【Article】

Annual Growth and Phenology of *Kyllinga brevifolia* (Rottb.) Hassk. in Temperate and Tropical Regions

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Abstract

Biomass and inflorescence number of *Kyllinga brevifolia* were surveyed in Hiroshima Prefecture, Japan (34 °18’ to 25’ N, 132 °26’ to 45’ E) and in Malang, Indonesia (7 °44’ to 8 °26’ S, 112 °12’ to 57’ E) to gain understanding of its survivorship in temperate and tropical regions. Monthly observations were conducted by using 1 m^2 plots of six study sites in Hiroshima from April 2000 to April 2001 while observations in Malang were carried out in ten study sites four times a year from March 2000 to March 2001. Considering to developmental stages in the temperate zone, the growing period of *K. brevifolia* started in the early of April as the beginning of bud sprouting and vegetative development. The generative organ started to appear in the end of May and the first matured seeds occurred in the last week of June. The growing period of *K. brevifolia* underwent until December 2000 with a peak in August. The inflorescences appeared from May to December where its maximum number was in October. Average daily temperature was significant correlated with the biomass pattern (r^2=0.792). On the other hand, in the tropical region this plant grew and flowered throughout the year with peaks of biomass and inflorescence number were in the end of the rainy season (March 2000/2001). The inflorescence number was minimum in the dry season (July 2000) while the lowest biomass occurred in the early rainy season (November 2000). Furthermore, the pattern of average daily precipitation appeared to be most similar with the flowering pattern. These diverse patterns of productivity and flowering of *K. brevifolia* may explain a great adaptation of this weed to different climate across the regions.

Key words: climatic zone, *Cyperus brevifolius*, invader species, life history, seasonality, weed.

1. Introduction

Kyllinga brevifolia (Rottb.) Hassk. *(*Syn. *Cyperus brevifolius),* family Cyperaceae, possesses a wide range of distribution over warm and temperate zones. It occurs predominantly in tropical lowlands and hills. Its distribution, however, sharply diminishes towards the temperate zones (Kern, 1974). Furthermore, the origin native area of this plant is still unknown. Only few very old records are found in Asia (Koyama, 1961; Delahaussaye and Thieret, 1967; Webb et al., 1981). Although they are commonly known as perennial weeds usually growing on various fields (Heyne, 1987; Yamakawa and Ueyama, 1991b; Holm et al., 1997) they can be prospectively implemented as perfume substance (Komai and Tang, 1989), source of medicine (Helliön-Ibarrola et al., 1999) and feed (Kern, 1974; Heyne, 1987).

K. brevifolia is a perennial plant spreading vegetatively through rhizomes and stolon as well as producing many viable seeds (Sumaryono and Basuki, 1984; Lowe et al., 1999a). In Japan this species was reported to sprout at the beginning of spring (March) until the beginning of autumn (September), and to flower from July to September (Yamakawa and Ueyama, 1991b) or from July to October (Kitamura et al., 1969). This plant is a C_4 species (Lin et al., 1993) so its growth is facilitated in areas where the temperature is approximately between 30-35℃(Black, 1973) and probably hindered by low temperatures such as in North America (Teeri and Stowe, 1976) and Australia (Hattersley, 1983).

In Indonesia, this plant grows and spreads easily. Once its growth is established, it cannot to be easily eradicated. So far, there are not many records about the biology of this plant from Indonesia. Sumaryono and Basuki (1984) have observed the growth and reproduction of this species from the beginning of germination in a green house. Yet, there is no report of its seasonal productivity under natural conditions. Even though some papers have identified the period of its growth and flowering in Japan (Kitamura et al., 1969; Yamakawa and Ueyama, 1991a, 1991b; Ohwi, 1992), its biomass and number of inflorescence have never been reported.

Due to the problem with *K. brevifolia* as a dangerous weed for numerous crops (Holm et al., 1997) and a highly invasive exotic species (Webb et al., 1981; Wagner et al., 1990), little is known about the phenology of *K. brevifolia*. Furthermore, resource and weed managements require knowledge of its biology including its survivorship in different regions. This study aims to describe life cycle, biomass and inflorescence number of *K. brevifolia* in temperate regions and emphasize comparing to tropical region.

2. Materials and Methods

The samples from the temperate region were collected from six study sites in Hiroshima Prefecture, Japan, located at 34 °18’ to 25’ N, 132 °26’ to 45’ E (**Fig. 1**). The six study sites were: (1) Paddy fields in Shitami, Saijo cho, Higashi-Hiroshima shi; (2) Open lawns in front of Faculty of Letter and behind of Faculty of Integrated Art and Sciences of Hiroshima University Campus; (3) Open lawns/river-sides near Yokogawa station and Mitaki station, Hiroshima shi; (4) Open lawns in Shimominaga, Saijo cho, Higashi-Hiroshima shi; (5) Paddy fields in Ootata, Kurose cho, Kamo gun; (6) Paddy fields in Kamidono, Fukutomi cho, Kamo gun. The samples from the tropical region were gathered from ten study sites in Malang, East Java, Indonesia located at 7 °44’ to 8 °26’ S, 112 °12’ to 57’ E (**Fig. 1**). The ten study sites are: (1) Riversides in Tlogowaru; (2) Open lawns in Puncak Buring Indah; (3) Open lawns in Buring; (4) Open lawns in Bukit Tidar; (5) Paddy fields in Karang Besuki; (6) Open lawns in Sumbersari; (7) Open lawns in Brawijaya University Campus; (8) Open lawns in Tanjung Sekar; (9) Open lawns in Pandan Wangi; (10) Paddy fields in Purwadadi.

Biomass was measured by taking whole parts of *K. brevifolia* (shoot and root). Due to complexity of plant structure, we could not take and count the number of individual plant. The plots, most of them

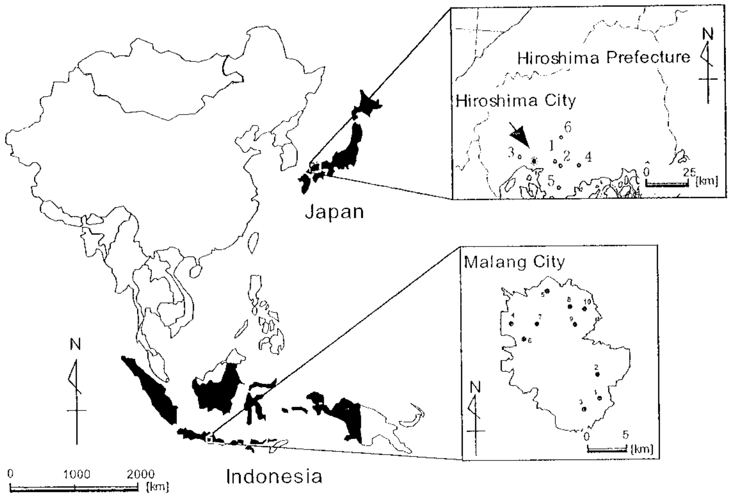

Fig-1. Location of six study sites in Hiroshima Prefecture, Japan [(1) paddy field in Shitami, (2) open lawn in Hiroshima University Campus, (3) open lawn/river-side in Yokogawa and Mitaki, (4) open lawn in Shimominaga, (5) paddy field in Kurose, (6) paddy field in Fukutomi]; and ten study sites in Malang, Indonesia [(1) riverside in Tlogowaru, (2) open lawn in Puncak Buring Indah, (3) open lawn in Buring, (4) open lawn in Bukit Tidar, (5) paddy field in Karang Besuki, (6) open lawn in Sumbersari, (7) open lawn in Brawijaya University Campus, (8) open lawn in Tanjung Sekar, (9) open lawn in Pandan Wangi, (10) paddy field in Purwadadi].

were pure stands, were set 1 m^2 within the study sites. In Japan the samples were taken monthly from April 2000 to April 2001. The samples from Indonesia were collected 4 times in the year 2000-2001 as follows: February 2000 (rainy season), July 2000 (dry season), November 2000 (transitional season) and February 2001 (rainy season). Soil and other plants (when they are) were washed off from fresh samples, and then dried at 80°C to constant weight.

To measure the number of inflorescences, three plots were surveyed by utilizing quadrats of 1 m^2 in the same study site at the same time as the biomass measurements were carried out. Four developmental stages (bud sprouting, tiller formation, flowering and ripening) of nine buds were recorded in each study site since March 2000. This observation was ended when all marked flowers ripped. Due to technical difficulties, this observation could only be done in Hiroshima, Japan.

Three included climatic factors have been previously suggested as the most important for the growth of C_4 plant and *Kyllinga* (Black, 1973; Molin et al., 1997; Lowe et al., 1999a, b). In Hiroshima, they were obtained from Higashi-Hiroshima Agriculture Research Centre (Anonymous, 2000 and 2001). The data from Malang were obtained from the Climatologic Bureau, Agriculture Faculty of Brawijaya University.

The Pearson correlation was used to examine correlation between dependent factors (the biomass and inflorescence number) and independent factors (the climatic factors). The significance level was set at < 0.05.

3. Results

3. 1. Biomass and Flowering Patterns of *Kyllinga brevifolia* in Temperate Region

In Hiroshima the growing season started when bud sprouting began to be distinguished on April 2, 2000 (**Fig. 2**). All observed buds completely sprouted on the third weeks of April. During development of sprouts new tillers appeared and the numbers increased rapidly with 9.22 average number for six weeks (17 April to 27 May, 2000). About six weeks after the bud sprouting, the flowering started. The flowers gradually changed color to brownish and took ripe for several weeks later (**Fig. 2**).

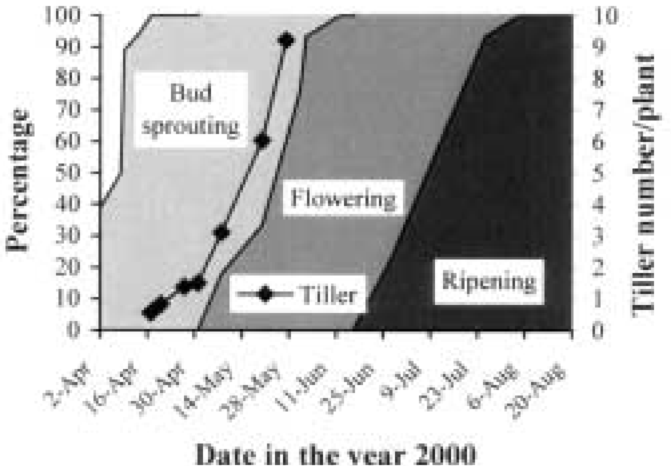

Fig-2. Changes of developmental stages (bud sprouting, tiller increment, flowering and ripeness) on the beginning of the growing season of *Kyllinga brevifolia* (Rottb.) Hassk. in Hiroshima Prefecture, Japan.

From April 2000 the biomass of *K. brevifolia* gradually increased until the summer and reached a peak in August 2000 (**Fig. 3B**). The biomass, then, decreased gradually and became stagnant after December 2000. This pattern seems to follow the tendency of the average daily temperature (**Fig. 3c**). Based on the correlation analysis, biomass of this plant in the temperate zone was significantly correlated to temperature factors (r^2= .792); other factors bore only slight correlation with the biomass (**Table 1, Fig. 3a,b**).

Table 1. Pearson correlation (r^2) between dependent factors (biomass and inflorescence number) and independent factors (daily temperature, precipitation and sunlight duration).

Countries	Dependent factors	Temperature (°C)	Precipitation (mm)	Sunlight duration (MJ/m^2)
Japan	Biomass	.792**	.338	.052
	Inflorescence number	.435	.477	.007
Indonesia	Biomass	.680	.140	.210
	Inflorescence number	.402	.726	.409

** indicated significant at P<0.01

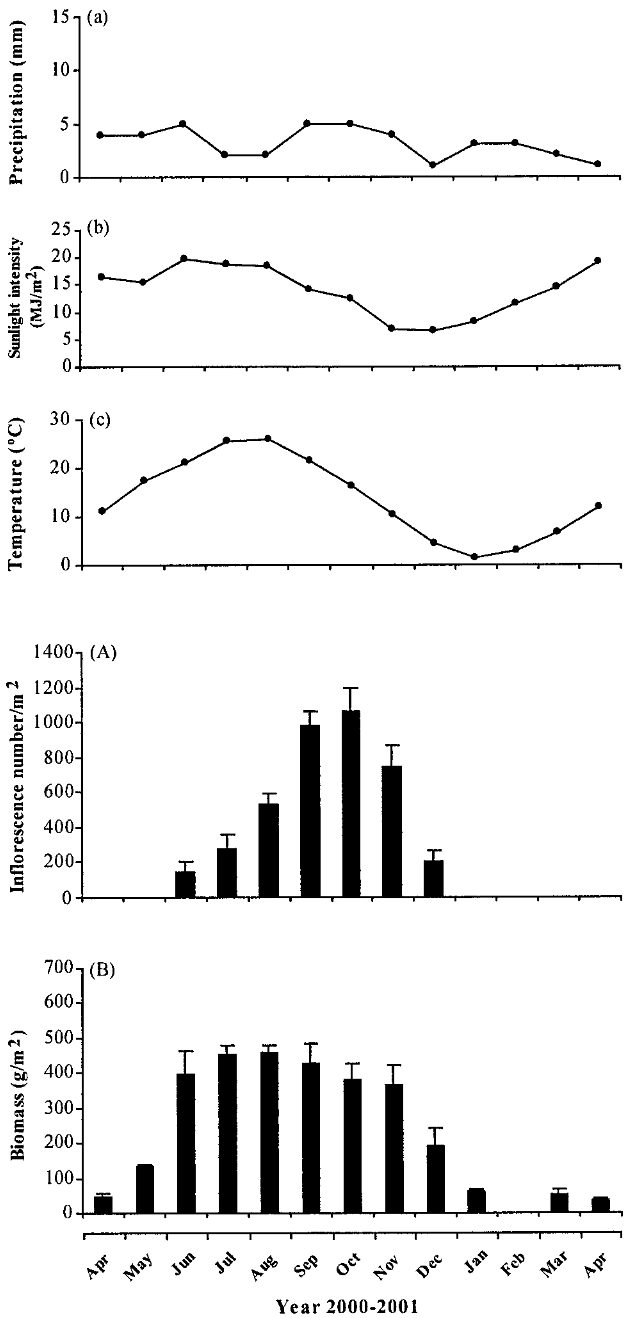

Fig-3. Patterns of inflorescence number (A) and biomass (B) of *Kyllinga brevifolia* in Hiroshima, transformed to fluctuating of precipitation (mm) (a), sunlight intensity (MJ/m^2) (b) and average daily temperature (°C) (c).

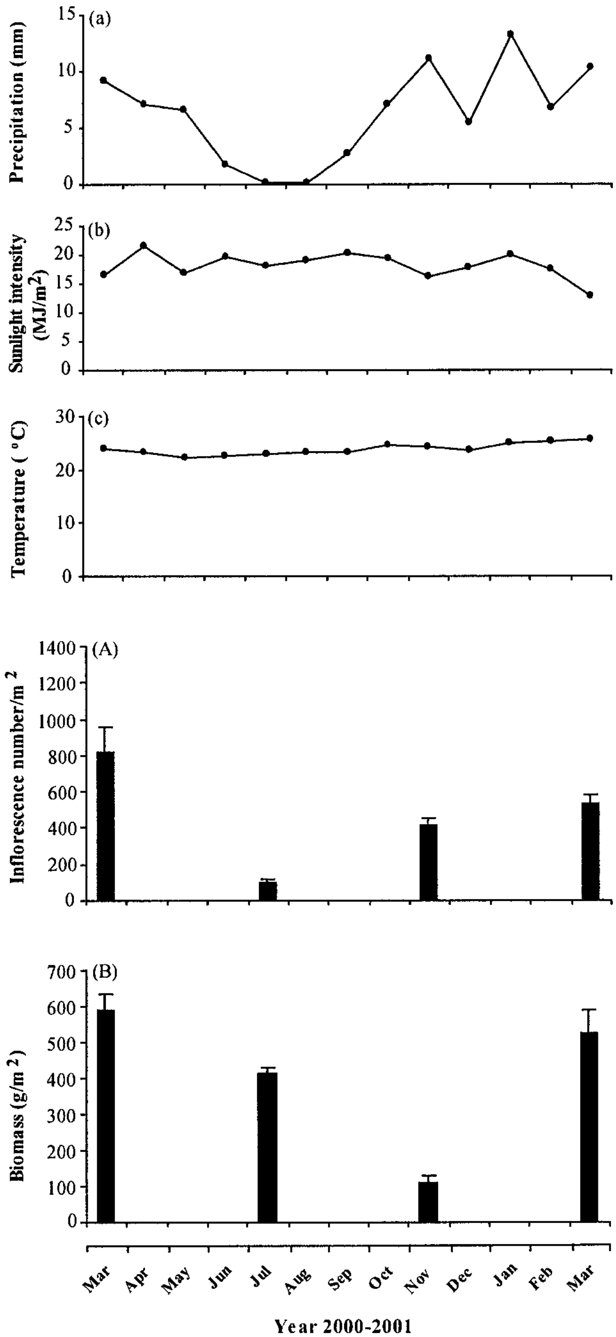

Fig-4. Patterns of inflorescence number (A) and biomass (B) of *Kyllinga brevifolia* in Malang, transformed to fluctuating of precipitation (mm) (a), sunlight intensity (MJ/m^2) (b) and average daily temperature (°C) (c).

Flowering evidence of *K. brevifolia* only occurred temporally during the growing season that started on May 2000 (**Fig. 2, Fig. 3A**). The number of inflorescence adjusted fast during the summer and reached a peak in October 2000 at the middle of autumn when the biomass and temperature decreased. This number decreased more sharply than that of biomass and then disappeared during the early winter. According to the analysis, there was no particular climatic factor strongly affecting the inflorescence number of *K. brevifolia* in the temperate zone (**Table 1**).

3. 2. Biomass and Flowering Patterns of *Kyllinga brevifolia* in Tropical Region

In Malang, *K. brevifolia* grew in all seasons, both rainy and dry seasons (**Fig. 4B**). In March 2000 and 2001, the highest biomass was reached. Those times were the end of the rainy season indicated by higher precipitation (**Fig. 4a**). The amount decreased on July (the dry season was subjected) and reached the lowest amount on November 2000 (the interchange season).

The flower number of *K. brevifolia* in Malang also got highest in the rainy season (March, 2000 and 2001) (**Fig. 4A**). During the rainy season, in March 2000 and 2001, the highest number of flowers was reached. The lowest number occurred in the dry season, July 2000, and then there was an increase towards November, the beginning of the rainy season. According to the analysis, there were no climatic factors significantly correlated to biomass and flowering pattern (**Table 1**).

4. Discussion

Kyllinga brevifolia, as other perennial plants, is characterized by a major reproduction effort using vegetative trait. As recorded in this study, it began to grow with breaking bud dormancy in the spring (**Fig. 2**). The sprouting of the buds might have been triggered by the change to a warm temperature since the temperature was the most important threshold factor for bud sprouting of some close species, such as *Cyperus rotundus* and *C. esculentus* (e.g. Holt and Orcutt, 1996; Li et al., 2000). This reveals that the heat availability is the most important factor for *K. brevifolia* appearances in temperate region. This phenomenon was also confirmed by high increments of tiller formation. Hence, flowering seems to come later after compliment of vegetative development (**Fig. 2**).

This result has also shown considerable different patterns of biomass and flowering of *Kyllinga brevifolia* happening between tropical and temperate regions (**Fig 3** and **Fig 4**). In temperate region, the lower temperature might strongly limit the growth as indicated by dormancy during the winter (**Fig 3B**). Then, when the warm season came the bud sprouting occurred and growing season started. The vegetative growth gradually increased proportionally to temperature and reached a peak in the summer and then the generative trait (flowering) followed. An experimental study by Lowe et al. (1999b) showed that growth and inflorescence number of *K. brevifolia* reached the highest levels in the day temperature of 33℃ and the night temperature of 24℃ (expecting the highest summer temperature). Considering its distribution in temperate area, *K. brevifolia* seems to take an advantage on such behaviour. Its capability to take dormancy and to propagate using creeping rhizomes as well as to produce seeds exclusively during appropriate warm condition might be its survival strategy to establish in invaded area such as temperate region.

In tropical region, *K. brevifolia* could be found along the year in both rainy and dry season **(Fig. 4A-B)**. Growth of *K. brevifolia* is supposed to be strongly favored by water availability during the rainy season (Hattersley, 1983) as indicating by the highest growth rate at this season. However, the phenomenon of lowest biomass in the interchanged time (November 2000) (**Fig. 4B**) was not certainly known. As visited study areas, we saw that other plants grew fast in the beginning of the rainy season. It might affect to *K. brevifolia* in taking a hard competition with neighboring plants, such as against to *Cynodon dactylon* (Kawabata et al., 1994; Molin et al., 1997). On the other hand, the pattern of flower numbers in the tropical zone seems to be similar with the seasonal changes, represented by precipitation (**Fig. 4A,a**). During the rainy season in March 2000 and 2001, the number of flowers was at the highest level. Furthermore, the lowest number occurred in the dry season, July 2000, and then there was an increase toward November (the beginning of the rainy season). This flowering evidence pattern was different in a particular way from the biomass pattern. In the dry season, the formation of flowers seemed to be strongly limited, unlike that of the biomass. Previous studies (Desclaux and Roumet, 1996; Li, et al., 2001) have suggested that a dry condition seems to trigger a signal causing an early switch to flower formation while wet condition stimulated more to vegetative reproduction. However, this conclusion was just opposite for *K. brevifolia*. In addition, according to the results (unpublished) of our experiment, flowering of this plant was extremely hindered by drought whereas tiller formation still took place. This phenomenon might indicate its survival strategy in facing unsuitable conditions. In dry conditions formation of vegetative organ might benefit to invest for generative organ (flower) on next suitable condition. It then has more ability to expand space when the competition with other grasses would be low.

In Hiroshima Prefecture, the highest biomass in the growing period was lower than that in the rainy season in Malang. This result confirmed that the productivity of plants in the lower latitudes is generally higher (Begg, 1965; Long et al., 1989). It might be due to the high light saturation value and high optimum temperature in tropical areas (Begg, 1965). The difference in *K. brevifolia's* productivity, however, was not significant if it is compared to the estimated value for ecosystem models, as suggested by Box (1988) and Choudhury (2000), that the annual net primary productivity (NPP) of natural ecosystem in latitude of 0-10 °S is estimated having about twice than latitude of 30-40 °N. For *K. brevifolia*, perhaps, its productivity might not be merely effectuated by comparable climatic factors between tropical and temperate regions, but probably also strongly influenced by high potentials to adapt in various habitat types. Rapid invasion of this plant to wider areas in the world (Webb et al., 1981; Bryson et al., 1997) is a phenomenon of how great this plant can adjust and naturalize in different region.

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