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SEED QUALITY INFLUENCE ON NITROGEN FIXATION OF RED FIELD BEAN (*Phaseolus vulgaris* L.)

DISSERTATION

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By

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General Discussion

The preservation of seed quality in tropical countries is an immense problem and one of the principal factors limiting crop production (FAO, 1975). It is now well recognized that seeds must possess high vigor to produce rapid and uniform seedling emergence under a wide range of field conditions (McDonald, 1980). Thus, one of the primary targets in field bean production as well as any other crop is to produce uniform stands with excellent seedling emergence to maximize N_2-fixation and consequent yield production. However, the success of establishing a crop stand and maximizing N_2-fixation and yield potential is dependent on the quality of seed planted. Since the initial stages of Rhizobium infection can be detected in soybean seedlings after only seven days following planting (Vest et al., 1973), the quality of the seed may play an important role in the initial success of nodule infection and formation.

Satisfactory seed germination and field emergence of seeds varying considerably in seed vigor can be obtained if

moderate planting conditions such as warm soils with sufficient moisture levels are used. Under these conditions, uniform stands can be achieved even with poor quality seed lots. Results of experiments in this study, however, indicate that the establishment of uniform stands does not assure maximum yield of the crop. The seed quality tests (SG, SVC, and Conductivity) confirmed that differences in seed quality existed in the different seed lots used in the study (Tables 6 and 7). Seed industries and Federal seed control agencies have used the SG test as the official test of seed quality. However, the SG test lacks sensitivity to detect changes in seed quality (Egli et al., 1979). The SG test has been recognized to consistently overestimate field emergence in soybeans (Tekrony and Egli, 1977; Johnson and Wax, 1978). In this study, however, field performance results were highly correlated with SG, SVC, and conductivity tests.

In 1980, Smith and Ellis provided the first report that seed quality influenced the rate of field emergence and the average number of tap root nodules per plant in soybeans. However, beyond these general observations, no assessment of the cause of enhanced root nodulation in high vigor seeds was made nor was the degree of N_2-fixation determined. Results of experiments presented in this study confirmed those reported earlier by Smith and Ellis (1980) for

soybeans. Regardless of whether the seeds were naturally or artificially aged, as seed quality decreased, the rate of emergence, plant growth, nodulation and N_2-fixation rate concurrently decreased. Furthermore, high vigor seeds continued these trends throughout the various growth stages sampled and this association ultimately culminated in yield increases of up to 30% compared to low vigor seeds. Also, increases up to 25 and 35% for nodulation and N_2-fixation rate, respectively, were observed in high vigor seeds relative to low vigor seeds. These general trends were consistent throughout the two year study and were observed both in the DR and Ohio. These findings suggest that similar associations between seed quality and N_2-fixation may be occurring in field beans as well as soybeans. Other studies also have shown that seed vigor has a profound impact on field bean yield (Wijandi and Copeland, 1974), snap bean yield (Toole et al., 1957; Viera, 1966), and soybean yield (Torrie, 1958; Wu, 1977; Tekrony and Egli, 1977; Johnson and Wax, 1978; Yaklich and Kulik, 1979).

The results obtained in this study fail to support the theory postulated by many investigators that "...because of the ability of the soybean plant to compensate for low plant density, differences in seed yield cannot be detected in seeds varying in vigor levels and that the principal benefit from using high quality seeds is to enhance stands" (Mason

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et al., 1982; Byrd, 1970; Johnson and Wax, 1978; Egli and Tekrony, 1979). The data presented here indicate that this theory does not apply for field beans under either tropical (DR) or temperate (Ohio) conditions. Thus, based on these findings and those who have reported reductions in yield as a consequence of either naturally or artificially aged seeds (Torrie, 1958; Wu, 1977), it is logical to conclude that low vigor seeds, whether they are a result of poor production pratices, severe weather conditions during seed development and maturation, or poor storage conditions can present a potential form of biological stress which culminates in reduced crop yields.

Significant seed yield increases due to the direct effects of inoculation with R. phaseoli seldom have been observed in field beans grown in the field (Graham, 1981). However, this report documents consistent yield increases in excess of 600 kg. ha^{-1} followin inoculation with R. phaseoli of high quality seeds relative to the uninoculated control in the DR and Ohio during two years. These findings clearly justify the continuation of studies to adapt inoculant technology for use by farmers in developing countries such as the DR.

It is well known that seeds are treated with fungicides to promote excellent seedling establishment, to reduce yield

loss, to maintain and improve quality and to avoid the spread of dangerous organisms. In this time course study of plant growth, field emergence was increased by fungicide application relative to the non-treated control for naturally aged seeds in Columbus and Santiago. However, no promotive effect on artificially aged seeds was observed. Even though seed treatment at San Cristobal showed no effect for naturally aged seeds, it increased field emergence for artificially aged seeds. This finding suggests that seed treatment is more effective for seeds that have been more deteriorated as a consequence of aging in which the incidence of pathogen invasion is increased. Although nutrient leakage does occur in seeds as a result of accelerated aging (Abdul-Baki and Anderson, 1972), the beneficial effect of fungicide seed treatment was not observed at Columbus and Santiago probably because these two locations were free from field bean diseases and fungi. These fields, at least in Columbus, have never been planted to field beans. These data contrast with those from San Cristobal where the incidence of pathogens was very high and the seed treatment effect was observed.

Seed treatment also influenced nodulation and/or N_2-fixation during early plant growth because the plant root system had not extended beyond the immediate toxic zone surrounding the seed. In general, seed treatment increased

nodulation and N_2-fixation in this study. A possible explanation for this enhancement is that the rhizobial inoculant used was a granular rather than a powder inoculant, avoiding the close contact between the fungicide and the inoculant. Graham (1980) and Rennie et al. (1985) were able to overcome the inhibitory effect of captan on nodulation by using granular inoculant.

No significant effect of seed treatment on seed yield was observed; however, a trend for increasing seed yield was found on treated seeds relative to nontreated seeds for both naturally and artificially aged treatments which could be economically important for field bean production.

Conclusions and Recommendations

The following conclusions are made:

o Both the SG and SVC tests were good predictors of field performance for field beans varying in seed quality level.

o Yields for field beans produced either under tropical (DR) or temperate (Ohio) climates were dependent on initial seed quality levels. These findings failed to support the theory that the field bean plant compensates for low plant density resulting in similar yields. The principal benefit, therefore, from using high quality seeds extends beyond enhancing stands to include increased yield. These findings confirm those reported earlier by Smith and Ellis (1980) for soybeans who showed that increased seed quality resulted in improved rates of field emergence, plant growth, nodulation and N_2-fixation. Moreover, high vigor seeds continued to display these trends throughout the growth of the crop.

o Since many Latin American countries possess high ambient temperatures and relative humidities, seed deterioration is often rapid. Such reductions in seed

quality have been shown in this study to decrease the incidence of subsequent rhizobial seedling nodulation (25%), N_2-fixation (35%), and yields (30%).

An improved understanding of the relationship between seed quality and rhizobium root colonization of field beans could potentially result in an increase of 8,850 metric tons of beans at a value of 6.6 million U.S. dollars in the DR alone. Considering the Latin American Region, this 30% increase in potential yield would provide an additional estimated value of 588 million U.S. dollars as well as an increase of 0.72 million metric tons of food.

o Early nodulation provided sufficient nitrogen necessary to support higher yields.

o Consistent yield increases of up to 600 kg. ha^{-1} following inoculation relative to uninoculated seeds were observed at both the DR and Ohio sites indicating that the field bean cultivar Pompadour Checa has the ability to respond to inoculation with R. phaseoli strain "DG-2". This finding clearly justifies the continuation of studies to adapt inoculant technology for use by farmers in developing countries such as the DR.

o Fungicide seed treatment increased field emergence in both naturally and artificially aged seeds but the effect was more consistent for artificially aged seeds suggesting

that fungicide seed treatment is more important for seeds that have been deteriorated as a consequence of aging stress.

o Fungicide seed treatment also produced enhanced nodulation and N_2-fixation. This was possible because of the use of a granular inoculant which avoided the intimate contact with the seed as would have been the case with a powdar inoculant.

o A trend of increasing seed yield due to fungicide application was also observed. This suggests that the use of fungicide seed treatment not only enhances field emergence but also results in greater economic benefit for the farmer.

Based on these findings, it is concluded that low vigor seeds, whether they are a result of poor production practices, severe weather conditions during seed development and maturation or poor storage conditions present a potential form of biological stress which can result in substantial crop yield losses. This study, therefore, serves as a framework from which other studies could be based. The following investigations are suggested:

1. Determine how reduced field bean seed vigor leads to reduced nodule formation and subsequent reduction in N_2-fixation.

2. The identification of inoculant strains which are efficient, compatible, and competitive should be examined because seed inoculants represent a convenient method of insuring root infection.

3. Quantification of the population of R. phaseoli in the soils of the principal bean producing regions is necessary in order to avoid inoculation failure due to competition with indiginous rhizobium populations in the soil.

4. Since most of the field beans planted in the DR are treated with captan and if the inoculant technology is going to be adopted, the general use of granular inoculant applied to the soil surface should be further evaluated.

5. Since the genetic constitution of the host determines whether or not nodulation occurs, the number of root-hair invasions, the number of nodules that form, and the speed with which infection takes place, breeding programs with high N_2-yielding cultivars of field bean should be established in order to insure higher N_2-fixation rates which would lead to increased seed yields.