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Soybean Seed Quality and Stand Establishment

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There are distinct advantages to producing seeds in geographical areas that have favorable environments, i.e., low precipitation, absence of early morning fogs and/or heavy dews, and low relative humidity during preharvest and harvest periods. In such favorable climates, seed set and recovery is usually optimum; there is low incidence and severity of insects and plant and seed diseases. Germination and seed vigor are quite high. Hence, seed quality is usually good when produced under such favorable conditions. It is not uncommon, however, to find production of many kinds and large quantities of planting seeds in the same general area where the crop is grown for other commercial uses. Unfortunately, these geographical areas are frequently characterized by environmental conditions that are unfavorable and often detrimental to the production of high quality planting seed. Thus, the environment becomes implicated as a major factor contributing to the rapid deterioration of seeds.

Rapid deterioration and subsequent loss of seed quality is frequently, and probably universally, referred to as "weathering." This simply implies that the seeds have been exposed to the weather components, i.e., the environmental conditions existing in the field during the time of seed formation, development, and maturation. In other words, the seeds are "stored" on the plants until they can be harvested. While "stored" in this manner, they are undergoing the natural physiological deteriorative processes common in all biological systems (senescence) and, at the same time, the environmental stresses are imposing their influence. It is quite likely, then, that soybean seeds can, and quite often do, undergo severe field deterioration that lowers their quality.

This environmental "complex" encompasses an array of daily ambient conditions that vary widely according to a specific geographical location. Of the combination of environmental conditions that may exist at any given time, however, the one(s) we know to exert unfavorable stress(es) upon developing (maturing) seeds, either singularly or in concert, are high temperature and relative humidity (RH) and/or frequent or prolonged precipitation. Constituting additional increments of this "total environmental complex" are diseases and insects that seem to thrive in the same conditions that are detrimental to seeds, i.e., hot, wet climates. These conditions, of course, are quite typical of the subtropical and tropical zones of the world.

LITERATURE REVIEW

Historically, soybeans were produced in the northern regions of the temperate climatic zones of the world, where environmental stresses were relatively minimal. However, as the world demand for vegetable oil and protein continued to increase, soybean production spread rapidly into the warm (hot), humid production areas, and more recently into the tropical regions (15, 26). Rachie and Plarre (24) point out that soybeans are already well established in the tropics at intermediate elevations and in the subtropics. They hasten to point out, however, that it is questionable whether soybeans can be established in the low latitude, low elevation tropics and suggest that success depends upon favorable conditions and good management. Delouche (5) has documented many instances of poor seed quality in soybean seed and strongly contends that adverse weather conditions during the postmaturation, preharvest period cause moderate to severe seed quality problems. With such mounting evidence that the environment plays a significant role in affecting the quality of soybean seed, a closer examination of specific environmental factors seems in order.

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Environmental Moisture

Environmental moisture of significance in subtropical and tropical soybean growing regions takes the form of either heavy early morning fogs, dews, or rain. Under these conditions, relative humidity varies considerably but usually remains high during the warm, humid growing season. Additionally, as the fogs lift, dews dry, and rains cease, a hot, penetrating sun bears down upon the developing seeds. Soybean seeds are very susceptible to such extremes of wetting and drying (dehydration and rehydration). Such cycles, particularly during the latter stages of seed maturation, are quite detrimental to seed quality and, in fact, cause rapid deterioration (5). Table 1 shows moisture fluctuations and germination percentage of four prominent soybean cultivars of the southeastern United States as they were harvested at intervals during and shortly after field maturation.

As early as 1950, Moorse et al. (16) reported that exposure to periods of dampness caused soybean seeds to deteriorate. In bean seeds, which are morphologically similar to soybeans, Moore (15) reported that alternate rehydration and dehydration following field maturity caused necrotic areas in the radicle and cotyledons and hairline fractures across the hypocotyl. In evaluating the effects of various field environments upon soybean seed quality, Mondragon and Potts (14) and Burdette (2) determined that supplemental water sprays, either daily or once or twice weekly, increased the rate and degree of field deterioration. Deterioration was retarded either by protecting the maturing seeds from the ambient field environment or by removing them completely from it. In 1959 Howell et al. (10) concluded that rain in the field or a simulated rain on intact pods increased the moisture content of the seeds, which delayed dehydration and prolonged rapid respiration that was of a magnitude to reduce the amount of sugars and other stored materials in seeds. Although they failed to relate the significance of these results to seed quality, no doubt loss of sugars and other materials from the seeds lowers their quality.

Timely harvest of mature soybean seeds is extremely important in protecting and maintaining high seed quality. Harvest delays beyond optimum maturity extend field exposure and intensify field deterioration. Wet field conditions frequently cause harvest delays. Green et al. (7, 8) reported that, when soybean harvest was delayed due to rain after the seeds had initially declined to 13.5 percent moisture content, seed quality declined with subsequent reductions in germination and field emergence. Tekrony and Egli (26) reported similar declines in vigor when seeds were harvested even within 30 days after "harvest maturity," especially if hot, humid conditions prevailed (Table 2). Nangju (18) reported that harvest delays were accompanied by an increase in purple stain and cracked, wrinkled, and discolored seed. He proposed the use of "delay-harvest plus rainfall" to evaluate for resistance to field weathering. Paschal and Ellis (22) obtained reduced sand germination and field emergence of 7 and 14 percent, respectively, by delaying harvest two weeks. Costa (3) obtained highest seed quality when 95 percent of the pods were mature and lowest seed quality when harvest was delayed 14, 28, or 42 days after 95 percent maturity.

Table 1. Seed Moisture Content and Germination for Four Soybean Cultivars at Intervals during Field Maturation

Harvest date	Hill		Dare		Mack		Lee	
	H_2O	Germination	H_2O	Germination	H_2O	Germination	H_2O	Germination
				percent				
10/3	16	87	33	93	...	...	60	90
10/10	15	78	16	87	15	66	51	88
10/17	13	71	13	92	13	79	15	79
10/24	12	34	12	54	12	41	11	78
10/31	22	32	23	37	23	40	20	86
11/9	37	27	37	28	10	35	35	64
11/16	14	11	14	33	14	7	14	70
11/23	32	0	31	24	31	14	31	68
11/30	18	0	18	11	23	4	16	47
12/8	...	...	14	16	14	5	14	50
12/14	...	...	12	12	13	6	12	46

Table 2. Maturation Dates and Seed Quality at Physiological Maturity and at Harvest Maturity

Parameter	Cutler 71 1973	Cutler 71 1974	Cutler 71 1975	Kent 1974	Kent 1975
Physiological maturity					
Date	9/19	9/24	9/16	10/1	9/30
Germination, %	98	94	86	94	93
Harvest maturity					
Date	9/29	10/7	10/6	10/11	10/14
Germination, %	87	97	73	91	94
Desiccation, days	10	13	20	10	14

Note: Adapted from Tekrony, Egli, and Phillips(26).

Environmental Temperature

High temperatures coupled with high moisture (either RH or precipitation) exert severe stresses upon developing soybean seeds. Moorse et al. (16) stated that hot weather during seed maturation often resulted in seedcoat wrinkling, which reduced germination. When Costa (3) evaluated 18 soybean lines in Brazil, he found that an alternation of rain and hot weather accelerated deterioration, and high temperature during final stages of seed maturation caused green seeds that were low in quality. Potts and Mondragon (15) reported that plants that were shaded to reduce incident solar insolation by 50 percent produced seeds that deteriorated at a slower rate than did seed produced on unshaded plants. Similarly, Burdette (2) demonstrated that seeds harvested from plants removed from the field and stored in open-sided sheds were higher in quality than those that remained exposed to the ambient field environment. In both instances the reduced rate of "field weathering" was attributed to cooler temperatures and a more stable microclimate.

Environmental Diseases

Tropical and subtropical climates with high rainfall and temperature are favorable for rapid disease development. Thus, seedborne diseases become associated with particular environments and must be included as part of the total climatic pattern. Certain microorganisms are pathogenic to seeds, and increased infection obviously leads to a reduction in seed quality. In 1971 Nicholson and Sinclair (20) and Nicholson et al. (21) reported that the incidence and severity of fungal invasion of seeds is increased by "weathering," which lowers seed quality. Hepperly and Sinclair (9) demonstrated that germination decreases were accompanied by increases in the incidence of *Bacillus subtilis* and *Phomopsis sojae*. They concluded that seeds infected by *P. sojae* were low in quality, since they were distorted in size and shape, covered by fungal mycelium, and low in test weight. Wilcox (28) showed that a loss in seed quality was due to increased incidence of *P. sojae* and other fungi when soybean harvest was delayed.

In 1978 Paschal and Ellis (22) grew 24 soybean lines in Puerto Rico to determine the incidence and effect of fungal infection on seed viability under tropical conditions. Seeds were harvested at maturity and two and four weeks later. The incidence of fungi increased from 9 percent on seed harvested at maturity to 45 percent for seed harvested four weeks later.

Environmental Insects

Insect pests are a part of the environment and may cause severe damage to developing soybean seeds. Some pierce the pods and subsequently the seedcoats, while others actually destroy portions of the pods. If insects pierce the pod walls and subsequently the seedcoats, they may either transmit diseases directly to the seeds or provide openings through which subsequent invasion by pathogens may take place. In addition, these minute openings allow moisture to penetrate into the pod cavity, causing deterioration. Insects that eat large portions of the pod and destroy the protection it affords allow moisture and pathogens to attack the developing seed.

In studies with the southern green stink bug, *Nezara viridula* (L.), Todd and Turnipseed (27) infested caged soybean plants with various population densities to determine their effects on seed quality. Significant increases in seed damage occurred from population densities of one, three, and five bugs per row foot, and seed germination and emergence and seedling survival were significantly reduced by all degrees of damage. Likewise, other investigators (11, 12) have reported that heavy infestations of stink bugs at the early pod-fill stage cause drastic reductions in seed quality. Other insects that have been implicated in the reduction of seed quality in soybeans are bean leaf beetle, *Cerotoma trifurcata* (Forester), which transmits bean pod mottle virus (BPMV) (4), and *Piezodorus guildinii* (Westwood), which reduced germination and seed quality in Brazil (3).

CURRENT RESEARCH AND DEVELOPMENTS

Prospects for improving the seed quality of tropically adapted soybean cultivars are encouraging. An initial approach is to exploit the genetic variability that cultivars exhibit to differences in rates of field deterioration. Lassim's (13) work showed that certain cultivars possess differential rates of deterioration even though the cultivars matured at the same time. Paschal and Ellis (22) and Costa (3) provided additional evidence that substantial genetic variation exists in different cultivars for seed quality characteristics measured under tropical conditions. Cultivars with small seed size appear to be better adapted to some tropical climates. They have been reported to resist weathering and invasion by pathogens and to germinate and emerge better. Since some "weathering" resistant characteristics have been identified, breeding programs may concentrate on incorporating them into commercially acceptable cultivars.

Altering planting dates to allow the critical stages of seed maturation to coincide with favorable segments of the field environment may prove feasible. In a study on the effect of planting and maturity dates on soybean seed quality, Green et al. (7) found that when soybean plants were planted early so seeds matured during hot, dry weather, seeds produced were low quality. On the other hand, seeds from plants that were planted later and reached maturity after the hot, dry weather conditions had ended were high in quality. Investigations in this area have been initiated in Kentucky and Mississippi.

The use of systemic fungicides to provide some degree of protection against "weathering" pathogens has received considerable attention, and their commercial use in soybeans has spread to some areas of the southeastern United States. It has been pointed out that delay in harvest results in an increase in seedborne fungi and subsequently a reduction in germination (9, 18, 19). Ellis and Sinclair (6) used foliar applications of benomyl to reduce the incidence of seedborne fungi at maturity and suppress the increase of internally seedborne fungi. Investigations with such materials could prove beneficial; however, the economics of using them must be thoroughly studied.

Recent investigations by Potts et al. (23) revealed the influence of hardseededness on soybean seed quality. Comparisons were made between seeds of "Dare" and those of an experimental hardseeded line (D67-5677-1) that is similar to "Dare" in growth type and maturity. Hardseededness was beneficial in maintaining the viability of seeds remaining in the field for up to nine weeks after seed moisture initially declined to 20 percent. Resistance to moisture reabsorption by the hardseeded line was clearly superior to that of "Dare" (Table 3). Continuing work with the hardseeded line by Miranda has revealed similar results, and of particular interest is the fact that seeds of the hardseeded line exhibit very low levels of internally seedborne pathogens.

SUMMARY

In many ways seeds are a product of their environment, even though they exhibit specific genetic characteristics through their inheritance pattern. The complex of environmental conditions frequently overrides the expression of genetic characters, causing seeds to exhibit additional traits attributed to the environment (moldy seed coats, shrivelled seeds, split or wrinkled seed coats, or necrotic areas on the cotyledons). These traits lower seed quality, and the seeds are generally referred to as "weathered." To improve seed quality in subtropical and tropical soybean-producing areas, breeding programs should incorporate resistance to unfavorable conditions while continuing to stress the necessity for improved management and production practices.

CONSTRAINTS ON EFFICIENT PRODUCTION

Economically successful soybean production depends upon rapid and uniform emergence from the seedbed of equally healthy, competitive seedlings from only one planting. This ensures uniform and rapid growth, uniform maturity, and optimum yield. Serious problems arise when seedlings either emerge erratically over an extended period of time or fail to emerge to an acceptable stand. Replanting causes

Table 3. Effect of Field Environment on Two Soybean Cultivars in 1973 and 1974

Harvest date	Dare		D67-5677-1			
	Moisture	Germination	Moisture	Germination	HS	Total viable seeds
			percent			
1973						
10/8	21	86	16	90	8	98
10/11	15	90	11	61	31	92
10/14	12	89	12	60	35	95
10/29	16	93	11	57	40	97
11/5	32	5	22	39	47	86
11/12	17	51	10	30	62	92
1974						
10/4	16	94	10	82	15	97
10/12	9	99	9	50	46	96
10/19	10	90	8	45	46	91
10/26	9	91	7	35	59	94
11/2	13	86	9	44	49	93
11/9	10	72	8	41	46	87
11/16	16	63	9	42	46	88
11/23	12	54	9	49	39	88
11/30	14	53	11	41	43	84
12/7	14	51	12	43	38	81

tremendous losses in time, investments and overall production efficiency. In fields where farmers decide not to replant even a poor, thin stand, production problems will continue to plague them throughout the crop season. Weeds, diseases, insects, and environmental conditions will continue to make an initially poor stand even more unacceptable as the season progresses.

Thus, it is essential that increased emphasis be devoted to the production of high quality seeds that posses the potential to produce a profitable crop under an array of field conditions. Seed producers or seed production units must be established and tutored in acceptable seed production techniques to insure the availability of the necessary production input, that is, good healthy seeds. Emphasis also must be placed upon the necessity of handling the delicate soybean with care in view of its sensitive physiological and structural makeup. Incorporating good cultural and management techniques into specialized "seed production" programs should help resolve stand establishment problems with the commercial crop.

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DISCUSSION

R.B. Dadson: Tropical climates have either a season of hot, wet conditions or only hot conditions without rain. We suggest to farmers that they produce seed in the second season, even though it is hot but without rain. Is this correct?

C.H. Andrews: Yes, I agree. You cannot alter an environment, but you can take advantage of certain seasons that minimize environmental interactions. That is, it is better to grow soybeans during a hot season (irrigating if necessary) than during a hot, wet season.

Lian Zheng Wang: Do you mean that hardseeded soybeans are all good, viable seed?

C.H. Andrews: Yes. If you scarify hard seeds, they will produce normal, viable seedlings. We have found that nearly all of our hard seeds are completely viable.

B.B. Singh: After how many months of storage do the hard seeds become permeable and germinate without scarification?

C.H. Andrews: Hardseeded soybeans gradually become permeable over time in storage. We can expect that a large percentage of the hard seeds will become permeable from the time of harvest and prior to the next planting season. It has been shown that mechanical harvest (and possibly animal or hand threshing) will create sufficient scarification for germination.