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THE FIRST OCCURRENCE OF INVASIVE *Amorpha fruticosa* L. (FALSE INDIGO) IN NORTH MACEDONIA

SUMMARY

Several specimens of *Amorpha fruticosa* - an invasive alien plant species of North American origin - were recorded in 2020 near the village of Stari Grad, and alongside Babuna river, in the central part of North Macedonia. In the course of a field survey, *A. fruticosa* was found mainly in highly fragmented forests, on forest paths and in forest clearings (coppice), on the edges of arable fields, in a neglected dry meadow, riparian areas and the river banks of Babuna river. In the areas where *A. fruticosa* was detected, it usually grows in association with nitrogen-loving species such as *Chenopodium album*, *Amaranthus retroflexus*, *Calystegia sepium*, *Urtica dioica*, *Sorghum halepense*, and *Rubus caesius*. *A. fruticosa* was found mainly on alluvium and fluvisol soils, predominantly on arable lands along roadsides and at the border between forested areas and arable lands. Control and eradication of *A. fruticosa* is very complicated and costly, mostly due to high reproductive capacity of the species.

Keywords: *A. fruticosa*, first occurence, ecological impact, control management

INTRODUCTION

The genus *Amorpha* L. (*Fabaceae* Juss.: *Amorpheae* Boriss.) contains 16 species, all of North America origin, with a diversity centre in the South-East of the USA (Isely, 1998; Weber and Gut, 2004; Straub *et al.* 2009; CABI, 2019; Grabic *et al*. 2022). Many of the species exhibit a highly restricted geographical distribution. However, the tetraploid *Amorpha fruticosa* L. (false indigo) (2n=4x=40) (Kreuter, 1930; Turner, 1956; Löve, 1982) exhibits "impressive" ecological adaptability (Wilbur, 1975) over its large geographic range, which overlaps that of all of the other species.

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A. fruticosa is able to grow on poor degraded, dry and well-drained sandy soils (Doroftei, 2009; Dumitraşcu *et al.* 2011, 2012). This plant can fix air nitrogen, create humus layers and increase soil fertility (Zhao *et al.* 2014), making it suitable for other invasive weeds. In recent years, Kucsicsa *et al*. (2018) reported that *A. fruticosa* is becoming adapted to very humid soils.

In some nature reserves in Romania, large areas invaded by *A. fruticosa* were seen in swamps, beside the forestry paths (Dumitraşcu *et al.* 2013; Dumitraşcu *et al.* 2014). Roadsides are also very important in the spread of this alien species (Kozuharova *et al*. 2020). Additionally, the emergence of *A. fruticosa* downstream from infested sites shows the plant can be spread by water (Fenesi *et al.* 2009). *Amorpha fruticosa* is a perennial, leguminose shrub, 1–3 (4) metres in height with strong woody offshoots. It was introduced to Europe in 1724 (Liovic *et al*. 2002; Karmyzova, 2014) as a plant favoured by beekeepers and for ornamental purposes due to its remarkable dark violet-purplish flowers (Hulina, 1998). Additionally, due to its extensive root system, which expands from horizontal root shoots up to 100 cm below ground, *A. fruticosa* has been utilised for erosion control, for slope stability, and has also been used as a plant to form hedgerows (Celesti-Grapow *et al.* 2009).

In the EPPO region, *A. fruticosa* is listed among the invasive alien plants recognized by the EPPO (EPPO, 2006). It is generally recognized as one of the EPPO regions most invasive alien plant species (Grabic *et al.* 2022), particularly in Central and Eastern Europe where it has been found in Romania (Dumitraşcu *et al.* 2014), Hungary (Varga *et al.* 2016), Slovakia (Kelbel, 2012), Ukraine (Ivanko and Gorban, 2017), Russia (Vinogradova, 2016), Belarus (Euro+Med, 2006), Slovenia (Jogan *et al.* 2012), Croatia (Novak and Novak, 2018), Serbia (Blagojević *et al*. 2015), Bosnia and Herzegovina (Maslo, 2023), and Bulgaria (Pedashenko *et al.* 2012). In Italy, it has become prevalent in northern areas, where it is established in the riverbeds and along the banks of rivers in the Po Plain and the neighbouring valleys (Celesti-Grapow *et al.* 2009).

A. fruticosa can survive extreme climatic conditions withstanding freezing temperatures below -25°C in a completely dormant state (Huxley, 1992). It is also very adaptable, being found from the cold continental climate within Northern US to the semi-arid subtropics of Northern Mexico (Huxley, 1992). The plant is adapted to different types of habitats and prefers moist and periodically flooded terrains, such as: river banks, unvegetated or sparsely vegetated shores, water-fringing reed-beds, and riverine (Anastasiu *et al.* 2008), being therefore a serious threat for fragile wet habitats, but can also be adapted to reduced soil moisture, (Dumitraşcu *et al.* 2014) mesophyle and xeromesophyle meadows (Sărăţeanu, 2010). According to Sărăţeanu *et al.* (2008) *A. fruticosa* is mesophytic, and moderate thermophyllic.

A. fruticosa is a strong competitor in the banks area and along the channels swamp ecosystem (Doroftei, 2009) and is found in riparian brushes (Anastasiu and Negrean, 2006) and natural riparian forests (Dumitraşcu *et al*. 2011). It may also take place in agricultural areas, but solely in locations where there is sufficient water availability and adjacent to irrigation channels. (Blagojević *et al.* 2015).

Previous studies showed that *A. fruticosa* exhibited vigorous coppicing (Takagi and Hioki, 2013) and demonstrated a significant ability for seed dispersal, rarely by sprouts or layering (Dumitraşcu *et al.* 2014). Sărăţeanu *et al*. (2007) demonstrated that grasslands were invaded by *A. fruticosa* due to poor management, large abandoned land offering favorable conditions for its spreading.

A. fruticosa propagates by seed, but can also propagate vegetatively by root shoots and plant fragments. Natural spread of propagules can be facilitated by water, small mammals and birds to feed on seeds and contribute to propagation (Doroftei *et al*. 2005). Seeds have a high viability with studies showing seeds gathered from plants growing in sunlight and shadow averaged 94% and 98%, respectively (Oršanić *et al.* 2006). In suitable habitats, viability of seeds in the soil extends from 3 up to 5 years (Stevenson, 2014).

A. fructicosa releases some chemical substances that affect the germination of some plant species (Csiszár *et al.* 2013). *A. fructicosa* also tolerates poor soil conditions (Kozuharova *et al.* 2017), characterized through its mutualistic symbiosis with some nitrogen-assimilating bacteria from genus Rhizobium. The bacteria establish nodules on the roots of the shrub, enabling the fixation of atmospheric nitrogen, which is subsequently utilized by *A. fructicosa* and, to some extent, by the surrounding flora, thereby colonizing an environment deficient in nitrogenous compounds (Wang *et al.* 1999; DeHaan *et al.* 2006). *A. fruticosa* fertilizes the soil with nitrogen (Navarrete-Tindall *et al.* 2003), making it suitable for other alien weeds.

A. fruticosa has a high capacity to outcompete indigenous plant communities when forming dense monospecific stands. Additionally, it can impact ecosystem services, for example, by obstructing the water flow, consequently increasing the flood risks (Csendes, 2012). In certain regions of Lithuania, *A. fruticosa* can become abundant and invade significant areas of meadow, forest-edge and various other open habitats (Gudžinskas and Žalneravičius, 2015). It has become one of the most harmful weeds in the drainage systems in Croatia (Hulina, 1998).

MATERIAL AND METHODS

Analyses for the recording of *A. fruticosa* were carried out during the 2020 in the central part of North Macedonia, close to the Stari Grad village (Latitude: 41°34′51″N, Longitude: 21°39′54″E). The first recording was carried out in May and in June a second site visit the population and the wider area was surveyed to investigated the extent of the invasion. Plants were also observed alongside borders of arable fields and neglected dry meadow, riparian areas and the riverbed of Babuna river.

The plant species was identified by using appropriate literature i.e. keys for identification (Kojić, 1981; Domac, 1984; Klapp and Optiz von Beberfeld, 1990). The recording of *A. fruticosa* was done randomly, depending on its spread in different areas.

RESULTS AND DISCUSSION

In this record, was documented the first occurrence of *A. fruticose* (fig. 1) in the central part of North Macedonia. On 25th of May 2020, while conducting field work in the central part of North Macedonia (fig. 2), and alongside Babuna river (fig. 3), a dense population of *A. fruticosa* - an invasive species in the Macedonian flora - was recorded for the first time in North Macedonia.

Figure 1. *Amorpha fruticosa* L. (False indigo) recorded in the central part of North Macedonia (photograph by Z. Arsov)

Figure 2. Map of Republic of North Macedonia revealing where *A. fruticosa* was detected. The green location is the region where the village Stari Grad is found and where the plants were discovered. The blue places indicate lakes. (https://makedonija.name/municipalities/caska/stari-grad)

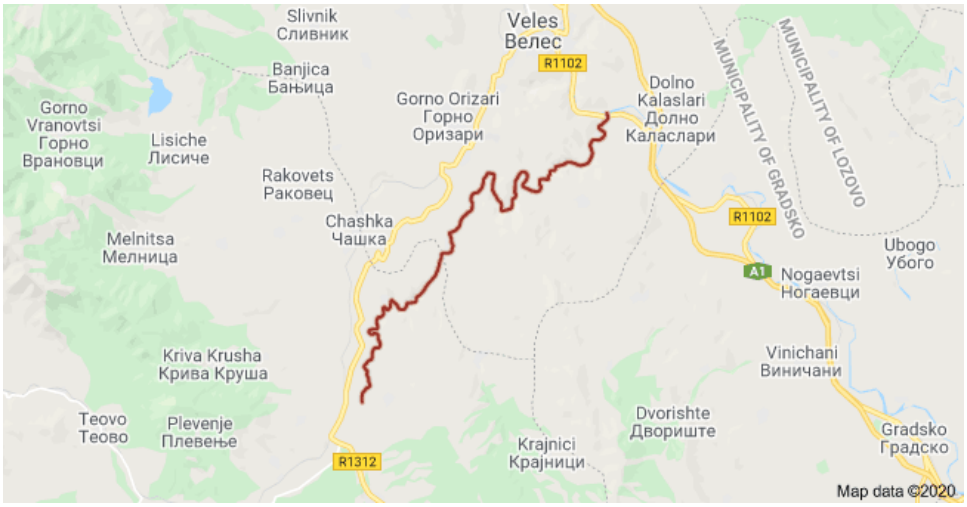

Figure 3. Map of Babuna river showing where *A. fruticosa* was found. (https://www.google.com/maps/@41.63997,21.73484,21398m/data=!3m1!1e3?entry=ttu)

During a second site visit on the 8th of June 2020, the population and the wider area was surveyed to investigated the extent of the invasion. The surveys indicated a significant increase during the intensive flowering stage, accompanied by a population density of *A. fruticosa* that ranged from low to medium. The density of the population was not measured; however, various stands of differing sizes were observed. The largest stands were approximately 100-150 metres at their widest point. During the second survey, the authors extended the area of observation, and the plant was found in moderate and mainly highly fragmented forests growing together with *Salix alba*, *Alnus glutinosa*, and *Ulmus minor*. Further population spread was observed along forest paths and in open spaces in the forest. Plants were also observed to have spread alongside borders of arable fields and neglected dry meadow, riparian areas and the exposed riverbed of Babuna river (fig. 4). The majority of the bushes were under 1 m in width and had several shoots, while only a few individuals exceeded 2 m in width. The roadsides seem to have the essential contribution in encouraging *A. fruticosa* establishment.

Similar to our findings, *A. fruticosa*, according to Hulina (1998) and Karmyzova, (2014), is frequently found in the lowland area, where it is mainly inhabiting riverbanks, drainage systems, forestedges and roadsides. Its spread has been rapid, particularly in disturbed wetland habitats, where it forms dense impermeable monospecific stands destructive for banks, and modifies habitat conditions becoming very competitive regarding autochthonous species (Liebhold *et al.* 2017; Boscutti *et al.* 2020; Pellegrini *et al.* 2021).

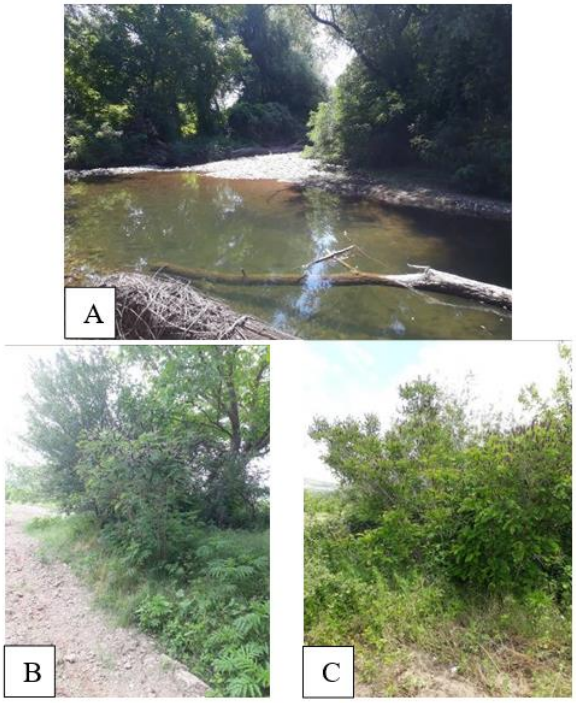

Figure 4. Population of invasive *A. fruticose*, growing in different environments close to the Stari Grad village and alongside Babuna river: (A)-river bank (B and C)-edges of arable land (photographs by Z. Arsov).

A. fruticosa demonstrates a preference for fragmented forest environments, indicating that forest fragmentation may heighten the vulnerability of ecosystems to invasive species and contribute to habitat degradation (Turner, 1989). An investigation conducted by (Sărăţeanu, 2010) indicted that *A. fruticosa* enhanced its invasive capacity on grasslands and shrublands. Conversely, dense forests limited dispersion of this heliophilous invasive plant. In this context, Magyar (1960) confirmed that *A. fruticosa* is seen as an inferior forest competitor due to excluding by trees, but because of its rapid growth, shadow superiority and possibly its allelochemical impacts (Elakowich and Wooten, 1995; Xiao *et al*. 2016; Novak *et al*. 2018) and nitrogen-assimilating capability (Wang *et al*. 1999), it is a superior competitor in grasslands (Szigetvári, 2002).

A. fruticosa is typically found growing in places where nitrogen-loving weed species including *Rubus caesius* L., *Urtica dioica* L., *Sorghum halepense* (L.) Pers., *Chenopodium album* L., and *Amaranthus retroflexus* L. coexist (Fig. 5). Similar conclusions were reached by Glišić *et al.* (2014) and Radovanović *et al.* (2017), who found a phytocoenological association with the dominance of *A. fruticosa* and *Rubus caesius*, which constitute the most harmful alien plant hotspot and pose a serious threat to native plants and their riverine habitats, including habitats downstream. According to Szigetvári's (2002) research, *A.*

fruticosa predominates along with a few other swampy plants and terrestrial creepers, such as *Calystegia sepium, Solanum dulcamara*, and the noninative *Echinocystis lobata* in the margins of the areas near to swampy ditches.

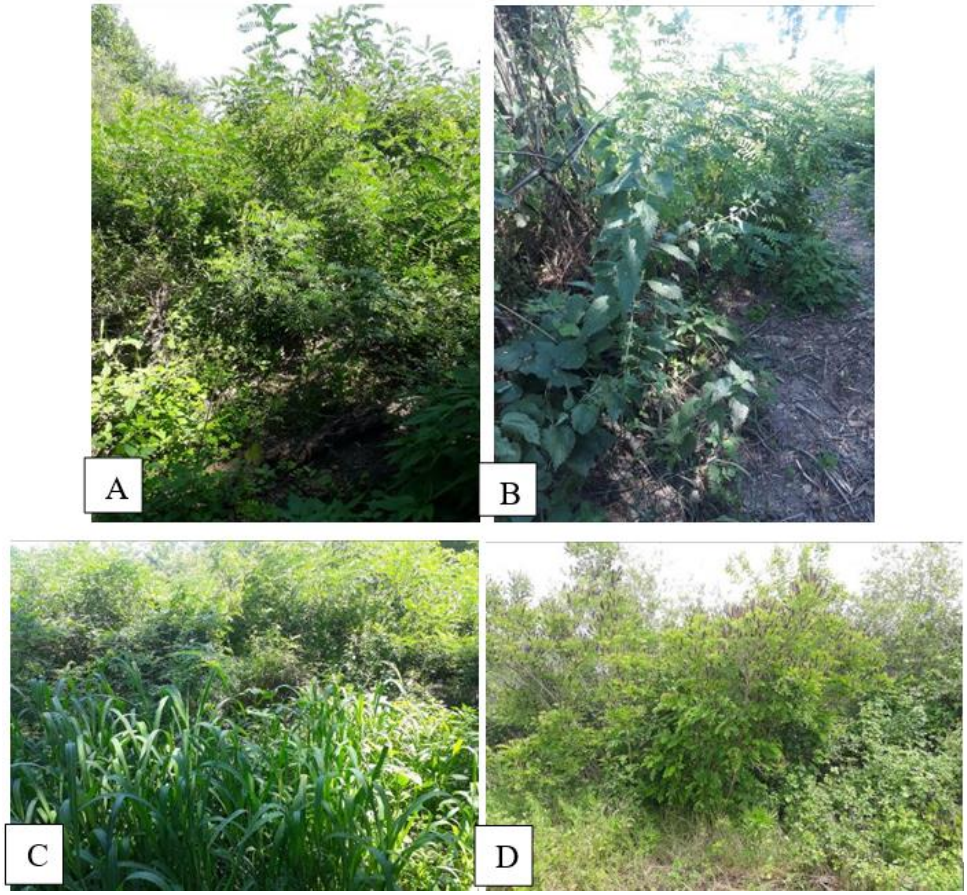

Figure 5. *A. fruticosa* grows in association with nitrogen-loving weed species such as, (A) *Chenopodium album*, *Amaranthus retroflexus*, *Calystegia sepium*, (B) *Urtica dioica*, (C) *Sorghum halepense*, and (D) *Rubus caesius* (photographs by Z. Arsov).

Ecological impacts

The most considerable negative consequence of the invasion of *A. fruticosa* is on natural vegetation in floodplains (Nagy *et al*. 2018; Kiss *et al*. 2019). In colonized habitats like swamps, it can have negative impacts on native plant populations and the ecosystem services, e.g. nutrient flow and ecosystem productiveness (Houlahan and Findlay, 2004; Brigić *et al*. 2014). Croatian studies show invaded habitats dominated by *A. fruticosa* are poorer in terms of herbaceous plants, diversity and richness compared to uninvaded habitats (Brigić

et al. 2014). In several continental regions in Croatia, *A. fruticosa* forms a monodominant community suppressing indigenous vegetation (Novak and Novak, 2018). The grassland species are either unable persist, or only a few persist in conditions of the dense, compact bush formed by *A. fruticosa*. *A. fruticosa* create a physical barrier to waterways and out-compete willow trees that many birds depend on. The environment becomes unsuitable for birds of prey and for the nesting bird species alike (Botta-Dukat and Balogh, 2008). Similarly, the fauna of *A. fruticosa* dominated habitats is impoverished. This kind of bush is nearly impenetrable for large mammals (e.g. deer, for example). These impassable, homogenous *A. fruticosa* stands in floodplains indicate a succession "sink", a particular type of "green desert" (Szigetvari and Toth, 2004). *A. fruticosa* changes indigenous vegetation in damp bushy associations along meadows, pastures, forests, as well as wet habitats, rivers, canals, and swamps. It particularly causes the enormous problems after large expanses in floodplain forests; it will extend very fast, and homogenous stands will be established if no provisions are made. The regeneration of forests in such habitats becomes not possible for comprehensive periods of time (Szigetvári, 2002). It damages the landscape aesthetically in semi-natural habitats, as well, making them impenetrable for visitors (Zavagno and D'Auria, 2001).

Control management strategies

A. fruticosa control management strategies are highlighted by numerous research worldwide, particularly from Asia and Europe (Essl and Rabitsch, 2002; Weber and Gut, 2004; Radulović *et al*. 2008; Takagi and Hioki, 2013; Lončar *et al*. 2020; Kus Veenvliet, 2021), but its control and eradication are complicated and requires substantial resources, due to high reproductive capacity of the species. The methods used are varied, including mechanical techniques, with smaller adverse consequences on the natural environment and surrounding vegetation. But, *A. fruticosa* is defoliation tolerant plant and is able to regenerate to a height of 1 m following annual cutting to 10 cm for period of 7 years (DeHaan *et al.* 2006). Therefore, its eradication by cutting means is labour-intensive. The most promising mechanical control method is the frequent defoliation and digging of the root. In recent years, in the protected areas along the Danube River and other major inland rivers, control measures against the spread of *A. fruticosa* were implemented. The only effective measure against this invasive species proved to be the mechanical removal of the plants followed by replanting native species (Pedashenko *et al.* 2012; Pellegrini *et al.* 2021). For mechanical treatment, the local community was invited to participate, and the branches and roots removed served as fuel wood. Useful initiatives were taken for managers in manufacturing pellets process (Brînzan *et al.* 2020). In order to eradicate *A. fruticosa* from the protected area in Mureș Floodplain Natural Park was mechanically controlled, by repeated cutting of the sprouts of *A. fruticosa*. After selecting the most affected territories by *A. fruticosa*, the shrubs were cut by a forest cutter, and the wood debris was left on the ground to enhance soil quality;

the roots were dislocked by a scarifier machine and they were used by the local communities for heating. The soil was plowed and prepared for sowing with a mix of grasses typically for this region. In order to prevent *A. fruticosa* resettlement, it was advised that control measures should be repeated for at least five years (Suciu *et al.* 2019). When controlled inefficiently, other natural stands, further away from the river meadows, involving partially closed and not too open habitats, may be slowly invaded by *A. fruticosa*.

Different treatment methods for controlling *A. fruticosa* stands, such as manual intervention, flail mowing and grazing by grey cattle was studied by Kapocsi and Danyik, (2015). However, a repeated treatment is necessary in relation to *A. fruticosa*, with costly mechanical flail cutting and grazing. Grazing in forests stands of floodways was possible without diminishing the timber yields, and at the same time it suppresses invasive *A. fruticosa* and has a substantial role in retaining local population as a secondary way of exploitation; coverage ratio of invasive species was diminished due to grazing (*A. fruticosa* non grazed: 50%, grazed 5%) (Varga *et al.* 2016). Mulching had to be repeated annually, which was performed during the autumn and winter periods, while grazing was performed by a cattle herd in cells (a process of managed rotational grazing) (Demeter *et al.* 2021).

Treatment of cut stumps with herbicides provided effective control of *A. fruticosa* (DiTomaso *et al.* 2013). The study of Uzonyi and Miklós (2015) showed that contiguous *A. fruticosa* shrubs were cut with small axes and hatchets, and then incinerated on site. A mixture of red paint, 1 litre of gasoline and 150 mL of triclopyr (Garlon 4E) was applied on the cut stumps, in accordance with nature conservation regulations. Unfortunately, this combination did not provide effective control. Although the stumps were destroyed, the next flood wave spread the seeds all over the cleared area, resulting in 2–3 meter-tall bushes within a year. Polypropylene tree shelters, when used alongside with a reduced rate of herbicides, provided excellent control of *A. fruticosa*. This approach is both cost-effective and environmentally sustainable, while also necessitating minimal human labor (Liovic *et al.* 2002). Also important are policies for the prevention of invasive species, Pötzelsberger *et al*. (2020) concluded that is clear need for more coordinated, science-based policies at the local and international levels is also important to maximize the benefits of non-native trees while mitigating any negative consequences.

CONCLUSIONS

Amorpha fruticosa is likely to continue to spread and invade new areas, especially in habitats that are prone to high levels of disturbance. Additional, future forest fragmentation and clearing, the extension of the transportation network and the abandonment of the agricultural lands will increase the potential spread of *A. fruticose*. Furthermore, planting *A. fruticosa* for different purposes (on the degraded lands, protection of dams or roads) will facilitate species' invasion within the important habitats and ecosystems. To cut twice a year for

three years, slowing the vegetative spread and reducing growth and seed production. The cultural control, by offering cover and competition, robust native plant communities will aid in limiting seed germination and preventing the invasion of *A. fruticosa*. Given that *A. fruticosa* is closely associated with certain landscape features, such as soil type, water depth, canopy closure, and road network, it is also critical to incorporate this knowledge into projections of the species' future distribution in habitats and ecosystems that share many of the same environmental conditions. Additionally, these findings can be used to identify the areas that this terrestrial alien species is most likely to colonize by using similar habitats where *A. fruticosa* occurrence is conceivable.

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