Seed Germination Ecology and Cultivation of Barnyardgrass after Italian Ryegrass in Unflooded Paddy Fields

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As a method of utilizing lowland paddy fields for growing crops other than rice in the summer season, an introduction of forage crops to unflooded paddy fields has been studied. The forage crops to be used for that purpose should have the high productivity competitive to rice which generally assures a high income. However, it has been a problem that usual temperate grasses show low yields, because the growth retardation so-called summer depression takes place after their spring flush, particularly in the southern part of Japan. Therefore, the use of tropical grasses suitable for growing in combination with winter crops has been examined.

In stead of using such existing crops, the author found out that barnyardgrass (*Echinochloa crus-galli* Beauv. var. *caudata* Kitagawa) can be used for that purpose, although it is a wild grass never been cultivated. The author observed that barnyardgrass could emerge under the sward of temperate grasses cultivated in winter, when it was mixed-sown with the temperate grasses, and could give a predominant growth by taking the place of the temperate grasses in the summer season.

In the present paper, the germination ecology of barnyardgrass, and the successive cultivation of barnyardgrass after Italian ryegrass that was established by taking advantage of the germination habit of barnyardgrass will be described.

Changes in seed viability and their responses to environmental factors

1) Acquirement of germination capacity (the ability to germinate when physiological and environmental conditions are filled) of the seeds was first observed on 5–8 days after heading. Percentage of the seeds having germination capacity increased following the experimental equation, $y=4.78x-14.53$ (in which y signifies the percentage of seeds having germination capacity and x the number of days after heading). On the other hand, shedding of seeds started on 8 to 9 days after heading, and increased linearly following the equation, $y=3.56x-23.62$ (in which y indicates the percentage of seeds shed and x the number of days after heading). Most of the shed seeds possessed germination capacity.

2) It was confirmed that all the seeds which acquired germination capacity remained in dormancy for a certain period of time.

For awakening from dormancy, the seeds were required to proceed following four phases (Fig. 1):

(1) The phase of deep domancy: No germination occurs under any conditions.

(2) The early phase of awakening: Germination can be observed in petri dishes, but a secondary dormancy-like phenomenon is still seen after some while of the thermal treatment (30–40°C) under wet conditions.

(3) The later phase of awakening: Ger-

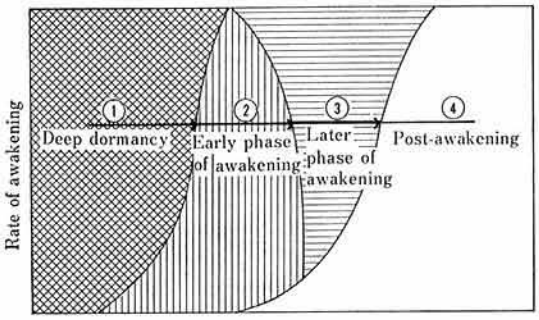

Fig. 1. Schematic model showing the progress of dormancy awakening of barnyardgrass.

mination is induced in petri dishes under diurnal fluctuations of temperature. No dormancy-like phenomenon is induced even though the seeds are treated with high temperature under wet condition.

(4) Post-awakening phase: Germination can be observed in petri dishes under constant temperature conditions.

The process shown above advances irreversibly from the phase 1 to the phase 4 and the seeds in the phase 4 are never brought back into dormancy phases (i.e. phase 1–3). The seeds in the phase 4 are able to germinate soon under suitable conditions, but they lose their "germination ability" (the ability to germinate when environmental factors are filled) if they are kept under unsuitable conditions for a certain period.

The duration of the each process varied depending on environmental conditions.

3) Within 6 to 8 weeks after harvesting, no awakening progressed in dormant seeds which were kept in soil at different temperatures. But, within 10 weeks after this period, most of the seeds were awakened at the temperatures suited for germination (i.e. 20–40°C). The low temperature was not essential to awake dormancy. The low temperature (5°C) could rapidly shift the seeds to the later phase of awakening, but could not completely break the dormancy. It needed for awakening to treat these seeds with high temperature (30°C) again.

Under natural temperature conditions, the viability of seeds buried in the soil changed as follows:

Awakening progressed up to the later phase of dormancy at low temperatures in winter. These seeds completed awakening by February to April in upland fields, and by June to July in submerged fields. Most of awakened seeds which were located in surface soil (0–3 cm in depth) sprouted during the season from late April to September. No emergence was found for the rest of the seeds in the surface soil and the seeds in deeper layers of soil. Most of them became extinct within three years.

4) It was confirmed that the seed coat of dormant seeds possessed the same permiability as awakened seeds did. Although the palea and lemma of seeds had no relation with the dormancy, the pericarp was related to the dormancy. The dormancy was broken by the removal and scarification of pericarps or by the sulphuric acid treatment on pericarps.

The dormancy was also broken by the chemical substances which inhibited the metabolism of oxdation-reduction system. It was suggested that the oxidizing enzyme in seeds was deeply concerned in the mechanism of dormancy.

Germination response of awakened seeds to environmental factors

1) Barnyardgrass germinates in the temperature range from 10 to 42°C (optimum: 30–33°C). At the temperatures lower than 20°C, germination was uneven and took many more days.

2) The percentage of germination was lowered to 30–40% by shading or dark treatments. But it was increased to 80–90% by the illumination for a quite short period such as 1 min. It is concluded that barnyardgrass seeds are light favored. However, the diurnal fluctuation of temperature is able to substitute for the role of the light, so that it is effective in accelerating the germination process even in darkness.

3) The germination could be observed in the gas containing only 2% of oxygen. But,

at the oxygen content lower than 10%, the germination was delayed and suppressed as the content decreased. The plant growth (especially root growth) after sprouting was suppressed also under such conditions.

4) Rapid and good germination with high percentage of germinated seeds was observed when the soil moisture content was about 70% to the maximum water capacity. Germination became uneven and delayed in the soil with 30% moisture content, and no more with 20%. On the other hand, in the soil with the moisture contents higher than 90%, the germination was observed only when the seeds were not covered with soil.

Successive cultivation after Italian ryegrass

1) Both of barnyardgrass and Italian ryegrass (*Lolium multiflorum* Lam.) were sown in the same field at the same time. But the seedling emergence in autumn occurred only with Italian ryegrass. The emergence of barnyardgrass was found under the sward of Italian ryegrass in the next spring. As shown in Fig. 2, the germination was observed during the period from the middle of May (average temperature about 18°C) to the middle of July, and mostly in the middle to late June (average temperature about 22–23°C). The number of emergence of barnyardgrass increased following a S-shape curve.

2) After the emergence under the sward of Italian ryegrass, some young seedlings of barnyardgrass ceased to grow because of the competition for light, water, etc. with Italian ryegrass. Some of the seedlings died because of injuries caused by the harvesting of Italian ryegrass. In spite of such problems, however, most of barnyardgrass seedlings could grow up with the decline of growth of Italian ryegrass and gradually took its place as the

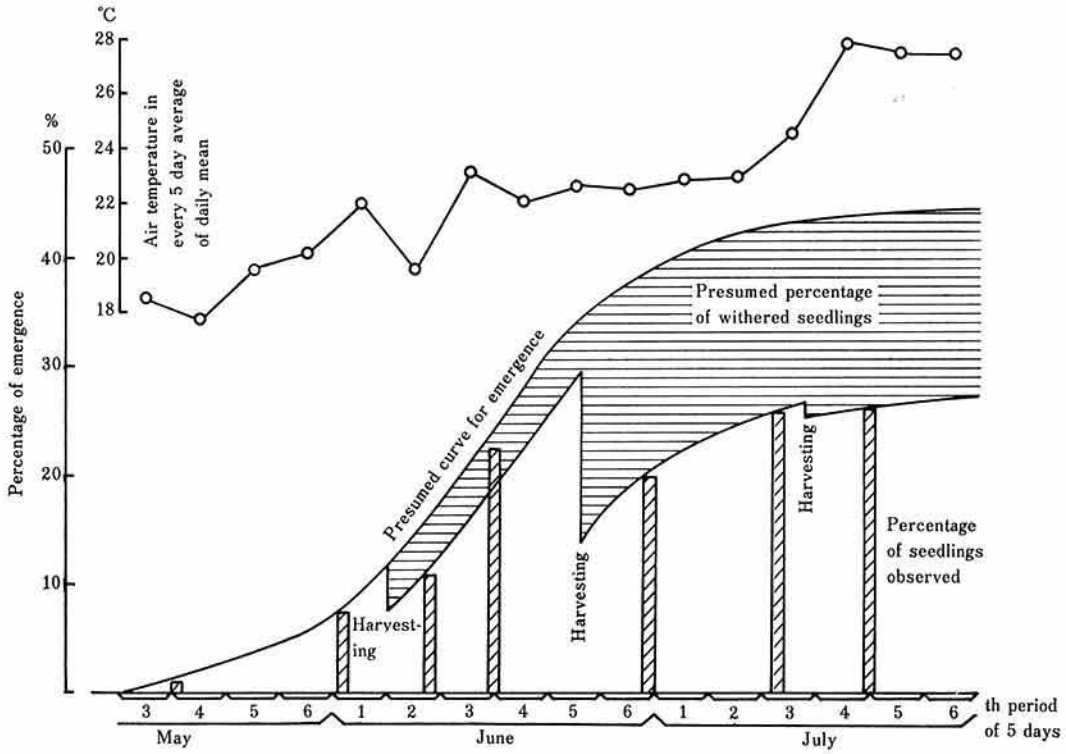

Fig. 2. Changes in emergence of barnyardgrass under Italian ryegrass sward.

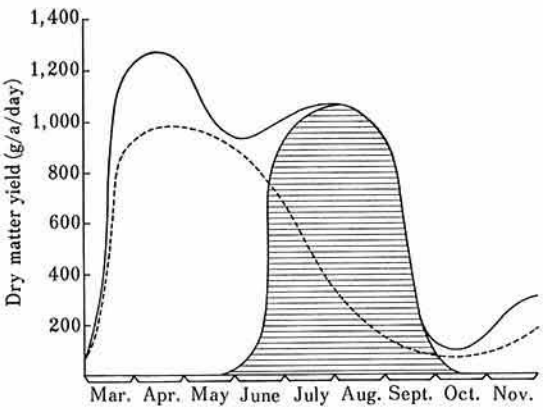

Fig. 3. Seasonal changes in dry matter yield.

——— Sum of Italian ryegrass and barnyardgrass

Barnyardgrass

------ Mixture of temperate grasses (orchardgrass, ladino clover, red clover & Italian ryegrass)

succeeding summer crop. It is useful for the successive cultivation that barnyardgrass possesses the habits to germinate sporadically and to grow vigorously. Thus, the barnyardgrass can grow without total damage and death, and gradually takes the place of Italian ryegrass. Because of the germination habits mentioned above, barnyardgrass cropping does not need to follow the ordinary works, such as ploughing and sowing, for continuous pasture production.

3) The seasonal trend of dry matter production in the cropping system of Italian ryegrass—barnyardgrass is shown in Fig. 3. Although average dry matter production rate per day decreased slightly during the period of succession from Italian ryegrass to barnyardgrass, it was continuously maintained to be high during the period from April to August (Fig. 3).

About 1.6–2.0 t/a of green fodder (or 200–240 kg/a of dry fodder) could be harvested from this cropping system in one year. About 30 to 50% of this yield was accounted for by barnyardgrass. The yields of this successive cultivation were much higher than those of temperate grasses alone and were more stable being not so much affected by cultural methods and climatic differences of years.

4) Sowing is unnecessary for the barnyardgrass cropping in the second year, owing to the seed shedding, but additional sod sowing of Italian ryegress is necessary to repeat this cropping system.

5) When the fields were switched back to flooded paddy fields, the population of barnyardgrass seedlings grown as the weed was varied depending on the methods of rice cultivation. That is, the populations in transplanting culture, late planting culture, or in ploughed and deep tilled fields were less than those in direct sowing culture, early planting culture, or in rotary tilled and shallow tilled fields, respectively. By using commercial herbicides, controlling weeds is not so difficult in the case of transplanting culture of ordinary to late planting rice.

6) Thus, a quite new and unique cropping system, which is labor-saving as well as high yielding, was established by combining barnyardgrass as a summer crop with a temperate grass, Italian ryegrass, as a winter crop by employing the method of mixed-sowing.

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