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Soybean

Seedbed Conditions and Prediction of Field Emergence of Soybean Seed

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Research Question

Seed quality (germination and vigor) is measured and reported to provide an indication of the expected emergence when the seed is planted in the field. Establishing consistent relationships between lab measures of seed quality and field emergence is difficult because emergence is influenced by seed quality and by the seedbed environment. Soil temperature, water and oxygen levels, microorganisms, and soil structure vary widely from field to field and help determine whether the seed will germinate and whether the seedling will emerge. Seedbed conditions must be included in any evaluation of the relationship between seed quality and field emergence. The objectives of this research were to evaluate the relationship between germination and vigor test results and seedling emergence as affected by (i) seedbed conditions, (ii) the percentage emergence required to produce adequate plant populations, and (iii) carryover and noncarryover seed.

Literature Summary

Correlation and regression analysis are used to evaluate the relationship between lab measures of seed quality and field emergence. Significant relationships for soybean seed have been found for standard germination (SG) and several vigor tests including accelerated aging germination (AA). However, the relationships were not consistent from experiment to experiment and could not predict potential field performance. Combining the results of several lab tests into a single vigor index or a multiple regression equation was no better than using the individual tests.

Study Description

Twenty-six field emergence experiments were conducted over 10 yr. Soybean seedlots that had either been harvested the previous fall or had been in warehouse or controlled environment storage for up to 30 mo (carryover) were planted in the field on two to four planting dates each year.

Standard germination and AA (seed vigor) were measured just before the first planting date each year. The field emergence index (FEI = mean field emergence/ mean SG $\times$ 100) was calculated for each experiment to characterize seedbed conditions. The performance of the seedlots was assessed by determining whether the emergence was equal to or above a minimum acceptable level. The prediction accuracy was computed for each field planting as the proportion of the seedlots having a defined lab quality level that had emergence above the minimum acceptable level.

Applied Questions

Is the predictive ability of lab quality tests affected by soil conditions?

Results of the SG and AA tests accurately predicted field performance (prediction accuracy of 100%) only in ideal field conditions. The prediction accuracy of both tests decreased as stress in the seedbed increased and eventually reached zero in severe stress conditions.

Full scientific article from which this summary was written begins on page 365 of this issue.

Was there any difference in predictive ability between standard germination and accelerated aging germination?

In ideal field conditions, the prediction accuracy of both tests was 100%. As soil stress increased the predictive ability of SG decreased faster than AA. In moderate stress conditions, the AA test always had a higher predictive ability than SG.

Was it possible to get acceptable prediction accuracy over the range in field conditions likely to be encountered by soybean producers?

To get predictions accuracy's of 80% or greater (80% of the seedlots produced acceptable stands) across the field conditions likely to be encountered by soybean producers in Kentucky, it was necessary to select seedlots with an AA of 80% or greater and use a minimum emergence standard of 60%.

Was there any difference between carryover and noncarryover seed?

The prediction accuracy for noncarryover seedlots with SG of 80% or greater was higher than for carryover seedlots, but the prediction accuracy for seedlots with an AA of 80% or greater was the same for carryover and noncarryover lots.

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D. B. Egli* and D. M. TeKrony

It has been difficult to develop consistent relationships between lab measures of soybean [*Glycine max* (L.) Merr.] seed quality (germination and vigor) and field emergence. Twenty six field emergence experiments (two to four planting dates per year) were conducted over 10 yr to evaluate the effect of seed bed conditions and carryover vs. noncarryover seed on the relationship between standard germination (SG) or accelerated aging germination (AA) and field emergence. Seedbed conditions were characterized by the field emergence index (FEI = mean field emergence/mean SG × 100) calculated for each experiment. The ability of the lab tests to predict field emergence was evaluated by the prediction accuracy (proportion of the seedlots in each test with a specified quality level that had a field emergence above the minimum level). The FEI varied from 108 to 44 and the prediction accuracy varied from 0 to 100%. The prediction accuracy was high for SG and AA for ideal field conditions (FEI ≥ 100) and decreased as soil stress increased. The AA test had higher prediction accuracy than SG in moderate stress. Lowering the minimum acceptable field emergence from 80 to 60% improved the prediction accuracy for SG and AA, but only seedlots with AA ≥ 80% showed acceptable prediction accuracy over a wide range of seedbed conditions. Noncarryover seed had higher prediction accuracy than carryover seed for SG, but there was little difference for AA. High vigor seed (AA ≥ 80%) provided adequate performance in a wide range of seedbed conditions only when the minimum acceptable emergence was lowered to 60%.

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ADEQUATE PLANT POPULATIONS are an important part of any soybean production system. Although soybean yields will remain constant over a range in population, there is a minimum population below which yield will be reduced (Egli, 1988). Minimum populations for acceptable yields in 30 in. rows were between 3 and 5 plants/ft of row (52 000 to 87 000 plants/ acre) (Johnson and Wax, 1978; Egli and TeKrony, 1979).

Planting rate and the proportion of the planted seeds that emerge (field emergence) combine to determine plant population. Field emergence can vary widely and is influenced by the quality (germination and vigor) of the planting seed, the depth of planting, and the conditions in the seedbed. Soil temperature, water and oxygen levels, microorganisms, and soil structure affect the ability of the seed to germinate and the seedling to emerge from the soil (Pollock, 1972; Burris, 1976; Powell, 1988).

Standard germination is the traditional measure of seed quality that is used to provide an indication of expected emergence when the seed is planted in the field. Although all seed is tested and labeled for germination, in recent years interest in measures of seed vigor, such as AA, has increased (TeKrony, 1983; Ferguson, 1990). It has been difficult, however, to establish a consistent relationship between lab measures of seed quality and field emergence. Significant correlations of SG and various measures of seed vigor with field emergence have been reported for soybean (Edje and Burris, 1971; TeKrony and Egli, 1977; Johnson and Wax, 1978; Yaklich and Kulik, 1979; Yaklich et al., 1979; Clark et al., 1980; Kulik and Yaklich, 1982). These relationships were not consistent across experiments and could not be used to

Abbreviations: AA, accelerated aging germination; FEI, field emergence index; SG, standard germination.

predict potential performance. Combining results from several tests into a vigor index (TeKrony and Egli, 1977) or a regression model (Luedders and Burris, 1979) did little to improve prediction accuracy. These inconsistent relationships between quality and emergence are probably due to variation in seedbed conditions. It may be unrealistic to expect tests conducted in controlled lab conditions to relate to performance in the wide range of soil conditions that may be encountered in the field.

Egli and TeKrony(1995) included seedbed conditions in their evaluation of the relationship between SG, AA, cold test, and field emergence of a large number of soybean seedlots in 26 field emergence experiments. All tests accurately predicted emergence in ideal soil conditions, but the ability to predict emergence decreased as soil stress increased. They reported that AA and cold test germination were better than SG in predicting field performance as stress increased. Thus, the relationship between results of the quality tests and field emergence was dependent on seedbed conditions.

Soybean seed quality can decline during storage, especially if the storage period extends beyond one planting season (Burris, 1980; TeKrony et al., 1993). The normal storage period is from the fall harvest until planting the next spring, however, at some locations seed is carried over for use the next year. Seed vigor declines during storage before SG or viability. Carryover seed can have high germination and low vigor at planting (Byrd and Delouche, 1971; Nelson, 1990; Fabrizius, 1993), which may affect the ability of the seed to emerge in less than ideal seedbed conditions. The ability of quality tests to predict the performance of carryover seed in a range of seedbed conditions has not been evaluated.

The objective of this work was to extend our previous work (Egli and TeKrony, 1995) by evaluating the relationship between germination and vigor test results and seedling emergence as a function of (i)seedbed conditions, (ii) the emergence level required to produce adequate plant populations and (iii) carryover and noncarryover seed.

MATERIALS AND METHODS

Field emergence experiments were conducted near Lexington, KY, for 10 yr using seedlots of commercially available cultivars (Table 1). A total of 272 seedlots were included with 12 to 52 seedlots of five to 21 cultivars tested each year (Egli and TeKrony, 1995). Some seedlots were harvested the previous fall (noncarryover) and some had been in warehouse or controlled environment storage for 18 to 30 mo (carryover lots). Standard germination (AOSA, 1993) and AA (AOSA, 1983) was measured before planting the first emergence test each year.

Field emergence experiments were planted at one to four dates each year (from early April to July) to provide a range in seedbed conditions (Table 1). Seeds were sown in a single 20 ft row at a depth of 1 to 2 in. at a seeding rate of 5 seeds/ft of row. The seedbed was prepared by conventional tillage (moldboard plow and disc-harrow) except for the second planting in 1984, which was no-till planted in wheat (*Triticum aestivum* L. em. Thell) stubble. There were three or four replications in a randomized complete block design.

Table 1. Mean seed quality and field emergence of the soybean seedlots used in the 26 field emergence experiments, 1980 to 1993.

		Germination		Field emergence experiment†					
				1		2		3	
Year	Seed lots	Standard	Accelerated aging	PD	EM	PD	EM	PD	EM
	No.	%			%		%		%
1980‡	40	82	62	7 Ap	54	21 Ap	57	1 My	64
1981	52	90	42	8 Ap	64	11 Je	79	--	--
1984	29	89	63	12 My	72	10 Jl	67	--	--
1985	12	77	50	16 Ap	64	29 Je	83	--	--
1987	16	91	77	29 Ap	79	14 My	86	15 Je	85
1988	33	91	61	4 My	54§	11 My	81	29 Jl	79
1989	17	88	60	25 Ap	39	4 My	45	8 Je	58
1991	15	95	82	17 Ap	64	5 Je	71	2 Jl	75
1992	38	94	62	20 Ap	64	3 Je	52	2 Jl	70
1993	20	90	41	2 Je	59	--	--	--	--

† PD = Planting date, EM = Emergence.
‡ A fourth planting was made 12 July 1980; mean emergence was 77%.
§ n = 17, only 17 seedlots were included in the first planting.

Final emergence counts (growth stage VE, Fehr and Caviness, 1977) were taken after emergence had stopped.

The FEI (Eq. 1) was calculated for each field emergence experiment as an index of seedbed conditions (Egli and TeKrony, 1995).

$$\text{FEI} = \frac{\text{Mean field emergence}}{\text{Mean SG}} \times 100 \qquad [1]$$

The FEI for any field planting equaled 100 when the average emergence of the test equaled the average SG, indicating ideal seedbed conditions. As the index decreased below 100, seedbed conditions became progressively less than ideal.

The performance of seedlots was assessed by determining whether the emergence was equal to or above a minimum acceptable field emergence level. A quality test accurately predicted the performance of a seedlot if the field emergence of the lot was above the minimum acceptable level. Prediction accuracy was computed for each field planting as the proportion of the seedlots having a defined critical lab quality level (e.g., SG ≥ 80 %) that had emergence above the minimum acceptable level (Egli and TeKrony, 1995). For example, if there were 10 seedlots in a field planting with SG equal to or above 80% (the defined critical quality level) and five of these seedlots had a field emergence of 80% or greater (the assumed minimum acceptable field emergence), the prediction accuracy for SG in that experiment would be 50% (5/10), Thus, only 50% of the seedlots produced acceptable plant populations. Prediction accuracy could vary from 0 to 100%. To compare a range in potential plant populations, we evaluated minimum field emergence levels of 60, 70, and 80%. The prediction accuracy concept evaluates predictive ability of a lab test relative to the seedlot producing an acceptable plant population instead of evaluating the ability to predict the exact level of emergence.

RESULTS

Average SG was above 80% for all years, except 1985 (Table 1), with only a few seedlots in each year germinating below 80% (Egli and TeKrony, 1995). The average AA for each year was much lower (varying from 41 to 82% across years) and the range across seedlots within each year was usually from 90% or greater to near zero (Egli and TeKrony, 1995). Mean field emergence varied from 39 to 86% and the lower levels tended to occur on the early planting dates (Table 1). The FEI varied from 44 to 108, reflecting the wide range in seedbed conditions across the 26 experiments.

In ideal field conditions (FEI ≥ 100), the prediction accuracy for seedlots with SG of 80% or greater was 100% for all three minimum field emergence levels (60, 70, and 80%) (Fig. 1). As seedbed stress increased (FEI decreased), the prediction accuracy decreased, and the decrease occurred faster for the highest minimum field emergence (80%, Fig 1A) than for minimum field emergence levels of 70 (Fig. 1B) or 60% (Fig. 1C). The prediction accuracy for 80% minimum field emergence at a FEI of 80 was 37% compared with 65 and 88% for minimum field emergence levels of 70 and 60%, respectively. Thus, most of the seedlots with 80% or greater SG produced satisfactory stands at an FEI of 80 if only 60% emergence was required, while less than half of the seedlots exhibited satisfactory performance if 80% emergence was required.

Selecting seedlots based on AA test results (AA ≥ 80%) provided higher prediction accuracy, compared with SG, as

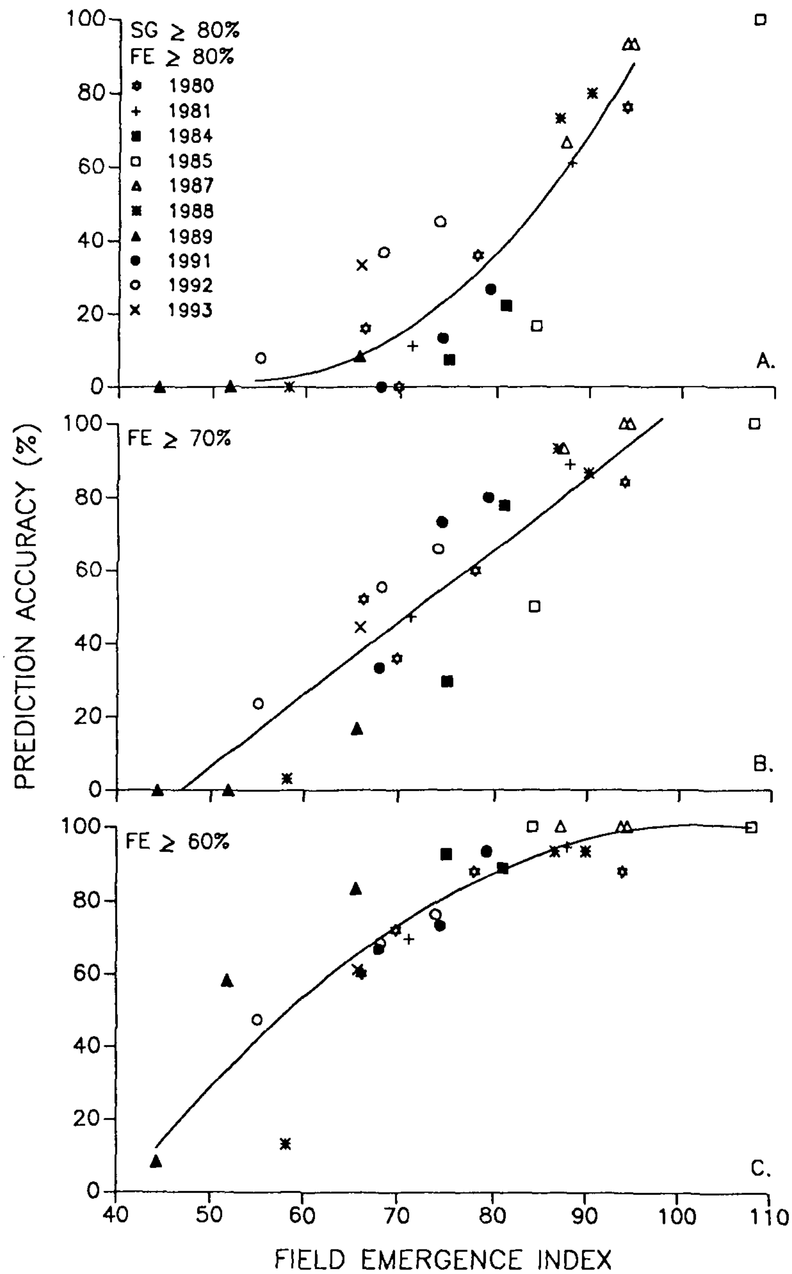

Fig. 1. The relationship between prediction accuracy and field emergence index (FEI) for seedlots with standard germination of 80% or more and a minimum field emergence of 80 (A) (from Egli and TeKrony, 1995), 70 (B), or 60% (C). The regression equations relating prediction accuracy (PA) to FEI are (A), PA = 162.23 − 5.88 FEI + 0.0539 FEI^2, R^2 = 0.80, *n* = 25, (B) PA = 92.374 + 1.977 FEI, r^2 = 0.82, n = 25, and (C) PA = −173.60 + 5.354 FEI − 0.026 FEI^2,R^2 = 0.81, n = 26. Data with an FEI ≥ 100 were not included in the regression analysis in panels A and B.

seedbed stress increased (lower FEI, Fig. 2). Prediction accuracy was above 80% for FEI of 85 or above when the minimum field emergence was 80% (Fig. 2A). If a minimum field emergence of 60% was used, however, the prediction accuracy was above 80% for FEI of 65 or greater (Fig 2C). A minimum field emergence of 70% showed an intermediate response (Fig 2B).

Carryover and noncarryover seedlots were included in 4 of the 10 yr (11 field emergence experiments). It was therefore possible to compare the predictive ability of lab quality tests on carryover and noncarryover seed in the same seedbed environments.

The average SG for carryover and noncarryover seedlots was similar and both were above 80% in all 4 yr (Table 2). However, the AA of the carryover lots was less than noncarryover lots by an average of 34 percentage points. Average field emergence was usually lower for carryover lots, but there were some field emergence experiments where there was little difference (Table 2).

The prediction accuracy for carryover lots was less than noncarryover lots (minimum field emergence of 60%) when SG (≥80%) was used to predict performance (Fig 3A). The prediction accuracy for noncarryover seedlots was never below 80%, while the prediction accuracy for carryover seedlots was as low as 25% in high stress soil environments (FEI ≤ 60). When AA (≥80%) was used to predict performance, however, the prediction accuracy was generally high

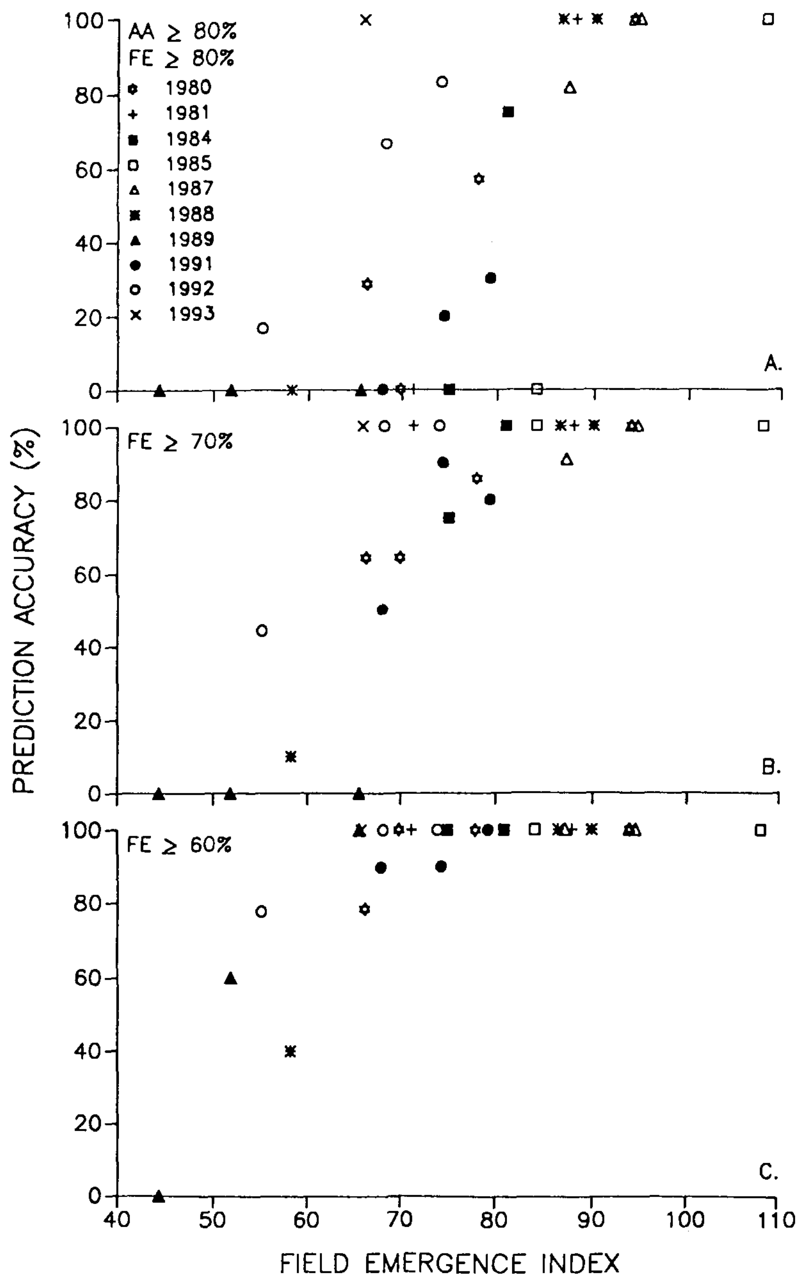

Fig. 2. The relationship between prediction accuracy and field emergence index (FEI) for seedlots with an accelerated aging of 80% or greater and minimum field emergence of 80 (A), 70 (B) and 60% (C).

Table 2. Seed quality and field performance of carryover and noncarryover soybean seedlots.

Year	No. of seedlots		Standard germination		Accelerated aging		Field emergence experiment 1		Field emergence experiment 2		Field emergence experiment 3	
	Carryover	NC	Carryover	NC	Carryover	NC	Carryover†	NC†	Carryover	NC	Carryover	NC
			%									
1980‡	27	13	81	81	56	73	46	72	52	67	62	66
1981	33	19	90	90	24	72	60	72	76	85	--	--
1988	16	17	89	92	41	79	74	87	72	87	--	--
1992	26	12	94	93	52	84	58	77	43	70	64	81

† Field emergence of carryover and noncarryover (NC) seedlots.
‡ A fourth field emergence experiment was conducted in 1980, mean emergence of the carryover lots was 71% and noncarryover lots was 88%.

and was the same for carryover and noncarryover lots in 9 of 11 field emergence experiments (Fig. 3B).

DISCUSSION

Prediction accuracy is a measure of the ability of lab quality tests to identify seedlots that produce satisfactory plant populations in the field. A satisfactory plant population will produce maximum yield and is defined by the planting rate and the level of field emergence. Ideally, prediction accuracy would equal 100%, meaning that all seedlots with the selected quality level produced satisfactory populations.

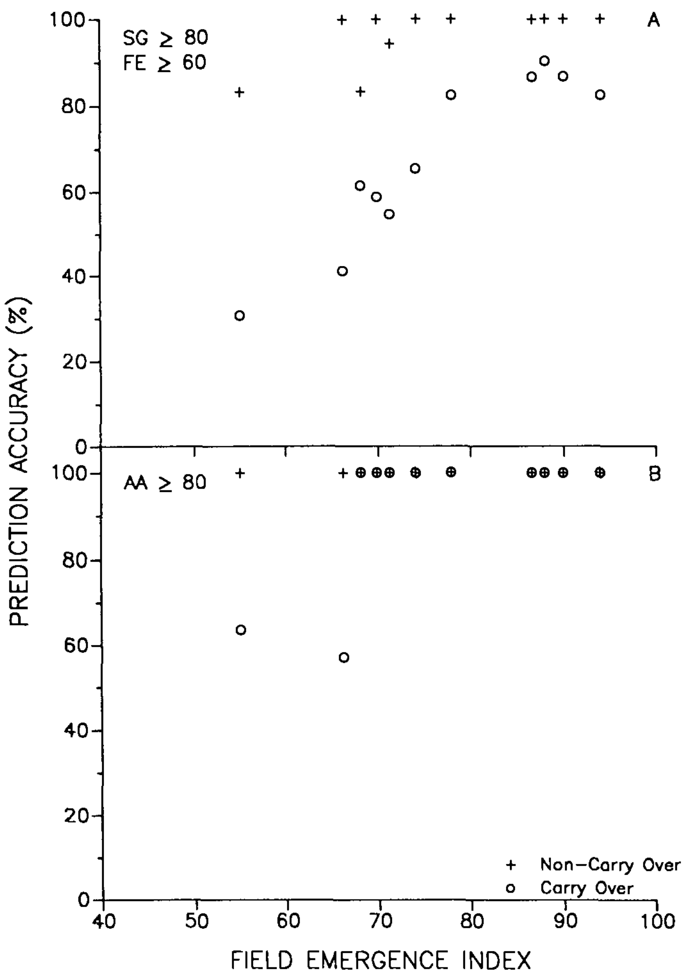

Fig. 3. The relationship between prediction accuracy and field emergence index (FEI) for carryover and noncarryover seedlots for standard germination (A) or accelerated aging germination (B) of 80% and a minimum field emergence of 60%.

This ideal level of prediction accuracy occurred for seedlots with SG ≥ 80% only in ideal field conditions, i.e., when the FEI was near 100 (Fig. 1). Thus, SG accurately predicted performance only in ideal field conditions as reported previously (TeKrony et al., 1987; Egli and TeKrony, 1995). Prediction accuracy for a vigor test, AA, were higher than for SG (Fig. 2) in less than ideal field conditions (FEI < 100), which is consistent with the widely held opinion that vigor tests provide better estimates of field performance in stress (TeKrony et al., 1987; Egli and TeKrony, 1995). Under severe stress (FEI < 60), neither test was able to accurately predict performance as reported previously (Egli and TeKrony, 1995).

The practical interpretation of our results obviously depends upon the level of seedbed stress (range in FEI) that will normally occur in producers fields. We found no relationship between soil temperature and FEI in these experiments (Egli and TeKrony, 1995), consequently we could not use soil temperature data to estimate FEI. However, our data from 26 field experiments covering 10 yr provide an estimate of the seedbed stress (FEI) that might occur in Kentucky. After deleting the unrealistically early April planting dates to avoid biasing the FEI downward, there were 18 field emergence experiments with planting dates in May, June, and July. The average FEI for these experiments was 78 and, more importantly, the range was from 52 to 108. The FEI of seven of the experiments (39%) was between 60 and 80. Thus, soybean seeds will frequently be planted in Kentucky in seedbeds with moderate levels of stress where the FEI is between 60 and 80. It would be helpful to have a quality test that had a high prediction accuracy in these moderate stress conditions.

Standard germination and AA did not produce high prediction accuracy at moderate stress levels (FEI between 60 and 80) when the minimum field emergence level was 80% (Fig. 1; Egli and TeKrony, 1995). Prediction accuracy is also influenced by the minimum field emergence used to determine accuracy. Lowering the minimum acceptable emergence to 70 or 60% resulted in higher prediction accuracy in seedbeds with moderate stress (FEI = 60 to 80) for both SG and AA (Fig. 1 and 2). Using 60% minimum emergence, the prediction accuracy for seedlots with an AA of 80% or greater was near 100% for FEI from 60 to 108. However, the prediction accuracy for seedlots with a SG of 80% or greater was less than 80% in the moderate stress seedbeds. Clearly, prediction accuracy can be improved by lowering the minimum field emergence. In fact, we were able to get high prediction accuracy over the range of FEI likely to be encountered in normal soybean production (60–100) in Kentucky by using high vigor seed and lowering the minimum field emergence to 60%. This raises the question, will 60% field emergence produce plant populations that are adequate for maximum yield?

Plant population is determined by the percentage emergence and the planting rate. Recommended planting rates in Kentucky are well above the populations needed for maximum yield. Herbek and Bitzer (1988) recommended a planting rate of 8 to 10 seed/ft of row in 30 in. rows, but Egli and TeKrony (1979) and Johnson and Wax (1978) found that 3 to 5 plants/ft of row produced maximum yield. This comparison suggests that 40 to 60% emergence with recommended planting rates would provide adequate plant populations. Apparently, recommended seeding rates are high enough that relatively low levels of field emergence will provide adequate populations. Thus, our use of a minimum field emergence of 60% seems justified.

As expected, the AA of most carryover seedlots was lower than noncarryover lots, although there was little difference in SG. These results reflect the common observation that, during storage, seed vigor declines first followed by SG (Byrd and Delouche, 1971; Nelson, 1990; Fabrizius, 1993). The difference in vigor was clearly evident in field emergence of these seedlots. Noncarryover seedlots with a SG of 80% or greater clearly performed better than carryover lots, especially as soil stress increased (FEI below 80; Fig.3A). However, the AA test accurately predicted the performance of the carryover seedlots and there was very little difference in prediction accuracy between carryover and noncarryover lots (Fig. 3B). Carryover seedlots with SG above 80% may not produce adequate populations if they are planted in seedbeds with FEI between 60 and 80. Carryover seedlots with an AA of 80% or greater will usually produce adequate stands for FEI above 60. These data clearly illustrate the value of using the AA test to assess the planting potential of carryover seed.

CONCLUSIONS

At planting time the objective of a soybean producer is to obtain a plant population that is adequate for maximum yield. Planting seed quality, seedbed conditions, emergence, and planting rate combine to determine the final population. Successful evaluation of the relationship between results of lab quality tests and field performance must include field conditions. We found that seedlots selected on the basis of SG produced adequate populations only in ideal field conditions. Seedlots with an AA of 80% or greater produced adequate populations across the seedbed conditions likely to occur in normal soybean production only when an adequate population was based on 60% or greater emergence. Many recommended soybean planting rates are high enough that 60% emergence will produce populations adequate for maximum yield.

An AA of 80% represents an estimate of the minimum vigor providing adequate field performance in most planting environments. Our analysis also clearly demonstrated, however, that there are some field environments where none of the seedlots, regardless of the vigor level, produced adequate plant populations.

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