due to eddies having their origin in stronger and more strictly tidal currents at other places.

In this respect the deep waters of British Columbia and Alaska show a marked contrast to such shoal waters as Nantucket Sound, Massachusetts, where the currents are almost entirely strictly tidal. As a physicist I feel sure that the difference is due primarily to the great influence of viscosity in the shoal waters and the lack of it in the deep. In the same capacity, I would guess that there would be still less influence of viscosity in such larger and deeper waters as Shepard, Revelle and Dietz have been studying. Therefore we may expect their conclusions to apply very generally in deep waters with rugged bottoms.

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PROBLEMS OF WOUND HEALING IN RED CLOVER STEMS

FORAGE legumes, like other herbaceous plants having no protective covering other than an epidermis, are subjected to injury by grazing animals and insects. In particular, the mowing of fields is a severe test both because of the wounds and also through the loss of the plant body including most of the buds. In spite of such injuries these plants are usually able to continue growth though frequently with some modification of form and size.

The stems of three important herbaceous legumes—*Trifolium repens* L., white clover, *Medicago sativa* L., alfalfa, and *Trifolium pratense* L., red clover—were studied with respect to the time and the nature of their wound responses. While primary interest centered in the healing processes, attention was given to various conditions, interrelated with lesion, which may cause the death of these legumes.

In connection with the healing of wounded herbaceous stems considerable credit must be given to the preliminary barrier or pseudocicatrice,[1] formed by death and collapse of tissue following injury. This, in itself, is protective in considerable degree and by checking the dying back of tissues permits certain underlying cells to develop a permanent barrier of wound cork, the cicatrice, which effectively heals the wound. Ultimately, in the three legumes studied, a region of solid living pith at some point in the injured stem permits the protective structures to be formed.

The pith in white clover generally remains alive and completely fills the central zone. Following a transverse cut a continuous pseudocicatrice quickly covers the injured surface. Suberin is demonstrable in the walls of the outermost living cells underneath the pseudocicatrice within thirty-six to forty-eight hours after lesion. By the sixth day suberization has extended from two to four cells further into the underlying tissues. About this time mitoses begin in subjacent cells, and this phellogen forms two to five additional layers of cork, which completes the cicatrice. Its development requires about fifteen days, and in final form it extends entirely across the stem, interrupted only by the vascular tissue.

However, in certain stems of white clover the central region of the pith dies and spaces develop. Following a cut across one of these hollow stems the pseudocicatrice can not be completed across the pith region, and water loss by way of this cavity causes the stem to die back to the nearest node. There a block of living parenchyma furnishes a foundation upon which a continuous pseudocicatrice is built. Four to five days may be required for the stem tissues to die back to this node, and both initiation and completion of the barriers are correspondingly delayed. Ultimately a cicatrice is always developed in the firm tissue of the node, similar to that which is built at the plane of injury in stems having solid living pith.

The pith of alfalfa stems is dead and broken throughout all internodes, but at the nodes there is usually a continuous living tissue. Consequently its healing processes correspond closely with those of white clover stems having dead pith. Dying back to the node takes five to ten days, but in the nodal zone the cicatrice is quickly formed. In general, mature alfalfa stems are safely healed within twenty-one days.

In red clover the pith is larger and makes up over half of the stem's diameter, relatively more than in white clover or alfalfa. Because this pith normally dies within two cm of the meristem, growth of the internodes breaks down the central tissue, leaving hollow stems. The nearest lower zone of solid living cells is at the junction with the crown, unless there is a growing lateral branch with sufficient living pith at the junction to permit the formation of protective barriers. The defective pith causes the whole axis to die downward to where a platform of living cells makes possible the establishment of the pseudocicatrice, which is quickly followed by the cicatrice of wound cork.

Due to this prolonged dying back of all wounded red clover stems there is necessarily a considerable delay in healing processes. When cut as low as four inches from the base there is a lapse of two to three weeks, even in midsummer, between the time of injury and the earliest evidence of healing. This means an interval of at least a month between the date of injury and completion of the cicatrice. This dying back of stems slows down later in the growing season and during the autumn months the development of healing tissues is greatly retarded or entirely inhibited. Rarely does a cicatrice reach completion before winter if a stem is cut across after early September. Successful healing takes place in the autumn only when

[1] Robert B. Wylie, *Bot. Gaz.*, 90: 260–278, 1930.

the lesion is very close to the crown in a region of living pith. Under no other circumstances has suberin been found in stems wounded as late as October.

While no growth responses are possible during the colder months the dying back of wounded stems continues even through the winter. During late autumn and early spring the unprotected junctions of these dead stems with the living crown are attacked by organisms which undoubtedly enter through the open hollow stubs. This infection leads to breakdown of tissue which extends into the crown and when spring growth is resumed the plants can not wall off these diseased parts. Consequently, as early as July the central region of the crown and the upper part of the tap root have largely decayed, leaving usually only a thin shell of living tissue. Such plants may look normal during the spring, but they are definitely less able to withstand the later periods of summer drought and nearly all of them die before autumn. In a general way these difficulties are commonly related to the hardships of the previous winter, but they go back instead to autumn injuries. The considerable time that elapses in red clover between the lesions of autumn and their effects the following summer has concealed the disastrous results of late wounding.

The nature of the pith on these legumes is a determining factor both with respect to the location of wound barriers and the promptness with which they are formed. In stems having solid living pith the cicatrice is developed quickly near the wound surface under the pseudocicatrice. But if there are dead or broken portions of pith the location of the barriers is necessarily shifted and stems die back to a plane of solid living pith. This long lag between injury and cicatrization is the critical period for red clover.

Since the summer of 1934 hundreds of clover fields throughout Iowa and neighboring states have been studied not only with respect to the immediate results of wounding, but also as to ultimate effects of cutting and pasturing. It is a common practice of long standing to clip or pasture red clover during the first fall after spring seeding. Careful check on large numbers of fields shows that there is a striking correlation between fall treatment and the percentage of infected plants at intervals during the following summer. These fields were selected at random from those having fair stands of clover and for which the cultural history could be obtained. A summary of these records shows, (1), that if the fields were heavily clipped during the late autumn the proportion of diseased plants during the following summer ranged from 50 to 95 per cent., and (2), that fields if left uninjured after the first of September had only 1 to 10 per cent. of infected plants by midsummer of the following year.

Apart from the effects of lesion, clover plants frequently die as a result of "winter-killing." This is especially true if crowns are exposed either by mowing or heavy pasturage late in the season. The death of such plants is undoubtedly caused by winter hazards other than those related to wounds. Nevertheless, it can not be stressed too strongly that late cutting or pasturing not only promotes this winter-killing, due to increased exposure as a result of removing plant cover, but, even if fields survive the winter, most of the plants inevitably suffer from crown infection the following growing season as a result of their inability to heal the wounds of the previous autumn.

It is not uncommon in eastern Iowa for entire fields of red clover to live through three growing seasons, and several cases are on record of four-year-old fields. But, in all the instances investigated where fields lived more than the second summer, the plants were neither cut nor pastured after the first of September and so went into the winter with considerable ground cover and with all wounds safely healed at or above the crown level.

It seems clear from study that in this region late-season treatment, apart from certain winter hazards, largely determines the fate of red clover in a given field.

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ROOTING NORWAY SPRUCE CUTTINGS WITHOUT CHEMICAL TREATMENT

At the New Haven meetings of the New England Section of American Plant Physiologists, held on May 12 and 13, a method was described by which cuttings of 39-year-old Norway spruce trees were successfully rooted in large numbers during the past winter. Vegetative propagation of this economic forest and ornamental species permits establishing clones with desirable growth characteristics. One of our immediate objects will be the propagation of Norway spruce trees that have a natural immunity to the spruce gall aphid.

The results of the rooting tests were based on 3,200 cuttings collected at monthly intervals from October to January, inclusive. The factors tested included (1) month of collection; (2) length of cuttings, short (5 to 10 cm) and long (10 to 20 cm); (3) cuttings with and others without a heel of two-year-old wood; (4) no preliminary treatment, standing in water 24 hours or in indole butyric acid solutions with 2.5, 5, 10, 20, 40, 60, 80 and 100 mgms of the chemical per liter. The cuttings were planted in builders' sand in an open greenhouse bench with day temperatures around 70° F. and night temperatures never lower than 55° F. Analysis of the data is based upon the examination of the bases of the cuttings 14 weeks after planting.

Detailed analysis of the influence of the several factors investigated must await subsequent publication.