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The Relationship Between Seed Density/Specific Gravity, Seed Quality and Plant Performance

C.C. Baskin

THE RELATIONSHIP BETWEEN SEED DENSITY/SPECIFIC GRAVITY, SEED QUALITY AND PLANT PERFORMANCE[1]

Charles C. Baskin[2]

Density is defined by Webster as "the ratio of the mass of an object to its volume." One common measure of density is weight/unit volume, for example weight per bushel. Specific gravity is defined by Webster as "the ratio of the weight or mass of a given volume of a substance to that of an equal volume of another substance." We generally think of liquids when we refer to specific gravity. The specific gravity of pure water is 1.0. Altering the viscosity of pure water changes its specific gravity. For example, dissolving a material such as sucrose in water will increase the specific gravity of the liquid. The specific gravity of numerous other liquids is less than one. These may be used alone or mixed with water. If mixed with water, the specific gravity of the water mixture becomes less than one. Thus, solutions that differ in specific gravity can be obtained and used to separate materials such as seed into specific gravity groups or classes in a manner similar to separations made with air and mechanical devices such as a gravity table that are used to separate seeds into density groups or classes.

Density and specific gravity are quite similar but not the same. Seed separated by either means will perform similarly, i.e., high density seed will perform similarly to high specific gravity seed. However, if a sample of seed is separated into density groups by mechanical means, then any one of the groups can be further separated into specific gravity classes using liquids. In general, a more precise separation can be made with liquids than with air or by mechanical means.

Both methods of separation have advantages and disadvantages. Liquids are generally more difficult to work with than mechanical equipment. Liquid systems, at present, are not very adaptable to high capacity seed cleaning and conditioning operations as are gravity tables and aspirators. Seeds such as soybeans absorb

[1]This article is mostly based on the works of graduate students of the several major professors in Agronomy-Seed Technology at MSU.

[1]Professor and Agronomist, Emeritus, Seed Technology Laboratory, Miss. State University, Miss. State, MS.

the liquids at a more rapid rate than seeds such as sorghum. This tends to create problems with soybeans and similar type seeds.

The general relationship of seed quality to density or specific gravity is that quality of the seed increases as they increase. This is relative to the viability of the seed, i.e., high density seed may be very low in germination and some low density seed may be alive and germinable. In a given population of seeds with 50 to 80% or higher germination, however, the high density seed will generally be better quality than the low density seed.

Seeds of the same kind with similar germinations generally have a similar density/seed quality relationship, however, differences among varieties has been reported for sorghum and rice. In a study by Wattiranggoon (1989), seeds of three sorghum hybrids were similar in that approximately 80 to 95% of the seed were in the 1.26 to 1.34 specific gravity classes, while 80 to 90% of the seed of the two other sorghum hybrids were in the 1.18 to 1.26 specific gravity classes (Table 1). Similar variation among varieties in distribution of seeds among specific gravity classes was observed in rice by Sung and Delouche (1962) (Table 2). A much higher percentage of seeds of the Belle Patna and Blue Bonnet 50 varieties was in the >1.16 specific gravity class than those of the variety Nato. This variation in specific gravity among hybrids and varieties is a phenomenon that might be expected among different varieties of other species as well. There are differences among wheat varieties in test weight, for example. There are several factors that may affect seed density:

- Seed kind (rice 45 lb/bu, corn 56 lb/bu, wheat 60 lb/bu)
- Variety
- Weathering (weathered seed are less dense)
- Insect and disease damage
- Mechanical damage
- Maturity (fertility and drouth can affect maturity, immature seed are less dense)

Relationship to Laboratory Performance

Germination generally increases as seed density/specific gravity increases. This relationship is well illustrated in the results obtained by Cortes (1987) for sorghum (Tables 3 and 4); Sung and Delouche (1962) for rice (Table 5); Peske (1976) for bahiagrass (Table 6), Unsrisong (1987) for soybean (Table 7), Johnson *et al.* (1973) for cotton (Table 8), and Srijugawan (1975) for wheat (Table 9).

Table 1. Distribution by weight (%) of seeds of five grain sorghum hybrids in seven specific gravity classes.

Brand	Hybrid	Specific Gravity						
		>1.34	1.30	1.26	1.22	1.18	1.14	<1.14
		---------------	---------------	---------------	%	---------------	---------------	---------------
Dekalb-Pfizer	DK-50	2.9	49.8	38.7	6.9	0.9	0.4	0.4
Dekalb-Pfizer	DK-46	7.9	42.6	33.6	10.9	2.8	1.1	1.3
Funk	HW-7380	12.1	69.8	13.2	2.6	0.9	0.4	0.7
Cargill	575	0.0	6.0	47.0	35.9	7.3	2.5	1.3
Cargill	1091	0.0	3.7	18.0	39.0	22.2	10.0	6.0

After Wattiranggoon (1989).

Table 2. Distribution by weight (%) of combine run rice seed of three cultivars in four specific gravity classes.

Cultivar	Specific Gravity			
	1.10	1.11	1.14	1.16
Belle Panta	4.30	0.13	4.02	91.55
Nato	10.37	6.59	12.88	70.16
Blue Bonnet	6.84	4.86	3.96	84.34

After Sung and Delouche (1962).

Table 3. Relationships between average weight per bushel (density) and average germination of seed of seven sorghum cultivars/lines.

Volume Weight (lb/bu)	Germination %
56.7 a*	92 a
55.9 b	86 g
52.6 c	67 d
Ungraded	81 c

After Cortes (1987).

*Means not followed by the same letter are significantly different at the 0.01 level of probability as determined by Student Newmans Kuel's test.

Table 4. Relationship between specific gravity and average germination of seed of four sorghum cultivars/lines.

Specific Gravity	Germination %
>1.34	97a*
1.30	96a
1.26	90ab
Ungraded	86b
1.22	68c
1.18	51d
1.14	39e
<1.14	26f

After Cortes (1987).

*Means not followed by the same letter are significantly different at the 0.01 level of probability as determined by Student Newmans Kuel's test.

Table 5. Germination percentage of rice seed by specific gravity class.

Cultivar	Specific Gravity						
	<1.00	1.05	1.10	1.13	1.16	1.20	>1.20
Belle Panta	57	92	92	97	98	97	97
Nato	48	77	87	78	95	92	95
Blue Bonnet 50	67	83	93	97	100	100	100

After Sung and Delouche (1962).

Table 6. Relationship between seed density and germination of pensacola bahiagrass.

Density (wt/bu)	Germination %
39 (ungraded)	57b
31	28c
40	58b
42	68a
45	72a

After Peske (1976).

*Means not followed by the same letter differ significantly at the 0.01 level of probability as determined by Duncans New Multiple Range Test.

Table 7. Relationship between seed specific gravity and seed germination at two quality of two cultivars of soybeans.

Specific Gravity	Germination %
<1.16	64 b
1.18	79 a
1.20	83 a
>1.20	83 a
Ungraded	81 a

After Unsrisong (1987).

*Means not followed by the same letter differ significantly at the 0.05 level of probability as determined by DMRT.

Table 8. Relationship between density and germination of two lots of acid delinted cottonseed.

Cultivar	Density Class (lb/bu)	Germination %
Stoneville 7A	49	82 a
	47 (Ungraded)	81 a
	46	76 ab
	42	68 b
	36	42 c
Stoneville 213	50	85 a
	48	83 a
	46 (Ungraded)	77 a
	47	79 a
	41	59 b

After Johnson *et al.* (1973).

*Means within cultivars not followed by the same letter differ significantly at the 0.05 level of probability as determined by DNMRT.

Table 9. Mean germination percentages within each weight class for 25 lots of wheat seed.

Weight Class	Mean Germination (%)
Original seed	87 bc
Light seed	84 d
Medium seed	89 ab
Heavy seed	90 ab

After Srijugawan (1975).

*Means not followed by common letter differ significantly at .05 level of probability according to DNMRT.

Cotton seeds ranged from 36 to 50 lb/bu in density and 42 to 85% in germination (Table 8). Wheat seeds from three classes (light, medium and heavy) ranged from 85 to 90% germination, while sorghum seeds ranged from 52.6 to 56.7 lb/bu and germinated from 67 to 92%, compared to 81% for the ungraded seed (Table 9). When separated into specific gravity classes ranging from less than 1.14 to greater than 1.34 sorghum seed germination ranged from 26% to 97% while ungraded seed germinated 86% (Tables 3 and 4). Rice seeds ranging in specific gravity from less than 1.0 to greater than 1.2 ranged in germination from 48% to 100% among three varieties (Table 5). Bahiagrass seeds ranged from 31 to 45 lb/bu and germinated from 28 to 72% with ungraded seed germinating 57% at 39 lb/bu (Table 6). Differences among density/specific gravity levels were more pronounced in the grains than in soybeans and to some extent than in cotton. The differences among varieties was quite pronounced.

Differences in performance of seed of different density/specific gravity levels is often evident in laboratory tests other than germination. Low density (light) wheat seed germinated lower after accelerated aging than did the original sample and other density fractions, (Srijugawan, 1975, Table 10). The speed of germination index was highest in Pensacola bahiagrass when density was 42 lb/bu or greater, (Peske, 1976, Table 11). Radicle and plumule growth of three varieties of rice were measured by Sung and Delouche (1962). Both plumule and radicle length increased as specific gravity increased. Again, there were differences among varieties Belle Panta and Blue Bonnet responded similarly, while Nato produced somewhat less plumule growth and considerably less radicle growth. Plumule and radicle growth of hybrid grain sorghum were measured by Wattiranggoon (1989). Differences were greater in radicle growth (Table 12).

Assman (1983) evaluated 12 lots of gravity graded soybeans using the tetrazolium test and found that the percent high vigor seeds increased and the percent low vigor seed decreased as weight per bushel increased (Table 13). Similar responses were reported by Gregg (1969) for cotton seed. As weight per bushel increased germination after accelerated aging and soil cold test emergence increased (Table 14).

Relationship to Field Performance

Field performance of seed of different specific gravity/density classes for the different crop species has not differed as consistently as have laboratory tests. Differences in plant growth responses in rice related to seed density were observed by Rocha (1975). Days to head exertion, anthesis and seed maturity decreased as seed specific gravity increased but the performance of plants from seed in the high specific gravity classes were not different from the ungraded sample (Table 15). Similar results were obtained by Islam (1976). Plants from seeds in the lower specific gravity classes required more time to head exertion, anthesis and

Table 10. Mean germination percentages within each weight class for 25 lots of wheat seed after accelerated aging at 40°C-100% relative humidity.

Weight Class	Mean Germination (%)
Original seed	82 ab
Light seed	78 c
Medium seed	82 ab
Heavy seed	84 a

After Srijugawan (1975).

*Means not followed by common letter differ significantly at .05 level of probability according to DNMRT.

Table 11. Relationship between seed density and speed of germination of pensacola bahiagrass.

Density (wt/bu	Speed of Germination Index
39 (Ungraded)	4.43 b
31	2.37 c
40	2.48 b
42	5.25 a
45	5.75 a

After Peske (1976).

*Means not followed by the same letter are significantly different at the 0.05 level of probability as judged by DNMRT.

Table 12. Effects of specific gravity of the seeds on the radicle length after 5 days under standard germination test conditions for five sorghum cultivars.

Specific Gravity	Cultivar				
	DK-50	DK-46	HW-7380	Cargill 575	Cargill 1091
	mm				
>1.34	95 A	106 A	113 AB	-	-
1.30	91 A	103 A	123 A	116 A	81 A
1.26	94 A	102 AB	116 AB	111 AB	80 A
1.22	84 AB	87 ABC	101 B	99 C	70 AB
1.18	79 B	79 BC	86 C	79 D	64 AB
1.14	66 C	87 C	67 E	67 E	57 B
<1.14	52 D	59 D	65 D	47 F	42 C
Control	81 B	97 AB	104 B	103 BC	73 A

After Wattiranggoon (1989).

*Means within a cultivar not sharing the same letter differ significantly at the 0.05 level of probability as determined by the SNK test.

Table 13. Percentage high and low vigor seed in twelve lots of soybean seed of different density classes; vigor ratings determined by tetrazolium test.

Seed Density Classes									
Ungraded		Heaviest		2		3		4	
High Vigor	Low Vigor	High Vigor	Low Vigor	High Vigor	Low Vigor	High Vigor	Low Vigor	High Vigor	Low Vigor
30.7	18.36	39.8	12.1	36.8	15.3	28.6	18.1	18.7	26.0

After Assman (1983).

*Means not followed by the same upper case (high) or lower case (low) letters are significantly different at the 0.05 level of probability as determined by SNK test.

Table 14. Standard germination, germination after accelerated aging and soil cold test emergence of seed from different density classes of 19 lots of acid delinted cottonseed.

Weight/Bu (lbs.)	Standard Germination (%)	Germination After Acc. Aging (%)	Soil Cold Test Emergence (%)
33	35	12	18
39	68	30	45
41	75	43	48
42	74	54	50
44	80	67	63
45	80	73	65
46	80	68	67

After Gregg (1969).

Table 15. Number of days to 50% panicle exertion, anthesis, and maturity of plants produced from five specific gravity classes of Starbonnet rice seed.

Seed Classes Specific Gravity	Days after Planting		
	Exertion	Anthesis	Maturity
Check	97.6	101.6	142
1.00-1.05	104.0	108.1	151
1.05-1.13	98.5	102.6	148
1.13-1.20	97.6	101.5	142
>1.20	96.3	100.3	142

After Rocha (1975).

Data were not analyzed statistically.

maturity, but there was no significant differences between the ungraded sample and the higher density classes. Differences in plant height of soybeans related to seed density were erratic (Unsrisong 1987). In 1985 there were no differences while in 1986 growth patterns did not correlate to seed density classes (Table 16).

Differences in field emergence and days to anthesis for plantings with different seed size classes of pearl millet seed were observed by Lawan *et al.* (1985). Small and medium size, low density seed were significantly lower in field emergence and required a longer period of time for anthesis than the other seed size/density fractions of the lot (Table 17). There were no significant differences in performance of medium and high density, small or medium size seed and no significant difference in performance of the large seed fraction of low, medium or high density seed.

Relationship to Yield

Differences in yield related to density of seeds plants have been demonstrated in some species but not in others. The performance of rice plants from seeds from different specific gravity classes was studied by Rocha (1975). Yield from the highest seed density class, >1.20, was significantly higher than other classes. When yields were compared, using the yield of the check sample as 100%, the highest density class produced 27.8% more rice. This is a considerable difference in yield. Islam (1976), however, did not find any significant differences in yield of rice plants between the check (ungraded sample) and the higher density seed classes.

Johnson *et al.* (1973) reported differences in yield among different seed density levels of gravity graded cotton seed (Table 18). Yield is favored for the higher density seed. With one exception, seed with a bushel test weight of 46 pounds or higher produced the higher yields. Unsrisong (1987) did not find any significant differences in yield between seed vigor levels or among seed density classes in soybean (Table 19).

Yet, evidence favoring the superior performance of high density/high specific gravity seed is abundant. Kreig and Bartee (1975) made the following statements:

- "Results suggest that seed density is the best predictor of cottonseed germination, emergence and potential seedling vigor".

- "Seed separation for improvement in seed quality (of cotton) should be based on density rather than other seed properties."

Tupper (1969) working with cottonseed stated:

Table 16. Differences in height of centennial soybean plants (cm) at 21 days are related to seed specific gravity class.

Specific Gravity Class	Year	
	1985	1986
>1.16	14.5 a	20.6 a
1.18	15.0 a	19.8 ab
1.20	15.5 a	18.9 b
>1.20	15.0 a	19.6 ab
Non-Separated Seed	14.9 a	19.2 b

After Unsrisong (1987).

*Means within columns not followed by the same letter are significant at the 0.05 of probability as determined by SNK test.

Table 17. Effect of seed density and seed size on field emergence and days to anthesis of pearl millet.

Seed Density	% Field Emergence			Days to Anthesis		
	Small	Medium	Large	Small	Medium	Large
Low	40	43	59	70	66	63
Medium	57	57	58	63	63	63
High	59	57	62	63	63	63

After Lawan *et al.* (1985).

LSD 0.05 for comparing interaction means; field emergences = 6% days to anthesis = 3.

Table 18. The relationship between seed density (wt/bu) and yield of two cultivars of cotton.

Density Class	Density wt/bu	Lint yield (lb/A)
	Stoneville 7A	
D - 1	49.3	989 a
Ungraded	47.3	900 a
D - 2	45.9	820 b
D - 3	42.3	929 a
D - 4	36.8	774 c
	Stoneville 213	
D - 1	50.0	1027 a
D - 2	48.3	969 a
Ungraded	46.0	944 a
D - 3	46.5	851 b
D - 4	41.4	772 b

After Johnson *et al.* (1973).

*Means not followed not followed by the same letter differ significantly at the 5% level of probability as determined by DNMRT.

Table 19. Yield of two cultivars of soybeans as influenced by seed quality level and specific gravity class.

Specific Gravity Class	Seed Quality Level	
	High	Low
	----------------tons/ha----------------	
>1.16	2.16	2.05
1.18	2.29	2.26
1.20	2.14	2.34
>1.20	2.13	2.14
Non-Separated Seed	2.36	2.23

After from Unsrisong (1987).

- ♦ "In a combined analysis of germination and growth, seed density had such a strong influence on the earliness of germination that it overshadowed the influence of seed weight on growth."

Although high density/specific gravity of planting seed does not always translate into yield, the increases in germination, rate of seedling growth, and earliness of plant development and maturation provide enough advantages to justify conditioning of seed to produce a high density product.

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