The Habitat Spatial Dispersal and Ecological Invasion of Two Exotic Plants in Taiwan

Exotic Plants and its Spatial Dispersal

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Abstract.

This study, based on different investigative documents and analytical methods, elucidates spatial distribution of habitats for two major invasive exotic plants, *Mikania micrantha* and *Leucaena leucocephala*, in Taiwan. Results show that *Mikania micrantha* is most harmful to broad-leaved trees and its invasion directly relates to changes in the physical environment. The upper limit for its distribution is 2,000M elevation; the lower the elevation, the more the detrimental effect. The most favorable environment for the plant to grow is that with abundant sunshine and moist soil. *Leucaena leucocephala* can bloom and bear fruits all year round and during the period of seeds sprouting and saplings, the invasion varies greatly among different soil types. *Leucaena leucocephala* prefers weakly acidic soil, though it grows well with other soil textures and nutrients as well. The average spreading rate of *Leucaena leucocephala* is 42.3% on abandoned farm land calculated from the aerial photographs taken in 1992, 1994, 1996, and 1998.

Key words: Exotic plants, Ecological invasion, Mikania micrantha, *Leucaena leucocephala*

1. INTRODUCTION

Failure of human beings to effectively control exotic plants they introduce for their own benefit may affect the original ecological system in a short period of time, and may even lead to reduction in the variety of species. Once exotic plants succeed in invading and occupying a certain plot within an ecological system, no matter what methods we adapt to prevent and control them, much time and effort, even with eradication procedures, must be invested. It will cause major impact on the ecological system over a period of time; therefore, prevention, control, and research on the invasion of exotic plants have been given much attention (Moody and Mack, 1998).

The number of exotic plant species on Taiwan island has recently reached 4,516 (Lai, 1995). Most of them were imported via human economic activity; yet, the introduced plants were planted and bred intentionally, and humans failed to manage them properly as they multiply. Therefore, exotics may diffuse out to open fields, harm the ecological system and become invasive plants. In recent years, *Mikania micrantha* has invaded plantations and orchards at lower elevations in mid-southern Taiwan, and has caused serious damage by twining around tree stem and killing the plants. The detriment to the ecological system by *Leucaena leucocephala* has already spread over the island now 2009, and many plants cannot grow and develop effectively in their usual habitats because of this invasion. The invasion and diffusion (augmentation) of alien species have long been recognized highly complicated processes. The uncertainty of these intrusions has resulted both from their extremely complicated mechanisms and the lack of information on the range and detail of the invasive species. Fundamental information derived from long term inspection is necessary for understanding and clarifying this uncertainty. The comprehensive data will enhance the accuracy of a postulated invasive pattern. It has been shown lately that the stronger the interference the easier the invasion, especially for artificial disturbance caused by humans (Duggin and Gentle, 1998；Petren and Case ,1998). The invasive plants establish their domains at forest edges or road corridors when sufficient sunlight becomes available due to the formations of artificially developed segments, abandoned farm and fragmented terrain due to the construction of roads and buildings (Song et al., 2005; Hawbaker and Radeloff, 2004; Chung and Lu, 2006).

In this research we used different methods to investigate two invasive plants, *Mikania micrantha* and *Leucaena leucocephala*, which seriously affect ecological environments in Taiwan. After analysis of the harmful effect on habitat, we review its spacial distribution and environmental impacts by means of global positioning system (GPS), geographical information system (GIS), remotely sensed data, and phenological study.

2. MATERIALS AND METHODS

2.1 The areas covered in this study

The climate of Taiwan includes both tropical and subtropical region. The southern area, north to Tropic of Cancer, has a tropical monsoon climate, and the northern area, south to Tropic of Cancer shows a subtropical monsoon. The climate over the entire island is characterized by high temperature, high humidity, and strong wind. There is a seasonal difference among all regions. The annual average temperature is about 20 ℃, while that for average rainfall is about 2,500 ㎜（highest during May to October, more in mountains than in flat land; more on the east coast than on the west coast；more in the north than in the south）(King and Su,1993). High temperatures and humidity facilitate growth and spread of exotic plants. This research was conducted on all national forest lands in Taiwan and the Hengchun Area in Southern Taiwan (Fig. 1) to determine the invasive status of *Mikania micrantha* and *Leucaena leucocephala*.

2.1.1 Ecological habit of *Mikania micrantha*

Mikania micrantha is a perennial broad-leaved vine (Asteraceae), originally native to shady areas in Middle-South America. The plant blooms from November to December, producing seeds over 170,000/m2.The seeds are spread by wind from

November to February, then begin to grow (Kuo et al., 2002). At present, this species has spread in middle-south and eastern Taiwan, and has caused serious ecological damage（Fig. 2）.

2.1.2 Eological habit of *Leucaena leucocephala*

Native to South America, *Leucaena leucocephala*, is a mimosaceae plant, 4-18 m. in height. Its legumen is flat, 14-26 cm long and 1.5-2.0 cm.wide. Every pod contains15-30 brown and lustrous seeds, 6-10 mm long. In the Hengchun peninsula (the most southern part of Taiwan), there are three new varieties of *Leucaena leucocephala*: var. *glabrata*, var. *Leucocephala* and Peru type. Resulting from the interbreeding among these varieties, new types have already come into being（Lu and Chen, 2002）.

The research investigated 365 *Mikania micrantha*-infested sampling points and the phenological data of *Leucaena leucocephal*. Numerous geographical data of Taiwan, are used for geographical analysis.

2.2 Research methods

2.2.1 Physical environment

The literature on floral development and distribution shows that for the habitat of plants, the primary conditions are seasonal distribution of rainfall and atmospheric humidity, whereas the secondary condition is terrain: altitude, slope, and aspect. The soil is usually affected by biology, rainfall, air temperature, geology, and terrain, and cannot be regarded as an isolated environmental factor of plant habitat(Ellenberg, 1968; Molles, 2002; Chapman & Reiss, 1999; Auerbach & Shmida, 1987). In large-scale ecological research, the physical environmental factors are ordinarily used to estimate the spatial ecological phenomena (Peterken and Game, 1984; Rossi and Kuitunen, 1996; King and Su, 1993). This study used GIS to build the following spatial models: slope, aspect, altitude, open sky space, and moisture gradient.

2.2.2 Analysis of the heterogeneity of habitat of *Mikania micrantha*

We used ARC/GIS to build 365 attribute data-bases of *Mikania micrantha* threatening sampling sites all over Taiwan, and in consideration of physical parameters of altitude, slope, aspect, open sky space, and moisture gradient. We used the G-test to determine heterogeneity in the emergence frequency of *Mikania micrantha*, and estimated its adaptability to the procreating environment using the relationships shown in equations (1)-(3).

$$G = 2\sum_{i=1}^{a} O \ln(O / E) \qquad (1)$$

In which, O is the observed frequency and E is the expected frequency. In order to make the G-test closer to $\chi 2$ distribution, we used equation (2) to carry out Williams' correction.

$$CF = 1 + \left(a^2 - 1\right) / 6nV \qquad (2)$$

Here, a is the number of observed items, n is the sum of observed value, and V is D.F. (degree of freedom).

Finally, we used G_{adj} to calculate the heterogeneity of the procreating environment of *Mikania micrantha*（equation (3) ）, and determine its selectivity on the physical environment.

$$G_{adj} = \frac{G}{CF} \qquad (3)$$

2.2.3 Research on the phenology of *Leucaena leucocephala* and its habitat

2.2.3.1 The phenology of *Leucaena leucocephala*

While studying the phenology, we adopted the quantized manner of observation, and divided the acryl observation board of 10cm × 10cm into 100 panes of 1cm × 1cm. During field investigation, we marked every sampling point with the observation position and direction, and in every observation at the same position and direction, the phenological change of tree crown was observed. We used the observation board to count the occupied pane number in the extension of tree crown of every species (a) and of, *Leucaena leucocephala* in particular (b) a partial pane was counted as one. In this process, we took formula b/a x 100 as the abundance percent of *Leucaena leucocephala*. We quantized and recorded the abundance percent with Braun-Blanquet measure. The cycle of this research was one month, and 32 sampling points were selected.

2.2.3.2 Growth status of *Leucaena leucocephala* in different land-use

There are different land use types in Hengchun area, so the growth manners of *Leucaena leucocephala* after invasion are different. We designated 65 sampling sections in the following 7 types of land: inner part of natural forest, edge of natural forest, mixed forest, *Leucaena leucocephala* forest, grass land, bare land, and plantation land. The size of each sampling section was 3m × 3m, except that of those at the edge of natural forest: 5m × 5m. In every sampling section, the number of *Leucaena leucocephala* of the following 3 heights was investigated and recorded: shorter than 30cm, between 30-120 cm, and taller than 120cm. The number of *Leucaena leucocephala*, taller than 120cm, was recorded in accordance with the following 5 diameter classes: less than 2.0 cm,2.0-4.0 cm,4.0-6.0 cm,6.0-8.0 cm, and larger than 8.0 cm. Sections were examined every 3 months and we transformed the number of *Leucaena leucocephala* of different height in every sampling section into tree number in every hectare area. This was used to analyze the growth state of *Leucaena leucocephala* on lands of different use types.

2.2.3.3 The relationship between the distribution of *Leucaena leucocephala* and physical and chemical properties of soil

The field investigation data was converted to a digital geographic theme and overlaid with the soil map to construct a map of the relationship between *Leucaena leucocephala* sampling points and physical and chemical properties of soil. This examination collected data on physical-chemical properties of soil to a 20cm depth, which included 11 items: sand content, silt content, clay content, pH value, organic matter, cation, aggregate stability, dispersion ratio, free iron, exchangeable K, and available P. We used all factors to analyze and discuss the relationship between the distribution of *Leucaena leucocephala* and physical and chemical properties of soil.

2.2.3.4 Analysis of the invasion and dispersion speed of *Leucaena leucocephala*

In order to determine the invasion and dispersion speed of *Leucaena leucocephala*, we used the IKONOS satellite photograph with resolution of 1m × 1m to demarcate the current distribution scope of *Leucaena leucocephala*. By using the manner of Lonsdale（1993）, we selected 3 sites from the aerial photography taken in

1992,1994,1996 and 1998, to judge and calculate the distribution scope of *Leucaena leucocephala*, and estimated its invasion and dispersion speed. The remote sensing technique is one of the best and widely method to investigate the damage area of exotic plants(Krumpe, 1972；Lonsdale, 1993; Bulman, 2000; David et al., 2000)

3. RESULTS AND DISCUSSION

3.1 The invasion status of *Mikania micrantha*

3.1.1 Imperiling describe

We used the survey data on invasion status of *Mikania micrantha* in national forest lands of Taiwan that were taken in 2001－2002 by Bureau of Forestry, to form a GIS chart（Fig. 3）. The general invasion area on Taiwan national forest lands is about 8,800 hectare, and the endangered area in the Nantou Forest District is the largest (5,000 hectare, that of Pingtung forest district takes the second place（3,000 hectare）, while that of Taitung is 300 hectare, and that of Hualian is 450 hectare. There was no damage due to *Mikania micrantha* in Xinzhu and Luodong forest districts. This shows that its endangered areas are mainly in south-central Taiwan, with prediction of dispersion in the north.

3.1.2 Result of the environmental adaptation analysis of *Mikania micrantha* habitat

We carried out a frequency analysis of the data on physical environment in the *Mikania micrantha* invasion area, and used a G-test to determine if the invasion area has selectivity to the emergence frequency of every physical environment factor. The results (Table 1) shows the relationship between *Mikania micrantha* and physical environment:

Aspect—We used the aspect data of *Mikania micrantha* invasion position to designate 8 aspects: north, northeast, east, southeast, south, southwest, west, northwest. We used a G-test to indicate any difference between the emergence frequency and emergence aspect of *Mikania micrantha*,. The results showed that the difference was not significant（G_{adj}=1.79), because the endangering probability of *Mikania micrantha* is the greatest in the area of man-made interference. Since the position has no significant relationship to aspect in the areas of man-made interference, the invasion probability has no significant relationship to *Mikania micrantha* habitat in different aspects.

Slope- After conducting frequency analysis of slope data in endangered areas, a G-test showed that the difference between areas was significant（(G_{adj}=98.06). For

Mikania micrantha, in the slope level of 10° ~ 40° , the emergence frequency is the highest, highly impacted by human activities.

Altitude- Altitude was divided into 500-meter sectors. Results of frequency analysis and G-tests showed that the difference among 500-meter sectors was significant（G_{adj}=70.84）. Among the 365 sampling points, the number at 0-500 m was 173, and the imperiling degree is 47% . The imperiling degree among 500-1,000 m is 41% , which showed that the imperiling distribution of *Mikania micrantha* is mostly below 1,000m altitude. In the areas at more than 2,000m altitude, there is no imperiling phenomenon. From this, we can see that the imperiling degree increases with the decrease of altitude, and 2,000m is the upper limit of its distribution.

Whole light sky space- We divided the sky light into 9 levels, and checked the emergence frequency with G-test. The result showed that the difference was significant(G_{adj}=69.82). Most *Mikania micrantha* grows in plantation areas with open sky space of 4~7 level(76~200. Areas where the illumination is too strong(8, 9 level) or too weak（1,2 level）, are not fit for its growth. From this we can see how great the illumination impacts on the survival of *Mikania micrantha*.

Moisture gradient- We divided the moisture gradient into 11 levels, and used G-test to determine the discrepancy of frequency distribution. The results showed that the difference was significant（G_{adj}=105.52）and that *Mikania micrantha* frequency differs among all moisture levels. The effect of moist environment is most harmful at moisture gradient level 2. In summary, *Mikania micrantha* grows best in areas with the following characteristics: low altitude, moderate illumination, and moist environment. Among all factors of physical environment, direct factors are: altitude, open sky space, and moisture gradient; and the indirect factors are: slope and aspect. The former represent the invasion adaptability and the latter represent the invasion probability.

3.1.3 The influence of *Mikania micrantha* on different species

In order to explore the threat of *Mikania micrantha* on a species, we calculated its frequency in plantation areas of different tree species *Mikania micrantha* is a parasite vine plant, and is mainly harmful to small broadleaf trees and trees that have lower clean length of trunk (Fig. 2.). Table 2 shows that, among all planted species, the following nine species type (prescence is over 3%) are particularly affected by *Mikania micrantha*: *Zelkova formosana*, Acacia confusa, shaw forest and bamboo, *Liquidambar formosana*, *Fraxinus formosana*, *Cinnamomum camphora*, *Pachira macrocarpa*, *Swietenia mahagoni*, *Pachira macrocarpa*.

3.2 The invasion status of *Leucaena leucocephala*

3.2.1 The phenology of *Leucaena leucocephala*

We started to investigate the phenology of *Leucaena leucocephala* in October, 2001, and continued for 15 months until December, 2002. Fig. 4 shows the results after quantizing every phenology with Braun-Blanquet measure method. *Leucaena leucocephala* in Hengchun area has a short life cycle and the following phenomena were observed all year round: flower budding, blossoming, fruit setting, fruit ripening, and fruit falling. According to phenology, the florescence of *Leucaena leucocephala* should be sub-annual; therefore, it must have at least two florescence phases in a year. With adequate moisture, it can blossom all the year round. Before the dropping off of the old legumens, the new legumens appear. Contrasting the result of phenological investigation with meteorological data, the phenology of *Leucaena leucocephala* is mainly affected by precipitation.

3.2.2 Growth status of *Leucaena leucocephala* on lands of different use types

Since December, 2001, we began to investigate, quarterly, the growth status of *Leucaena leucocephala* in lands of different use types. In every sampling section, the number of trees was recorded according to the following height categories: less than 30 cm, 30-120 cm, and higher than 120 cm. Trees of taller than 120 cm were recorded in accordance with 5 DBH (diameter at breast height) categories: less than 2.0 cm, 2.0-4.0 cm, 4.0-6.0 cm, 6.0-8.0 cm, and greater than 8.0 cm. The recorded data were transformed into the number of trees per hectare (Table 3).

Table 3 shows *Leucaena leucocephala* can not only be found in pure forest, but also frequently appears at the edge of natural and mixed forests. Its growth status varies in lands of different land use types due to environmental differences.

3.2.2.1 Natural forest

We found no *Leucaena leucocephala* taller than 30cm survived in any natural forest. Natural forest in Taiwan normally has high crown density, unless natural hazards, such as typhoons, north-east monsoon. If large gaps are created in the crown level, then plenty of sunlight will penetrate and the seeds of *Leucaena leucocephala* can germinate. Lacking sunlight when they reach a certain height will kill these trees. From the fact stated, it is quite difficult for *Leucaena leucocephala* to invade into the natural forest with integrated tree crowns, unless the natural forest community is badly destroyed.

3.2.2.2 Edge of natural forest

Table 3 shows that, for *Leucaena leucocephala* in the natural forest, if its height is either taller than 120 cm, between 30cm and 120 cm, or less than 30 cm, the average proportion of tree number per hectare is about 1.0, 3.5,or 4.5 respectively. It is obvious that the number of seedling trees is many times that of grown trees in this area, because there is plenty of sunlight at the edge. Although *Leucaena leucocephala* has hardy renewal ability at the edge of natural forest, it is quite difficult for *Leucaena leucocephala* to penetrate into the inner part of natural forest, unless the edge of natural forest is continually destroyed or the number of *Leucaena leucocephala* is too high to have an allelopathic effect to restrain the renewal and growth of other seedling trees (Chou and Chen, 1976; Chou, 1980; Chou and Kuo, 1986).

3.2.2.3 Mixed forest

From Table 3, the average number of *Leucaena leucocephala* per hectare in the mixed forest is1.0, 1.7, and 5.3 respectively for those trees of three heights: less than 30cm, between 30-120 cm, and taller than 120cm. In this specific area, although *Leucaena leucocephala* may increase its dispersive chances by the germination of a jillion seeds, there are not many trees taller than 30cm, resulted from the fact that *Leucaena leucocephala* not only scramble for nutrient with other species, but also competes within the same breed.

3.2.2.4 *Leucaena leucocephala* forest

In *Leucaena leucocephala* forest, the crown cover can obstruct the sunlight, making the trees compete for nutrient and space. The growth of *Leucaena leucocephala* seedling becomes comparatively difficult. In every hectare, the average number of *Leucaena leucocephala* is about 1.0, 5.0, and 15.2 (Table 3), which is according to tree height: lower than 30cm, between 30-120 cm, and higher than 120cm. It shows that the number of seedlings (lower than 30cm) is far more than that in mixed forest and that at the edge of natural forest. However, there is only one that can grow into 120cm or higher among 15 seedlings.

3.2.2.5 Grass land

Most of the grass lands are formed because of animal husbandry, and *Leucaena leucocephala* is the best feed for the flocks and herds in Hengchun area. When *Leucaena leucocephala* is hardly germinating the flocks and herds enjoy it and therefore it's difficult for *Leucaena leucocephala* to break into the grown forest. Once the browsing stops, without seeds of *Leucaena leucocephala* being trampled and eaten by the flocks and herds, the *Leucaena leucocephala* will break into the grassland and gradually grow into forest.

3.2.2.6 Bare land

Following the wind, the seeds of *Leucaena leucocephala* can spread to the bare land given up to cultivation, and germinate easily. After 3 months, the seedlings become taller than 30cm, and the DBH can be measured 6 months-to-one year later. As for the bare land selected in Chart 3, its forming time is not very long, so there are not too many *Leucaena leucocephala* seedlings, whose DBH is mostly smaller than 120cm. It is appropriate to check, remove, and prevent the invasion of *Leucaena leucocephala* every half a year.

3.2.2.7 Plantation land

In the previous 5-time investigations on the plantation land, no *Leucaena leucocephala* seedling was recorded. We found in the sixth investigation, however, that *Leucaena leucocephala* had invaded and grown. In the early days of managing a plantation, the interspace of woodlands is usually large. That makes it the best habitat for *Leucaena leucocephal*., The most possible reason is the some-years lagging of tending treatment after plantation has completed in Taiwan. From what we learned in the process, the importance of forest tending and upbringing for controlling the invasion of *Leucaena leucocephala* is clearly stated.

3.2.3 The relationship between the dispersal of *Leucaena leucocephala* and physical and chemical properties of soil

We used the IKONOS satellite image (2001) with resolution of 1m × 1m, to demarcate the distribution scope of *Leucaena leucocephala*. After counting and clearing up the result, we found that the distribution area of *Leucaena leucocephala* was 3,354 hectare，which occupied 15.7 % of the investigated area, 21,363 hectare，and was distributed in belt or block shape (Figure 5).

In order to analyze the relationship between the distribution of *Leucaena leucocephala* and the physical and chemical properties of soil, we converted and overlaid the investigation data onto the soil map in GIS processing, while 249 points were selected and the soil depth of 20cm was designated as the benchmark. We used 11 soil component factors to analyze and discuss the relationship between the distribution of *Leucaena leucocephala* and the properties of soil. The result in Table 4 shows that 11 physico-chemical properties of soil can be concluded into 3 components. Component one includes: sand, silt, clay, aggregate stability, organic matter content, free iron, cation exchange energy, and the amount of variation is 54.8 %. Component two includes: dispersion ratio and available phospherous, and the amount of variation is 14.6 %. Component three includes: pH value and exchangeable potassium with 11.4 % as the amount of variation.

Combining the analytical data and field survey results, we understand that the physico-chemical properties of soil components, decides whether a habitat fits the growth of *Leucaena leucocephala*. Besides the degree of soil acidity(in the whole sampling area, the pH values for soil is always lower than 7）, the characteristics and nutrient condition of non-acidic soil is favorable for *Leucaena leucocephala*. The main reason for *Leucaena leucocephala* to spread widely is its vigorous life force and special genes.

3.2.4 Analysis of the invasion and dispersal speed of *Leucaena leucocephala*

In order to analyze the dispersion speed of *Leucaena leucocephala*, we chose at the beginning an aerial photograph taken in 1998 to select 3 sites with most abundant *Leucaena leucocephala*, and caompared carfully the aerial photograph of the same sites taken in1992, 1994, and 1996 (Fig. 6 and Table 5).

In Fig. 6, *Leucaena leucocephala* forests can be found in the north and northeast areas of the three sampling sections. Consequently, the northeast monsoon favors the invasion of *Leucaena leucocephala* in Hengchun area in the winter. Studying the aerial photograph taken in 1992, and compiling the content of interviews with local people, we can postulate that jowar, corn, fruit tree, and other vegetable crops should be planted in the three sampling sections. The invasion phenomenon of *Leucaena leucocephala* only appears after cultivation is given up. Fig. 6 also shows that *Leucaena leucocephala* was distributed in A, B and C sampling sections in the form of dispersive colonies in 1992; every colony gradually expanded in 1994; in 1996 several dispersive colonies gathered into one in sampling area A, while in B and C, sampling sections they were still distributed in the form of colonies, though with expanded range; and finally all investigated sites were covered with *Leucaena leucocephala* in 1998.

Table 5 shows that *Leucaena leucocephala* began to invade every sampling area from 1992, and sampling sections A, B and C presented: 17.5, ,14.7 , and15.2 % of the general distribution area respectively in 1998. The annual average dispersion speed of *Leucaena leucocephala* in the three sampling sections is about 42.3%. Using regression analysis to estimate *Leucaena leucocephala*'s dispersion curve on different area and time, we found that the dispersion speed approximately appears as a quadratic curve, with a correlation coefficient of 0.979. The annual average dispersion speed of *Leucaena leucocephala* is related to the lands of cultivation given up.

4. CONCLUSION

Mikania micrantha and *Leucaena leucocephala* are two important invasive plants in Taiwan, and their damage often results in territorial disintegration of biodiversity, which makes the ecosystem expenditure piles up every year to prevent their invasion. The results showed that these two plants have strong adaptability to the environment. Once the environment has been disturbed to a certain degree, the ecosystem deterioration occurs. The effect of manpower prevention is usually trivial. On the contrary, these two plants could not invade easily in the close canopy of woods. They cannot cause a big endangerment area even if several can grow. Keeping the forest integrated is therefore the most important policy to prevent their entrance. As for the prevention work in disastrous areas, *Mikania micrantha* must be rooted out before florescence to prevent the spreading of the seeds every year, and cut off the of *Leucaena leucocephala* seedlings every half a year, to prevent them from extending.

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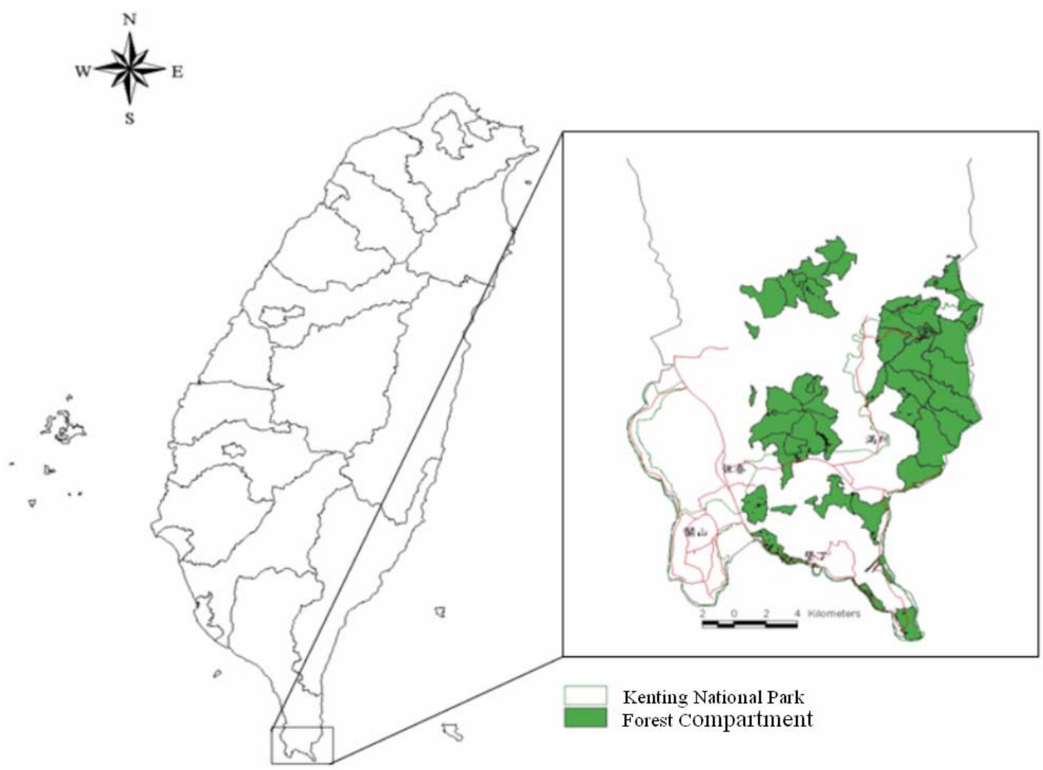

Fig. 1. Maps showing Taiwan and the location of the Hengchun area.

Fig. 2. The damage caused from *Mikania micrantha* dispersal.

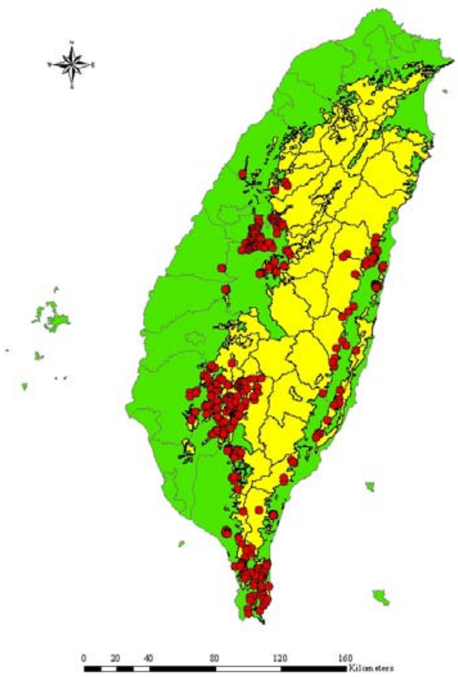

Fig. 3. The distribution map of *Mikania micrantha*

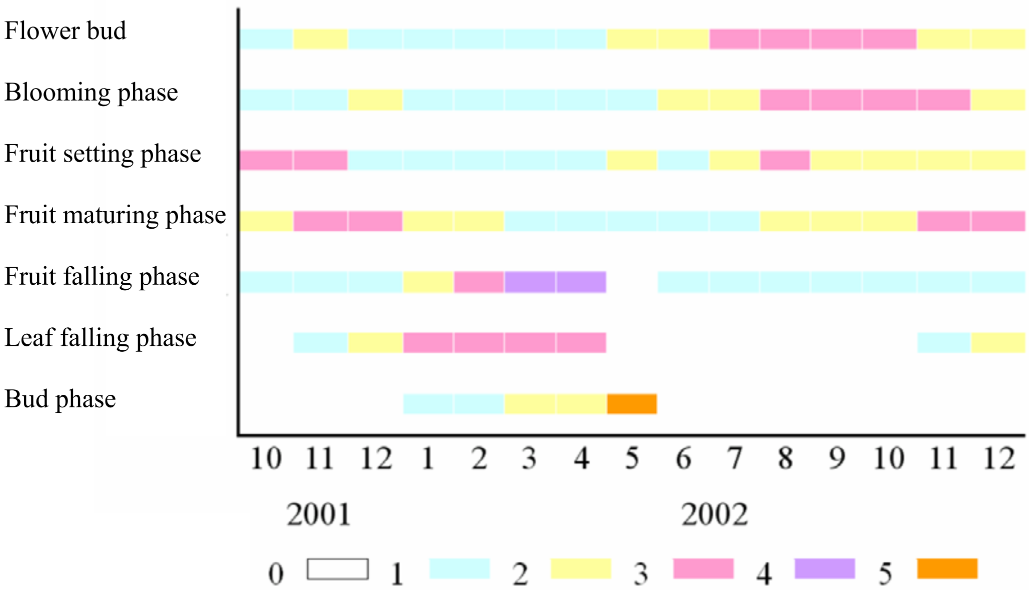

Fig. 4. The phenology of *Leucaena leucocephala*

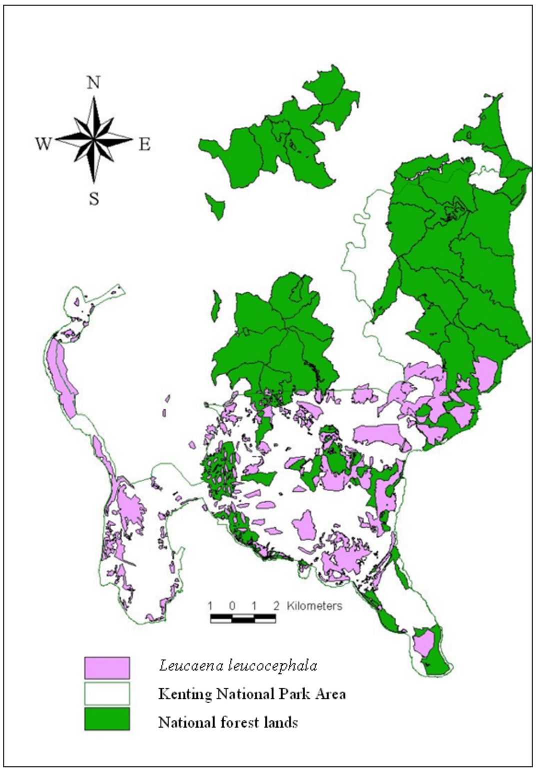

Fig. 5. The dispersal of *Leucaena leucocephala* in Hengchun area.

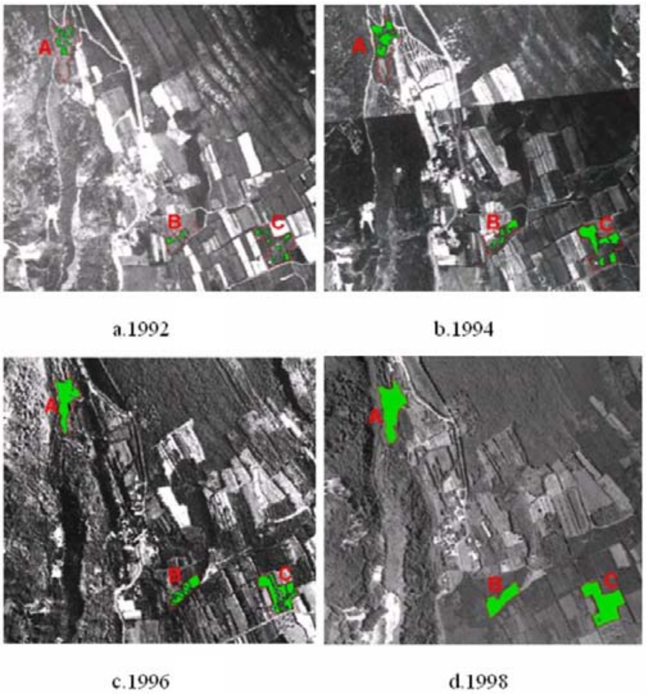

Fig. 6. The aerial photographs of Leucaena leucocephala spread in 1992, 1994, 1996 and 1998.

Table 1. The spatial dispersal statistics table of *Mikania micrantha*

Slope	Frequency (%)	Aspect	Frequency (%)	Altitude	Frequency (%)	Open sky space	Frequency (%)	Moisture gradient	Frequency (%)
North	8.22	0~10°	5.49	0~500m	47.40	1	0.55	0	1.36
Northeast	11.23	10~20°	21.70	500~1,000m	41.37	2	3.01	1	1.09
East	10.14	20~30°	36.26	1,000~1,500m	7.67	3	7.67	2	43.21
Southeast	13.15	30~40°	29.39	1,500~2,000m	3.01	4	20.00	3	6.25
South	12.88	40~50°	5.77			5	26.30	4	4.35
Southwest	12.60	50~60°	1.10			6	21.10	5	1.90
West	17.26	60~70°	0.27			7	14.52	6	6.52
Northwest	13.42					8	3.84	7	7.61
						9	2.74	8	5.98
								9	15.49
								10	6.25
χ^2	**14.60**		**14.60**		**50.257**		**14.39**		**14.60**
G_{adj} value	**1.79**		**98.06****		**70.84****		**69.82****		**105.52****

** Within columns, value is significantly different from its pair (in the row above) at the 0.01 probability levels, respectively.

Table 2. The table of appearance frequency of *Mikania micrantha* in woods

Species	%	Species	%	Species	%	Species	%
Zelkova formosana	15.2	*Cunninghamia lanceolata*	2.2	*Euphoria longana*	0.8	*Alstonia scholaris*	0.3
Acacia confusa	11.2	*Acacia auriculiformis*	2.2	*Cyclobalanopsis glauca*	0.8	*Terminalia catappa*	0.3
mixed broadleaf	10.7	*Tectona grandis*	2	*Bischofia trifoliate*	0.8	*Phyllostachys makinoi*	0.3
Bamboo	9.1	*Prunus mume*	1.9	*Mangifera indica*	0.8	Broadleaf tree	0.2
Liquidambar formosana	6.0	*Dendrocalamus latiflorus*	1.7	*Albizia falcataria*	0.6	*Pinus morrisonicola*	0.2
Fraxinus formosana	6.0	*Michelia compressa(Maxim.)*	1.2	*Paulownia fortunei(Seem.)*	0.6	*Pinus L.*	0.2
Cinnamomum camphora(L.)	5.4	*Pterocarpus indicus*	1.2	Fruit tree	0.6	*Litchi chinensis*	0.2
Pachira macrocarpa	5.4	*Pistacia chinensis*	1.2	*Eucalyptus*	0.6	*Camellia oleifera*	0.2
Swietenia	3.	*Aleurites*	1.	*Canarium album*	0.	*Rhus vernicif*	0.

mahagoni	1		2		3	*lua*	2
Pachira macrocarpa	5.4	*Pistacia chinensis*	1.2	*Eucalyptus*	0.6	*Camellia oleifera*	0.2
Mixed forest	0.2	*Areca catechu*	0.2	*Cryptomeria japonica*	0.2		

Table 3. The average number of *Leucaena leucocephala* of different height in each land-use type (per ha.)

<30cm	2001/12	2002/03	2002/06	2002/09	2002/12	2003/03	2003/06
Natural Forest	1389±532	3056±699	2222±786	1389±532	1389±278	1024±365	897±476
Edge of Natural Forest	5067±1852	14800±4636	20553±4292	15600±3124	8400±2433	12352±2678	17895±4285
Mixed forest	16089±2690	16000±2794	26133±3136	20756±3397	22844±3114	21078±2473	20014±2352
Leucaena leucocephala	19091±2438	29495±3294	100808±16991	53232±6345	31818±5274	31242±3245	32115±14745
Grass land	0	0	0	667±444	222±222	544±311	0
Bare Land	0	444±246	1556±502	1222±509	556±185	645±231	1544±325
Plantation	0	0	0	0	0	556±556	556±556
30 cm - 120 cm							
Natural Forest	0	0	0	0	0		
Edge of Natural Forest	8000±2498	10553±5197	12267±2336	10400±2880	7867±1881	9891±3548	9124±3447
Mixed forest	4667±1058	5467±1307	7244±1440	7467±1637	7955±1619	7687±1423	7354±1254
Leucaena	10505±1	13434±1	14949±203	17172±1	17576±2	16872±1	15234±17

leucocephala	455	967	4	824	003	980	65
Grass land	0	0	0	0	444±272	666±288	666±288
Bare Land	0	0	222±148	889±277	1333±432	1656±540	1843±565
Plantation	0	0	0	0	0		
120cm<							
Natural Forest	0	0	0	0	0		
Edge of Natural Forest	2400±692	2400±692	2800±400	3200±400	3200±231	3100±220	3050±300
Mixed forest	3378±227	3689±229	3600±267	3867±249	4933±223	4823±227	5034±265
Leucaena leucocephala	3535±293	4140±271	3637±338	3940±378	5051±407	5672±534	5587±432
Grass land	0	0	0	0	0		
Bare Land	0	0	0	0	0		
Plantation	0	0	0	0	0		

Table 4. Structural Matrix of Leucaena leucocephala dispersal and physical&chemical properties of soil

	成份		
	1	2	
Sand content	-.984	.115	.125
Silt content	.984	-.082	.027
Aggregate stability	.960	-.255	-.077
Clay content	.870	-.162	-.383
Organic matter	.800	-.050	.212
Free iron	.757	.022	.147
Cation Exchange Capacity (Cec)	.723	-.026	-.275
Dispersion ratio	-.229	.859	-.232
Available P	-.047	.852	.221
pH value	-.502	-.129	.680
Exchangeable K	.582	.272	.643

Table 5. The distributed area in each sample plots of Leucaena leucocephala in different year (ha.)

Sample plot	1992	1994	1996	1998
A	2627	6522	10431	14997
B	1159	2761	5094	7905
C	2550	7487	9895	16670
average	2112±826	5590±2497	8473±2938	13190±4653
Distributed rate		82%	17%	28%