

Investigation and Study on the Main Invasive Plants for Agriculture in Henan Province

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At present, the number of alien invasive species confirmed by the state has reached 544, more than 100 of which have spread on a large scale and caused severe harm. Due to their numerous invasion channels, high rate of reproduction, and harmfulness, invasive species are threatening biodiversity and causing huge economic losses in China. The advanced transportation network and suitable environmental conditions in Henan Province have provided conditions for the invasion and survival of harmful species. Tian et al. (2005) reported the presence of 30 alien invasive plants in Henan Province; on December 28, 2005, Henan Daily announced 12 alien invasive plants; Zhang (2006) reported 26 alien invasive plants in the agricultural regions of eastern Henan Province. Likewise, Liu Ying et al. (2008) discovered 34 alien invasive plants (including 1 aquatic plant and 33 terrestrial plants), and Zhu et al., (2007) and Dong et al., (2007) respectively reported 53 alien invasive plants found in Henan Province. However, Dong et al., 2007 mistakenly included *Eleusine indica*, *Nasturtium officinale*, *Ludwigia prostrata*, *Cuscuta japonica*, *Prunella vulgaris*, and other plants in the list of alien invasive plants. Jiang et al., (2009) declared the number of alien invasive plants in the suburbs of Xuchang to be 46; Zhang et al., (2010) described nine newly-confirmed alien invasive plants. In 2011, Xu and Jian (2011) listed 62 alien invasive plants found in Xinxiang; Wang and Gao (2012) discovered four alien invasive plants in their investigation on highways in Henan Province. The coverage of alien invasive species by previous studies used ambiguous concepts and failed to provide either voucher specimens or photographs, making it difficult for successors to confirm their results. In addition, these studies only recorded the species of invasive plants in Henan Province, but did not perform any dynamic monitoring on the main invasive plants for agricultural lands in Henan Province.

Thus, for the purposes of investigating and monitoring invasive plants in Henan Province, it is valuable to conduct a province-wide investigation on the regions of distribution, area of spread, invasion route, and law of spreading of the main alien invasive plants for agriculture, creating an information database, distribution map, and propose targeted control schemes and measures.

1. Investigation design and methods

1.1 Investigation design

First, the herbarium specimens and literature were investigated nationwide. Then, field investigations were conducted according to literature materials, and years of follow-up investigation on plant distribution, spreading routes, and speed of spread were carried out. Finally, the characteristics of spreading of the invasive plants were summarized and the historical process of their invasion and dispersal was reconstructed.

1.2 Investigation methods

Literature investigation methods: Through referring to the specimens and literature materials stored at herbaria nationwide, we have gained a general understanding of the invasion history, distribution, harms, prevention and control technology, and other related information; Interview and investigation methods: By consulting related departments of township governments and agricultural bureaus, local people, technicians, experts, and so forth, we can understand the introduction time, source, distribution, and other related

information; Field investigation methods: Field investigations were conducted to observe and confirm the distribution of the target species, or it focuses on places where invasive plants may emerge.

2. Results and analysis

2.1 Results

2.1.1 Definition of concept

Alien species: “Alien species” is a term relative to the endemic species in a place of origin. For an ecosystem, an alien species is a species that previously did not exist in the ecosystem and was either intentionally or unintentionally introduced from other ecosystems through overcoming spatial obstacles that could not be naturally overcome without human activities. **Alien invasive species:** When an alien species is introduced into a new ecosystem, if the local climate and soil conditions are suitable, it will establish its population and alter or threaten local biodiversity. In this case, it will become an alien invasive species.

2.1.2 Main alien invasive plants for agriculture in Henan Province

In 2007–2017, our research team conducted a follow-up investigation on eight of the main alien invasive plants for agriculture.

(1) *Alternanthera philoxeroides*. Place of origin: South America.

Distribution in China. In 2003, *A. philoxeroides* was included on the list of the first batch of alien invasive species in China. It was first found in 1892 on an island near Shanghai, and a relatively early domestic record dated back to the specimen collected by H. Migo in 1933 in Zhelin Town, Fengxian District, Shanghai. Since the 1980s, due to its rapid growth, strong adaptability, and difficulty eliminating this species, it has frequently formed monodominant communities, endangered farmlands and fishponds, and clogged rivers. As one of the world-recognized malignant weeds, it has spread almost entirely throughout the regions south of the Yellow River. **Distribution in Henan Province:** *Alternanthera philoxeroides* was first found in Huaibin County of Xinyang in 1985, and had dispersed throughout Xinyang in 1986. In 2007, a scattering of *A. philoxeroides* was found in Tanghe County, Nanyang and Lushi County, Sanmenxia. In 2010, it was found in small areas in Wugang, Pingdingshan; Queshan County, Zhumadian; Lingbao, Sanmenxia; and other regions. In 2013, it was found in the peripheral regions of Zhengzhou; currently it is wide-spread in Henan Province, and especially concentrated in Xinyang (Figure 1).

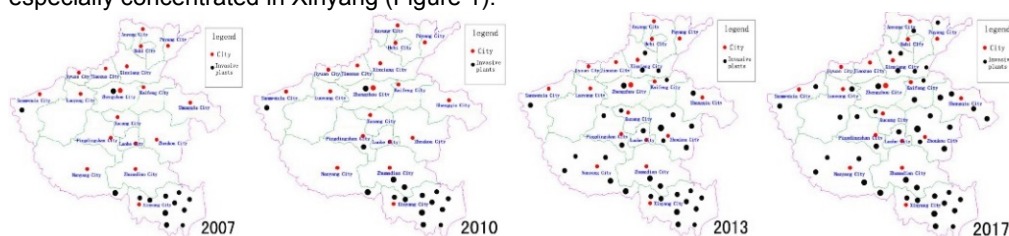


Figure 1: Distribution dynamics of *Alternanthera philoxeroides* in Henan Province

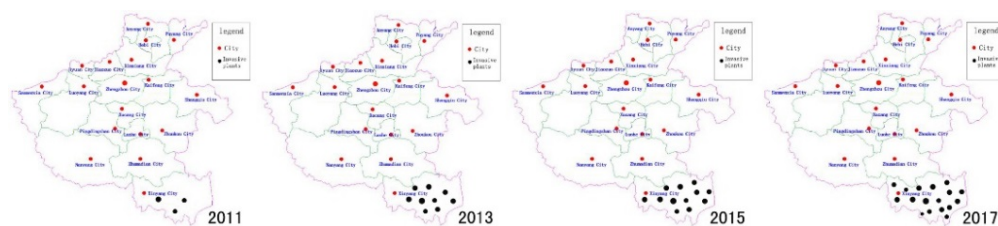


Figure 2: Distribution dynamics of *Ambrosia artemisiifolia* in Henan Province

(2) *Ambrosia artemisiifolia*. Place of origin: The Sonoran Desert region in southwestern America and northern Mexico. **Distribution in China:** According to specimen records, *A. artemisiifolia* was first found in Hangzhou in 1935, Liaoning in 1976, Shandong and Guangdong in 1982, Hubei in 1983, Hebei in 1987, and Jiangxi in 1993. Currently, it is wide-spread in about 15 provinces and municipalities directly under the central government in northeastern China, northern China, central China, eastern China, and etc. **Distribution in Henan Province:** *Ambrosia artemisiifolia* was first found in Xinxian County, Xinyang in 2001; in 2005, it was discovered in large area in the same region. In 2011, about 200 strains were found in Luoshan County and

Xinxian County of Xinyang. In 2013, there were large-area outbreaks in Guangshan County, Luoshan County, and Xinxian County, Xinyang, mainly dispersed along highways; currently, it is wide-spread in Xinyang (Figure 2).

(3) *Flaveria bidentis* (L.) Kuntze. Place of origin: South America.

Distribution in China: In 2001, *F. bidentis* was found for the first time on the campus of Nankai University in Tianjin and in Hengshui, Hebei Province. Six years later, it spread to Henan, Shandong, and many other provinces and cities; currently, its most severe outbreaks are in Hebei Province.

Distribution in Henan Province: In 2006, *F. bidentis* was found for the first time in Anfeng Township, Anyang County; in 2007, it spread to several villages in Anfeng Township, Anyang County. In 2008, it was also found in ten townships and towns in Anyang County, Neihuang County, Tangyin County, and other counties (districts), and on both sides of main traffic arteries in Qingfeng County and Nanle County, Puyang. In addition, it was found in five townships and towns of Neihuang County, Nanyang (i.e., Chengguan Town, Zhanglong Township, Mashan Township, Chuwang Town, and Tianshi Township). In the summer of 2009, its seedlings were found in the green belt at the gate of the west campus of Xinxian University, but no flowering plant was reported that year. In the spring of 2010, its seedlings were detected at the same spot, and plants in full-bloom were found beside farmland not far away from the spot in September. In 2015, it was found in small amounts in Mianchi County, Sanmenxia and Mengjin County, Luoyang. Currently, it is mainly distributed in the peripheral regions of Anyang, Puyang, and Xinxian (Figure 3).

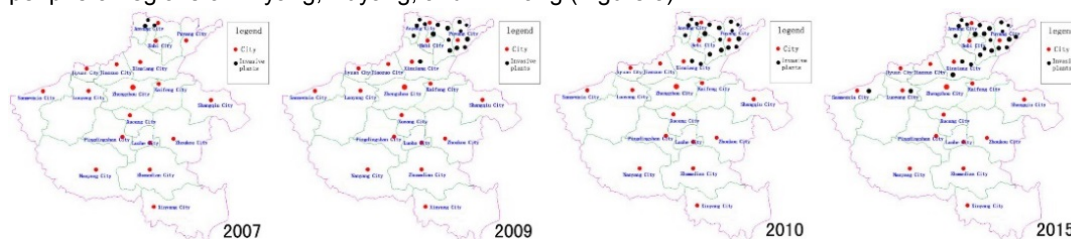


Figure 3: Distribution dynamics of *Flaveria bidentis* (L.) Kuntze in Henan Province

(4) *Chenopodium ambrosioides*. Places of origin: Central and South America.

Distribution in China: According to specimen records, *C. ambrosioides* was first found in Taipei, Taiwan Province in 1864, Guangdong in 1907, Hong Kong in 1927, Shanghai in 1930, Fujian in 1932, Hubei in 1975, and Beijing in 1982. In the Yangtze River basin, it is the dominant or constructive species of weed communities, and frequently invades and threatens the habitats on the Yangtze River embankment. It usually grows in farmlands, by the roadside and the riverside, and in other wastelands.

Distribution in Henan Province: In the 1980s, *C. ambrosioides* was cultivated sporadically in various regions of Henan Province. Existing specimen records were first found in Tongbai County in 2005. It was found in Zhengzhou before 2008 and in Shangqiu, Henan Province in June 2009. In early September 2009, it was found on the new campus of Xinyang Junior College of Agriculture. In 2010, it was found in Xinxian County of Xinyang and Shangcheng of Nanyang. In 2013, it further spread to Guangshan County, Xinyang; Dengzhou and Baihe Wetland, Nanyang; and other regions. In 2015, a scattering were found at the junction between Zhengzhou and Xinxian. Currently, it is mainly distributed in Xinyang, Nanyang, Shangqiu, and other regions (Figure 4).

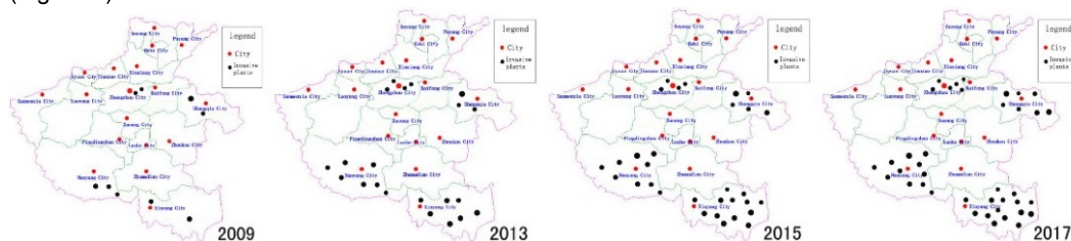


Figure 4: Distribution dynamics of *Chenopodium ambrosioides* in Henan Province

(5) *Chenopodium pumilio*. Place of origin: southern coastal regions of Australia;

Distribution in China: *Chenopodium pumilio* was first found in Henan, and, because of the similarity between the climate conditions of Henan and that of the place of origin, it has rapidly reproduced in Henan. Currently, it is distributed all over the county; Distribution in Henan Province: In 1993, Professor Zhu Changshan collected specimens of the species for the first time in a lawn on the campus of Henan Agricultural University, and

reported the species for the first time in 2006. According to existing specimen records, it was found in Zhongmu in 1996, Huayuankou and Miaozi Township, Yingyang in 1998, and in Mangling and Maozhuang in 2004. In 2016, it was abundantly scattered in northern Zhengzhou, extending from the area south of the Yellow River Road to Agricultural Road (Figure 5).

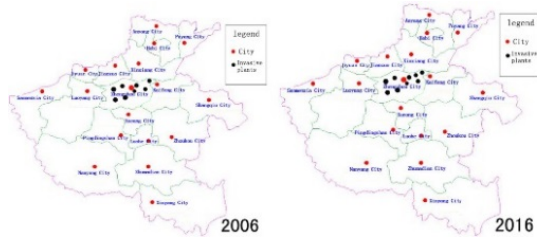


Figure 5: Distribution dynamics of *Chenopodium pumilio* in Henan Province

(6) *Gaura parviflora*. Place of origin: North America.

Distribution in China: According to specimen records, *G. parviflora* was first found in Songjiang District, Shanghai in 1934, Beijing in 1979, Shandong in 1981, Jiangsu in 1951, and Hebei in 2009. Henan released its list of harmful alien invasive plants for the first time in 2005, in which *G. parviflora* was included. In recent years, it has dispersed rapidly in Henan, Hebei, Shandong, Anhui, Jiangsu, and other regions; Distribution in Henan Province: According to a literature review, *G. parviflora* was first found in Henan Province in 1964 in Fengqiu County. In 2007, it was found in Huixian County of Xinxiang; in 2008, it spread to downtown Zhengzhou. In 2009, it dispersed westward to Jiyuan Yellow Chinaberry Forestry Management Area and Jiaozuo, and eastward along both banks of the Yellow River. In 2011, it dispersed to Sanmenxia and other regions; in 2013, it was found in many regions of Zhengzhou. In 2015, a scattering was found in Mengjin County of Luoyang. Currently, it is mainly distributed in Zhengzhou, Sanmenxia, Jiyuan, and etc. (Figure 6)

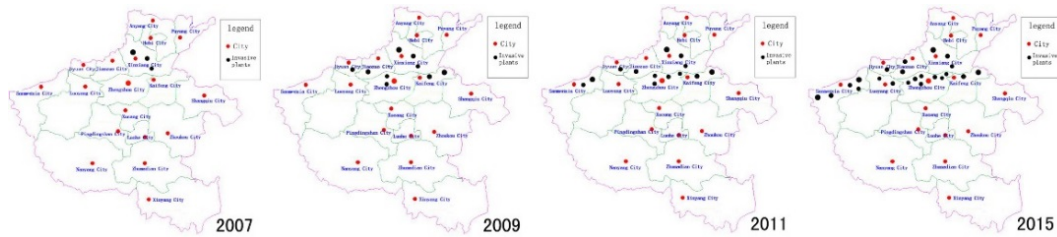


Figure 6: Distribution dynamics of *Gaura parviflora* in Henan Province

(7) *Eichhornia crassipes*. Place of origin: South America.

Distribution in China: According to specimen records, *E. crassipes* was first found in Wengyuan County, Guangdong in 1924, Guangxi in 1928, Zhejiang in 1932, Yunnan in 1933, Hunan in 1942, Jiangxi in 1957, and in Hubei and Guizhou in 1959. Currently, it is widely distributed all over the country, and its invasion is especially severe in Jiangsu and Zhejiang and in Henan, Hubei, and other region; Distribution in Henan Province: In 2006, *E. crassipes* was found in Xiliu Lake, Zhengzhou and in waterways in Xuchang. In 2007, many individuals were found in the watercourse near the Qingshui River in northern Kaifeng; in 2010, it was found in Chen Zhai Flower Market, Zhengzhou. In 2013, it was found in some parks in Anyang. In 2017, it was found in the Luoyang Botanic Garden (Figure 7).

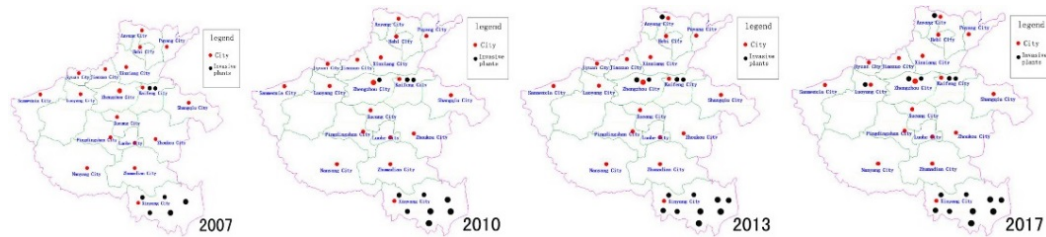


Figure 7: Distribution dynamics of *Eichhornia crassipes* in Henan Province

(8) *Lolium temulentum*. Places of origin: The Mediterranean region, Europe, Central Asia, the Siberian region of Russia, the Caucasus region, and Asia Minor;
 Distribution in China: According to published records, *L. temulentum* was naturalized in Heilongjiang in 1957, and spread to 45 counties in Heilongjiang in 1961. Today, it is distributed in all Chinese provinces except Tibet and Taiwan (Zhou, 1996);
 Distribution in Henan Province: In the early 1960s, *L. temulentum* was introduced into five regions of Henan (i.e., Xinayng, Zhoukou, Shangqiu, Zhumadian, and Nanyang) with Funo wheat seeds. In 1986, because of the introduction of 7,859 wheat seeds from *L. temulentum*-infected regions of Shaanxi, it was introduced into Luoyang and scattered throughout various regions. In 1987, it was found in Yanshi, Songxian County, and Mengjin County, Luoyang. In 2010, there was a large-area outbreak in Xinyang. After years of control, *L. temulentum* is distributed only sporadically in Xinyang, Zhumadian, and Nanyang (Figure 8).

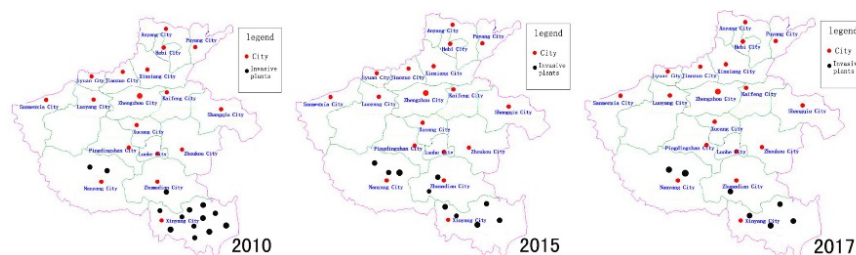


Figure 8: Distribution dynamics of *Lolium temulentum* in Henan Province

2.2 Analysis

2.2.1 Characteristics of alien invasive plants in Henan Province

According to investigations, since 2005, many alien invasive species, such as *A. artemisiifolia*, *F. bidentis*, and *C. ambrosioides*, have had exacerbated outbreaks. Most alien invasive plants are widely distributed in farmlands, roads, and unused lands, mainly because of frequent trading activities, the prospering tourism industry, and massive abandoned farmlands. Xinyang is a region in Henan Province that is severely afflicted by alien invasive plants. According to the literature, the species that have invaded Xinyang include *A. philoxeroides*, *E. crassipes*, *A. artemisiifolia*, and so forth. This is likely due to the specificity of the geographical location. That is, Xinyang is the southern gate of Henan Province and has a subtropical monsoon climate, both of which provide invasion opportunities and suitable conditions for invasive plants.

2.2.2 Spreading routes of alien invasive plants in Henan Province

Introduction of species: Sometimes, people intentionally introduce plants from other regions for purposes such as improving the environment, beautifying the landscape, developing economy, for food, ornamental purposes, and etc. Adaptation to local climate conditions or the local environment causes these introduced plants to often experience rapid reproduction and large-area dispersal within a short period of time. Combined with a lack of management, they soon “evolve” into invasive plants. For instance, *A. philoxeroides* was first introduced as pig feed and was rapidly cultivated on a large scale in Xinyang in 1985. Now, it is impossible to eliminate. *Eichhornia crassipes* was mainly introduced for the purification of water sources; however, it has shown a trend of large-area outbreaks in recent years. **Unintentional introduction:** Relative to intentional introduction, unintentional introduction mainly relies on human activities or means of transportation to spread from one region to another. Among the eight alien invasive plants under critical investigation, most were first found in coastal cities, such as Shanghai, Hangzhou, Guangdong, Hong Kong, and Tianjin, before further spreading to inland regions. Zhengzhou, the transportation hub of central China, witnesses frequent internal and external exchanges, and as soon as alien plants enter this region, they will disperse to peripheral regions.

3. Discussion

3.1 Establish a sound legal system

Because of the lack of attention on the part of relevant state departments for investigations, studies, and detection of alien invasive plants, and because of the limited existing national legal system in regards to alien invasive species (largely consisting of supplementary provisions), there is an absence of targeted content about how to monitor and control invasive alien species. With the increase in both the regions invaded by invasive alien plants and the economic losses hereby incurred, the state should improve relevant laws and

regulations as soon as possible, and establish laws governing the management of intentionally introduced species in terms of a quarantine system. In terms of supervision management, a definite division of labor should be conducted to strengthen cooperation. In regards to legal responsibilities, besides clearly defining the responsibilities of parties concerned, it is also necessary to severely punish those who violate laws and regulations.

3.2 Build professional teams

The lack of professionals and the weakness of technical forces also contribute to the rapid spreading of alien invasive plants. As indicated by this investigation, there is a lack of staff specialized in botany or ecology in rural environmental protection stations at all levels, and, because of their unfamiliarity with the names, characteristics, and spreading routes of invasive plants, the prevention and control of invasive alien plants has been directly compromised. Thus, it is urgently necessary to equip a batch of professional technicians, or improve the professional competence of existing staff through professional training.

3.3 Enhance publicity

First, relevant departments at various levels should strengthen the publicity of the list of alien invasive plants, so that citizens can get acquainted with alien invasive species. Second, the harm that alien invasive plants cause should be publicized through multiple channels so that the general public can understand invasion rates, reproduction characteristics, and harm. Third, it is also necessary to increase publicity about the control of invasive alien plants, so as to enhance the general public's prevention consciousness.

3.4 Strengthen epidemic information management

The control of alien invasive plants is a long-term task. Due to the uncertainty, rapid ability to spread and destructiveness of alien plant invasion, studies on the early warning signals, and continuous and effective control measures against alien invasive species should be constantly strengthened. First, the agricultural sector should take the lead to create alien invasive species databases, and include alien invasive species already found in China and in neighboring countries. Second, studies on the monitoring systems and control methods related to alien invasive species should be enhanced. Third, it is also very important to further compile dynamic information about invasive alien species and related information network systems.

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