



Original article

Societal perception on environmental and socio-economic implications of *Tithonia diversifolia* (Hemsl.) A. Gray invasion in an Indo-Burma biodiversity hotspot

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ABSTRACT

Tithonia diversifolia (Hemsl.) A. Gray is an emerging and little studied plant invader in North East India, an Indo-Burma biodiversity hotspot. Identifying the impacts of its invasiveness in terms of both harmful and economically beneficial facets is required for the formulation and implementation of sustainable management options. An environmental and socio-economic implication survey through the pragmatic questionnaire method is a useful approach to explicitly elucidate the holistic influence of *T. diversifolia* on ecosystem resilience. The interaction of *T. diversifolia* with the local people of Mizoram was assessed in this study in terms of its effects on their livelihoods, socio-economic, and ecological factors. Results of the survey in relation to agricultural implications revealed that 42.68% of the respondents opined that the dried litter of *T. diversifolia* can improve soil fertility. Also, 63.41% people during their interview perceived *T. diversifolia* as an effective tool to prevent. However, 70.73% of rural people did not consider *T. diversifolia* to be a good source of livelihood for income generation or socio-economic status. Since, the respondents were not aware of chemical and biological control measures to regulate the spread of invasive alien plant species, physical methods such as slashing (46.34%), burning (13.41%), chopping and burning (29.27%) were widely applied for the control and management of invaded areas of *T. diversifolia* at selected study sites. Thus, the survey gave a brief idea to the other local people, farmers, and agriculturists of Mizoram to control the invasive spread of *T. diversifolia* in forestry and agroforestry systems. Also, other Himalayan landscapes infested with *T. diversifolia* can generate awareness and identify the sustainable strategy for their management to conserve the indigenous biodiversity.

KEY WORDS: socio-economic, *Tithonia diversifolia*, invasive alien plant, livelihood, sustainable management

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1. Introduction

Invasive alien plant species have been introduced into a new area by human activity and become widespread, causing significant economic, ecological, and social impacts (ESCHEN ET AL., 2021). They have been spreading progressively and reported to be widely distributed in global landscapes (MURPHY ET AL., 2012). The rapid growth of invasive alien plants is usually confined to fallow lands, wastelands, roadsides, and disturbed habitats (HAYSOM & MURPHY, 2003). The increased diversity and distribution of

invasive alien plant species pose a threat to natural forest ecosystems (RAI & SINGH, 2020).

Tithonia diversifolia (Hemsl.) A. Gray commonly known as tree marigold or Mexican sunflower is a perennial shrub belonging to the Asteraceae that grows rapidly with vigorous reproductive attributes, reaching 2 to 3 m in height, it grows well at an altitude of 800-1500 m, and flowers annually in November and December (BURAGOHAIN, 2016; ROJAS-SANDOVAL ET AL., 2018). *T. diversifolia* is native to Mexico and Central America, however, in the current scenario it has a pantropical distribution and has naturalized across South America, the West Indies,

Africa, Asia, Australia and across the Pacific and Indian Ocean (USDA, ARS, 2018; GRIIS, 2018; ROJAS-SANDOVAL ET AL., 2018). The historical trend of *T. diversifolia* depicts that its introduction into the African region took place around 1970 (OBIAKARA & FOURCADE, 2018). However, in Indian landscapes, its introduction history is not very clear and it may have existed there since between 1980 and 1990. *T. diversifolia* was initially introduced as an ornamental plant in Mizoram and subsequently became invasive and threatened the native plant diversity and agricultural productivity (WITT ET AL., 2019; SENGUPTA & DASH, 2020). *T. diversifolia* is one of the new, or emerging, plant invaders and in the context of Mizoram it was first studied in Phawngpui National Park and Lengteng Wildlife Sanctuary however, explicit ecological research on it is still limited (SENGUPTA & DASH, 2020). In addition to Mizoram, *T. diversifolia* has also been found to be abundant in the N.E. Indian states of Arunachal Pradesh and Manipur (NMHS, 2017).

T. diversifolia exhibits allelopathic properties having water soluble allelochemicals in its plant parts and a phytotoxic potency capable of suppressing crop plant development and nutrient accumulation (OTUSANYA ET AL., 2015). However, the allelopathic potential may vary over time as concentration and function of allelochemicals usually change with vegetation succession (MUSCOLO ET AL., 2006; ZHAO ET AL., 2011; DJURDJEVIC ET AL., 2015). The aqueous extracts of *T. diversifolia* are more phytotoxic than *Chromolaena odorata* L. extracts, in reducing plant growth (OTUSANYA ET AL., 2015).

A household survey conducted in the lowlands of Bale zone, Ethiopia, showed that although invasive plant species have certain economic and ecological benefits the local communities considered invasive plant species have negative impacts on biodiversity, threaten ecosystems, livestock and livestock products, crops, animal and human health. The most prevalent invasive plants recorded on the survey site were *Parthenium hysterophorus* L., *Xanthium strumarium* L., *Argemone ochroleuca* L., *Caesalpinia* spp, *Acacia* sp., *A. mellifera* (M.Vahl) Benth., *A. seyal* DEL. and *A. tortolis* (Forssk.) Hayne (MUSSA ET AL., 2018). Further, it is reported that *T. diversifolia* contains some allelochemicals and thus its infestation in the crop field pose a serious threat to plantations of rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* (L.) Moench), and maize (*Zea mays* L.) (IMEOKPARA & OKUSANYA, 1994). Likewise, the fast spread of *T. diversifolia* could devastate the environment and have an impact on the community's socio-economic and livelihood prospects (WITT ET AL., 2019). The landscape selected in this study (Aizawl, Mizoram, North East India) is of extreme ecological and

socio-economic relevance as it is an integral landscape within the Indo-Burma biodiversity hotspot (RAI, 2012, 2015, 2022; RAI & SINGH, 2021). Nevertheless, in India, a comprehensive study on *T. diversifolia* is limited and negligible especially in the context of a biodiversity rich region i.e. north-eastern states (VANLALRUATI & RAI, 2021). From an Indian perspective, most of the studies have been conducted on a small number of invasive alien plant species and nearly half of these studies are focused on *Lantana camara* L., *Parthenium hysterophorus* L., *Mikania micrantha* L., *Ageratum conyzoides* L., and *Eichornia crassipes* (Mart.) Solms (water hyacinth) etc., and only limited research has been done on the invasion ecology and environmental, and socio-economic implications of *T. diversifolia* (REDDY, 2008). To better understand and elucidate the ecology of *T. diversifolia*, an initial, and urgent, research in the biodiversity rich traditional state of Mizoram was conducted. In this respect, a socioeconomic survey was undertaken in this study to determine the associated benefits and drawbacks of *T. diversifolia*. Identifying the positive, or economically, beneficial and negative, or harmful, impacts of *T. diversifolia* invasiveness are required in order to evaluate the consequences of invasion processes, gaps in socio-economic implications, and to implement management measures.

2. Methods

Aizawl, the state capital of Mizoram, lies between 92°3'- 92°60' E longitude and 21°58'- 24°85' N latitude and is located in the north-eastern part of India (Fig. 1 and Fig. 2). It occupies an area of 3576.31 square kilometers and accounts for 16.96% of the total geographical area of the state. The study area falls within the Indo-Burma biodiversity hotspot with about 86% forest cover (of the total geographical area) which comprises a great variety of flora and fauna and has a significant endemic component, particularly in the case of plants (TORDOFF ET AL., 2012; RUATI & RAI, 2021; SAKACHEP & RAI, 2021). The endemic plants in north-east India can be listed as orchids (existing record of 730 orchids out of 1229) and bamboos (record of 65 bamboo species out of 130) which denote this region for biodiversity conservation priorities (RAI, 2012). However, about 70% of the plant diversity of this Indo-Burma hotspot region is threatened due to multiple anthropogenic perturbations such as infestation of invasive alien plants (RAI & LALRAMNGHINGLOVA, 2010). The present survey was conducted between December 2020 and February 2021 at different sites within Aizawl city and towns

(viz. Ramthar, Tanhril, Chawlhmun, Zemabaw, Zuangtui, Thuampui, Durtlang, Selesih and Sihphir) where *T. diversifolia* occurs abundantly (Table 1 and Fig. 2). It is important to mention that the roadsides and marginal lands were the places or ecotopes where the dominance of *T. diversifolia* was observed at a maximum. Fig. 3 shows *T. diversifolia* within the selected study area.

Table1. Demographic profile for the socio-economic survey

L. No	Parameters	No of individuals (n)	Percentage (%)
A	Age		
	10 to 20 years	12	14.63
	21 to 30 years	18	21.95
	31 to 40 yeass	33	40.24
	41 to 50 years	10	12.20
	51 to 60 years	5	6.10
	61 years old or more	4	4.88
	Total	82	
B	Gender		
	Male	37	45.12
	Female	45	54.88
	Total	82	
C	Education		
	Up to high school	27	32.93
	Bachelor's degree	30	36.59
	Master's degree or higher	12	14.63
	N/A	13	15.85
	Total	82	
D	Occupation		
	Farmers	22	26.83
	Students	11	13.41
	Retired	5	6.10
	Govt. servant	10	12.20
	Private sector	13	15.85
	Others*	21	25.61
	Total	82	

*Others includes: Driver, housewife, business owner, electrician, labour, storekeeper

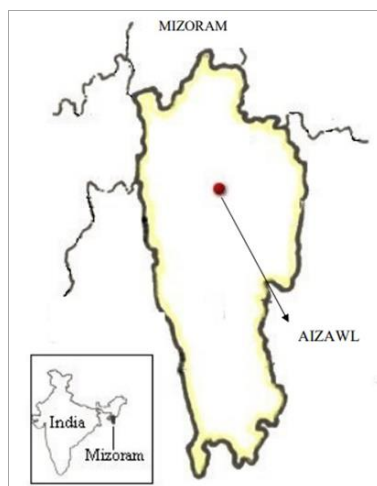


Fig. 1. Location of the study area of Aizawl, Mizoram, North East India (an Indo-Burma global biodiversity hotspot)

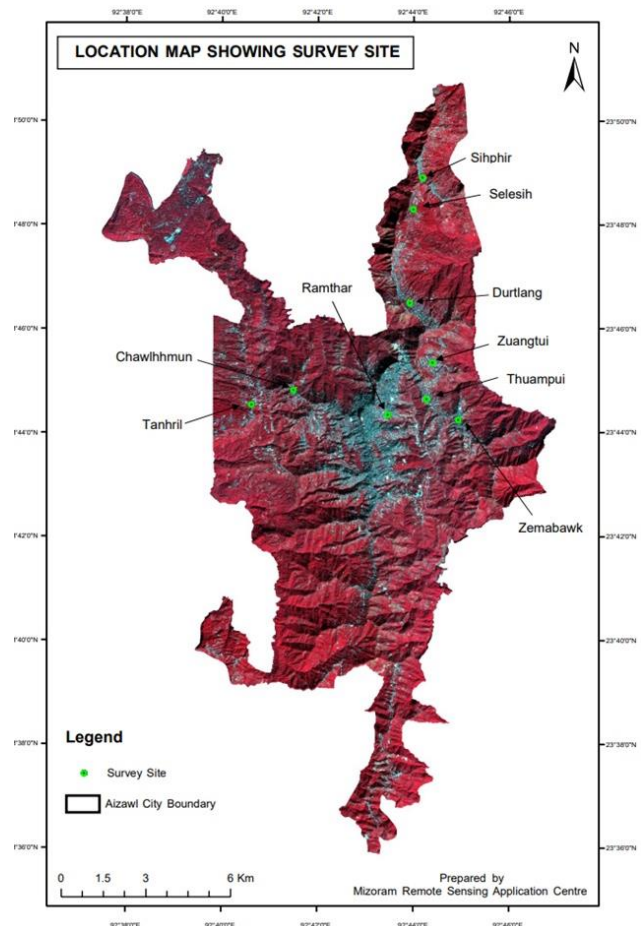


Fig. 2. Map showing survey sites to assess societal perception on environmental and socio-economy impacted by invasion of *T. diversifolia*



Fig. 3. *T. diversifolia* at the selected area of Mizoram (Photo Courtesy of Vanlalruati)

The environmental and socio-economic implications of *T. diversifolia* invasions were assessed by interviewing 82 individuals using semi-structured questionnaires. The questionnaire was made with the aim to gather information on the introduction history and spread of *T. diversifolia* in the study area, an integral part of the Indo-Burma hotspot

region. The questionnaire was further structured to investigate the existing harmful and economically beneficial aspects of *T. diversifolia* in the forestry/ agro-forestry systems of the study area. The respondents were selected from the study areas based on the knowledge that he/she has of *T. diversifolia*. The responses of the individuals were recorded and noted down on the questionnaire. In addition, the data recorded were summarized and processed for references. The environmental and socio-economic implication survey is a useful method to understand the impact of *T. diversifolia* on the local people, their livelihood, and the interrelationships between economic and ecological factors (MUKHERJEE, 2003; WITT ET AL., 2019).

3. Results and discussion

3.1. The spread and introduction of *T. diversifolia* in Mizoram

Tithonia diversifolia is locally known as 'Bawngpu par', 'Nihawi par', 'Khawldaipar' and 'Vaivakawn par'. Among the respondents, none of them could mention the exact year when *T. diversifolia* arrived in Mizoram. Although there were no formal records of the year of invasion, *T. diversifolia* was known to invade Mizoram during the 1960s (as per 53.66% of respondents). In this aspect, 46.34% did not notice the arrival and presence of *T. diversifolia* in their area. All the respondents (100%) strongly believed that it is an invasive plant and could not be considered as a native plant species. There were 39.02% of the respondents who considered that humans deliberately introduced *T. diversifolia* as ornamental plants in Mizoram which facilitated their spread. Other respondents (36.59%) thought that climatic factors (such as wind and rain) were one of the reasons for the rapid spread of *T. diversifolia*,

while 15.85% believed that it was spread by livestock as they act as a carrier or vector for the spread of *T. diversifolia*. There were people (8.54%) who did not have any idea and were unsure about the agents responsible for its spread (Table 2).

Table 2. Respondents opinions on how *T. diversifolia* has spread in Mizoram (n=82)

Sl. no	Parameters	Responses	%
1	Mode of introduction	Human activities (such as ornamental, medicine, etc)	39.02
		Climatic factors (such as wind, rain, etc)	36.59
		Livestock	15.85
		No idea	8.54

3.2. The influence of *T. diversifolia* on agro-ecosystems/agro-forestry systems

Around 65.85% of people responded that *T. diversifolia* grew very well in their locality and the plants occupied a large geographical area of their land. The farmers residing on the outskirts of Aizawl considered it to be a threat since *T. diversifolia* was a hindrance to them when accessing their crop plants in agricultural systems especially during the growing and flowering period (i.e., September to February). While several (21.95%) respondents concluded that the occurrence of *T. diversifolia* on their crop land do not pose a threat to the native crop plants. They just considered it as a plant which beautifies their land as the flowers are aesthetic and provide a recreational essence. Others (12.2%) responded that although *T. diversifolia* caused a threat to the native plants on their cultivated lands the problem to their agriculture systems is manageable, however, it may be of more concern in the near future (Table 3).

Table 3. Overall opinions of the respondents on the positive and negative impacts of *T. diversifolia* (n=82)

Sl. no	Parameters	Percentage of respondents who consider positive impact (%)	Percentage of respondents who consider negative impact (%)	No idea (%)
1	Agro-forestry	21.95	65.85	12.2
2	Bio-fertilizer	42.68	37.81	19.51
3	Socio-economic purposes	29.27	70.73	-
4	Medicinal plant	3.66	-	96.34
5	Soil erosion	63.41	-	36.59
6	Livestock feed	24.39	-	75.61
7	Pest and weed control	-	-	100

3.3. *T. diversifolia* as a bio-fertiliser

In the questionnaire survey, people (42.68%) opined that the dried litter of *T. diversifolia* improved the soil fertility. The respondents opined that after the flowering period was over, the plants dried out and the heavy left-over litter on the ground caused a problem for the farmers as the plants are usually long and bushy within dense thickets. Therefore, physical treatment sometime becomes pertinent for their fast decomposition. The respondents also thought that the plant litter and residues enriched the soil by providing organic matter to the soil. Despite the slow rate of decomposition, *T. diversifolia* biomass increases the soil fertility, thereby increasing the production of *T. diversifolia* each year. However, other respondents (37.81%) did not consider *T. diversifolia* to be a good option to use as a bio-fertiliser. In this context, 19.51% of respondents did not have any idea about the role of *T. diversifolia* in augmenting the soil fertility. Moreover, none of the respondents used *T. diversifolia* for mulching to improve soil fertility (Table 3).

3.4. Use of *T. diversifolia* for socio-economic/livelihood prospects

In relation to socio-economic uses, 70.73% of respondents did not consider *T. diversifolia* to be a good source of income, especially as an ornamental flower because the flowers wither away very fast. The flowers therefore required preservation for selling purposes. The respondents also thought that if there were more options for further processing the flowers, or the plant parts, into ornamentals or for medicinal purposes, it would be a good source of income. Besides some respondents (29.27%) sold *T. diversifolia* plants to cattle or livestock rearer at affordable prices (Table 3)

During the survey it was known that 3.66% of the respondents used *T. diversifolia* for medicinal purposes but not for economic purposes. In this respect, the leaves of *T. diversifolia* were crushed and boiled with water. The leaves of *T. diversifolia* contain an anti-inflammatory compound which acts as an anti-bacterial agent (OLUKUNLE ET AL., 2014; OMOLOLA, 2020). The residue of boiled leaves was used as a paste and applied on the wound and the filtered liquid was used for the treatment of abdominal pain. Nonetheless, *T. diversifolia* has not been recorded as a medicinal plant locally. This may be due to lack of documentation in the context of ethnomedicinal attributes of *T. diversifolia* in Mizoram. Accordingly, 96.34% of the respondents did not know about the medicinal purposes of *T. diversifolia* (Table 3).

Some respondents from Zuangtui and some farmers from Selesih reported that *T. diversifolia* is used for fencing around homesteads and to demarcate the boundaries between their farms from other farms. Due to the attractive colour of its flowers, people used them for home decoration. In the context of aquatic ecosystems, *T. diversifolia* was observed to grow successfully near rivers banks. In Aizawl, *T. diversifolia* did not grow very well with other invasive alien plants of the Aizawl region. However, it grows well along with other invasive plants in certain patches located in the remote outskirts of Aizawl. At these sites, *Ageratum conyzoides* L., *Lantana camara* L. and *Mikania micrantha* L. were noted as co-dominants with *T. diversifolia*. In some places farmers chopped and mixed the leaves of *T. diversifolia* with wheat grains and fed them to their cattle and broilers (24.39%) whereas the majority of the respondents (75.61%) did not use *T. diversifolia* for any purpose (Table 3).

3.5. Use of *T. diversifolia* for the control of soil erosion

T. diversifolia was considered to be an effective tool to prevent soil erosion by the respondents (63.41%) of the survey. In this sense, the biomass of *T. diversifolia* tightly binds the soil particles together with their root system and thereby serves as an effective protective layer to help and prevent soil erosion. Due to their strong roots and dense blossom, the respondents considered these as a protective wall or barrier to the ground and soil against harsh winds and extreme rainfall. Of the respondents 36.59% were neither aware, or not, of any scientific knowledge about an applicable mechanism of *T. diversifolia* in preventing soil erosion (Table 3).

3.6. The negative and economically beneficial impacts of *T. diversifolia* invasions

The negative response pertaining to the local perception of *T. diversifolia* included various aspects. The long stalks and leaf litter of *T. diversifolia* occupied more ground space and took time to decompose on the ground unless they were adequately chopped into fine pieces. Also, the leaves and stalks of *T. diversifolia* disturbed the growth of the young, or native, plants and eventually inhibited the growth of other plants. Respondents admitted that the thickness of the plants blocked the incoming sunlight for smaller plants, replaced native vegetation, affected the natural regeneration of other plants, and hindered the growth of other plants on land and along riverbanks. In respect of the eradication

and management of *T. diversifolia*, farmers required high manpower as it was mainly abundant along roadsides with steep slopes (Table 3).

The positive aspects included the use of *T. diversifolia* for ornamental and decorative purposes. People from Zuangtui and some farmers from Selesih used *T. diversifolia* for fencing around homesteads and to demarcate the boundaries between their farms and other farms. Due to the attractive colour of the flowers, people used them for make-up and home decoration. *T. diversifolia* was also used as a traditional medicine for the treatment of wounds and abdominal pain. In the context of aquatic ecosystems, *T. diversifolia* was observed to grow successfully near riverbanks. In Aizawl, *T. diversifolia* did not grow very well with other invasive alien plants of Aizawl. However, it grows well along with other invasive plants in certain patches located in the remote outskirts of Aizawl. At these sites, *Ageratum conyzoides*, *Lantana camara* and *Mikania micrantha* were noted as co-dominant with *T. diversifolia*. In some places the leaves of *T. diversifolia* was chopped and mixed with wheat grains and fed to their cattle and broilers (24.39%) whereas the majority of respondents (75.61%) did not use *T. diversifolia* for any purpose (Table 3). It is worth mentioning that although *T. diversifolia* offers some economic uses, these should not be considered as positive effects in terms of biodiversity conservation (RAI & KIM, 2020). Therefore, sustainable management options should be formulated to mitigate the spread of *T. diversifolia* in the landscape of this Indo-Burma hotspot region.

3.7. The control and management of *T. diversifolia* in Aizawl, Mizoram, North-East India

Respondents opined that the physical method was the best way to control the growth of *T. diversifolia* and were ignorant about ecological economics and ecosystem-based repercussions. This is because farmers and local people do not have the proper awareness of the control and management of plant invasions by either chemical or biological strategies. Since *T. diversifolia* is tall and spreads quickly, it occupies a large area and hampers the growth of other plants. It is convenient for farmers and local people (46.34%) to attempt to reduce the growth of plants either through slashing or cutting the root. Other respondents (13.41%) burnt the plants after flowering and senescence in-situ i.e., with-in the habitat area itself, while 29.27% first cut/chopped the plants and left it to dry for a few days and later burned the *T. diversifolia* plants. However, 10.98% of respondents were neither concerned about the growth of this invasive

plant, nor about their control or management. All respondents interviewed (100%) were totally unaware of using chemicals/secondary metabolites (such as insecticides or pesticides) for the management of *T. diversifolia*. They added that since *T. diversifolia* is present on sloping areas they do not have any need to control the growth and distribution either biologically or chemically (Table 4).

Table 4. Percentage of respondent who performed different kinds of methods to manage the control of *T. diversifolia* (n=82)

Sl. no	Methods	Management practices	%
1	Physical	Slashing	46.34
		Burning	13.41
		Chopped and burnt	29.27
2	Chemical	-	-
3	Biological	-	-
4	Nothing/Not sure	-	10.98

The socio-economic analysis of people's perceptions in the present study aimed to outline the possible effects of *T. diversifolia* on the economy, agriculture, and livelihoods of the local people. In Zambia, the invasion of *T. diversifolia* caused a serious problem to farmers who were forced to abandon their land but in the study areas there were no such cases observed during the survey (WITT ET AL., 2019). In Kenya, *T. diversifolia* was used for soil fertility management when there was a scarcity of animal manure (KIPTOT, 2008) whereas in Aizawl, only 42.68% of respondents considered *T. diversifolia* improved the soil fertility. Since, *T. diversifolia* forms dense stands the plants act as barriers to minimize the impact of heavy rainfall on the soil, thus limiting soil erosion. Also, *T. diversifolia* was used for fencing around homesteads and to demarcate the lands of different stakeholders.

4. Conclusions

The questionnaire surveys conducted on people's perception of *T. diversifolia* revealed both economically beneficial and negative, or harmful, effects in terms of their environment and livelihoods. However, the beneficial economic effects do not license human society to encourage the spread of *T. diversifolia* and effective mitigation strategies are warranted to augment its sustainable management. This study explicitly indicated that *T. diversifolia* has a great potential in multiple sectors related to agriculture, farming and even in ethnopharmacology, if clinically tested or validated for secondary metabolites based on its medicinal values. Nevertheless, these beneficial, or economic uses,

should not facilitate the spread of *T. diversifolia* as it can be deleterious in terms of biodiversity conservation. Also, other invasive alien plants such as *C. odorata* and *M. micrantha* were introduced for their beneficial effects, or economic uses, however, these have exerted severe threats to the environment, biodiversity conservation, socio-economics, and human well-being. The present study also noted that the people of Mizoram are not much concerned about the invasion of *T. diversifolia* and further studies are warranted to elucidate its invasion ecology, impacts, and to devise sustainable control measures before the landscape spread of this emerging weed.

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