THE FORMATION OF NODULES BY DIFFERENT VARIETIES OF SOYBEANS¹

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Variation in nodule formation among different varieties of soybeans has been reported from different parts of Wisconsin. In many cases a certain variety has failed to show inoculation when treated with a culture of known origin, while among different varieties growing side by side one has been inoculated and the other has remained free or practically free from nodules. Similar observations have been made in other parts of the United States.

Vorhees (2) of New Jersey found that in a mixture of Brown and Haberlandt grown on medium heavy clay loam soil the two varieties did not show the same nodule formation. Although their root systems were closely associated in the soil, only the Brown variety produced nodules. Morse (2), in discussing Voorhees' paper, reports that at the West Tennessee Experiment Station the Acme and Tokio varieties of soybeans failed to form nodules, while the Mammoth variety under the same conditions formed many nodules. Similar results were obtained the next year.

Leonard (1), on the other hand, as a result of laboratory and green-house tests concluded that a culture of bacteria isolated from a single strain of soybeans will form nodules on other varieties. In his experiments the organism was isolated from the Medium Yellow variety of soybean. Nineteen different varieties of soybeans were studied, including Amherst, Arlington, Barchet, Chernic, Chestnut, Cloud, Guelph, Haberlandt, Hope, Ito San, Jet Manhattan, Medium Yellow, Pekin, Taha, Virginia and Wilson.

It seems from these reports that the ability to form nodules varies among the different kinds of soybeans. Apparently certain varieties are more easily inoculated than others. It is also true that the time of ripening of one variety may influence the infection and subsequent formation of nodules. For instance, an early and late variety may show differences in inoculation as a result of variation in plant food at different times of the year. Repeated investigations have proved that the formation of nodules is influenced to a considerable degree by the reaction and salt concentration of the soil water as well as by other factors.

Because of the importance of soybeans in Wisconsin, it seemed of interest to measure under field and laboratory conditions the effect of different strains of soybean bacteria on the assimilation of nitrogen by different varieties of

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soybean plants and to contrast pure-culture inoculation with soil inoculation. The results of these studies are presented in this paper.

Pure cultures of the different strains of bacteria were obtained from known varieties of soybeans, and their ability to cause inoculation was determined previous to these experiments. The soil used for inoculation was from a field on the Experiment Station Farm where well inoculated soybeans had been grown for several years. Although the records are not available, it is highly probable that the varieties grown on this soil were Wisconsin Black and Ito San soybeans.

GREENHOUSE TESTS

Glazed earthenware pots were filled with pure white silica sand to which had been added an excess of CaCO_3 . These were sterilized and then planted in duplicate for each culture to Manchu, Mammoth Yellow, Wisconsin Black,

TABLE 1

Effect of different strains of soybean bacteria on the nitrogen content of different varieties of soybeans, greenhouse test

SOURCE OF BACTERIA	NITROGEN CONTENT OF TOPS, ROOTS AND NODULES			
	Manchu	Mammoth Yellow	Wisconsin Black	Medium Early Green
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Not inoculated.....	1.85	1.64	1.35	1.42
Mammoth yellow.....	2.85	3.13	2.95	
Medium yellow.....	3.02	2.95	2.74	
Manchu.....	3.02	3.02	2.68	
Haberlandt.....	3.01	2.85	2.76	2.93
Soil from soybean field.....	2.37	2.79	2.45	2.87

and Medium Early Green soybeans, which had been treated immediately preceding planting with either the desired pure culture or with soil. For example, Manchu soybeans were inoculated with bacteria from Mammoth Yellow, Medium Yellow, Haberlandt, and Manchu varieties of soybean. Nitrogen-free plant food was added at intervals in quantities sufficient for plant growth.

Within three weeks after planting, a well defined contrast was noticeable in size and color of the inoculated and uninoculated plants. The uninoculated plants were smaller and at the end of five to six weeks decidedly yellow. At this stage the plants were washed from the sand and their appearance as to size, color, and inoculation was carefully noted.

The combined tissue of the two parallel pots was used for analysis. Table 1 gives the percentage of nitrogen in the dry soybean plants, tops, roots, and nodules. Under the conditions of this experiment all indications are that pure cultures of bacteria from the nodules of Mammoth Yellow, Manchu, Haberlandt, or Medium Yellow soybeans may be used interchangeably on

the different varieties of the soybeans and are almost equally effective in assimilating nitrogen.

The same conclusions are to be drawn from the use of well inoculated soil as a source for soybean bacteria. The general appearance of the soil inoculated plants as to size and color of plants and number of nodules was equally as good as that of the plants inoculated with pure cultures, and on analysis the tissue showed a comparable percentage of nitrogen fixed.

FIELD TESTS

A plot of sandy soil on the farm of Mr. J. R. Williams at Montello was selected for this study. This soil had never grown soybeans. It had been cropped in corn and grain for the last 6 or 8 years and was in rather poor

TABLE 2

Effect of different strains of soybean bacteria on the dry weight and percentage of nitrogen of different varieties in soybean field test

SOURCE OF BACTERIA	WEIGHT AND NITROGEN CONTENT OF DRY STALKS AND PODS							
	Manchu		Wisconsin Black		Ito San		Black Eye-brow	
	<i>lbs.</i>	<i>per cent</i>	<i>lbs.</i>	<i>per cent</i>	<i>lbs.</i>	<i>per cent</i>	<i>lbs.</i>	<i>per cent</i>
Not inoculated.	306.5	5.45	613.0	6.04	540.2		824.7	5.44
Manchu.	573.3	5.36	949.0	6.10	637.2	6.0	1217.2	6.23
Mammoth Yellow.	641.7	5.45	826.9	6.45	692.4		1226.0	6.45
Haberlandt.	793.8	5.40	959.2	6.48	597.6	5.96	1226.0	6.61

state of fertility. No fertilizer or manure was added. The reaction was medium acid. On May 25 the plots were laid out; each plot consisted of two 30-inch rows twelve rods long, planted to soybeans with a small hand drill. All check plots were planted first; Ito San, Manchu, Mammoth Yellow, Wisconsin Black, Black Eyebrow, and Hollybrook varieties of soybeans were used. Then quantities of each variety of seed sufficient to plant a single plot were inoculated with the Manchu strain of soybean bacteria. When these had been planted the hopper of the planter was washed with water and the operation repeated for the seed which was inoculated with the Mammoth Yellow and the Haberlandt strain of bacteria respectively. On September 27, one-thousandth of an acre was harvested from each plot, bagged, and expressed to Madison. There were practically no nodules on any plants in the check plots, while all plants in the treated plots showed numerous nodules. The plants in the treated plots were in all cases larger and greener than those of the checks.

The oven-dry weights of the pods and stalks together with the percentage of nitrogen are recorded in table 2. The Mammoth Yellow and Haberlandt varieties were too late in ripening to be of any value and were not analyzed.

The general appearances were about the same for all varieties of soybeans

regardless of the source of the culture of bacteria used to inoculate. Apparently one strain of bacteria was as efficient as another. The uninoculated soybeans produced a much smaller amount of dry seed and also a lower percentage of nitrogen.

From the results of these laboratory and field studies, there is no evidence to conclude that the nodule bacteria of soybeans are highly specific, but on the contrary it was found that the bacteria of one variety will readily infect another. Variation in nodule formation as seen under field conditions must be due to some factor other than difference in bacteria.

REFERENCES

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- (2) VOORHEES, J. H. 1915. Variations in soybean inoculation. *In* Jour. Amer. Soc. Agron., v. 7, p. 139-140.