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Studies on Dry Matter Production and Leaf Area Expansion of Kudzu-Vine (*Pueraria lobata* Ohwi)

III. The emergence of current year's stems from overwintering stems.

Hyoe TSUGAWA*, Thomas W. SASEK**, Munetoshi TANGE*, and Kin-ichi NISHIKAWA*.

Synopsis

TSUGAWA, H., T.W. SASEK, M. TANGE, and K. NISHIKAWA (1987): Studies on dry matter production and leaf area expansion of kudzu-vine. III. The emergence of current year's stems from overwintering stems. J. Japan. Grassl. Sci. **32**, 337-347.

Fundamental aspects of foliage production of kudzu-vine are evaluated in this paper, including time of current year's stem emergence from buds at the nodes of overwintering stems, the number of current year's stems produced per node of overwintering stem (NCPN), the difference in the contribution of left, middle and right buds to the emergence of current year's stem and percentage mortality of current year's stem.

Current year's stem emergence commenced in early April and terminated in early June, although about 80% of the total number of current year's stems emerged by the end of April. NCPN decreased gradually from 0.61 in May to 0.15 in October in the overwintering stems with one vascular bundle ring (one-ring overwintering stems). In two-ring overwintering stems, NCPN did not show a distinctly seasonal change, ranging from 0.11 to 0.18. NCPN for overwintering stems with more than three vascular bundle rings was even lower. Nodes of overwintering stems were classified into seven types on the basis of which of the three buds produced a current year's stem. The left and right buds made a greater contribution than the middle one to the production of current year's stems. In one-ring overwintering stems, percentage mortality of current year's stems started increasing from July and reached the highest value (22.2%) in the final examination. Percentage mortality was generally lower in two-ring overwintering stems than in one-ring stems. No dead current year's stems were observed in the overwintering stems with more than three vascular bundle rings.

From these results and the fact that the nodes of one-ring overwintering stems were 76% of the total number of nodes examined, it is concluded that the emergence of current year's stems occurs mainly on buds of one-ring overwintering stems and that the left and right buds play a more important role than the middle one in the current year's stem-emergence.

Key words : Bud, Legume, *Pueraria lobata,* Stem.

* Faculty of Agriculture, Kobe University, Rokkodaicho, Nada-ku, Kobe 657 Japan
** Department of Botany, Duke University, Durham, NC 27706, USA.

Introduction

Understanding the dry matter and leaf area productivities of kudzu-vine is necessary to better utilize it as a cover crop in order to prevent soil erosion, to intercept solar heat to buildings such as factories and warehouses, and to cultivate as a forage crop. In spring, kudzu plants produce current year's stems from the buds on overwintering stems and rapidly develop a leaf canopy during the summer. Previously, in order to study the growth of current year's stems which play an important role to the canopy development, the seasonal changes in total stem length, dry weight and leaf area per current year's stem were examined in a natural kudzu stand[5]. In addition, the seasonal changes in dry matter and leaf area partitioning between the main stem and the branches of current year's stems were reported[6].

The current year's stems are produced by sprouting of three adjacent buds at the nodes of overwintering stems. It is not, however, clear when current year's stems emerge, how many current year's stems are produced per node and what percent of them die. There also appeared to be differences in the number of current year's stems produced per node among overwintering stems differing in the number of vascular bundle rings. This study was designed to document the emergence of current year's stems, in order to analyze dry matter and leaf area productivities of a natural kudzu stand more effectively.

Materials and Methods

1. Time of current year's stem emergence

Twenty two fixed 1-m^2 quadrats were set up in a natural kudzu stand, located in Kitabata, Okamoto, Motoyama-cho, Higashinada-ku, Kobe. The number of current year's stems newly arising from the buds on the overwintering stems was recorded daily. This examination was conducted from late-March until mid-June of 1982. It was considered that a current year's stem had been produced when the 1st trifoliate leaf of the stem became visible outside the 1st stipule, and the tips of leaflets were separated from one another as shown in **Fig. 1-④**. That day was termed the emergence date of the current year's stem.

2. The number of current year's stems produced per node of overwintering stems and percentage mortality of current year's stems.

Seven to ten 1 m^2-quadrats were placed in the natural kudzu stand and the overwintering stems in these quadrats were harvested on the 1st day of the month from May to October 1982. The number of living and dead current year's stems arising from the nodes of overwintering stems in these quadrats were counted separately. The number of current year's stems produced per node of overwintering stem and percentage mortality of current year's stems were calculated separately for the overwintering stems differing in the number of vascular bundle rings according to the following equations :

No. of current year's stems produced per node of overwintering stem (hereafter represented as NCPN) = total no. of current year's stems (including dead current year's stems)/no. of nodes on overwintering stems

Percentage mortality of current year's stems = no. of dead current year's stems/total no. of current year's stems × 100

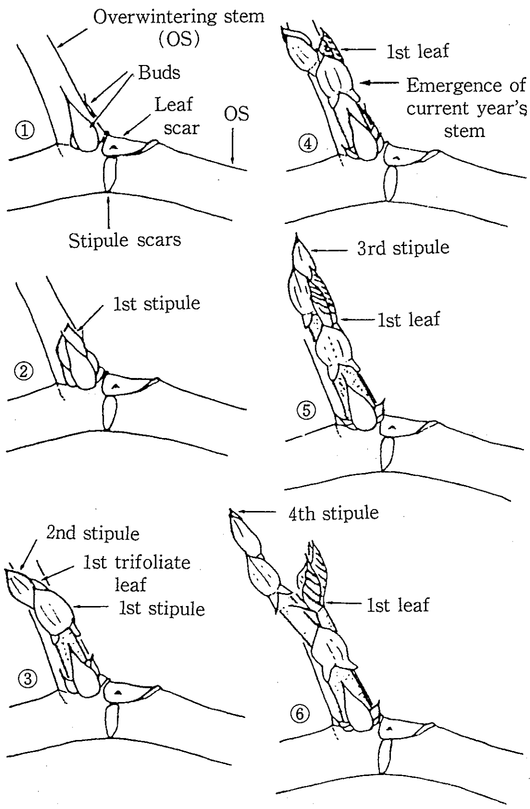

Fig. 1. Early developmental stages of leaf and stem in a current year's stem.

Notes : ① In dormancy ; ② Bud break ; ③ Appearance of the 1st trifoliate leaf. The leaflets of the 1st leaf remain folded ; ④ The tips of the leaflets are separated from one another ; ⑤ the leaflets appear completely from the stipules ; ⑥ The entire 1st leaf appears (see Table 4-A).

In both equations, 'dead current year's stems' indicates the current year's stems that died on living overwintering stems. A few dead overwintering stems with dead current year's stems were found. The dead current year's stems on the dead overwintering stems were omitted from the calculations because they may have been produced before 1982.

Table 1 lists the number of quadrats used at each sampling time and the number of nodes on the overwintering stems differing in the number of vascular bundle rings in those quadrats.

3. Classification of overwintering stem-nodes on the basis of the position of the buds producing a current year's stem

The nodes of overwintering stems were classified into seven groups on the basis of the position of buds producing a current year's stem ; such as Type I (**Fig. 2, left**) in which only the left bud produced a current year's stem, Type II (**Fig. 2, middle**) in which the middle bud produced a current year's stem or Type V (**Fig. 2, right**) in which the left and right buds produced a current year's stem. Table 4-A and 4-B list the classification of all seven node types.

Table 1. The number of 1-m square quadrats used and the number of nodes examined of overwintering stems differing in the number of vascular bundle rings.

Time	No. of quadrats	No. of vascular bundle rings in internodes*				
		1	2	3	4	5
May	10	727	319	36	10	3
Jun.	10	814	116	17	1	0
Jul.	7	754	202	19	11	0
Aug.	8	690	152	11	2	0
Sept.	9	639	183	18	4	1
Oct.	8	424	132	13	7	1

Note ; * Determined by the number of vascular bundle rings in the internodes immediately below the nodes examined (see previous papers[1,2]).

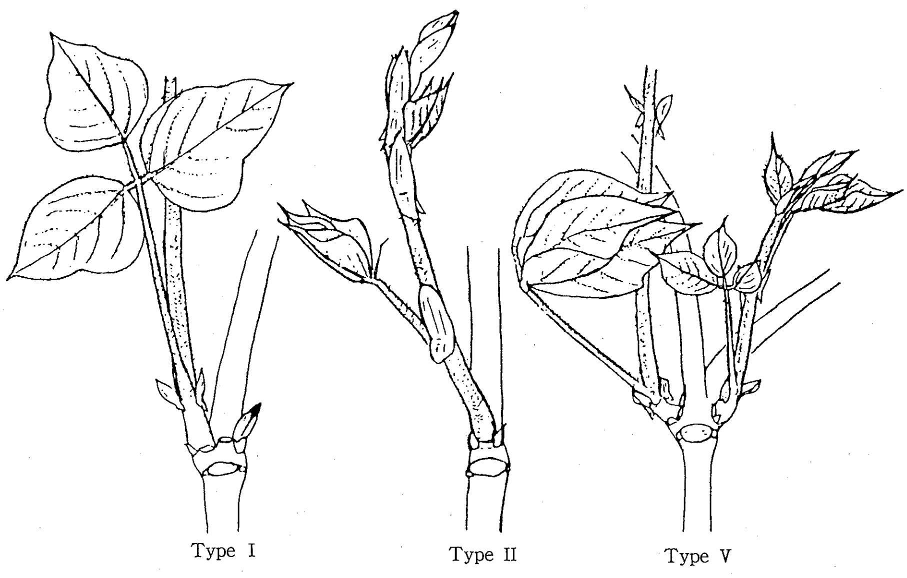

Fig. 2. Examples of the node types classified on the basis of position of buds producing a current year's stem.

Notes : On the left (Type I), the middle bud has already died and disappeared. The right bud died after sprouting. In the middle (Type II), the left and right buds are dormant. On the right (Type V), the middle bud had already sprouted and produced a branch in the previous year.

Results

1. Weather conditions

Table 2 lists daily mean temperature, precipitation and sunshine hours during the period in which the emergence of current year's stems was examined. The daily mean temperature was below normal (30 year average, see Table 2) for early and mid-April. It was above normal from late April until the end of May and was lower thân normal by 0. 3 to 2. 1°C from June onwards. Rainfall for April to June and for Septenber was below normal, especially in June and September when it was more than 50% lower than normal. Sunshine hours were 15 to 30% longer during the months from April to June and 12 to 20% shorter than normal from July onwards.

2. Time of current year's stems emergence from the buds on overwintering stems

The emergence of current year's stems from the buds of overwintering stems is shown in **Fig. 3.** The first current year's stem emerged on April 3. The number of current year's stems increased rapidly around April 10. About 50% of the current year's stems examined were produced by April 21 and 75% by April 27. The daily rate of increase in the number of current year's stems decreased thereafter, but the emergence of current year's stems extended into early June.

3. NCPN and the percentage mortality of current year's stems

As listed in **Table 3,** in the overwintering stems with one vascular bundle ring (one-ring overwintering stem), NCPN decreased gradually from 0. 61 in May to 0. 15 in October, with a considerably large decline of about 20% between May and June. In two-ring overwintering stems, NCPN did not show a distinctly seasonal change, ranging from 0. 11 to 0. 18 throughout the 6-month period of examination. In the overwintering stems with more than three

Table 2. Weather conditions during the growing season in 1982.

Time		Temperature (℃)	Rainfall (mm)	Sunshine hours
April	early	10.9 (−1.1)	61.0 (+14.2)	58.6 (− 1.3)
	mid.	12.5 (−1.6)	40.5 (− 8.5)	87.1 (+29.5)
	late	16.4 (+0.7)	28.0 (−21.6)	73.6 (+12.0)
May	early	19.1 (+2.2)	68.5 (+23.3)	61.9 (− 1.4)
	mid.	19.1 (+0.9)	16.0 (−32.4)	86.2 (+18.3)
	late	19.8 (+0.2)	16.5 (−31.0)	92.2 (+16.3)
Jun.		21.5 (−0.3)	80.5 (−135.1)	205.1 (+45.5)
Jul.		23.8 (−2.1)	230.0 (+ 39.6)	152.7 (−40.8)
Aug.		26.1 (−1.1)	232.0 (+124.2)	175.8 (−43.5)
Sept.		22.2 (−1.3)	84.5 (− 92.1)	143.1 (−20.1)

Notes : The weather data were obtained from the observations at Kobe Marine Meteorological Observatory situated about 9 km west of study site. Figures in parentheses show the differences from the normal year. The normal values for temperature, rainfall and sunshine hours were given by the mean of the observed values for 30 years from 1951 to 1980.

The observatory and the study site are located at an elevation of 60 and 160 meters, respectively, on south facing slopes of the Rokko mountains.

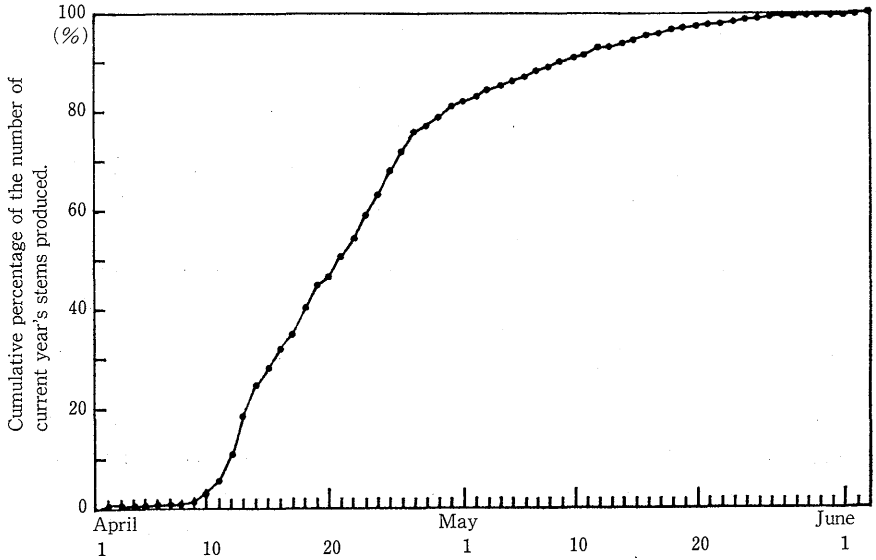

Fig. 3. Time course of emergence of current year's stems from the buds of overwintering stems.

Note : The time course of emergence of current year's stems was followed on 1090 current year's stems arising in the twenty two 1-m^2 quadrats examined.

Table 3. The number of current year's stems produced per node of overwintering stem (NCPN) and the percentage mortality of current year's stem (%M).

Time	No. of vascular bundle rings in internodes*									
	1		2		3		4		5	
	NCPN	%M	NCPN	%M	NCPN	%M	NCPN	%M	NCPN	%M
May	0.61	0.0	0.17	0.0	0.00	0.0	0.30	0.0	0.33	0.0
Jun.	0.40	0.3	0.11	0.0	0.00	0.0	0.00	0.0	—	—
Jul.	0.31	10.1	0.14	13.8	0.00	0.0	0.00	0.0	—	—
Aug.	0.22	17.8	0.18	3.7	0.00	0.0	0.00	0.0	—	—
Sept.	0.22	15.4	0.16	10.0	0.28	0.0	0.25	0.0	0.00	0.0
Oct.	0.15	22.2	0.12	0.0	0.00	0.0	0.00	0.0	0.00	0.0

Note : * Determined by the number of vascular bundle rings in the internodes immediately below the nodes examined (see previous papers[1,2]).

vascular bundle rings, there was no distinct trend, due to the small number of nodes examined. Considerably high NCPN was observed at certain times but it was nil at other times.

The percentage mortality of current year's stems in one-ring overwintering stems (Table 3) started increasing in July and reached the highest value of 22% in October. The percentage mortality for two-ring overwintering stems was generally lower than that of one ring overwintering stems, with no distinctly seasonal trend. None of the current year's stems died on overwintering stems with more than three vascular bundle rings.

4. Percentage distribution of different types of overwintering stem nodes classified on the basis of the mode of current year's stem emergence

Tables 4-A and -B present the frequency distribution of the nodes belonging to Types I to VII in one-ring and two-ring overwintering stems, respectively. In one-ring overwintering stems, Types I to III (in which any one of three buds produced a current year's stem) ranged from about 20 to 37%. Types I and III (in which a left or right bud alone produced a current year's stem) had higher percentages than Type II (in which only the middle bud produced a current year's stem) at all examination dates except July and August. The proportions of Types IV to VI (which gave rise to current year's stems from two of the three buds) ranged from 0 to 18% and were lower than those of Types I to III. Of the former three types, Type V (in which both left and right buds produced current year's stems) had the highest value. The percentage distribution of Type VII was lowest, ranging from 0 to 1.5%.

Table 4-A. Node types classified on the basis of the production of current year's stems and their percentage distribution in one-ring overwintering stems.

Node type	Position of bud producing current year's stem			Time						Average
	Left	Middle	Right	May	Jun.	Jul.	Aug.	Sept.	Oct.	
				(%)	(%)	(%)	(%)	(%)	(%)	(%)
I	○			32.6	33.6	32.0	28.3	27.1	25.4	31.5
II		○		20.3	26.6	32.4	30.3	22.7	30.5	27.1
III			○	26.8	27.3	28.3	36.6	34.1	35.6	31.5
IV	○	○		0.8	0.7	0.0	0.7	0.0	1.7	0.7
V	○		○	18.1	11.4	6.8	4.1	4.6	5.1	8.4
VI		○	○	1.1	0.4	0.0	0.0	0.0	1.7	0.5
VII	○	○	○	0.3	0.0	0.0	0.0	1.5	0.0	0.3

Note: Circles indicate the emergence position of current year's stems.

Table 4-B. Node types classified on the basis of the production of current year's stems and their percentage distribution in two-ring overwintering stems.

Node type	Position of bud producing current year's stem			Time						Average
	Left	Middle	Right	May	Jun.	Jul.	Aug.	Sept.	Oct.	
				(%)	(%)	(%)	(%)	(%)	(%)	(%)
I	○			38.6	36.4	27.6	42.3	27.6	46.6	36.5
II		○		4.6	0.0	48.3	19.2	20.7	26.7	19.9
III			○	38.6	45.4	24.1	34.6	48.3	20.0	35.2
IV	○	○		0.0	0.0	0.0	0.0	3.4	0.0	0.6
V	○		○	18.2	18.2	0.0	3.9	0.0	6.7	7.8
VI		○	○	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VII	○	○	○	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: Circles indicate the emergence position of current year's stems.

The average proportions of nodes belonging to Types I and III were higher in two-ring overwintering stems than in one-ring stems but the reverse was true for Type II. Averaged across sampling dates in Type IV to VI, the mean proportion of these types in one-ring overwintering stems was higher than that of two-ring stems. No Type VII nodes, in which all three buds produced a current year's stem, were observed in two-ring overwintering stems.

In three-ring overwintering stems, the nodes that produced a current year's stem were observed only at the September sampling and consisted only of Types I and III (80 and 20%, respectively). In four-and five-ring stems, only Type I nodes were observed (data not shown).

5. Differences in the contribution to the production of current year's stems among left middle and right buds

Table 5 lists the percentage distributions of the three buds producing a current year's stem in overwintering stems differing in the number of vascular bundle rings. In one-ring overwintering stems, the percentage distributions of left and right buds were about 15 and 12 % higher, respectively, than that of middle buds. Percentage distributions of left and right buds were higher in two-ring overwintering stems than in one ring stems, wheres the percentage distribution of the middle bud was lower in two-ring stems. There was no emergence of current year's stems from middle buds in stems with more than three rings.

Discussion

Previously, TSUGAWA examined changes in the number of current year's stems arising from overwintering stem nodes during the period from early April to early June 1975[4]. The patterns of emergence of current year's stems were similar in the 1975 and 1982 studies. However, 50% and 75% of the total number of current year's stems examined emerged by April 16 and 23 respectively in 1975, indicating that the emergence of current year's stems was earlier in the 1975 examination than in the present study. This may be associated with differences in mean daily temperatures for early and mid-April that were 0.6 and 2.3°C higher

Table 5. Percentage distribution of the number of current year's stems produced from the three buds at nodes of overwintering stems differing in the number of vascular bundle rings.

No. of vascular bundle rings in internode*	Position of buds		
	Left	Middle	Right
	(%)	(%)	(%)
1	39.0	24.3	36.7
2	40.3	18.9	40.8
3	80.0	0.0	20.0
4	100.0	0.0	0.0
5	100.0	0.0	0.0

Notes : * Determined by the number of vascular bundle rings in the internodes immediately below the nodes examined (see previous papers[1,2]).
Values are expressed as percentages of the number of current year's stems arising from respective buds to total number of current year's stems produced, including current year's stems that died.

respectively in 1975 than in 1982.

The results obtained from this study show that buds on overwintering stems differing in the number of vascular bundle rings do not contribute equally to the number of current year's stems produced. The buds on overwintering stems with one or two vascular bundle rings are mainly responsible for the emergence of current year's stems. Nodes on overwintering stems with more than three vasucular bundle rings had low values of 0.08 in NCPN averaged across the sampling dates (Table 3) and they are a small percentage of the total number of nodes that are present (about 3%, Table 1). In addition, it is likely that almost all buds on a stem have already produced a current year's stem or have died by the time a third vascular bundle ring is formed.

Left and right buds are more important than the middle one in producing current year's stems. They had greater percentage emergence of current year's stems in overwintering stems with any number of vascular bundle rings (Table 5). It is known that almost all branches developed at the nodes of current year's stems arise from the middle of the three axillary buds[3]. Therefore, it is likely that there is a relationship of apical dominance between the middle and the left or right buds. In the apical dominace, the inhibitory effect of the middle bud on sprouting of the left and right buds delays sprouting of the left and right buds until the following year. It is assumed that since considerable numbers of middle axillary buds sprout in the same year as they are formed, percentage emergence of current year's stems in the following year have a higher value in the left and right buds than in the middle one. This pheromenon was probably reflected in the results of Table 5.

NCPN showed no distinctly seasonal change and remained fairly constant in the two-ring overwintering stems, whereas it gradually declined from May to October in one-ring overwintering stems (Table 3). This fact appears to be associated with the death of overwintering stems that produced current year's stems during the period of examination. In an overwintering stem in which all internodes have the same number of vascular bundle rings, if NCPN is smaller near the stem base compared with the terminal portion, and if the number of dead nodes in the terminal portion continues to increase, the NCPN of the whole stem decreases gradually. Although no appropriate data were collected to substantiate this hypothesis, it seems to be responsible for the decline in the NCPN of one-ring overwintering stems based on the author's experience from field experiments of kudzu-vine (unpublished).

Considerably high percentage mortality of current year's stems was observed in one- and two-ring overwintering stems from July onward. If the supply of water to the current year's stems is not adequate to counterbalance the transpiration from the leaves, especially in the terminal portion with rudimentary conductive tissue, death of the current year's stems may occur. The large increase in percentage mortality of current year's stems between June and July and between September and October (Table 3) may be associated with 50% less precipitation than normal in June and September. The death of current year's stems may be ralated to competition for water and nutrients, although there are no data to document it. In addition, it is supposed that severe limitations in the water supply are considered to be at least partially linked to the death of the overwintering stems themselves. Further research is needed to evaluate the water relations and nutrio-physiology of kudzu-vine.

Furthermore, as the examination of current year's stem emergence was terminated in mid-June in both the 1975 and 1982 studies, it is not known if current year's stems were produced thereafter during the growing season. However, late-emerged current year's stems are thought to be few, if any, extrapolating from the large decline in the NCPN.

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クズの乾物生産ならびに葉面積の拡大に関する研究

Ⅲ. 越年茎の節における当年茎の発生

津川兵衛*・トーマス サセック**・丹下宗俊*・西川欣一*

*神戸大学農学部（657 神戸市灘区六甲台町）

**デューク大学植物学科（ダーラム，ノースカロライナ，27706 アメリカ合衆国）

要　　約

本研究では，越年茎の節にある芽からの当年茎の出現時期，越年茎の節当り当年茎発生数，当年茎の枯死率および当年茎発生に対する3つの芽の貢献度のちがいのようなクズの茎葉生産に関連する最も基本的な問題について検討した。本研究結果は六甲山系山麓部に当る神戸市東灘区本山町岡本北畑にあるクズの自然群落から得られた。

越年茎の芽からの当年茎の発生は4月上旬から6月上旬まで続いたが，当年茎数の80%は4月末までに現われた。越年茎の節当り当年茎発生数は，維管束環数1環の越年茎では5月から10月にかけて0.61から0.15まで次第に低下した。2環の越年茎ではそれは調査期間を通じて0.11～0.18の範囲にあり，はっきりした季節変化は認められなかった。3環以上の越年茎の節当り当年茎発生数は前2者よりかなり低かった。越年茎の節の3つの芽のうちどれが当年茎を発生したかにより節は7つのタイプに分けられた。当年茎発生については中央の芽よりも左右の芽の貢献度が大であった。当年茎の枯死率は1環の越年茎では7月から10月にかけて上昇し続けた。2環の越年茎では枯死率は1環の茎にくらべて低かった。3環以上の茎では当年茎の枯死は認められなかった。

以上のことから，当年茎は主に維管束環が1環の越年茎の節にある芽から発生し，3つの芽のうち中央の芽よりも左右の芽の方が当年茎発生に重要な役割をはたしていると結論される。

キーワード：茎，クズ，マメ科，芽.

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