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Growth and Development in Soybeans in Relation to Soil Nitrogen Source Croissances

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Growth and Development in Soybeans in Relation to Soil Nitrogen Source

Croissances et Développement du Soja par Rapport avec la Fertilisation Azotée

Wachstum und Entwicklung von Sojabohnen in Abhängigkeit von der Stickstoffquelle im Boden

William F. Brinton Jr.

Abstract

Various parameters of above- and below-ground plant development were used to study the response of soybeans to four soil N-treatments (control, raw manure, compost, and NPK) in root-box and greenhouse pot experiments. Development curves are presented that integrate observed parameters, all of which are assumed to have equal weight. Compost was found to be excellent with respect to early plant development, nodulation, yield, and overall growth index. In the root-box experiment raw manure (with slurry) inhibited early root development but not nodulation, and NPK inhibited nodule formation and probably N-fixation. In the greenhouse pot experiment raw manure (without slurry) performed better, but NPK caused earliest senescence. Observations of morphogenesis were found to be sensitive to differences between treatments and more revealing than the measurement of just yield.

Résumé

Différents paramètres ayant trait soit au développement végétatif, soit au développement racinaire ont permis de montrer une réponse différente du soja à quatre différentes fertilisations azotées (témoin, fumier frais, fumier composté et NPK), tant en vases d'exposition racinaire qu'en pots (sous serre). Les courbes de développement faisant intervenir les différents paramètres sont commentées. Le compost s'est très bien comporté en ce qui concerne le développement juvénile, la nodulation, le rendement et d'une manière générale, l'indice de croissance. Dans les vases d'exposition racinaire, le fumier frais (avec du lisier) a inhibé le développement racinaire mais pas la nodulation. Par contre, le traitement NPK a réduit la formation de nodules et certainement la fixation azotée. Dans l'expérimentation avec les pots, c'est le fumier frais (sans lisier) qui s'est le mieux comporté, le traitement NPK favorisant la sénescence de plantes. Des observations de morphogénèse ont permis de mettre en évidence des différences de comportement d'une manière plus complète que la simple mesure du rendement.

Zusammenfassung

Verschiedene Parameter hinsichtlich der Pflanzenentwicklung über dem Boden und im Boden wurden verwendet, um die Entwicklung von Sojabohnen bei vier verschiedenen N-Applikationen (Kontrolle, unbehandelter Mist, Kompost und NPK) in Wurzelkästen und Gefässversuchen im Gewächshaus zu studieren. Entwicklungskurven werden vorgestellt, welche sämtliche beobachteten Parameter integrieren, von denen angenommen wird, dass sie gleichgewichtig zu betrachten sind. Kompost zeigte eine hervorragende Wirkung hinsichtlich der Pflanzenfrühentwicklung, Knöllchenansatz, Ertrag und auch beim gesamten Wachstumsindex. In den Experimenten mit Wurzelgefässen verhinderte unbehandelter Mist (mit Jauche) die Frühentwicklung der Wurzeln, aber nicht die Knöllchenbildung; NPK verhinderte dagegen die Knöllchenbildung und wahrscheinlich auch die N-Fixierung. In den Gefässversuchen im Gewächshaus schnitt unbe-

handelter Mist (ohne Jauche) wesentlich besser ab. NPK-Düngung führte zu einer Frühreife der Pflanzen. Die Beobachtungen der morphologischen Entwicklung war äusserst empfindlich hinsichtlich der Unterschiede zwischen den Behandlungen und zeigte sich als wesentlich befriedigender im Vergleich zur reinen Ertragsmessung.

Introduction

This paper comprises a preliminary descriptive study of plant development using the response of soybeans to three different sources of soil N to generate data for analysis.

My position is that the gross visual attributes of a plant should be seen as an integration of all of the many environmental influences, which are immediate and distant, both in time and space; and that significant differences in environmental response are understood more clearly by studying morphogenesis than such criteria as yield or the composition of those nutrients that are commonly determined (Bockemühl 1975).

When observing plant response to various soil amendments, the measurement of an abstracted attribute, such as yield, can conceal other changes that may be important in aiding our understanding of the processes involved.

Experimental Design

In Experiment #1 uninoculated seeds of the field soybean (*Glycine max* var Woodworth) were grown outdoors in glass sided growing boxes (40 x 75 x 10 cm) with removable side covers to exclude all light. By tilting the boxes at a 25° angle from the vertical, the pattern of root growth can be seen against the lower sheet of glass. In Experiment #2 soybean plants were grown in greenhouse pots (3000 cm^3) under controlled moisture and temperature conditions. Two replicates in Experiment #1 and three in Experiment #2 of each of the following four treatments were employed for these observations.

1. Control (Penn Silt Loam, pH 6.0, 60% base saturation).

2. Raw cow manure (including some slurry in Experiment #1), together with the same soil as above. 70,000 kg(wet wt.)/ha.

3. Composted cow manure plus soil. 70,000 kg(wet wt.)/ha.

4. NPK (5.10.10) plus soil. 1100 kg/ha.

Soil density in the root-boxes was adjusted to 1.6 g/cm^3.

The amendments were incorporated into the soil several days prior to planting the seeds so that the N would be available during the 15 to 30 day pre-fixation stage. The amount of each amendment was adjusted to be equivalent to 55 kg soluble N(as NH_3 plus NO_3)/ha. This means that relatively large amounts of organic N (about 1000 kg/ha for organic treatments) were present.

In both experiments the following parameters of growth were measured at suitable intervals (14-20 days) over a 120 day period. Observations of young plants necessarily involved fewer parameters:

1. height of plant
7. yield (pods and beans)

2. breadth of plant
3. total leaf area
4. mean petiole length
5. number of stem branchings
6. total number of seed pods
8. % of leaves attacked by insects
9. cumulative root length
10. amount of nodules and % of active nodules (the level of red leghaemoglobin being taken as a measure of active bacteroids)

In addition, in Experiment #1, root tracings were made every two weeks to record the pattern of root development. In both experiments, treatments were compared with controls by calculating relative morphological indices using the following weighted average formula: $2 - (\bar{x} \div x)\ 100$, where $\bar{x}$ = control mean for any particular character and x = the mean value for the same character in one of the treatments. In this procedure, slightly more weight is assigned to treatments that are inferior to the control than to those that are superior. The indices were tabulated cumulatively in order to graph the "development" curves that are shown in Figures 1 and 2.

Results and Discussion

The response of soybeans to soil amendments containing N is complicated by the fact that during the 15 to 30 day pre-fixation period, all N must be obtained from the seeds and the soil, however, the presence of too much N will inhibit nodulation and subsequent N-fixation (Weber 1966). Also, although soybeans may acquire up to 75% of their N from soil (Skinner 1976), this amount can be reduced (and fertilizer expense saved) if nodulation can be encouraged, and if N is supplied gradually from the soil amendment in small amounts (I.I.T.A. 1975), or not at all. While some authors have recorded an increase in soybean yields following careful applications of nitrogen (AVRDC 1975), most sources recommend against adding fertilizer N (Berg 1967).

For the above reasons I suspected that compost, with its expected rich supply of different species and strains of *Rhizobium*, and slow rate of N-release (Schudel *et al.* 1979), would prove to act differently as a soil nitrogen amendment than either raw manure or NPK fertilizer. This, in fact, was found to be the case, as indicated by the graphs of cumulative growth indices shown in Figures 1 and 2. It must be emphasized that these development curves represent integrations of all of the measured parameters, which are all assumed to have equal weight. These are, therefore, not the usual growth curves, which are based on dry matter gain; rather they represent changes in the visual image of the plant. It is felt that focusing on criteria such as "yield" direct the attention away from the totality of plant expression.

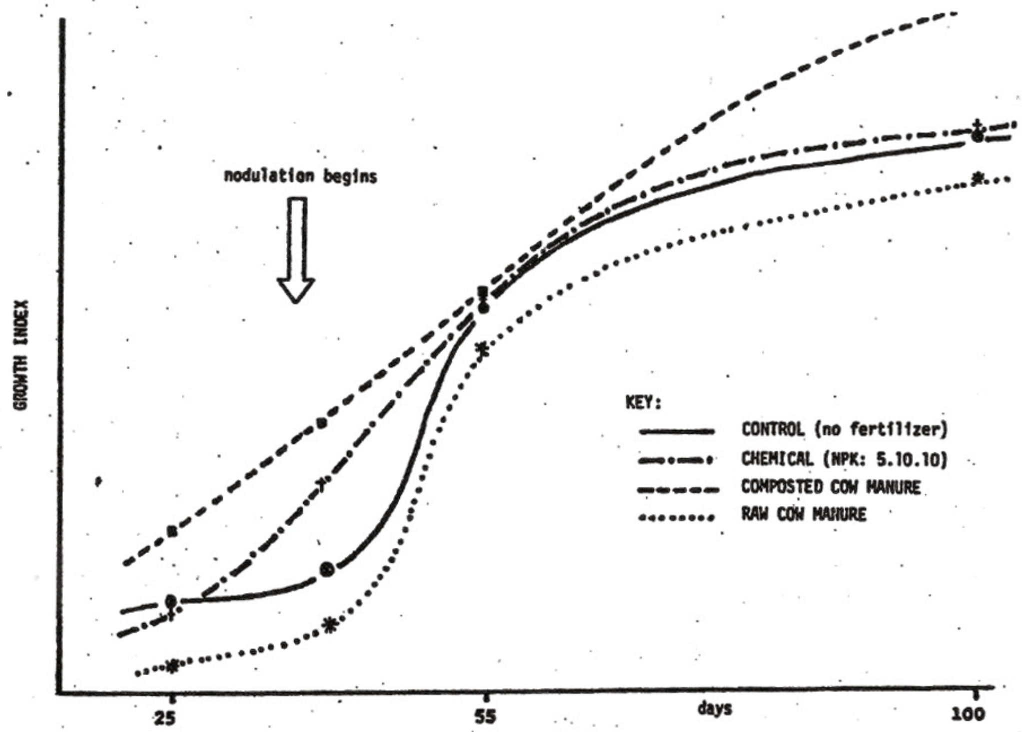

Figure 1. Experiment #1. Soybean Growth Curves.

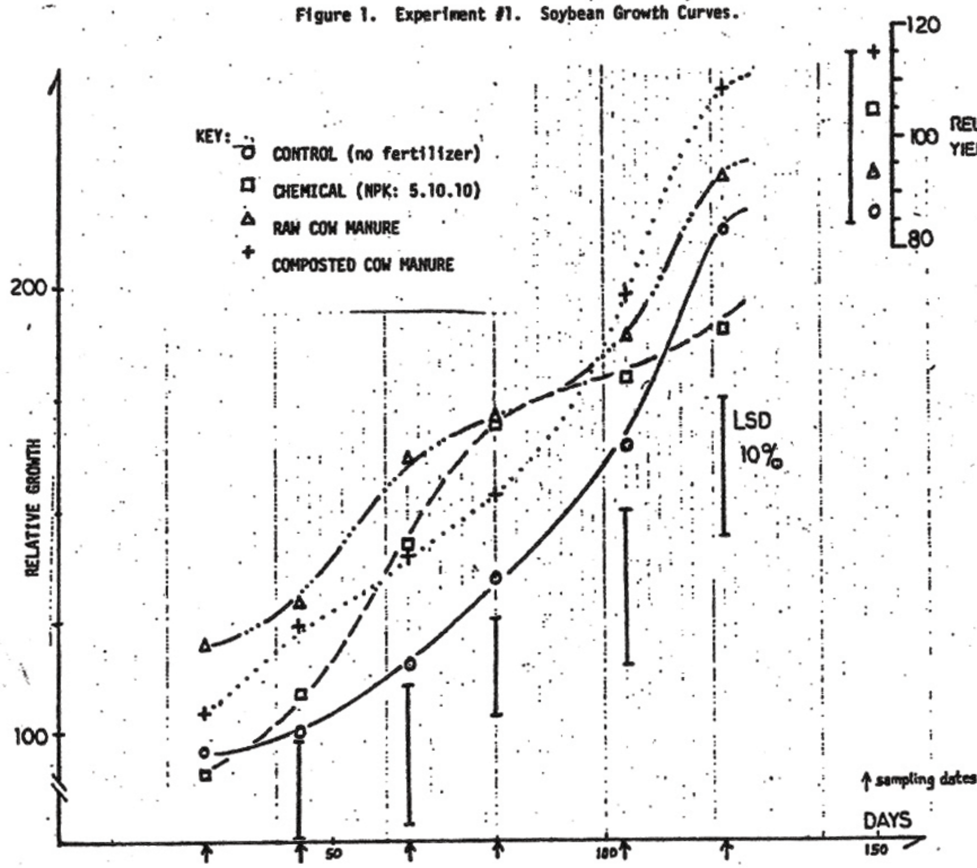

Figure 2. Experiment #2. Soybean Growth Curves.

Observations of root development in relation to above-ground growth are shown in Figures 3 and 4. Cumulative root length (excluding minute root hairs) in metres after 25 days was 1.3 for NPK, 1.9 for raw manure, 2.2 for compost and 2.9 for control (Figure 3).

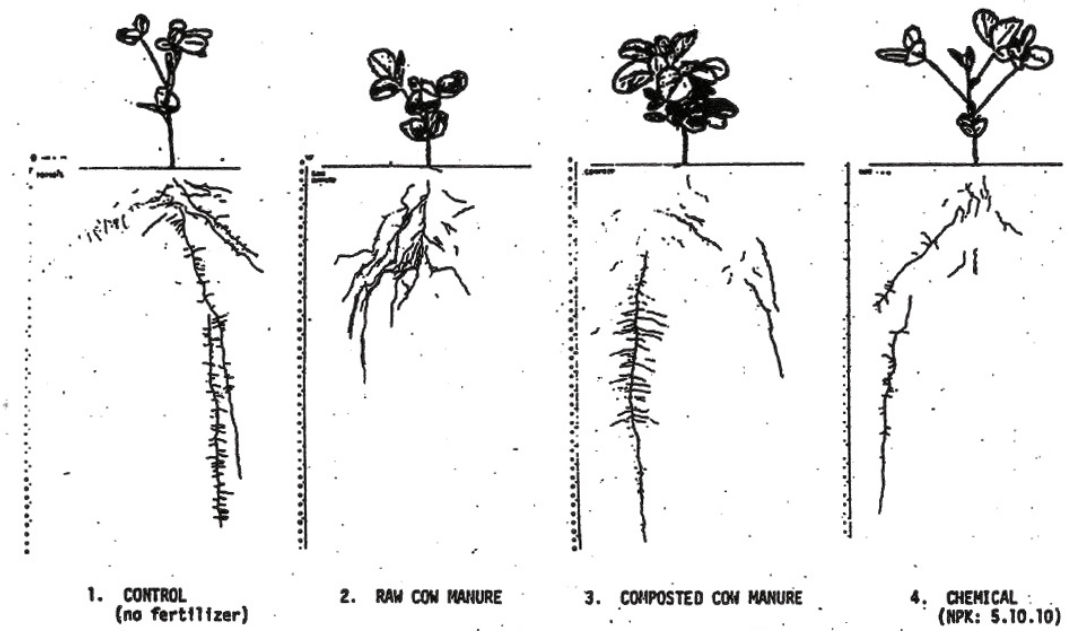

Figure 3. Soybean Development @ 25 days.

The NPK plant roots showed reduced early development and branching, and the raw manure (with slurry) ones exhibited severe inhibition, as indicated by their club-like roots with little secondary root development. These latter roots could also be seen to avoid and grow around pockets of manure in the soil, probably because of a lack of oxygen from manure BOD and/or the presence of ammonia and other inhibitory compounds associated with the anaerobic slurry.

Above-ground development in these same plants at 25 days was similarly variable (Figure 3). The controls exhibited an open structure, with a small leaf surface and long inter-nodal lengths. The NPK plants were similarly loosely structured, but with a larger leaf area. Raw manure plants were unusually compact and stunted. Compost plants had the largest leaf area, the most branching and the shortest inter-nodal and leaf petiole lengths. At this early stage, it was felt that these latter plants exhibited the most "harmonious" development.

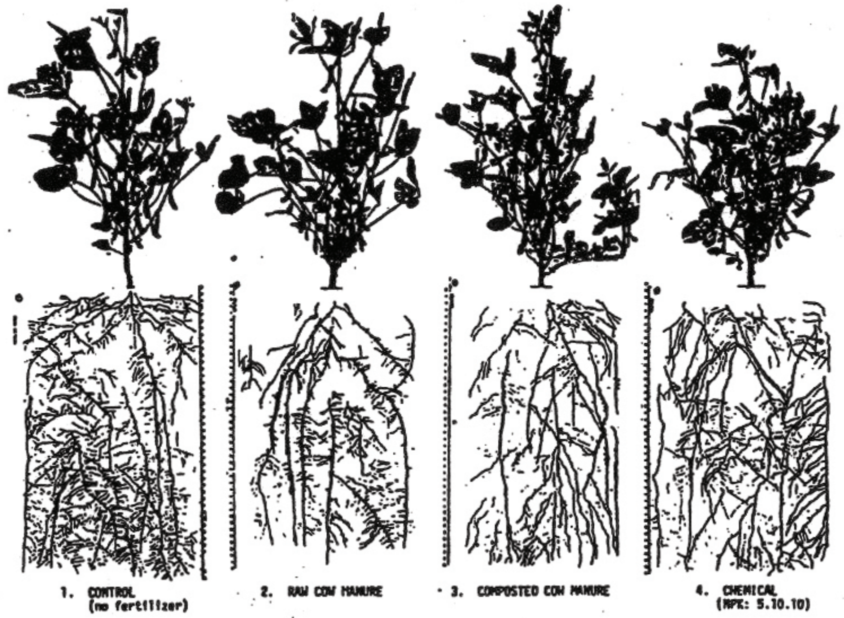

Figure 4. Soybean Development @ 100 days.

By the 100th day, the above differences were significantly ameliorated (Figure 4). Root length in metres was 14 for the control and NPK plants (although it should be noted that the latter had very few nodules), 13 for raw manure and 17 for compost.

With respect to above-ground development, the control plants exhibited least stem branching and least pod development. The raw manure (with slurry) plants showed exceptionally long leaf petioles but improved pod development over the controls. While the NPK plants were superior to the control and raw manure ones, the compost plants exhibited the densest structure, greatest amount of branching, shortest petiole lengths and greatest amount of developed pods. Bockemühl (1975) described some of these differences in morphologic development of bush beans that were exposed to various fertilizer treatments.

Yield was extrapolated from these root-box and pot experiments to farm-scale by using published yield potential data together with information from local farmers (for converting amount of pods to bean yield).

SOYBEAN BEAN YIELD (air dry wt.)

Treatments	Root-Box Expt. (#1)		Greenhouse Pot Expt. (#2)	
	t/ha	bu/a	t/ha	bu/a
Composted Cow Manure	2.8	42	1.10	17
Chemical (NPK: 5.10.10)	2.5	38	1.05	16
Raw Cow Manure	2.3	35	0.91	14
Control (no fertilizer)	2.0	30	0.89	13

$r = 0.98^*$, $p < .05$

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Nodule examination of root-box plants revealed them to be well developed and all active in raw manure and compost plants, and approximately 70% active in control plants. Those of the NPK plants were so few and so small that it was not possible to determine their activity. Therefore, while yield for NPK plants was superior to that for the control and raw manure ones, the virtual absence of nodules on these plants make them inferior in terms of their contribution to soil nitrogen. Yield trends were very similar in the two experiments (r = .98*).

Suitable *Rhizobia* strains were probably introduced into the soil via the compost, and possibly also via the raw manure. It is interesting to note that despite early root inhibition by raw manure (with slurry) in the root boxes these plants achieved excellent nodulation later on, in contrast to NPK plants, which did not show this effect.

Insect damage to the root-box plants, especially by the Japanese beetle (*Popillia japonica*), was evaluated in terms of percentage of leaves that were heavily damaged. Raw manure plants suffered 25% damage, NPK 22%, compost 17%, and controls 13%. It should be noted, however, that the Japanese beetle rarely attacks soybeans this heavily in the field.

The development of senescence in control and compost plants was significantly different, the compost delaying the onset of leaf senescence (Figure 5). Delayed senescence is usually associated with continued N-fixation in late stages of seed set (Abu-Shakra *et al.*).

In the greenhouse pot experiments a significant correlation was observed between number of senescing leaves and petiole lengths (r = .66*; 120 days), while petiole length was found to correlate strongly with plant leaf area (r = .68*, .82**; 80 and 100 days respectively). This suggests that there is a positive relationship between early senescence and vegetative growth. Although compost plants exhibited early vegetative superiority, NPK and raw manure plants demonstrated most overall vegetative growth in terms of height and leaf area. It would be interesting to investigate the relationship between these characteristics and overall N-fixation.

I. CONTROL (no fertilizer) II. COMPOSTED COW MANURE

Figure 5. Soybean Senescence Traits @ 125 days.

Conclusions

As can be seen from the data presented above, plant response to different nitrogen amendments is an intricate matter and cannot be fully interpreted in a mechanistic way, particularly with respect to N-fixation. The observation of plant morphogenesis offers a valuable means for studying such phenomena, for morphogenesis is as complex as the internal physiological system of the plant, yet is fully accessible to the unaided senses.

For example, in the greenhouse pot experiments, while yields were not different at the $p \leq .05$ level, selected morphologic traits did differ significantly during growth. Thus, the recorded response to different nutrient sources is dependent on what aspects of that response are observed and measured.

At the present time a significant gap exists between our quantitative knowledge of the components of plants and their morphogenesis (Salisbury and Ross 1978). It is generally assumed that genes control the synthesis of enzymes, which in turn control cellular chemistry, which finally must account for the visual aspects of growth and development. Whatever eludes us in our search for connections here, it is plainly evident that environmental influences - in this case, the nutrient source - are readily translated through the plant system into a gross morphologic attribute or set of attributes; and these can be detected and, at least, partly comprehended without knowing the internal physiologic or chemical processes that are involved. Traits that can be ascribed to these minute mechanisms can readily be re-attributed to the environment.

It is hoped that in the future increased efforts will be made to relate growth conditions to whole plant development with an aim of using the information gained to achieve more meaningful, and therefore useful, visual interpretation of plant growth.

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