

Growth Properties of Central and Peripheral Ramets in a *Zoysia sinica*'s Clone

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ABSTRACT: A natural, tidal-flat clone of *Zoysia sinica* was studied to compare ramet growth properties in central area with in peripheral area. In new stolon and rhizome, internode length, weight, shoot height and weight, and spike production were monitored on July 25, 2004. The weight/height rate of shoot between stolon and rhizome, the shoot/stolon (or rhizome) rate in weight between central and peripheral area were not different. However, other properties differed in stolon from rhizome or between central and peripheral area significantly differed: 1. The rhizome in central area had a larger node number, shorter internode length, higher shoot height, larger shoot biomass, and higher rate of non-shoot nodes than that in peripheral area. 2. The stolon in central area had a smaller node number, shorter internode length, and smaller biomass than that in peripheral area. 3. In the same area, the rhizome had a larger node number (except for central area), shorter internode, higher shoot height, larger shoot biomass, higher rate of non-shoot node, and higher rate of node having over two shoots than the stolon. No relationship could be found between shoot size and spike production in shoot on vertical rhizome (lower node of old shoot).

Key words: Internode, Node, Ramet, Rhizome, Shoot, Stolon, *Zoysia sinica*

INTRODUCTION

More than two-thirds of the commonest perennials show pronounced vegetative propagation (Silvertown 1982). Various plants in vegetative reproduction have structures similar to those of the stolons or the rhizome which carry ramets into the space around the mother plant (Abrahamson 1980, Cook 1983). The stolons or the rhizomes vertically or horizontally grow to form clones (Pavlik 1983). These ramets in clonal plants function as nutrient passages among the modules effectively support clones in integration and are used in a way a clone forages a favorable environment (Salzman and Parker 1985, de Kroon and Schieving 1991, Evance 1991, Stuefer et al. 1994). Moreover, the growth pattern of the stolons or the rhizomes takes a significant part in forming and spreading a clone because a clone is composed of ramets that vary in the number or the size and germinated from the fixed locus (mainly node) on the stolon or the rhizome. On the other hand, the stolon or the rhizome have two growth types-vertical and horizontal- and energy invested to vertical growth or to horizontal growth differs depending on the plant species (Pavlik 1983). The vertical rhizome system produces a tussock pattern of tillers and a poorly dispersed bud bank. However, horizontal rhizome system widely disseminates shoots, and produces a spreading pattern and a low density clone (Pavlik 1983).

When the peripheral environment is favorable to a clone in a horizontal rhizome system the rate of horizontal increase of a clone is high, and clones have benefit by using resources and space in advance of other clones or species. When the environment and spreading velocity are consistent in the peripheral area of a clone, a new clone grows to form a circular patch and the ramets in central area grow more vigorously than those in peripheral area (Kershaw 1962). However, after a period of time, ramets in central area of a clone fall off in size, whereas those in peripheral area increase in size. Perkin (1968) suggested a population structure with five stages for *Nardus* tillers. In his structure, the ramets in outmost area mostly grow vigorously. Kershaw and Looney (1985) prescribed this phenomenon to edge effect -the age of a clone can be estimated by analyzing each stage and the increasing rate of clone in a year (Oinonen 1967, Chung 1988). Then, it is not easy to conclude from present knowledge whether density-dependent mortality or the density-dependent birth of new stolon is generally more responsible for the regulation of stoloniferous populations (Silvertown 1982). It is difficult to design an experimentation than can clear this fact. Moreover, results diverse among the species (Hutchings 1979, Silvertown 1982), and the degree of integration or independence among ramets within clones influences such ramets response to neighbors, the sensitivity of their growth and reproduction in the presence of a heterogeneous neighborhood (Hartnett

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and Bazzaz 1985). Therefore, investigation into ramet's properties at each stage or in each location in a clone is necessary to clarify the growth pattern of a clonal plant.

In Korea, many studies for *Zoysia* have been reported. *Zoysia* plants grown in field are classified into 4 or 5 species by morphological characteristics, but intraspecies variations appeared in a large extent along the habitat (Yu et al. 1974, Kim 1983). According to the data derived from RAPDs analysis, many hybrids and varieties grow in field of Korea, including of 5 species (Choi et al. 1997). Of the species of *Zoysia* genus, many studies for *Z. japonica* have been carried out in terms of productivity (Jin and Huh 1986), seed germination (Yeom et al. 1985), and shading effect on shoot growth (Yim and Kim 1995). Still, ecological studies for *Z. sinica* are presently needed. *Z. sinica* is a typical halophyte and is commonly distributed in coastal area of Korea. This species distributes from intertidal-flat which is inundated by sea water for 3 hours a day to the mesic area which consists of soil with high salt content and insignificant direct influence of sea water (Min 1998). *Z. sinica* is a clonal plant and reproduces asexually by stolon (on the soil surface) or rhizome (in underground), as well as sexually by seeds (Kim 1983). When stolon is located in underground by sedimentation of particle in sea water, the limit between stolon and rhizome becomes ambiguous. Moreover, a rhizome grows up to the sediment surface from underground and changes into a stolon, and *vice versa*. Recently, coastal plants were taken as interesting objects in studying restoration for disturbed shoreline in Korea. *Z. sinica*, one of the coastal plant species, plays a role in suppressing the erosion at an intertidal-flat.

In this paper, a population growth pattern of *Z. sinica*, a clonal plant, is presented and the ramet's growth properties between central and peripheral area are analyzed especially.

MATERIALS AND METHODS

The study area is located at Namdong, Ansan city, Gyeonggi Province (37° 12' 30" N, 126° 35' 00" E) (Fig. 1). *Z. sinica*'s patch is formed near the mean high tide level. Patch is circular form and its size is about 6 m in diameter. In *Z. sinica*'s patch, the altitude of the central area is a little higher (about 20 cm) than that of the peripheral one, so that its patch forms a topographic mound (Fig. 2). Coverage in the central and peripheral area is 95% and 50%, respectively. Near the *Z. sinica* population grows *Suaeda japonica*. Its height and coverage are 30 cm and 5~20%, respectively. Except for *S. japonica*, *Triglochin maritimum* and *Phragmites communis* grow in small patch form, and *Limonium tetragonum* is separately distributed.

Field survey was carried out on July 25, 2004. *Z. sinica* was

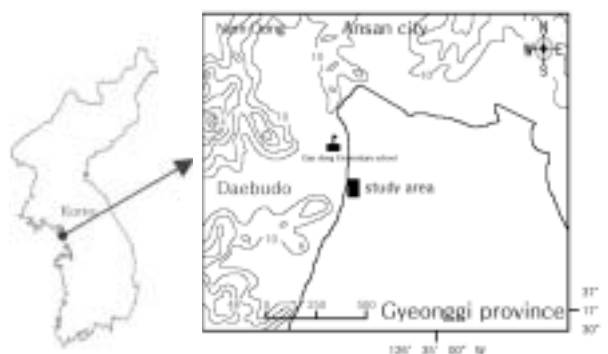


Fig. 1. Map showing the study area.

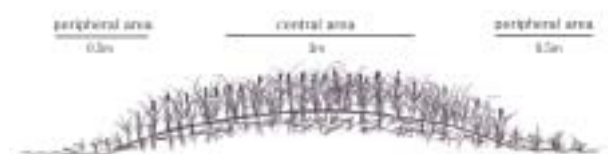


Fig. 2. Schematic diagram of *Z. sinica* population and sediment mound.

sampled at two areas in a patch (central area and peripheral area) by two processes. Central area is located within 1.5 m and peripheral area is located between 2.5 m and 3.0 m from the patch center. One process was to estimate the biomass and the other was to compare growth pattern of ramets in central area with that in peripheral area. In estimating the biomass, *Z. sinica* was sampled 5 times by 20 cm × 20 cm quadrat at each area. Alive parts of the plant materials were first separated from the dead parts; alive parts were then split into shoots (including spike and stem), rhizomes (in underground), stolons (on sediment surface) and roots. The number of shoots was separately depending on the spike's presence. All materials were oven-dried at 80°C for 48 hours and weighed by chemical balance at mg unit. The biomass and the number of shoot were converted into square meter. In comparing ramets in central area with in peripheral area, plant materials were rooted up from the apex of stolon or rhizome to the node of the first branch that germinated. Particularly, in central areas, the shoots that germinated from old shoot's basal node were sampled. The numbers of stolons, rhizomes and shoots were as shown in Table 1. Lengths of internode were separately measured and materials were oven-dried and weighed. To examine the relationship between shoot size (height and weight) and spike production, plant sizes were divided into 7 classes.

Sediment samples to analyze the soil texture were sampled at 10 cm depth (central area and peripheral area), dried in a lab, and sorted out with 2 mm sieve before analysis. Soil texture was analyzed with

Table 1. The number of horizontal stolon (rhizome), node and shoot using to study growth properties of *Z. sinica* population. Parenthesis indicates the number of shoot germinating from vertical rhizome (=on node of old shoot)

Organ	Locate	Number	Total
Stolon	Center	20	90
	Periphery	70	
Rhizome	Center	16	38
	Periphery	22	
Node	Center	482	1,620
	Periphery	1,138	
Shoot	Center	758(428)	1,988
	Periphery	1,230	

approximately 100 g sample by Queen's Apparatus and sieve, and classified into clay, silt, fine sand and coarse sand.

RESULTS AND DISCUSSION

Soil Texture of Sediment

Of the three components (clay, silt and sand), the percentage of sand was the highest -over 95%- in two areas (Table 2). Of the sands, fine sand took a predominantly proportion than coarse sand; particle sizes of the central area varied more than those of the peripheral area; particularly, there were more clay in the central area than the peripheral area. These results were thought to be effects

Table 2. Soil texture of the central and peripheral sites of *Z. sinica* population

Locus	Soil texture(%)			
	Clay	Silt	Fine sand	Coarse sand
Center	4.1	0.8	73.4	21.7
Periphery	2.4	1.4	82.8	13.4

Table 3. Biomass of center and periphery sites of *Z. sinica* population

Locate	Biomass (g · DW/m ²)					Density (plants/m ²)
	Dead part	Shoot	Stolon(rhizome)	Root	Total	
Center	378 ± 149	187 ± 64	258 ± 57	146 ± 109	969 ± 371	2,723 ± 621
Periphery	7 ± 1	109 ± 114	132 ± 46	134 ± 98	382 ± 257	453 ± 75
SL (%)	0.01	1	0.1	-	1	0.1

SL; significant level.

of *Z. sinica*'s patch on sediment deposition process. In other words, the dense plant shoots in the central area diminished the wave energy and the drift of a current, so that small particles had a relatively prolonged deposition period. Moreover, *Z. sinica* accelerating the deposition of a particle could explain topography of intertidal-flat changing from flat to a mound with the increase of *Z. sinica*'s patchy size. The fact that vegetation accelerate the sediment deposition in salt marsh has been well known from long ago (Chapman 1964).

Biomass and Shoot Density

Biomasses (including dead part) of the central and the peripheral area were 969±371 g · DW/m² and 382±257 g · DW/m², respectively. Biomasses of the central area was thus 2.5 times greater than those of the peripheral area, and the difference between the two areas was significant at an 1% level. Especially, dead part was more conspicuous in the central area than in the peripheral area. This result was thought to be due to high shoot density and a number of senile roots in the central area. However, the root biomasses of two areas were similar.

In Nagdong river estuary, the *Z. sinica*'s biomass was 1,950 g · DW/m² (Kim et al. 1989). The biomass in Nagdong river estuary was exceptionally more abundant than that of this study, and this result can be interpreted as following; organic matter continuously inflowed from inland by fresh water. Moreover, *Z. sinica*'s population were established and stabilized at this time in Nagdong river estuary, whereas, this study area was not.

The shoot densities were 2,723±621 shoots/m² in the central area and 453±75 shoots/m² in the peripheral area. Therefore, the number of shoots was 6 times more in the former area than in the latter area. According to the field survey, the shoots which were on old rhizomes in the central area were damaged, dead, and small. However, the fact that fairly old rhizome could germinate shoots was thought to be a strategy sustainable for high-density population in the central area.

Difference of Ramet Growth between the Central and the Peripheral Area

Among four ramets, the node number was the largest on the rhizome in the central area (Rc), 18.4 ± 3.5 , and the smallest on the stolon in the central area (Sc), 9.4 ± 2.4 (Table 4). The node number difference between Rc and rhizome in the peripheral area (Rp) and between Sc and stolon in peripheral area (Sp) were significant at an 1% level, respectively. Moreover, the node number difference between Rc and Sc was conspicuous and significant below a 0.1% level. However, the node number on Rp was similar to that on Sp. Because shoot is germinated from the node, the shoot-germinating potential was thought to be the highest in Rc. This result might be interpreted as a main apex dominantly growing without branching.

The mean lengths of internodes were 1.88 cm on Rc, 2.44 ± 0.17 cm in a Sc, 2.41 ± 0.39 cm in a Rp and 4.52 ± 1.01 cm in a Sp. The differences between two organs, Rc and Rp, Sc and Sp, Rc and Sp, Rc and Rp, were significant below or at 0.1% level. It was concluded that the more rhizome or stolon could receive the sunlight, the longer their lengths became. Especially, the Rc was thought to receive the smallest amount of light and for this reason its length was the shortest among the four organs. In case of *Z. japonica*, stolon and rhizome decreased its growth by 55% and 35% shading, respectively (Yim and Kim 1995). The main factor restricting on growth is the presence of neighbors competing for light (Jerling 1988). However, *Glechoma herbacea* which grows under unfavorable conditions produces long internodes and fewer branches (Slade and Huchings 1987). Therefore, it can be concluded that the growth responses of a rhizome or a stolon for light are various along the species. Ramets growing in the peripheral area can receive relatively more amount of sunlight than those of in the central area. Furthermore, rhizome or stolon in the central area grow in length quickly. This characteristic is thought to be favorable for a clonal plant's process following sunlight.

The weights per 1 cm of rhizome and stolon were the largest in the Rc, 11.74 ± 2.36 mg, and the smallest in the Sc, 7.90 ± 1.83 mg. The weight difference between Sc and Sp was significant at a 5% level but the others were not. Therefore, the slenderness of, or the resource allocation to rhizome or stolon was similar regardless of location or organ.

The shoots were the highest on Rc, 16.08 ± 4.02 cm, and the lowest on Sp, 8.22 ± 4.38 cm. Kim (1983) reported the mean height of *Z. sinica*, 21.3 cm. Thus, *Z. sinica* in this study was thought to be poor in growth. The shoot height difference between Sc and Sp was not significant. However, the shoot heights among the organ or location were different below 0.1% level significantly, except for the case of Sc and Sp. This result might be interpreted as following. First, the shoots in the central area must compete for light and as a result create high density and grew up straightly. Second, in order to keep up with the shoot heights on stolon, the underground shoots

Table 4. Properties of new stolon, rhizome and shoot sprouting from vertical stolon in *Z. sinica* population with the locate (SL = significance level, %)

Properties organ	Horizontal locate		SL
	Center (mean±SD) (C)	Periphery (mean±SD) (P)	
Node number			
Rhizome	18.4 ± 3.5 (n=16)	11.0 ± 1.7 (n=22)	1
Stolon	9.4 ± 2.4 (n=20)	12.8 ± 4.5 (n=70)	1
SL	< 0.1	not	
Internode length (cm)			
Rhizome	1.88 ± 0.24 (n=16)	2.41 ± 0.39 (n=22)	0.1
Stolon	2.44 ± 0.27 (n=20)	4.52 ± 1.01 (n=70)	< 0.1
SL	< 0.1	< 0.1	
Weight per 1 cm (mg/cm)			
Rhizome	9.91 ± 1.91 (n=16)	11.74 ± 2.36 (n=22)	not
Stolon	7.90 ± 1.83 (n=20)	9.87 ± 2.07 (n=70)	5
SL	not	not	
Shoot height (cm) (A)			
Rhizome	16.08 ± 4.02 (n=122)	10.83 ± 5.83 (n=170)	< 0.1
Stolon	8.22 ± 4.38 (n=154)	8.03 ± 3.36 (n=827)	not
SL	< 0.1	< 0.1	
Shoot weight (mg)(B)			
Rhizome	73.1 ± 31.3 (n=122)	52.5 ± 33.8 (n=170)	1
Stolon	27.5 ± 19.9 (n=154)	38.5 ± 23.3 (n=827)	1
SL	< 0.1	< 0.1	
Rate of B/A (mg/cm)			
Rhizome	4.73 ± 1.16 (n=122)	4.64 ± 1.29 (n=170)	not
Stolon	3.72 ± 1.30 (n=154)	4.59 ± 1.62 (n=827)	< 0.1
SL	< 0.1	not	
Rate of shoot/RS weight			
Rhizome	1.91 ± 0.64 (n=16)	1.56 ± 1.14 (n=22)	not
Stolon	1.36 ± 0.71 (n=20)	0.93 ± 0.53 (n=70)	not
SL	not	not	
Node having the first spike			
Rhizome	17.7 ± 0.5 (n=14)	–	–
Stolon	–	10.6 ± 1.4 (n=22)	–
Rate of non-shoot node			
Rhizome	53.1% (156/294)	20.7% (50/242)	–
Stolon	7.7% (14/188)	5.0% (17/896)	–
Rate of over two shoots on a node			
Rhizome	2.1% (6/294)	9.1% (22/242)	–
Stolon	6.4% (12/188)	14.2% (127/896)	–

RS; rhizome or stolon.

on rhizome must grow as long as the rhizome depth to a minimum. As mentioned above, *Z. sinica* was sensitive to the shades and this characteristic might lead to higher growth under insufficient light regime. With decreased light intensity, *Z. japonica*'s leaves became longer up to 75% (Yim and Kim 1995). In terms of growth response to light, *Z. japonica* and *Z. sinica* were thought to have similar properties.

The shoot weights were the largest on Rc, 73.1 ± 31.3 mg, and the smallest on Sc, 27.5 ± 19.9 mg. The shoots on rhizome were heavier than those on stolon. The shoot weight differences between rhizome and stolon, and between central and peripheral area were significant at a 0.1% and 1% level, respectively. The reason why shoots on the rhizome were heavier than those on stolon was the difference of height, as mentioned above. However, the shoot weight on Sp was heavier than that on Sc. This fact might be interpreted as competition for the light among the shoots. Summing up, the shoots in peripheral area were lower in density, weaker in competition for light and broader in leaf breath than ones in central area. It was thought that each shoot in two areas had a proper strategy.

The values of the shoot's weight/height rate were the largest on Rc, 4.73 ± 1.16 mg/cm, and the lowest on Sc, 3.72 ± 1.30 mg/cm. The latter was different from others at a significant 0.1% level. With this result, the shoots on Sc were the most slender of the four. This strategy was thought to be favorable to clone plant in case of high-density population. In planted *Z. japonica*, the leaf area, the increase rate of leaf and stem number, and biomass decreased with the increase of density (Jin and Huh 1986). This phenomenon was thought to appear in *Z. sinica*.

The weight rates of shoot/rhizome (or stolon) were the largest in Rc, 1.91 ± 0.64 , and the smallest in Sp, 0.93 ± 0.53 ; however, variations among the ramets were remarkable and their differences were not significant. This result can conclude that a rhizome or stolon's growth was affected by its own microhabitat or mother plant. Significant linear relationships between rhizome biomass and vegetative biomass were found in *Solidago canadensis* and *Pityopsis graminifolia* (Hartnett 1990, de Kroon and Schieving 1991). This theme is in need of study in the future.

The shoots producing a spike were on Rc and Sp, but not on Rp and Sc. The mean nodes bearing the first shoot which produces a spike were 17.7th on Rc and 10.6th on Sp from the apex of rhizome or stolon. Therefore, Rc was more producible for the shoot with a spike than Rp was.

The rates of non-shoot nodes were the highest on Rc, 53.1%, and the lowest on Sp, 5.0%. Moreover, regarding the rates of non-shoot nodes, the rhizome and the central area were higher than the stolon and the peripheral area, respectively. As mentioned above,

the node number of Rc was large but the number of nodes producing a shoot was very small. Therefore, I can conclude that Rc do not contribute to the increase of shoot. The increase of shoot was thought to be depended on Sc or Sp. Especially, Sp not only had many nodes per stolon but also was high in the shoot germination rate. Thus, the increase of patch size was depended on Sp. However, the shoot density was higher in central area than in the peripheral area as mentioned above. This resulted from the shoots in the central area which mainly generated on the lower part's node of old shoots rather than on rhizome or stolon. The lower part of old shoot was regarded as a vertical rhizome. Moreover, by the field survey, the lower part of old shoot had many roots on node.

The rates of node producing over two shoots were the highest on Sp, 14.2%, and the lowest on Rc, 2.1%. Moreover, the rate of nodes producing over two shoots was higher on stolon than on rhizome, and higher in the peripheral area than in the central area.

These results can be summarized as following. First, the central area's rhizome had many nodes, tall and heavy shoots, many non-shoot's nodes and was short in internode in contrast with the peripheral's rhizome. Second, the central area's stolon had fewer nodes, tall and light shoots, and was short in internode in contrast with the peripheral area. Third, the rhizome had tall and heavy shoots, many non-shoot nodes and was short in internode in contrast with the stolon. Therefore, the rhizome or stolon in the central area was high in potential but low in productivity of shoots, in contrast with those of peripheral area. Considering shoot density and sunlight available, the strategy of the peripheral rhizomes and stolons shoot productivity was higher than that of the central area rhizomes and stolons which were thought to be favorable to clonal plants. In *Aster acuminatus* and *Glaux maritima*, light and disturbances play an important role in explaining clone structure, population dynamics and vegetation pattern (Pitelka et al. 1980, Ashmum and Pitelka 1984, Jerling 1988). Therefore, *Z. sinica* was thought to be severely affected by light on clonal growth pattern just like other plants. Generally, the length of stolons or rhizomes should decrease and intensity of clonal branching should increase with improving habitat favorability (Slade and Huchings 1987, Huchings and Mogie 1990). However, *Z. sinica* partially showed the contrast to other reports.

Spike Production along the Shoot Size

In the central area, the rate of shoot producing a spike was total of 54.6% and the highest in the plant height class of 14.0~15.9 cm (76.5%) (Fig. 3). However, the range of other classes was evenly distributed between 44.7% and 53.3%. Moreover, the rate had no relation to the plant height. Considering that the spike's height was higher than that of the leaf, the leaf height of shoot producing a spike was lower than that of non-spike one.

In the central area, the rate of shoot producing a spike was the highest in the plant weight class of 150~179 mg (73.9%) (Fig. 4). However, the relationship between the shoot's size and the spike production had no correlation. Especially, the lightest class (below 60 mg) showed the spike production of 44.4%. If the spike weight had been subtracted from the total shoot weight, the net shoot (leaf and stem only) weight producing a spike was thought to be lower than that of non-spike one.

With this result, the relationship between the shoot's size and the spike production has no interrelation. *Z. sinica*'s flowering time is from June to July (Kim 1983). By this time, only the shoot which had grown up to a certain point only was thought to be producible to a flower. The shoot germinating in the late growing season should tally the growth in order to avoid the shading by other shoots. As

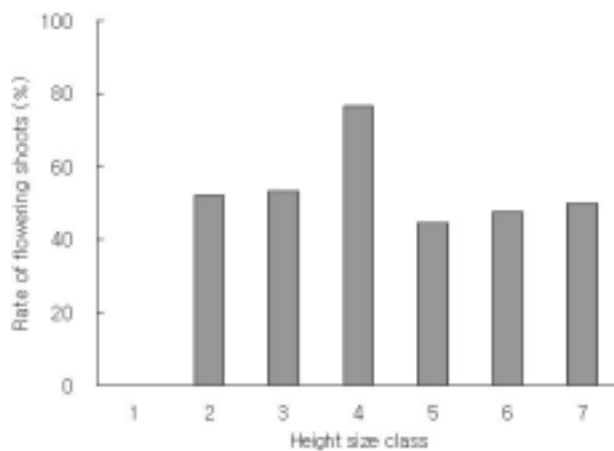


Fig. 3. Rate of flowering shoots along height (cm) size classes. 1; <10.0, 2; 10.0~11.9, 3; 12.0~13.9, 4; 14.0~15.9, 5; 16.0~17.9, 6; 18.0~19.9, 7; 20.0≤.

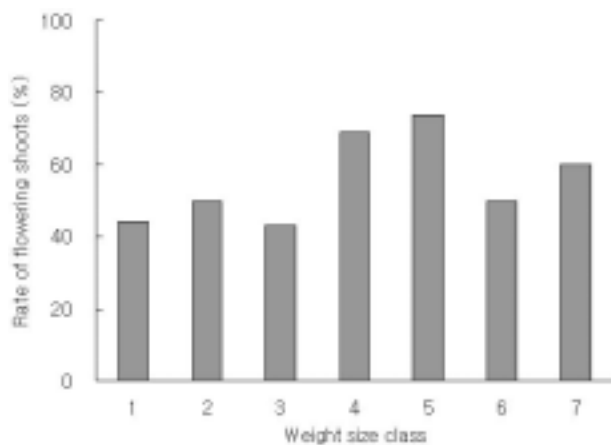


Fig. 4. Rate of flowering shoots along weight (mg) size classes. 1; <60, 2; 60~89, 3; 90~119, 4; 120~149, 5; 150~179, 6; 180~209, 7; 210≤.

a result, the shoot in the late growing season was thought to be higher and heavier than one in the early growing season.

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(Received March 2, 2006; Accepted April 25, 2006)

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