〔韓作誌(Korean J. Crop Sci.) 40(1) : 103~112(1995)〕

Formation and Development of Abscission Layer between Pedicel and Rachilla, and Changes in Grain Shedding during Ripening in African Rice, *Oryza glaberrima* Steud.

Il Doo Jin* · Yeong Hwan Bae* and Jun Inouye**

아프리카 벼 *Oryza glaberrima*의 種實 離層組織의 발달과정과 登熟기간 중 脫粒性의 변화

陳 日 斗* · 裵 英 煥* · 井之上 準**

ABSTRACT : Six African rice varieties, two each from three types having the characteristics of partially, irregularly, and completely developed abscission layers, were selected and grown 1) to investigate the histological differences during the formation and development of the abscission layers and 2) to evaluate the changes in the breaking tensile strength required to detach a grain from its pedicel during ripening period in relation with developmental stage of the abscission layers.

In African rice, the panicle and spikelet grew rapidly from 15 days before heading and almost completely grown in length at five days before heading. The abscission regions were recognized at 15 days before heading. However, any apparently developed abscission layers were not recognized in the lemma side for partially developed abscission layers. A group of parenchymatous cells could be observed sporadically in the abscission layers of the lemma side for irregularly developed abscission layers.

At ten days before heading, abscission layers consisting of one or two layers of parenchymatous cells were clearly distinguished from neighboring cells due to thickened and lignified cell walls. There were a number of individual parenchymatous cells scattered sporadically in the lemma side of partially developed abscission layers, and a number of grouped parenchymatous cells scattered randomly in the lemma side of irregularly developed abscission layers.

At two weeks after heading, the grains became almost fully filled. The cracking of abscission layers between rachilla and pedicel was observed, and the breaking tensile strength required to detach a grain from its pedicel was as low as that at harvest time.

Key word : *Oryza glaberrima* Steud., Grain shedding, Abscission layer

* 順天大學校 農科大學(College of Agriculture, Sunchon Nat'l Univ., Sunchon 540-742, Korea)
** 日本 九州大學 農學部(Faculty of Agriculture, Kyushu Univ., Fukuoka 812, Japan)
이 논문은 1991년도 교육부 지원 학술진흥재단의 지방대학 육성과제 학술연구 조성비에 의하여 연구되었음. 〈'94. 12. 5. 接受〉

Most African rice varieties formed complete abscission layers between pedicel and rachilla which were similar to those of Asian rice that cracked almost completely at harvest time. Jin et al.[10] reported two types of incomplete formation of the abscission layers in some varieties of African rice: one type is partially developed abscission layer that is formed only in palea side but not in the lemma side, and the other type is irregularly developed abscission layer which is formed in both sides with very irregularly developed layers in the lemma side.

In Asian rice, the abscission layers were distinctively developed at about 12 days before heading as the length of panicle reached 50~80mm and the length of spikelet was 3~4mm[8]. Also at 2 to 3 weeks after heading, the cracking of the abscission layers was observed[3,4,6,9,12,13] and the breaking tensile strength rquired to detach a grain from its pedicel decreased rapidly[4,5,6,9]. Unfortunately, there are few reports on African rices with partially or irregularly developed abscission layers.

The objectives of this study were 1) to investigate the histological differences among the three types of abscission layers during their formation and development and 2) to evaluate the temporal changes in the breaking tensile strength required to detach a grain from its pedicel in relation with developmental stage of the abscission layers during ripening period.

Materials and Methods

Six varieties of African rice were used in this study: varieties N-1 and F-11 for partially developed abscission layers, N-2 and F-31 for irregularly developed abscission layers, and N-9 and F-8 for completely developed abscission layers. The experiment was conducted at Sunchon National University in 1991. Plants were grown in plastic pots of 4ℓ volume each, 2 hills per pot and one plant per hill. Twenty plastic pots were used for each variety. All plants were grown under 8-hr day-length until the stage of panicle formation, and then under natural day-length condition thereafter.

Formation of abscission layers: From panicle formation stage to heading, about ten panicles from main stem and the primary tiller were sampled at intervals of 5 days. The panicle length and length of spikelet at the tip of panicle were measured. And then the tip spikelets with 5 mm long abscission region were sampled and fixed in F. A. A. solution. After embedded in paraffin wax using standard procedures, the samples were cut into longitudinal serial sections of 10 μm thick with rotary microtome. Paraffin sections were stained with Safranine, Fast Green and Hematoxylin. After mounting them with Canada Balsam, morphological features of the abscission layers were examined by using an optical microscope.

Changes in the degree of grain shedding and development of abscission layers during ripening period: The degree of grain shedding was investigated by mea- suring the breaking tensile strength required to detach a grain from its pedicel by using an unbonded gage type transducer (UT=1Kg) and an automatic null balancing recorder. To measure the breaking tensile strength, three to four panicles per plant were sampled at intervals of one week from main culm and the primary tiller during ripening period. About 30 spikelets at the upper part of the panicles were used to measure the tensile strength. From the same panicles used to measure the breaking tensile strength, about 20 abscission regions between rachilla and pedicel were collected to observe the developmental processes of abscission layers by the same method described in the previous section. In addition, grains were harvested from the main stem and the primary tiller at intervals of one week from heading date. The grains were then dried and 1,000 grain weight was measured to investigate the relationships among grain weight, degree of grain shedding, and the development of abscission layers.

Since there were no significant differences in the formation and development of the abscission layers and in the degree of grain shedding between the two varieties in each type of abscission layers, the results in this report were derived with three varieties, one from each type, that is, N-1 for partially developed, N-2 for irregularly developed, and F-8 for completed developed abscission layers.

Results and Discussion

1. Formation and developmental processes of abscission layer

Growth of panicle and spikelet (Fig. 1): In Asian rice, the length of panicle was 2~5 mm at 20 days before panicle emergence (DBPE), 50~80 mm at 16 DBPE, and the length at 4 DBPE was almost the same as that of panicle at the heading date[8]. Although some variations in the length of panicles were recognized among the varieties of African rice used in this study, it was distributed within the range of 15~20mm at 20 DBPE and 40~70mm at 15 DBPE. Thereafter the panicles grew rapidly so that they reached in the range of 170~220 mm at 5 DBPE and remained almost the same until panicle emergence time. The length of spikelets attached at the upper part of panicles at 20, 15, and 10 DBPE were 1~1.5, 2~3, and 7~8mm, respectively. At 5 DBPE, spikelets grew almost fully so that their length were similar to those at harvest date. These results were almost the same as Asian rice[8,11].

Formation and development of abscission layers: In Asian rice, the region where the abscission layers are formed can be recognized at 20 DBPE, but the layers are not clearly distinguished from neighboring tissues at this point. At about 16 DBPE, the abscission layers can be clearly distinguished since they have smaller cells with dark stained cytoplasm, while the cells of the neighboring tissues are elongated with well-developed vacuoles. Also the abscission layers became more distinctive at 12 DBPE as the cells

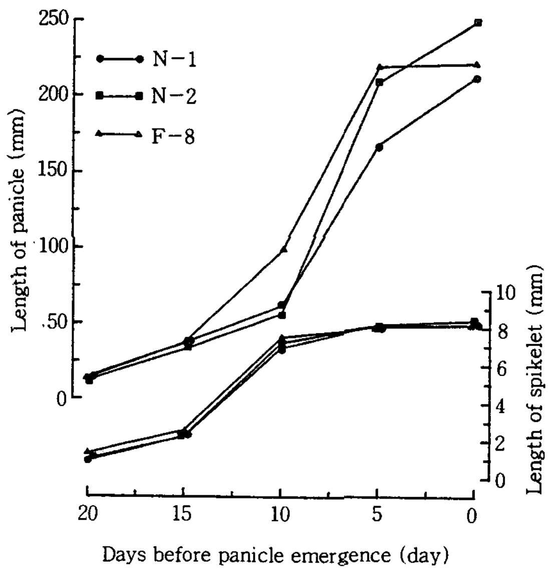

Fig. 1. Changes in the length of panicle and spikelet of African rice varieties during booting stage.

around pedicel are further elongated, thickened and lignified[8].

The results of this study indicated that abscission layers of palea side of spikelet of African rice also showed similar developing process as that of Asian rice regardless of the type of abscission layers (Fig. 2). Although the region for the abscission layer to be formed was recognized at about 20 DBPE, the cells in the sides of pedicel and spikelet were so similar to the cells in the abscission region that they could not be distinguished from those in the region (Fig. 2-A, B, C). Since the cells in the side of pedicel were elongated with developed vacuoles from about 15 DBPE, while the cells in the abscission layers were smaller and had darker stained cytoplasm compared with the neighboring ones, the abscission layers could be distinguished from their neighbor (Fig. 2-D, E, F). At 10 DBPE, the distinguishment between the cells in the abscission layers and those in the side of pedicel became clear since the latter were stained red by Safranine as a result of the thickened and lignified secondary cell walls while the former were consisted of parenchyma cells with primary cell walls and thus stained green by Fast Green (Fig. 2-G, H, I). This phenomenon became more distinct at about 5 DBPE without further development upto penicle emergence (Fig. 2-J, H, L).

There were some differences in the formation and development of abscission layers in the lemma side of spikelet among the types of abscission layers (Fig. 3). At about 20 DBPE, the region forming the abscission layers was distinguishable in the lemma side for all the three rice varieties regardless of the types of abscission layers which was the same with the palea side, but the formation of the abscission layers was not recognized (Fig. 3-A, B, C). Although the variety N-1 formed partially developed abscission layers at about 15 DBPE, the cells around pedicel showed elongation and well-developed vacuoles while the cells around abscission region and spikelet showed cell division in part but no elongation, so the boundary between pedicel and lemma was distinguishable and no distinct abscission layers were recognized due to irregular distribution of parenchymatous cells (Fig. 3-D). On the other hand, the varieties N-2 and F-8, which formed either irregularly developed or completely developed abscission layers, showed both elongation and development of vacuoles in the cells of pedicel, which enabled to recognize the boundary between pedicel and lemma. Furthermore, 1~2 layers of regularly arranged and vigorously dividing parenchymatous cells located between pedicel and spikelet made it possible to distinguish the abscission layers clearly (Fig. 3-E, F). In the variety with irregularly developed abscission layers, a group of parenchymatous cells located in some parts of abscission layers were observed. The position and size of the grouped parenchymatous cells varied greatly among individual sections.

At 10 DBPE, the thickening and lignification of the cell walls progressed simultaneously in the cells between lemma and pedicel for the varieties with partially developed abscission layers, which disabled the recognition of the existence of abscission layer. Parenchymatous cells were scattered sporadically one by one in the abscission region and cell division of them ould be observed (Fig. 3-G, arrow mark). On the contrary, in the variety forming irregularly developed abscission layers, the abscission layers occupied partly by groups of parenchymatous cells were observed (Fig. 3-H), and for the variety which

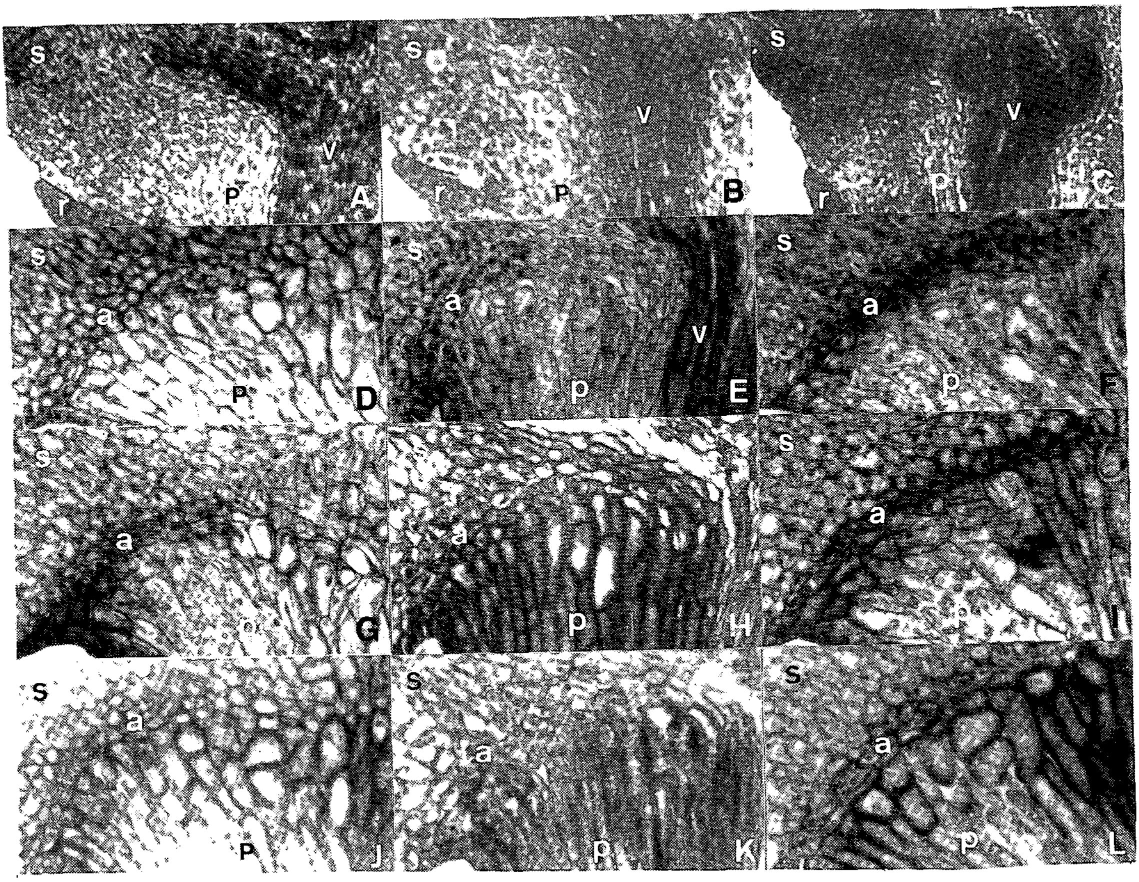

Fig. 2. Longitudinal sections of palea side of the abscission region between pedicel and rachilla of partially developed (top), irregularly developed (middle) and completely developed (bottom) abscission layers (X 400) at 20 days (A, B, C), 15 days (D, E, F), 10 days (G, H, I) and 5 days (J, K, L) before panicle emergence.
Abbreviations: a: abscission layer, ar: abscission region, p: protrusion at the top of pedicel, r: rudimentary glume, s: sterile lemma, v: vascular tissue.

formed completely developed abscission layers, the abscission layer consisted of 1~2 layers of small parenchymatous cells with primary cell walls were clearly distinguished as in the case of palea side. The same phenomenon was observed at 5 DBPE (Fig 3-J, K, L) and also at heading time.

The above results may indicate that the partially developed abscission layers were formed because of the low activity of cell division in the lemma side of abscission region which caused to stop cell division and to differentiate into sclerenchyma cells at the earlier stage of development than in palea side. The reason for the formation of the irregularly developed abscission layers was the progress of cell wall thickening except the partially grouped parenchymatous cells in the lemma side.

2. Change in the degree of grain shedding and abscission layer during ripening period

There have been several reports on the change of breaking tensile strength between

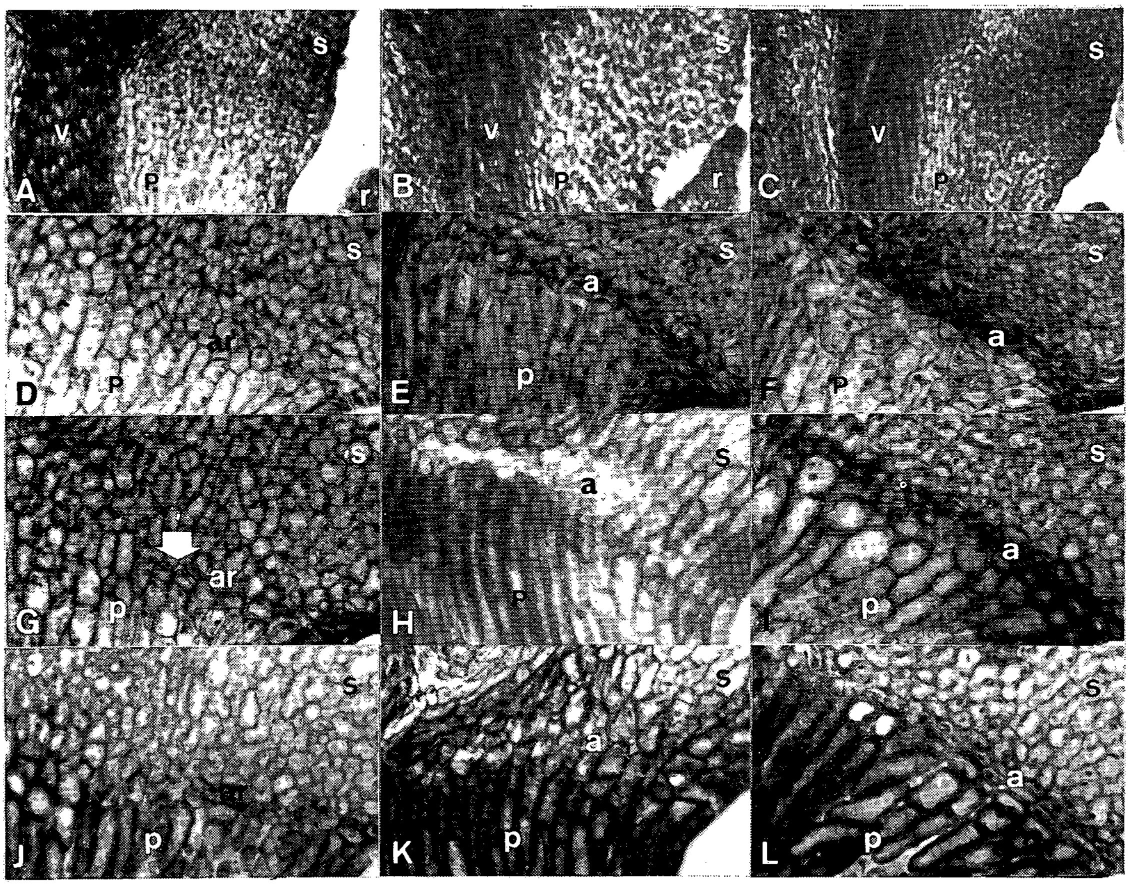

Fig. 3. Longitudinal sections of lemma side of the abscission region between pedicel and rachilla of partially developed (top), irregularly developed (middle) and completely developed (bottom) abscission layers(X 400) at 20 days (A, B, C), 15 days (D, E, F), 10 days (G, H, I) and 5 days (J, K, L) before panicle emergence.
Abbreviations: same as Fig. 2.

rachilla and pedicel from heading to harvest. Indica type rices[4,5,6], Indica-Japonica hybrids[9], and easily-shattering Japonica type rices[9] showed gradual increase in tensile strength from heading to one week thereafter. The tensile strength decreased gradually from two weeks after heading, and at three weeks after heading, the strength was almost as weak as that of harvest time. However, some varieties of Japonica type rice resistant to grain shedding rarely showed any decrease in tensile strength for the period from 2 to 3 weeks after heading[1,7].

The result of this study showed that all the three varieties of African rice had higher breaking tensile strength at one week after heading than at the heading date, but the breaking tensile strength at two weeks after heading was so low that it was almost the same as that of harvest time (Fig. 4).

The decreasing rate of the breaking tensile strength calculated at 2 weeks after heading as a percent of that at 1 week after heading were about 40% to 50%.

It has been reported that, in Asian rice, there is a close relationship between the decrease in breaking tensile strength and the degree of ripening such that at three weeks after heading the breaking tensile strength is reduced to a magnitude comparable to that at harvest time and the grains were filled as much as those at harvest time.[4,5,9] In all the three varieties of African rice in this study, the breaking tensile strength was the same as that at harvest time and the grains were almost completely ripen at two weeks after heading (Fig. 5).

Hu et al.[3] reported that the cracking of the abscission layer between rachilla and pedicel occurred at 30 days after flowering for Indica type rice and at 10~15 days after flowering for wild rice. Also cracking of abscission layer was observed with Indica type rice[4,6] and Indica-Japonica hybrids[9] at three weeks after heading when the breaking tensile strength between rachilla and pedicel was almost the same as that at harvest time and the ripening was completed.

In this research, the breaking tensile strength between pedicle and rachilla was the highest at one week after heading when the cells in the sides of pedicel and rachilla were as much thickened and lignified as those at harvest time, and development of abscission layers and the histological peculiarities were similar to those at heading time (Fig. 6-A, C, E). However, at two weeks after heading, all the three varieties showed complete cracking of the abscission layers in the palea side as in the case of harvest time. In the lemma side of abscission layer (Fig 6-B, D, F), no cracking was observed for the variety with partially developed abscission layer due to the lack of the layer (Fig. 6-B), and partial and complete cracking were observed for the varieties

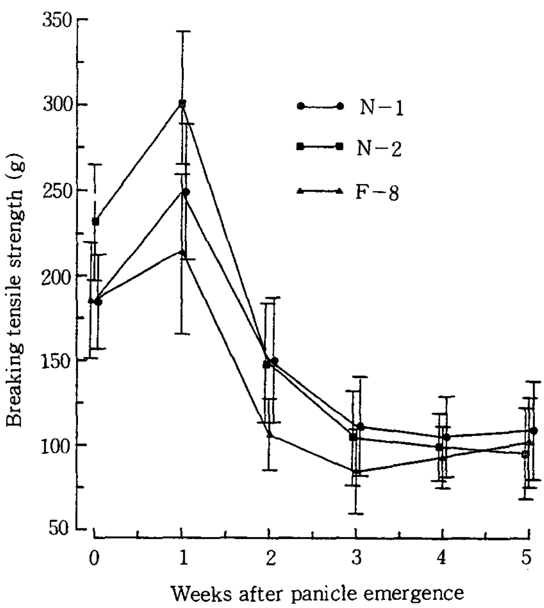

Fig. 4. Changes in the breaking tensile strength required to detach a grain from its pedicel of African rice varieties during ripening period.

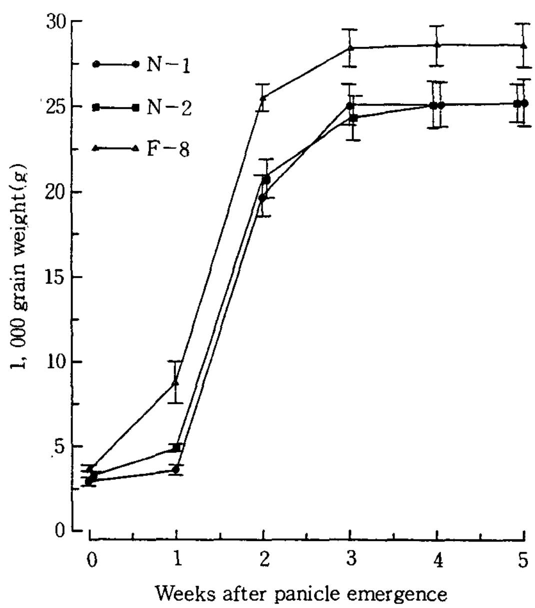

Fig. 5. Changes in the 1000 grain weight of African rice varieties during ripening period.

with irregularly or completely developed abscission layers, respectively (Fig. 6-D, F).

The African rice generally ripen earlier than Asian rice so that the cracking of the abscission layer between rachilla and pedical occurred to decrease the breaking tensile strength at 2 weeks after heading when the grain became almost fully ripen.

摘　　要

아프리카 벼에 있어서 벼알과 小枝梗 사이에 形成되는 離層組織의 特異性에 따라, "部分離層", "不規則離層" 및 "完全離層"의 品種을 各各 2品種씩 供試하여 幼穗形成 以後 幼穗와 穎花의 伸長에 따른 離層組織의 形成 및 發達過程을 解剖形態學的으로 觀察하였다. 또한 出穗後 收穫期까지 登熟

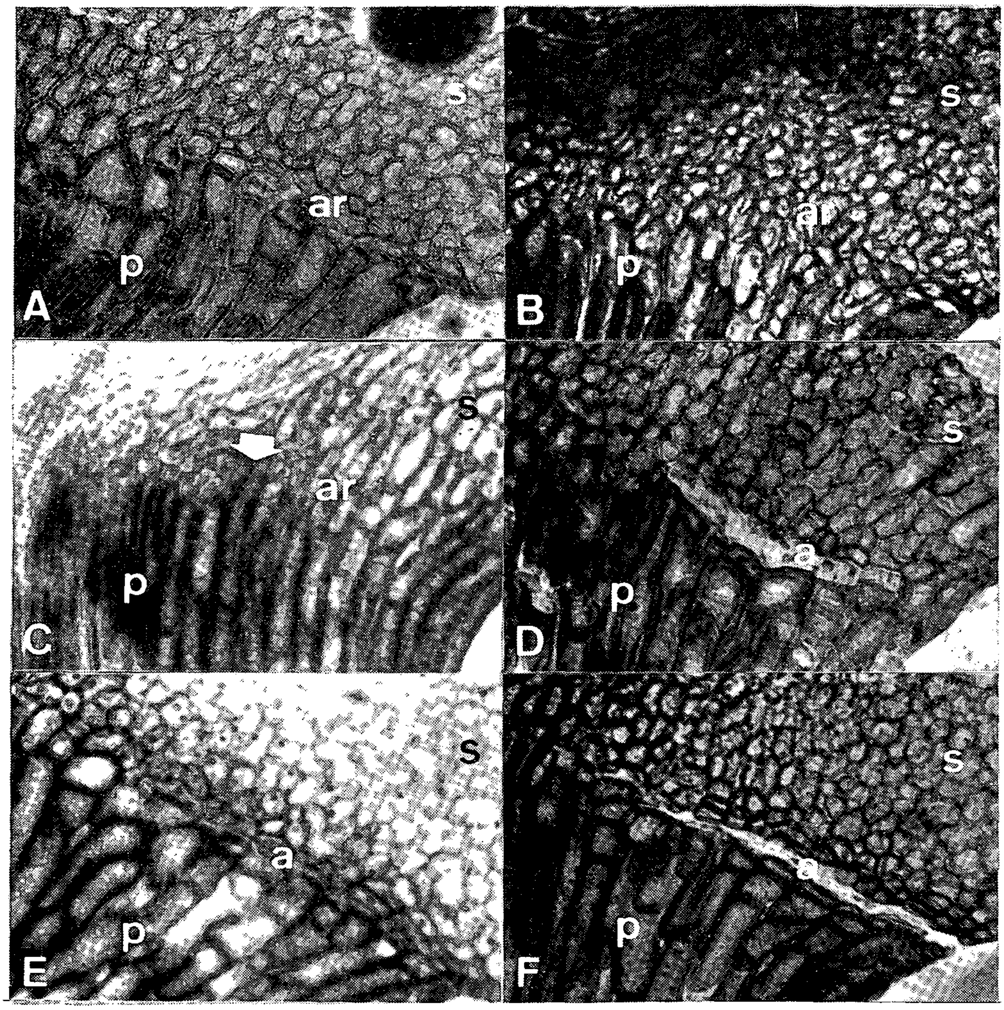

Fig. 6. Changes in the histological peculiarities of lemma side of the abscission region between pedicel and rachilla of partially developed (top), irregularly developed (middle) and completely developed (bottom) abscission layers, from 1 week (left) to 2 weeks (right) after panicle emergence(X 400).
Abbreviations: same as Fig. 2., white arrow mark indicate irregularly developed parenchymatous tissue in the abscission layer.

過程에 있어서 脫粒性程度의 變化와 離層組織과의 관계에 대하여 검토하였다.

아프리카 벼의 幼穗와 穎花는 出穗前 15일 以後 急激한 伸長을 보여 出穗前 5일 경에는 出穗期와 거의 同一한 길이로 伸長되었다. 出穗前 15일 경에는 작은 柔組織細胞로 構成된 離層組織의 形成部位를 認定할 수 있었는데, 部分離層의 外穎쪽에는 離層組織의 形成部位를 認定할 수 없었고, 不規則離層의 外穎쪽에는 部分的으로 集團化되어 있는 小形의 柔組織細胞들을 觀察할 수 있었다. 出穗前 10일경 離層組織 周邊의 細胞들은 細胞壁이 肥厚하고 木化되어 1-2層의 柔組織細胞로된 離層組織을 더욱 뚜렷하게 구분할 수 있었는데, "部分離層"의 外穎쪽에는 厚壁組織속에 1-2개의 柔組織細胞가 混在되어 있었고, "不規則離層"의 外穎쪽에는 不規則하게 集團化된 柔組織細胞를 觀察할 수 있었다.

아프리카 벼에 있어서는 出穗後 2週째 벼알의 登熟이 收穫期와 거의 비슷하게 진전되었는데, 이때 離層組織의 崩壞現象을 觀察할 수 있었으며, 또한 벼알과 小枝梗 사이의 引張強度도 收穫期와 同一하게 低下하였다.

引 用 文 獻

1. Goshima, K., J. Inouye and K. Ito. 1970. On the relationship between the strength of a grain shedding and earliness of flower open in paddy rice plant. Rep. Kyushu Branch Crop Sci. Soc. Japan. 33:33-35. (in Japanese)
2. Hoshikawa, K. 1975. The growing rice plant －an anatomical monograph－. Nobunkyo. Tokyo. 217-244. (in Japanese)
3. Hu, C. H. , K. N. Kao and C. C. Chang. 1964. Histological and genetic studies on shedding and lodging habits of rice plant. Bot. Bull. Acad. Sinica. 5:170-179.
4. Inouye, J., Il-Doo Jin and V. T. Xuan. 1990. Degree of grain shedding and histological peculiarities of abscission region of floating rice and companion weed rices in the Mekong Delta. Japan. J. Trop. Agr. 34:61-67.
5. Inouye, J., V. T. Xuan and M. Miyazato. 1974. On the growth habits of floating, single- and double-transplanting rice plants in South Vietnam. III. Degree of grain shedding. Japan. J. Trop. Agr. 18:12-17.
6. Islam, Q. R. , H. Hakoda and J. Inouye. 1989. Grain shedding of Bangladesh deepwater rice. Japan. J. Trop. Agr. 33:81-87.
7. Ito, K., J. Inouye and K. Tikai. 1968. Studies on the grain shedding in some crop - On the measuring of grain shedding in rice plant. Proc. Crop Sci. Soc. Japan. 38:247-252. (in Japanese)
8. Jin, Il-Doo. 1986. On the formation and development of abscission layer in rice plants, *Oryza sativa* L. Jap. J. Crop Sci. 55:451-457. (in Japanese)
9. ——— and J. Inouye. 1982. Relationship between grain shedding and abscission layer in pedicel of Japonica-Indica hybrid rices in Korea. Jap. J. Crop Sci. 51:43-50. (in Japanese)
10. ———, ——— and Nyat. Quat. Ng. 1990. Histological peculiarities of the abscission layers of African rice. *Oryza glaberrima* Steud. and its relation with degree of grain shedding. Jap. J. Crop Sci. 59:475-480. (in Japanese)
11. Matsushima, S. and T. Manaka. 1956. Developmental process of rice panicle and its diagnosis. Asso. Agr. Techn. Tokyo 1-58. (in Japanase)
12. Yein, C. F. 1978. A biometrical genetics and anatomical exploration on the histological structure of abscission layer in rice

plant. J. Agri. Asso. China. 101:18-26. (in Chinese)
13. Zee, S. Y., B. S. Vergara and T. M. Chu. 1979. Abscission layer in rice plant. IRRN 4:5-6.