Root Development and Function of White Clover in Warmer Region of Japan

By MASAHIKO UENO

Faculty of Agriculture, Miyazaki University
(Funazuka, Miyazaki, 880 Japan)

In southern Japan, as in other parts of the world, sown pastures cannot be maintained for a long period. Most pastures tend to degenerate after the second growing season, especially those which consist mainly of legumes such as red clover (*Trifolium pratense* L.) and white clover (*T. repens* L.). This decline usually occurs during the summer season, partly because of high temperature and low soil moisture and partly because of damage by insects and disease. The most marked injury to the plant may be shown in the roots; the taproot systems of many of these plants die.

As is well known, white clover has two different root systems; one is a taproot which is established first and forms a deeply penetrating root system, and the other consists of nodal roots which emerge from all nodes on the stolons, and these usually are less deeply penetrating and more numerous than the taproot and its laterals.

In this paper, the author attempts to make clear the relationships between physiological activities of roots of white clover and its herbage production in relation to summer growth depression.

Factors affecting taproot decay during the summer season

Taproot survivals of three legumes, white clover (var. Oregon ladino), red clover (var. Kenland) and alfalfa (*Medicago sativa* L. var. Williamsburg) were investigated with regard to stand-thinning which occurs so often in warmer region of Japan. These plants were space-planted on the field and half the plants was applied to severe cutting treatment; six times at the height of 5 cm in a year, including summer defoliations, and the other half was applied four times at 15 cm. Total non-structural carbohydrates (TNC) content of the taproot was analysed once a month.

Stand-thinning was markedly observed on red clover; almost all plants disappeared from the field by August irrespective of cutting treatments and this was closely related with the growth of its taproot. Taproot also decayed in white clover. However, its stand-thinning was temporarily and thinned area was soon recovered by the elongation of newly grown stolons after September, though there observed some lateness in recovery on the severe cut stand. Alfalfa stand kept very well throughout the growing season, none of the stand-thinning being observed. This coincided with the vigorous taproot growth of this species. TNC contents in the taproot revealed that there were some grounds for susceptibility to the disease on the side of plants, because the minimum content of TNC was observed just before the occurrence of root decay.

It was observed that one of the main causes of the root decay in clovers might be the contraction of soil bore diseases and that some preceded attacks of insect in the soil favored this disease invasion.

From these, it may be suggested that the stand-thinning or life-shortening of clovers is due to the taproot decay and that this root decay can be caused primarily by soil-living insects, followed by soil disease invading through the wound on the root surface[1].

Some observations were made on insect and disease which were concerned with taproot decay of white clover. Larvae population of clover weevil (*Scepticus gricius*) in the soil was at the highest in the middle of May, coincided with the large occurrence of root-surface gnawing. Dusting insecticide was effective to reduce the population. Root rot fungi, mainly *Rhizoctonia solani* isolated from red clover were inoculated on red clover seedlings. The similar root decay was observed on the inoculated plant as well as by field survey, indicating that this fungus could be one of the causes of root death. When the soil was sterilized by steam, all plants survived completely, none of their taproot decayed and root weight reached nearly twice as much as that of not-sterilized plant[2].

Role of the existence of taproot for the foliage production

Contribution of the taproot for the leaf growth was estimated by growing the plants under three ways; one group of plants was prevented from establishing nodal roots (Taproot only), the taproot of second group was removed after the nodal roots were established (Nodal root only) and third group was allowed to grow normally with both taproot and nodal roots intact (Control).

As shown in Table 1, the intact plants produced greatest leaf weight throughout the experiment period. In earlier stage of growth, the growth of plants grown on taproot only was quite similar to that of control plants, but it decreased toward the end of experiment, suggesting that the physiological activity of taproot might cease by the summer season. In plants without taproot, a large denuded area occurred around the center of the plant base immediately after taproot removing and the plant shaped as a doughnut in appearance, indicating the taproot played a vital role on the growth even after establishing of nodal root system.

This role of the taproot was also observed in a tracing of the seasonal changes of development of root system grown in a big glass-sided root box; the root system without taproot could not distribute evenly in the soil media[3].

In the next trial, absorption by the taproot and by different nodal roots and translocation of ^{32}P were investigated to find to what extent nodal roots can compensate for the absense of a taproot.

^{32}P absorbed by the taproot was distributed evenly within the whole plant. When translocation from the 2nd and 7th nodal roots was examined, similar distribution was obtained only from the nodal root closer to the center of the plant as shown in Fig. 1. The backward movement of ^{32}P absorbed by the nodal roots at the base of the plant increased as the root size increased. Removal of taproot resulted in temporary depression of translocation; its effect disappeared within 3 weeks. From this, the ability of nodal roots to compensate for loss of the taproot depends on their position and size. If the position of the nodal root is far from the plant base, it distributes its absorbed minerals only in one direction—towards the growing point[4].

There are a large number of ecotypes in white clover. Varietal differences in the growth habit of the nodal roots of five varie-

Table 1. Weights of leaves, stolons and roots (Dry weight g/plant)

Date	Control			Taproot only			Nodal roots only		
	leaves	stolons	roots	leaves	stolons	roots	leaves	stolons	roots
July 16	65.0	—	—	68.0	—	—	53.5	—	—
Aug. 8	50.0	—	—	35.0	—	—	55.0	—	—
Sept. 17	78.5	47.5	24.9	26.0	48.5	7.8	69.0	44.5	26.0

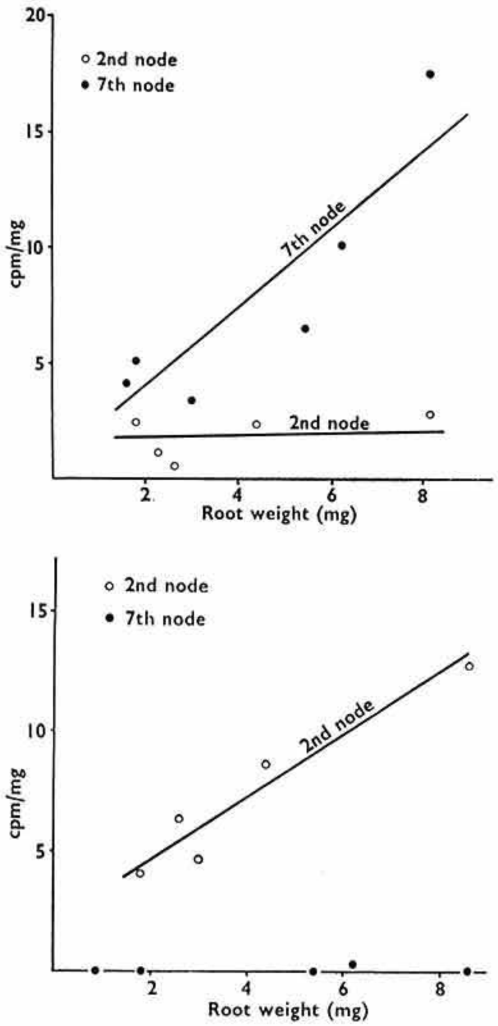

Fig. 1. Relationship between the weight of absorbing root and the distribution of ^{32}P in distal part (above) and proximal part (below)

ties; Oregon ladino, Witte Cultuurklaver C. B., Welsh S-100, Kersey and Wilkla Witte Weideklaver were compared in relation to the denudation of the stand after disappearance of the taproot.

The mean length of the internode positioned around the plant base was shorter in the following order; Wilkla<Kersey<S-100<Oregon and Witte. Mean weight of nodal root was less in Kersey and Wilkla. Denuded area around the plant base after the taproot removal occurred more markedly in varieties Wilkla and Kersey.

It was cleared that when the taproot was lacking, the ability of nodal roots to compensate for the role of it seemed to be higher in the variety which possessed the short internode and the better root growth around the plant base[5].

Growth of nodal roots

In white clover, one nodal root is usually produced at each node of the stolon from one side, which is the nearest to the soil surface, of the axillary bud. Occasionally two roots appear at the same node, on each side of the axillary bud which is to develop into secondary stolon. Stolons of white clover are creeping stems and as in many plants with these stems, the leaves are usually rather horizontal in orientation and confined to the two sides of the stem. This leaf-orientation causes the axillary bud to incline slantwise as shown in Fig. 2, because an axillary bud on the node locates at the base of the leaf which has a

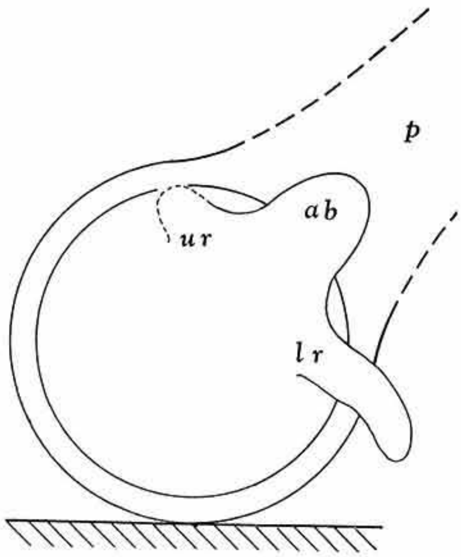

Fig. 2. Diagram of the rooting of the nodal root in white clover
ab: axillary bud, ur: upper rooting-place, lr: lower rooting-place, p: petiole of the leaf

specific angle of orientation to the stem.

By using indolebutyric acid (IBA), the mechanisms of rooting at the node could be interpreted as the results of transverse polar gradient in the root forming hormone. When the node is placed under normal leaf orientation as is shown schematically in Fig. 1, the flow of root forming hormone shows a longitudinal polarity in geotropic movements and this promotes the nodal root to arise from the lower rooting-place. However, the situation alters this pattern, e.g. when the shoot or the leaf orientation is changed by laying the stolons on their back on the soil, or when IBA is applied to the upper rooting-place, another nodal root is produced from the upper rooting-place[6].

Penetration of the nodal roots to the soil is severely disturbed in the summer season. Cutting, soil temperature and soil moisture treatments were applied to the stolons in order to determine which environmental factor related with disturbing penetration of nodal roots.

The most detrimental factor on the root penetration disturbance was dry condition of the soil surface. When the soil surface was kept fairly wet, the rate of the nodes possessing the penetrated nodal root was 90% of the total nodes on the stolon, whereas that of dried soil was 40%. So far as the root system was concerned, it was important for root penetration to keep soil surface wet and make the stolon contact to soil surface as near as possible[7].

Conclusion

In order to prevent the growth depression of white clover during the summer season in warmer region of Japan, it is necessary to develop well established nodal roots, especially around the plant base in the earlier growth stage. For development of the well established nodal roots, it is better to increase the number of nodal roots and establish them to the soil media effectively than to promote root elongation, since the climate in these area is still severe for the root elongation.

References

1) Ueno, M. et al.: Studies on the root of herbage legumes. 1. Taproot survivals of three legumes, ladino-, red-clover and alfalfa. *J. Jap. Grassl. Sci.* 11, 110–114 (1965) [In Japanese with English summary].
2) Ueno, M. & Yoshihara, K.: Studies on the root of herbage legumes. 2. Some observations on root rot of clovers. *J. Jap. Grassl. Sci.*, 12, 198–201 (1967) [In Japanese with English summary].
3) Ueno, M., Yoshihara, K. & Hidaka, M.: Studies on the root of herbage legumes. 3. Estimation of the role of the taproot in ladino clover. *J. Jap. Grassl. Soc.*, 13, 100–104 (1967) [In Japanese with English summary].
4) Ueno, M. & Williams, R. D.: Absorption of radio-active phosphorus from tap- and nodal roots of white clover (*Trifolium repens* L.). *J. Brit. Grassl. Soc.*, 22, 165–169 (1967).
5) Ueno, M. & Yoshihara, K.: Studies on the root of herbage legumes. 4. Varietal difference of nodal root growth in relation to the compensation of taproot in white clover. *J. Jap. Grassl. Sci.*, 13, 195–198 (1967) [In Japanese with English summary].
6) Ueno, M. & Tsuchiya, S.: Rooting habit of adventitious roots in white clover. *J. Jap. Grassl. Sci.*, 14, 116–118 (1968).
7) Ueno, M. & Yoshihara, K.: Studies on the root of herbage legumes. 5. Effect of some environmental factors on the penetration of the adventitious roots of white clover to the soil. *J. Jap. Grassl. Sci.*, 14, 100–103 (1968) [In Japanese with English summary].

(Received for publication, July 7, 1982)