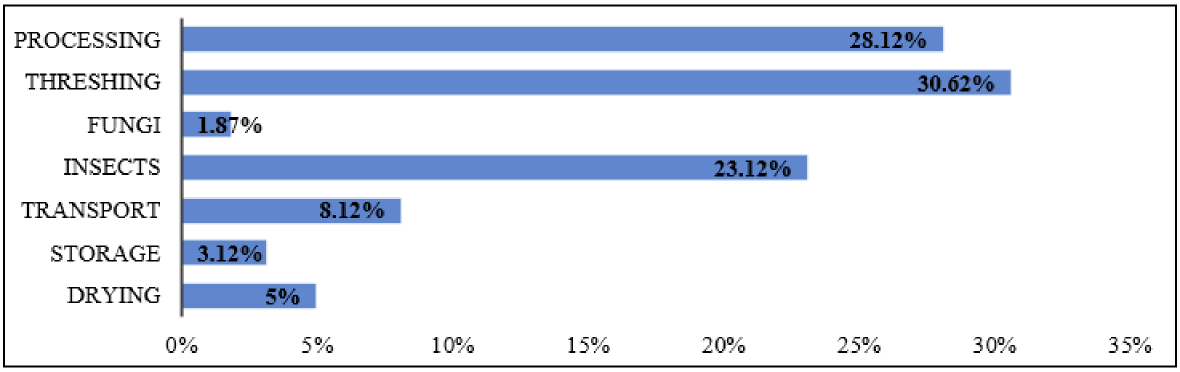

Figure 6: Grain losses

3.6 Evaluation of Grain Treatment Pesticides

Most of those surveyed say that chemical pesticides are very effective, but their potential harm to human health and the environment should not be overlooked. Local producers rate their toxicity at 100% and their effectiveness against rodents at 74.37%, whereas local preservation products are less effective and pose very little risk (Table I). Although the use of pesticides may be a public health concern, it remains necessary at times for the proper preservation of grains, particularly sorghum.

Table I: Assessment of Pesticides

Ratings	Pesticides	Number of respondents	Frequency %
Effective against rodents	Local pesticides	41	25.625
	Chemical pesticides	119	74.375
	Total surveyed	160	100
Hazards of preservatives	Local pesticides	0	0
	Chemical pesticides	160	100
	Total surveyed	160	

3.7 Those Responsible for Managing Sorghum Grains

In Balimba Canton, grain management is carried out much more by men (83.75%) than by women (16.25%) (Figure 7). Survey responses indicated male dominance in post-harvest the sorghum after the harvest.

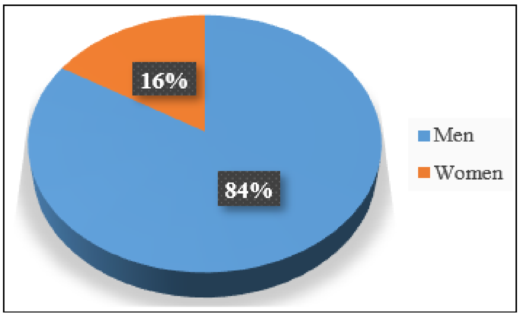

Figure 7: Sorghum Grain Management Officials

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3.8 Uses of sorghum post-harvest products

Sorghum grains are used for human and animal consumption, as seed, and for sale. 73.12% use sorghum grains for human consumption, 24.37% of respondents use them for seed, sale, and alcohol production, while 2.5% of producers use them for animal feed. Crop residues such as stalks, leaves, and bran are left in the fields (as organic matter) and/or fed to animals. These account for 75.62%, while 20% and 4.37% of producers use the stalks for building huts, seko, sheds, mouthpieces, and packaging systems, respectively (Table II).

Table II: Use of post-harvest products

Variables	Conditions	Sample Size (Respondents)	Frequency %
Grains	Seeds, sale, and production of alcohol	39	24.37
	Human consumption	117	73.13
	Animal consumption	4	2.5
Crop residues	Parking system	7	4.37
	Organic matter and livestock feed	121	75.63
	Building materials and mouthpieces	32	20

4. Discussion

4.1. Methods of sorghum drying

The different drying methods used in Balimba Canton are in the field and at home. According to Ramatoulaye *et al.* (2020), these drying methods remain viable as long as the duration and conditions of drying ensure proper preservation of the grains or panicles. In contrast, Chantereau *et al.* (2013) describe drying panicles in the field or near dwellings on drying racks or raised platforms. Thus, Gandaho *et al*. (2017) presented various drying curves showing the change in moisture content over time. Drying sorghum is necessary to prevent spoilage by microorganisms during storage (Chantereau *et al*., 2013). In tropical conditions characterized by temperatures above 25°C, sorghum grains must be dried to a storage moisture content of 12.5% or less. Grains always carry a large number of microorganisms (molds, yeasts, bacteria) that can grow if placed in favorable humidity and temperature conditions (Chantereau *et al.,* 2013).

4.2. Methods and Locations for Sorghum Storage

According to studies conducted by Kange *et a*l. (2014), in Kenya, sorghum grains are stored either hulled (88.4%) or as panicles (11.6%). In our study area, the two main storage methods (in panicles or as grains) are also practiced by producers. The research of Ramatoulaye *et al*. (2020), which indicates that storing sorghum as grains remains the predominant and preferred method among producers. Grain storage is essential because it allows for the creation of reserves for human or animal feed, the preservation of seeds for future growing seasons, and the building of stocks for potential marketing (Chantereau *et al*., 2013). Analysis of the surveys reveals that 11% of producers store their harvest in community warehouses and 67% of producers store it in rooms or huts. These basic principles for grain storage locations are similar to those described by Ramatoulaye and colleagues in 2020. During storage, care must be taken to ensure that this safety moisture content of 12.5% is not exceeded. The goal is to keep the grains thoroughly dry at the lowest possible temperature and protected from the risk of re-moisturization and attacks by pests. Today, farmers often face a shortage of plant materials (wood, straw, etc.) for building traditional granaries and are increasingly resorting to storing grains in bags inside their homes or in small village warehouses (Chantereau *et al.,* 2013).

4.3. Products Used for Sorghum Preservation

According to the survey, 86 respondents (53.75%) use chemical products such as powdered pesticides (Mancozeb). Hamé *et al*. (2013) found in their research that 58.8% use chemicals. According to Manga *et al.* (2023), chemical control is the technique that ensures effective protection of stocks and their storage sites quickly and efficiently. However, according to the World Health Organization (WHO), each year, pesticides accidentally cause some 20,000 deaths and affect nearly 750,000 people suffering from their specific or non-specific chemical effects, mainly in developing countries (Gueye *et al.,* 2012). These chemical insecticides are dangerous to humans and domestic animals due to residues that can contaminate grains—the extent of which varies depending on the doses applied (Chanteau *et al*., 2013)—and can pollute the environment and lead to the development of resistance (Zongo *et al*., 2015). The uncontrolled use of plant protection products due to a lack of training can be a source of harm to human health and the environment (Kanda, 2013; Ngakiama *et al*., 2019). The survey data indicated that farmers in Balimba Canton are aware of the use of plant protection products and the risks associated with them. Although the use of pesticides can be a public health concern, it is nonetheless sometimes necessary for the proper preservation of grains. However, the use of natural products instead of chemical ones is preferable but is not always the case among farmers. In Balimba Canton, some sorghum farmers use inert materials (21.25%) such as neem (Azadirachta indica), pigment, ash, and salt. According to the respondents, these inert materials have shown their limitations when the volume of sorghum stock is large and there are difficulties in sourcing these materials. In contrast, Hamé *et al*. (2013) used inert substances such as fine sand and ash in their study on farmers' knowledge of sorghum and millet storage in the Aguié Department of Niger.

4.4. Grain Losses and Use of Post-Harvest Products

Farmers in Balimba Canton report grain losses depending on the stage of processing, such as during threshing, winnowing, and bagging (30.62%), during grain processing into flour at the mill (28.12%), due to insect and fungal attacks (25%), and 16.25% during drying, transport, and storage. According to Chantereau *et al*. (2013), harvesting too late can cause significant losses due to spontaneous shattering of the panicles or damage from pests (insects, rodents, birds, etc.).

Sorghum grains are used for human consumption, seed, and sale (73.12%), for human consumption and the production of local alcohol (24.37%), and for animal and human feed (2.5%). These results are similar to those of Ramatoulaye *et al.* (2020), who found in their research that sorghum grains are used for self-consumption, seed, and livestock feed, and commercialization. A large portion of crop residues, such as stalks, leaves, and chaff, are left in the fields as soil fertilizer and/or used during the dry season as livestock feed (75.62%). Chantereau *et al.* (2013) confirm these findings. They state that straw is used to feed animals during the dry season; the stalks alone are used for domestic purposes: cooking food, producing potash, making fences, and covering huts. Beyond its use as food, sorghum offers documented agroecological benefits and environmental services such as soil improvement and conservation, pesticide reduction and remediation, and the detoxification of polluted soils (Ndiaye *et al*., 2018)

5. Conclusion

The study demonstrates that traditional drying and storage practices dominate sorghum post harvest management in Balimba Canton, with significant losses linked to inadequate preservation methods and pesticide misuse. Improving farmer training, promoting safer storage technologies, and strengthening post harvest monitoring systems are essential to reduce losses and enhance food security. Future research should quantify contaminant risks and evaluate improved storage interventions under local agroecological conditions.

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