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A COMPARISON OF LEAF NUMBER, INTERNODE AND MESOCOTYL LENGTHS IN DWARF-1 AND NORMAL ZEA MAYS L.

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The three studies presented here possess the common feature that they deal with the degree of expression of the gene dwarf-1 in mature organs of maize. The effects of a simple environmental variable on gene expression as illustrated by leaf number and mesocotyl length is investigated.

The first study is a comparison of total leaf number in plants homozygous recessive for the gene dwarf-1 and their phenotypically normal sibs under field and greenhouse conditions and the possible effect of planting depth on the total number of leaves produced. The second is concerned with the relative lengths of internodes as related to both genetical constitution and to position in the plant. The third is a study of the effects of planting depth on gene expression in mesocotyl length.

MATERIALS AND METHODS

Field Grown Plants—The seed used was taken from a culture segregating for dwarf-1 (d_1) against a genetic background of Minnesota Agric. Exp. Sta. Inbred A21. The stock carrying d_1 had been backcrossed to A21 for five generations. These experimental plants were grown during the summer of 1953 in the experimental plots of the Institute of Agriculture of the University of Minnesota, St. Paul, Minn. At maturity five phenotypically dwarf plants and five phenotypically normal sibs were collected. Leaf counts were made by removing the leaves present and counting all nodes from the base of the plant to the tassel. The location of the major ear node was also recorded. Lengths of internodes were measured to the nearest mm. except in the case of the lowermost internodes whose adventitious roots interfered with accuracy of measurement. The numbering system used in locating leaves and internodes as a matter of convenience assigns the lowest number to the leaf immediately subtending the tassel. Thus, internode number 1 and leaf number 1 are the ones subjacent to the tassel. This method of numbering is inversely related to the order of leaf initiation and is that used by L. B. Abbe (1936).

Greenhouse grown plants—Plantings of 50 seeds each from a culture essentially identical with the one mentioned above (and therefore comparable with it) were planted at 0, 1, 4 and 7 cm. depths in the Department of Botany greenhouse at the University of Minnesota in

Sept. 1953. The seeds planted on the soil surface were covered with cheesecloth for two days to prevent drying. Fourteen hour artificial light was provided as a supplement to daylight. Ten dwarf-1 plants and ten phenotypically normal sibs were collected from each of the four plantings after the tassel had differentiated in order to assure that all leaves could be easily counted. A single exception to the preceding was in the dwarf-1 planting at the 7 cm. depth; here but one plant survived to tasseling time. The leaves were removed from the plants and their number recorded. Mesocotyl lengths in these same plants were measured to the nearest mm.

OBSERVATIONS AND DISCUSSION

I. *Leaf Number at Maturity Under Field and Greenhouse Conditions.* Earlier studies on the mature morphology of mutant dwarf-1 plants and of their normal sibs by L. B. Abbe (1936) indicated that while there is a striking reduction in the length of internodes in the mutant, the number of leaves which is possessed was essentially the same as that of the normals. It seemed desirable to check these results on one of the quite different strains used in morphogentic research by this laboratory.

TABLE I

AVERAGE LEAF NUMBER AT MATURITY UNDER FIELD AND GREENHOUSE CONDITIONS

		Greenhouse—Planting Depth in cm.				
Phenotype	Field	0	1	4	4	G. H. Ave.
Normal (D_1)	15.0	13.0	13.2	13.2	13.2	13.1
Dwarf-1 (d_1)	17.9	16.0	15.9	15.2	16.0	15.9
Percent d/D	119	123	121	115	121	121

Table I ("Field") permits a comparison of leaf numbers in dwarf-1 with that of their normal sibs. The dwarf-1 plants produced an average of nearly three more leaves than did their normal sibs. That is, the plants homozygous recessive for d_1 exceed their phenotypically normal sibs by nearly 20% when grown under field conditions.

Because depth of planting so profoundly influences the growth of the young corn plant, it was decided to determine its influence, if any, on total leaf number. As mentioned in the section on materials and methods, seeds segregating for dwarf-1 were accordingly planted at depths of 0, 1, 4 and 7 cm. The number of leaves in the dwarf-1 plants at the various planting depths was essentially the same (Table 1), averaging 15.9. The same was true of the normal sibs although these

averaged 13.1 leaves. Thus, the dwarf-1 plants, as in the field grown plants produced on the average almost three more leaves than did the normal plants. This difference in number of leaves between dwarfs and normals was found at all planting depths and the percentage of difference between them was essentially the same at all four depths, averaging 21 percent. But, under greenhouse conditions the total number of leaves in both dwarf-1 and normal plants averaged two less than in field grown plants. Under both field and greenhouse conditions, however, the dwarf-1 plants produced about 20 percent more leaves than did their normal sibs which indicates that the degree of expression of the gene dwarf-1 is relatively unaltered by these different growth conditions. Certainly, depth of planting, within the range studied, has no demonstrable effect on total number of leaves produced. On the other hand, greenhouse conditions had a consistently inhibitory effect in this respect.

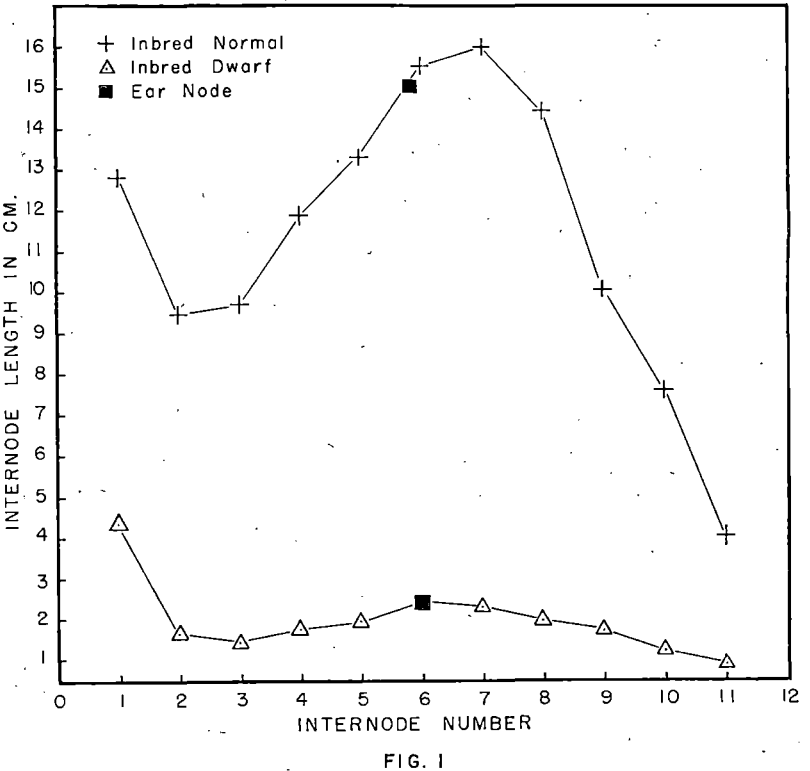

FIG. 1

II. *The Pattern of Internode Length at Maturity.* The field grown plants were also utilized for a study of the relative lengths of homologous internodes in dwarf-1 and normal plants. Because each internode is

a semi-autonomous growth unit each one can be considered to be a separate theater of gene expression. By comparing successive homologous internodes in dwarf-1 and normal plants there may be obtained a measure of the influence of location of an organ on the degree of gene expression within the plant.

In both dwarf-1 and normal plants the pattern was very much the same (Fig. 1 and Table II). The first internode is quite long, those below it are shorter but increase gradually in length to a maximum in the vicinity of the ear node and then decrease in length toward the base of the plant. The ear node is, in both cases, about six internodes below the tassel.

TABLE II

INTERNODE LENGTH IN CM. AT MATURITY

	Internode Number										
Phenotype	1	2	3	4	5	6	7	8	9	10	11
Normal (D_1)	12.8	9.5	9.7	11.8	13.4	15.6	16.1	14.2	10.0	7.6	4.0
Dwarf-1 (d_1)	4.3	1.7	1.5	1.7	2.0	2.5	2.3	2.0	1.7	1.2	0.9
Percent d/D	34	19	15	14	15	16	14	14	17	16	22

The striking similarity between these two patterns indicates that there may be some factor which controls the pattern of internode length which is triggered at either the tassel or the ear node. No definite conclusions in this respect can be drawn from a study of mature material as is the case in the present investigation. However, it may be pertinent to point out that the ear node is formed earlier in ontogeny than the tassel.

The degree of gene expression was found to vary in successive internodes (Table II). The internodes of the dwarf are most like those of the normal plants near the tassel. The difference increases progressively with each lower stem unit until the vicinity of the ear node is reached. There the internodes of the dwarf-1 plants are least like those of their normal sibs.

Continuing downward from this region the differences between dwarf-1 and normal decrease toward the base of the plant. It appears, therefore, that the location of an internode on the plant does influence the degree of expression of the gene dwarf-1.

III. *Mesocotyl Length at Maturity in Relation to Planting Depth.* The greenhouse grown material readily lent itself to a concurrent study of gene expression in length of corn mesocotyls as related to planting depth. This study presents the effect of an environmental variable on gene expression.

The mesocotyls of both dwarf-1 and normal plants elongated with increasing planting depth (Table III). At all planting depths the mesocotyls of the normal plants were longer than those of the dwarf-1 plants. It appears that the genetic limit of mesocotyl elongation was reached when they had reached a length of about two cm. The genetic limit of elongation in the normal plants may not have been reached in the present experiment. However, it can be noted that, at the 7 cm. planting these stem units on the normal plants did not quite elongate to 7 cm. while at the other plantings mesocotyl length was slightly greater than planting depth. The elongation seemed to be leveling off at this point and probably indicates that the genetic limit was being approached, if not achieved.

The ratio of mesocotyl length of the normal plants to that of the dwarf-1 plants at the 7 cm. planting depth was found to be 3.3 to 1. This ratio is essentially the same as that determined by Hansen (1950) although her plants were of a different genetic background. They were grown in darkness to permit maximum mesocotyl elongation. The actual total length of these in her material was about ½ as great as those measured in the present study.

TABLE III

MESOCOTYL LENGTH IN M.M. IN RELATION TO PLANTING DEPTH

	Planting Depth in cm.			
Phenotype	0	1	4	7
Normal (D_1)	8.8	26.5	43.1	65.8
Dwarf-1 (d_1d_1)	5.4	10.8	18.5	20.0
Percent (d/D)	61	41	43	30

The percentage of difference between lengths of mesocotyls in dwarf-1 and normal plants varied greatly with increased planting depth. The dwarf-1 plants were most like the normals at the surface planting. The difference became more pronounced the greater the planting depth. Therefore, it seemed that gene expression as illustrated by the amount of mesocotyl elongation was influenced by depth of planting.

SUMMARY

The dwarf-1 plants produced an average of three more leaves than did their normal sibs under field and greenhouse conditions. Although the field grown plants, both dwarf-1 and normal, produced an average of two more leaves than those grown in the greenhouse, the degree of gene expression remained essentially the same (about 20%). Variations in the depth of planting seemed to have no effect on the total number of leaves produced and therefore on the degree of gene expression.

The overall pattern of internode lengths in both dwarf-1 and normal plants was found to be strikingly similar. The degree of expression of the gene dwarf-1 was greatest near the ear node and least at the tassel end of the plant. Apparently, the expression of the gene dwarf-1 is influenced by the location of an organ on the plant.

The mesocotyls of the dwarf-1 and normal plants elongated with increasing planting depth within certain genetic limitations. The degree of expression of the dwarf-1 gene was least at the surface planting and greatest at the deepest. Therefore, it appeared that planting depth has an effect on gene action in respect to mesocotyl length.

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AN ANALYSIS OF GROWTH RATES IN SUBSTAGE A OF PLASTOCHRON NINE IN ZEA MAYS L.

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INTRODUCTION

The present study was made in an effort to determine whether heterogeneity of growth rates exists within a genetically homogeneous population during a single plastochron. Earlier studies (Abbe, Phinney, and Baer, 1951; Abbe and Stein, 1954; Stein, 1952) described growth in a sequence of plastochrons, the assumption being made that arithmetic growth occurs within each. Furthermore, these studies emphasized the average behavior of the population and thus tended to mask any variation in the rate of leaf initiation. The relatively long sampling intervals used also tended to minimize any variations of growth rate in the population sampled.

The general method of measuring rate of leaf initiation is by periodically sampling a growing population and determining the mean number of leaves initiated at the time each sample is harvested, or the average time of occurrence of plants with a given number of leaves (Stein and Weber, 1954). From such data the mean length of time between the initiation of successive leaves (termed a plastochron, Askenasy, 1880) can be calculated. By sampling a population at very short intervals, however, as was done in this experiment, it becomes possible to determine whether any variations in the rate of leaf initiation exist within a plast-