EMERGENCE, YIELD, AND YIELD-COMPONENTS RESPONSES TO SIZE AND DENSITY SEPARATIONS OF PEARL MILLET SEED PRODUCED BY THREE MANAGEMENT PRACTICES

by

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INTRODUCTION

Pearl millet [Pennisetum americanum (L.) Leeke] is one of the most important food crops in the semi-arid regions of Africa and Asia due to its ability to tolerate the harsh environment of low, irregular rainfall and high temperatures. Though statistics are not complete, an estimated 65 to 70 million hectares of millet are grown worldwide yielding an estimated 40 to 45 million metric tons (Rachie and Majmudar, 1980). In a 1975 survey of millet use in northern Nigeria, about 85 percent had been used for human consumption, 14 percent was still intended for consumption, and only 1 percent was sold (Thakare, 1977). High protein and amino acid contents make millet important for local diets.

Suboptimal plant stands are thought to be one of the major problems in the production of pearl millet. Part of the problem is the small size of millet seed (5-12 g/1000 seeds) as compared to other crops of the area (eg: sorghum (Sorghum bicolor (L.) Moench): 20-40 g/1000 seeds, cowpeas (Vigna unguiculata): 100-200 g/1000 seeds, or groundnuts (Arachis hypogaea): 250-500 g/1000 seeds). So small a seed requires shallow planting for emergence which then increases the risk of moisture depletion during germination and early seedling growth. Nutrient reserves within a small seed are minimal so very quickly the seedling is dependent on the environment for its nutrient uptake. Harsh environmental conditions can further hurt stand establishment.

Part of the Kansas State University research effort has been aimed at improving millet seed characteristics by cultural management practices. Work by Modiakgotla (1985) showed an emergence response of millet seed exhibiting increased size, weight, density, and protein content as a result of management practices.

Some have felt that seed differences realized by imposing management practices here in the Great Plains would not be equally effective in semi-arid regions where the environment is more variable and harsh. It is reassuring to see that Berhe and Mohamed (1983) found that seed produced by the management practice of head cutting has increased seed weight in Sudan. These heavier seeds produced taller and more vigorous seedlings.

The objective of this study was to determine if size and density separations of seeds produced by different management practices effected subsequent seedling establishment, yield, and yield-components.

LITERATURE REVIEW

Seed Size and Seedling Growth

Seedling size (growth rate) has been related to seed size (including weight and density) in a number of studies with a variety of crops. This relationship has been demonstrated by two methods. First by comparing different varieties of a crop. With wheat (*Triticum aestivum* L.) Evans and Bhatt (1977) showed seed size influenced seedling vigor in all cultivars tested regardless of seeding depth. There was a tendency for protein levels to be higher in large seed size classes. Correlation between seed protein content and seedling vigor was highly significant. Maiti (1977) found that with different genotypes of millet, plant dry weight seven and fifteen days after emergence was positively correlated with seed weight. This degree of association decreased over time. In wheat, Ries and Evenson (1973) found a high positive correlation between seedling vigor and seed size. Rogler (1954) reported that different lines of crested wheatgrass [Standard, *Agropyron desertorum* (Fisch.) Schult., and Fairway, *A. cristatum* (L.) Gaertn.] separated by size and planted at shallow depths had equal emergence but seedlings from large seeds grew more rapidly and were larger.

The second method was to divide a seed lot into large and small seeded fractions. Burris et al. (1973) divided four varieties of soybeans (*Glycine max* L.) into four size divisions. The three largest sizes showed superior leaf area and field height. Delouche et al. (1985) stated that within a line the smaller seeds of sorghum and millet produced plants that grew slower than those from seed of average or large size. Working with millet, Gardner (1980) reported that separating seeds on the basis of size and density selected the most vigorous seeds in a seed lot. Gelmond (1972) realized significant leaf area differences from large versus small seed of cotton (_Gossypium hirsutum_ L.). In barley (_Hordeum vulgare_ L.), seed size affected the size of the first two leaves (Kaufmann and Guitard, 1967). Kiesselbach (1924) found small wheat seeds produced plants which tillered less and were shorter than plants from large seeds. Kneebone and Cremer (1955) divided native grass seeds into size lots and found that larger seeds had the more vigorous seedlings. Krieg and Bartee (1975) found seed density to be the best predictor of cotton seedling vigor. Lawan et al. (1985) reported that millet seedling height at 24 days was positively related to seed density. Working with grain sorghum, Maranville and Clegg (1977) found seedling size related to seed size. Radwan et al. (1972) reported that early seedling growth in berseem clover (_Trifolium alexandrium_ L.) was significantly affected by size only.

The advantage of larger seed is credited to increased protein by Ries and Evenson (1973). They found that large seed had more mg protein per gram seed weight than small seed and thus attributed the early growth advantage to protein. Arnolt (1975) found a greater amount of endosperm to be available for heterotrophic growth and the transitional period into autotrophic growth. All seeds need to utilize an initial quantity of substrate for mesocotyl growth. A greater percent is used in small seeds thus lowering root and leaf growth rates.

Seed Size and Germination

The relationship of seed germination to seed size is basically of two kinds of results. 1) Germination percentage within a seedlot is equal across size classes. Gelmond (1972) found large and small cotton seed germinated equally in laboratory tests. There were no differences in germination between seed sizes in buffalograss (*Buchloe dactyloides*), indiangrass (*Sorghastrum nutans* L.), sand bluestem (*Andropogon hallii*), and sideoats grama (*Bouteloua curtipendula* Michx.) (Kneebone and Cremer, 1955). Lawan et al. (1985) found that millet separated by size had no germination differences. Ratwan et al. (1972) evaluated the importance of seed size among seedlots of berseem clover under controlled germination. Within a seedlot, size did not affect germination but there was an effect between seedlots.

2) Others have found similar germination for large and medium sized seed, but smaller, lighter seeds show lower germination. With witchweed, Bebawi et al. (1984) found significant size and weight effects on germination when going from large, heavy seeds to small, light seeds. Small millet and sorghum seeds within a population at a location

were generally inferior in germination (Delouche et al. 1985). Germination was affected by size of switchgrass seed (Kneebone and Cremer, 1955). In cotton, Krieg and Bartee (1975) found density to be the best predictor of germination. Working with grain sorghum, Maranville and Clegg (1977) reported that dense seed had higher germination. Sung and Delouche (1962) found similar results with rice (Oryza sativa).

Seed Size and Yield

Grain yield has shown variable response to seed size. Burris et al. (1973) found that soybean yields were a function of seed size when plant populations were equal. Chhina and Phul (1982) also found millet to give a positive yield response to increased seed size when populations were equal. With equal weights of seed (more small seeds were planted) the differences were less. Kiesselbach (1924) divided wheat seed into size and density fractions. With plots planted on an equal number of seeds or weight basis, plants from large seed out-yielded plants from small, light seed. When large seed was compared to unselected seed on an equal number of seeds or weight basis the yield advantage was only 4% and 1%, respectively. He concluded that there was no practical advantage to grading small seed which is reasonably free of trash and inert matter. Lawan et al. (1985) found that density affected millet yields positively. With sorghum Maranville and Clegg (1977) reported that yield was not a function of size or density when the same number of viable seeds were planted. Robertson (1984) found wheat to give a positive yield response to seed size.

Seed Size and Emergence

Percent emergence has usually been positively related to seed size. Abdullahi and Vanderlip (1972) found sorghum establishment was highest with medium to large seed. With witchweed, Bebwai et al. (1974) reported a significant difference in emergence when going from large, heavy seed to small, light seed. Burris et al. (1973) found three larger classes of soybeans to have superior emergence over the smallest class. Emergence was generally inferior for small seed of millet and sorghum grown in any one season and location (Delouche et al. 1985). Gardner (1980) found the largest density fraction of millet seed gave higher percent emergence. Buffalograss and sideoats grama showed no significant emergence differences while switchgrass did show differences among seed sizes (Kneebone and Cremer, 1955). Sizing seed according to density was the best predictor of emergence for cotton (Krieg and Bartee, 1975). With millet, Lawan et al. (1985) found seed size and density to be effective criteria for field establishment. Crested wheatgrass planted at the 5-8 cm depth showed a high positive correlation between seed size and percent emergence. At the 1-3 cm depth emergence differences between seed sizes were not significantly different (Rogler, 1954). Rice seed with higher specific gravity showed superior emergence as compared to seed of low specific gravity (Sung and Delouche, 1962). Wilkes et al. (1968) stated that cotton seed density and weight are directly related to rate of emergence and total emergence.

Germination and Establishment

The role of seed germination in establishment is variable. Laboratory germination tests as prescribed in Rules for Testing Seeds (Anon., 1954) should predict planting rates and expected field stands for seedlots under favorable conditions. Singh et al. (1971) found millet germinated best at 30 to 32° C and germination was complete in three to four days. Field conditions at and after planting are often sub-optimal thus standard germination results often overestimate field establishment.

With onions, Clark and Klien (1962) showed that standard germination test and the cold test proceedures provide limits within which to expect establishment. Mwageni (1978) worked with vigor measurements on millet. He found standard germination was consistently higher than field establishment. Vanderlip et al. (1973) stated that standard germination test overestimated field establishment of sorghum.

Establishment and Yield

Since sub-optimal plant stands are thought to be one of the major constraints to production of millet in the semi-arid tropics (ICRISAT, 1981) the relationship between establishment and yield is interesting. Pearl millet was grown at ICRISAT using 20 populations ranging from 50,000 to 400,000 plants per hectare. Grain yields per hectare increased to a maximum at 150,000 plants per hectare and was maintained through 400,000 plants per hectare due to plasticity in productive tiller number per plant (Carberry et al. 1980). Gardner (1980) showed small seeds of millet to have lower percentage emergence which carried forward to lower head numbers and grain yields. By thinning half of the millet plots to a constant stand Modiakgotla (1985) had significantly different plant populations, but there were no significant differences in heads per hectare, 1000 seed weight, or yield. Mortlock (personal communication) found no difference in yields of pearl millet in populations ranging from 24,000 to 400,000 plants per hectare at Manhattan, Kansas in 1985.

Mechanical Separations and Management Production

Seed size (including weight and density) has been shown to have effects on germination, establishment, and yield. Most research has been based on laboratory separations of seed by size. Derera and Bhatt (1972), working at the field plot level, found the use of sized sieves on harvest combines resulted in a greater percent of individual wheat seeds possessing increased kernel weight than seed unselected for size.

Mechanical separations are not the only way to obtain improved seed characteristics. Modiakgotla (1985) reported that the crop management classes of head cutting, spikelet removal, and head selection produced improved seed characteristics (size, weight, density, and protein) and retained their germination viability for a longer time than control seed. Earlier work by Okonkwo and Vanderlip (1985) showed head selection and spikelet removal effective in millet seed quality improvement. Continuous selection of large seed in wheat by Taylor (1928) showed significant increases in yield and a small tendency to increase bushel test weight.

Introducing these procedures to small farmers in the semi-arid regions of Asia and Africa must involve easy, small scale crop management practices. In Sudan, Berhe and Mohamed (1983) reported heavier seeds were obtained in sorghum and millet by reducing head size by 1/2 to 2/3 immediately following flowering. Superiority was measured by seed weight, rate of emergence from deeper planting, and by seedling vigor.

MATERIALS AND METHODS

Seedlots

Seed used in this study was of a Senegal Bulk population originally from the Fort Hays Branch Experiment Station. In 1984 the following crop management practices were applied in the production of the seed for this study.

1. Control: Customary management practices were used to produce the seed.
2. Head cutting: The top 2/3 of each panicle was cut off after it had emerged from the flag leaf.
3. Spikelet Removal: Spikelets were removed from an area 1.5 cm wide from top to base of each panicle after it emerged from the flag leaf.

For the remainder of this paper, management classes refer to the above methods of seed production. Table 1 indicates the characteristics of the seed produced by these management classes.

Seed size, both percent of seeds greater than 0.22 cm and average seed diameter, showed a significant advantage to the head cut and spikelet removal management classes. In comparison with previous years seed weights, the 1984 management class weights were not as varied as in other years (Table 2).

Table 1. Effect of crop management on seed quality.

Management	%>.22cm	1000 Sdwt (g)	Density (g/cc)	Av Sd Dia (cm)
Control	52.18 b*	7.97 a	1.220 a	.2228 b
Spikelet Removal	63.44 a	8.32 a	1.219 a	.2298 a
Head cut	62.90 a	8.30 a	1.203 b	.2302 a
LSD (.05)	5.39	.37	.012	.0035

* Means with the same letter within a column are not significantly different.

Table 2. Comparison of 1000 seed weights, 1980-1984.

Management	1980[1]	1981[1]	1982[2]	1984
Control	8.38 b*	10.9 b	8.4 b	7.97 a
Spikelet Removal	9.18 a	12.8 a	10.4 a	8.32 a
Head Cut	----	----	----	8.30 a

* Means with the same letter within a column are not significantly different (P = .05).

[1] Data from Okonkwo, 1983.
[2] Data from Rubottom, 1982.

The following mechanical separations were performed within each management class:

1. Control: No mechanical seed separation.
2. Large: Seeds retained in a 0.24 cm round-hole sieve were used. Small seeds were discarded.
3. Dense: Seeds were sorted by density using a sucrose-water solution (56%-44% by weight). About a liter of the solution was put into a funnel with the bottom closed. Seeds were poured into the solution,

the lighter seeds rose and seeds with a density greater than 1.265 g/cc settled to the bottom. Opening the bottom of the funnel the high density seeds were separated out, rinsed with clean water and air dried. The low density seeds were discarded.

4. Bold: The bold class was a combination of the size and density separations. A quantity of large seed was given the 1.265 g/cc density separation and a quantity of dense seed was given the 0.24 cm size separation. The equal mixing of these two separations became the bold class.

5. Wet Control: To check that there were no effects resulting from seed soaked in the sucrose solution, a control sample was soaked in the sucrose solution, rinsed, and dried similar to the dense and bold class.

Through the remainder of this paper these will be referred to as separation classes.

Germination

Germination tests were made on all seedlots. Individual management class by separation class combinations will be referred to as seedlots (15 combinations are possible). Four replicates of 25 seeds from each seedlot was placed on double filter paper in petri dishes. The filter paper was moistened with a 0.26% sodium hypochlorite (Chlorox) solution. Petri dishes were randomly placed in a germinator at 30^{o} C for 4 days. Seeds were considered germinated when they had produced both a plumule and radicle. Germination was calculated as a percent of the original 25 seeds in the dish.

Yield Trials

Field trials were conducted in 1985 at the Ashland Agronomy Farm, Manhattan, and the Sandyland Experimental Field, St. John. The soil type at Manhattan is a Haynie fine sandy loam (Mollic Udifluvent; coarse-silty, mixed, mesic) while at St. John the soil type is a Pratt loamy fine sand (Psammentic Haplustalf; sandy, mixed, thermic).

Both locations had good growing season conditions (Table 3.) Spring rains provided good moisture in the soil profile. Planting at both locations was into good moisture. The mean temperatures for the growing season were below normal at both locations. Rainfall at St. John was above normal and at Manhattan below normal.

Table 3. Growing season rainfall and temperature summary, 1985.

	St. John				Manhattan			
Month	Rainfall (cm)		Mean Temp (C°)		Rainfall (cm)		Mean Temp (C°)	
	1985	Ave*	1985	Ave	1985	Ave	1985	Ave
June	8.9	9.1	22.3	24.3	10.1	13.4	20.6	23.8
July	6.1	7.4	26.9	27.1	3.2	10.1	26.0	26.6
Aug	11.0	5.9	24.4	26.1	13.1	7.9	22.6	26.1
Sept	9.6	7.0	19.7	21.2	11.9	10.3	19.1	20.7

* 30 year averages.

The experimental design was a split-plot with thinning to a constant stand and no thinning as main plots and seedlots as the subplots. Each main plot was replicated four times. Establishment was replicated eight times because seedling stands were recorded before the split-plot treatment was applied. Comparison of thinned and unthinned plots separates establishment effects from seed quality effects on yield and yield-components.

Subplots consisted of four rows 7.5 m long, with 0.75 m between rows. Planting was with a two-row air planter. Seed was placed about 4 cm deep. Furadan (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl-carbamate) was placed in the furrow with the seed at 1.12 kg/ha (1 lb/a) to control chinch bugs (Blissus leucopterus). No herbicide was used at either location; weed control was by cultivation and hand weeding.

Trials were planted 14 and 24 June at St. John and Manhattan, respectively. The planting rate was 100 seeds per 7.5 m row. Establishment counts and thinning treatments were made 18 days after planting. Plants in the split-plots were thinned to 37,300 plants per hectare at both locations.

Of the inner two rows of each four row plot, only 4.5 m of row was hand harvested, heads dried, and threshed. Grain yields were adjusted to 13% moisture. The number of heads per plot was recorded. Thousand-kernal weights were oven dry. Seed number per head was calculated fron head number, total weight, and seed weight.

RESULTS

Germination

Analysis of variance for percent germination is shown in Table 4. Only differences due to crop management effects were significant. Seed separation effects and interactions were not significant.

Table 4. Analysis of variance, percent germination, 1985.

Source	df	Mean Squares
Rep	3	60.0
Management	2	957.1 **
Separation	4	165.7
Management * Separation	8	42.7
Error	42	104.6

** Significant at 1%

All seed regardless of class had low germination. Seed from the spikelet removal management class showed significantly higher germination than control (Table 5). Head cut was not significantly different from control.

Table 5. Effect of crop management on percent germination, 1985.

Management	%Germination
Control	51.0 b*
Spikelet Removal	60.0 a
Head Cut	46.4 b
LSD (.05)	6.5

* Means with the same letter are not significantly different.

Comparing 1984 management classes to studies with seed produced by similar methods in earlier years showed 1984 seed to be of lower germination (Table 6). The factors causing lower germination were not identified. Causes of low germination could be any of a number of factors ranging from 1984 growing season effects to seed threshing, handling, storage, or dormancy.

Table 6. Effect of crop management on percent germination, 1980-1984.

	Year seed was produced			
Management	1980[1]	1981[1]	1982[2]	1984
Control	97.7 a*	96.0 a	76.5 b	51.0 b
Spikelet Removal	99.7 a	92.5 b	85.8 b	60.0 a
Head Cut	----	----	----	46.4 b
C V	1.9	3.0	8.3	19.5

* Means with the same letter within a column are not significantly different.

[1] Data from Okonkwo, 1983.

[2] Data from Robottom, 1982.

St. John Field Trials

Analysis of variance on establishment (Table 7) showed strong replication effects and significant management and separation effects at St. John.

Table 7. Analysis of variance, establishment, St. John, 1985.

Source	df	Mean squares
Rep	7	240.6 **
Management	2	106.3 *
Separation	4	81.7 *
Management * Separation	8	43.0
Error	98	32.1

* Significant at 5%
** Significant at 1%

Differences between replications were visible in the field with west to east showing decreased establishment (Table 8). There were eight replications of establishment data because the counts were taken before the split-plot treatment of thinning to a constant plant stand. Progressive change in establishment across the field was possibly related to soil properties.

Table 8. Effect of replication on percent establishment, St. John, 1985.

Replication	% Establishment
1 (West)	35.7 a*
2	35.0 a
3	32.7 ab
4	34.3 ab
5	30.4 bc
6	27.6 cd
7	25.3 d
8 (East)	27.0 cd
LSD (.05)	4.1

* Means with the same letter are not significantly different.

Management effects on establishment showed the spikelet removal class better than head cut (Table 9). Control was not significantly different from spikelet removal or head cut. Spikelet removal showing better establishment than head cut could relate back to percent germination which had a similar relationship.

Table 9. Effects of crop management on percent establishment, St. John, 1985.

Management	% Establishment
Control	30.6 ab*
Spikelet Removal	32.8 a
Head Cut	29.6 b
LSD (.05)	2.5

* Means with the same letter are not significantly different.

The effect of separation classes on establishment showed dense seed significantly better that control (Table 10). The wet control class not being different from control signifies that soaking in sucrose for the density separation had no influence on the seeds establishment characteristics. Large seed was not different from control seeds. Bold seed was not significantly different from any other separation class.

Table 10. Effect of seed separation on percent establishment, St. John, 1985.

Separation	% Establishment
Control	30.2 b*
Large	29.9 b
Dense	33.7 a
Bold	32.0 ab
Wet Control	29.3 b
LSD (.05)	3.2

* Means with the same letter are not significantly different.

The analysis of variance of yield and yield-components (Appendix Table 1) shows strong replication differences in yield, heads per hectare, plants per hectare, and 1000 seed weight. Looking at these replications (Table 11) show yield and heads per hectare significantly less in replication 1 as compared to replications 2 to 4. Plants per hectare were greatest on replication 1, this agrees with establishment data. The replication differences in yield and heads per hectare probably resulted from southwest winds that sandblasted replication 1. There was good establishment in replication 1, but head number and yield was down.

Table 11. Effects of replication on grain yields, heads per hectare, plants per hectare, and 1000 seed weight, St. John, 1985.

Replication	Yield (kg/ha)	Heads/ Ha	Plants/ Ha	1000 Seed Weight (g)
1 (West)	2,017 b*	112,169 b	48,790 a	7.753 b
2	2,554 a	133,455 a	48,216 a	8.133 a
3	2,665 a	146,896 a	42,428 b	7.867 b
4 (East)	2,779 a	142,065 a	41,902 b	7.953 ab
LSD (.05)	295	12,299	3,812	.209

* Means with the same letter within a column are not significantly different.

Thinning, as expected, reduced plants per hectare (Table 12). Variability within the thinned plots was minimal due to thinning. Unthinned plots ranged in population from 33,005 to 83,230 plants per hectare.

Table 12. Effect of thinning on plants per hectare, St. John, 1985.

Split	Pl/Ha
Thinned	37,310 b*
Unthinned	53,358 a
LSD (.05)	11,689

* Means with the same letter are not significantly different.

The absence of significant effects in yield, heads per hectare, 1000 seed weight, or seed per head suggests that millet in thinned plots had the capacity to compensate for low population by tillering. In population trials in the same fields Mortlock (personal communication) found no yield differences in populations ranging from 24,000 to 400,000 plants per hectare.

Management effects on subsequent grain yield and 1000 seed weight gave a significant advantage to the control and head cut class over spikelet removal (Table 13). The head cut class was also significantly higher than spikelet removal in seeds per head.

Table 13. Effects of crop management on grain yields, 1000 seed weight, and seeds per head, St. John, 1985.

Management	Yield (kg/ha)	1000 Seed Weight (g)	Seeds/ Head
Control	2,592 a*	8.025 a	2,360 ab
Spikelet Removal	2,294 b	7.821 b	2,257 b
Head Cut	2,626 a	7.935 a	2,450 a
LSD (.05)	258	.181	132

* Means with the same letter within a column are not significantly different.

These findings are counter to those for germination and establishment where the spikelet removal class gave higher germination and establishment. Looking at the random distribution of plots within each replication, the first and second replications have 13 of the 20 spikelet removal combinations along the south and west edge of the field where blowing sand was a problem. Thus effects of the spikelet removal class on yield and yield-components could have been the result of location in the field.

Gardner (1980) showed an establishment advantage for the dense class over control. This did not carry over into a yield advantage. These results agree because there were no separation effects in this trial.

Thinning by management class interaction showed a significant advantage (10% level) for unthinned head cut over unthinned spikelet removal seedlots when considering heads per hectare (Table 14). This did not carry over into yield or yield-components. Again, low head number from the unthinned spikelet removal seedlots could have been a location effect since 8 of 10 of these plots in replication 1 and 2 were on the south side of the field where sandblasting occurred.

Table 14. Effects of thinning by crop management interaction on heads per hectare, St. John, 1985.

Thin * Management	Heads/Ha
Thinned Control	134,388 ab*
Thinned Spikelet Removal	134,173 ab
Thinned Head Cut	127,284 ab
Unthinned Control	139,195 ab
Unthinned Spikelet Removal	124,414 b
Unthinned Head Cut	142,423 a
LSD (.05)	15,604

* Means with the same letter are not significantly different.

Manhattan Field Trials

Analysis of variance on establishment shows there were effects of replication, separation, and seedlot on establishment (Table 15).

Table 15. Analysis of variance, establishment, Manhattan, 1985.

Source	df	Mean squares
Rep	7	50.2 +
Management	2	5.6
Separation	4	58.5 +
Management * Separation	8	54.0 +
Error	98	26.0

\+ Significant at 10%.

Establishment was low with separation class means ranging from 25.6 to 28.9 percent. Effects of separation classes on establishment showed large and bold classes significantly better than control (Table 16). Dense and wet control classes were not significantly different from any other class. These results are not consistent with the St. John results where the dense class was of significantly higher establishment.

Table 16. Effect of seed separation on percent establishment, Manhattan, 1985.

Separation	% Establishment
Control	25.6 b*
Large	28.9 a
Dense	28.4 ab
Bold	28.7 a
Wet Control	26.2 ab
LSD (.05)	2.9

* Means with the same letter are not significantly different.

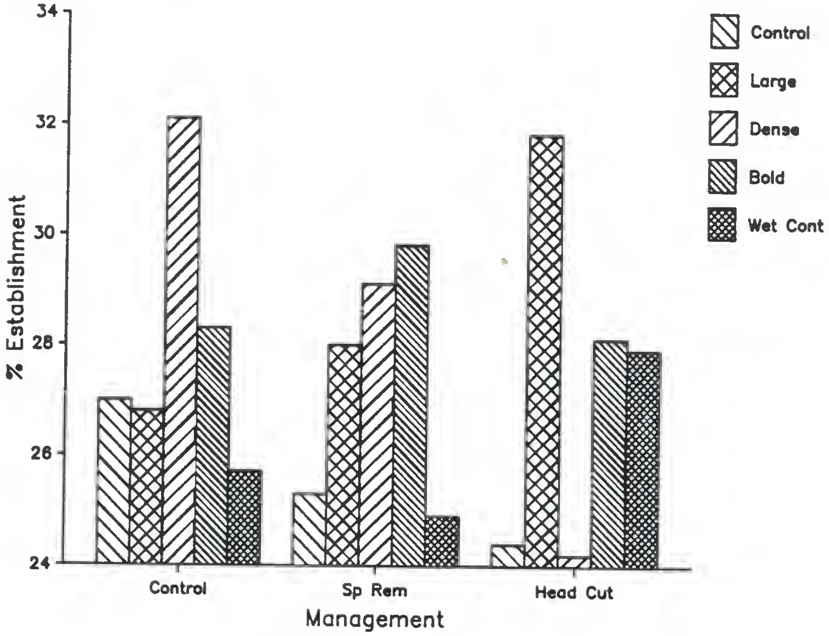
The effect of seedlots on establishment was significant. Table 17 and Figure 1 show these interactions.

Table 17. Effect of seedlot on percent establishment, Manhattan, 1985.

	Separation				
Source	Control	Large	Dense	Bold	Wet Cont.
Control	27.0 abcd*	26.8 bcd	32.1 a	28.3 abcd	25.7 cd
Sp. Rem.	25.3 cd	28.0 abcd	29.1 abcd	29.8 abc	24.9 cd
Head Cut	24.4 d	31.8 abc	24.2 d	28.1 abcd	27.9 abcd
LSD (.05)	5.1				

* Means with the same letter are not significantly different.

Figure 1. Effect of seedlot on percent establishment, Manhattan, 1985.



Yield and yield-component analyses of variance (Appendix Table 2) showed the thinning split treatment with a significant difference. Thinned plots had lower numbers of plants and heads per hectare (Table 18). This was not a large difference in heads per hectare (P<10%), yet it does show that the crop did not compensate fully.

Table 18. Effects of thinning on heads per hectare, plants per hectare, and seed per head, Manhattan, 1985.

Split	Heads/Ha	Plants/Ha	Seed/Hd
Thinned	150,125 b*	36,760 b	2,213 a
Unthinned	163,303 a	48,096 a	2,088 b
LSD	(.10) 11,686	(.05) 5,438	(.05) 105

* Means with the same letter within a column are not significantly different.

Effects of thinning on plants per hectare was expected to be significant because plots were thinned to a constant 37,310 plants per hectare except for a few plots with low natural stands. Unthinned plot populations ranged from 21,525 to 64,575 plants per hectare. Since there was no significant effect of thinning on yield or seed weight and there were more plants and heads in unthinned plots, seeds per head must have been the compensating factor.

The management classes spikelet removal and head cut did not increase yield over the control (Table 19). Head cut produced significantly higher yield than spikelet removal. This is reverse the effect of management on germination.

Table 19. Effect of crop management on grain yields, Manhattan, 1985.

Management	Yield (kg/ha)
Control	2,832 ab*
Spikelet Removal	2,753 b
Head Cut	2,927 a
LSD (.05)	155

* Means with the same letter are not significantly different.

The effect of separation classes on heads per hectare showed control significantly better than large, dense, and wet control, and similar to bold (Table 20).

Table 20. Effect of seed separation on heads per hectare, Manhattan, 1985.

Separation	Heads / Ha
Control	168,194 a*
Large	154,023 b
Dense	148,762 b
Bold	158,747 ab
Wet Control	153,844 b
LSD (.05)	13,619

* Means with the same letter are not significantly different.

In Gardner's work (1980) the advantage of large seed in establishment was carried through to a yield advantage. These results gave no yield advantage.

All thinning by management class yield means were equal except for the thinned spikelet removal class being significantly lower (Table 21).

Table 21. Thinning by crop management mean yields, Manhattan, 1985.

Thin * Management	Yield (Kg/Ha)
Thinned Control	2,827 a*
Thinned Spikelet Removal	2,578 b
Thinned Head Cut	2,848 a
Unthinned Control	2,836 a
Unthinned Spike Removal	2,928 a
Unthinned Head Cut	3,006 a
LSD (.05)	219

* Means with the same letter are not significantly different.

DISCUSSION AND CONCLUSION

The objective in setting up this study was to determine if an advantage could be achieved by selecting seeds for size or density characteristics from seed produced in three different ways. Results showed that large and bold seed were significantly better than control in establishment at Manhattan and dense seed were significantly better at St. John.

Neither management class, spikelet removal or head cut, was better than control except for germination where spikelet removal was better.

What are some possible reasons for not getting more differences, or should we not expect differences? In the literature we often see significant results when comparing seed separations of large versus small or heavy versus light, but large versus control separations less significant results. Management seed classes used in this test did not have the size differences from control as previous years (Table 2).

Okonkwo (1985) stated that effects on seed quality in crop performance may be greater under stress conditions than with good growing conditions. The 1985 cropping year was a good year with adequate rain and moderate temperatures. There was little stress on the crop at either location except during windy days when some seedlings were sandblasted. The 1984 and 1985 yields at St. John may reflect differences in growing season stress. Yields were

0.67 to 0.72 tons per hectare in 1984 as compared to 2.55 to 2.78 tons per hectare in 1985.

The compensating capability of millet is fantastic when populations from 24,000 to 400,000 plants per hectare show no yield differences (Mortlock, personal communications).

So, with seed showing no strong management differences, with this years good crop production environment, and with millets compensating capability, no significant differences should be expected, especially in yield.

Yield should not be the important factor in work in Kansas unless we go to spaced plant measurements under stress conditions. Studies of mechanical separated versus management produced seed characteristics and subsequent emergence capabilities at multiple depths would be valuable. Multiple planting dates in dryer and harsher environments would also test emergence capabilities.

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Appendix Table 1. Analyses of variance of yield and yield-components, St John, 1985.

Source	df	Mean Squares				
		Yield (kg/ha)	Heads/Ha	Plants/Ha	1000 Seed Weight (g)	Seed/Head
Rep	3	3,406,747 **	7,077,373,283 **	404,723,513 **	.0771 **	163,863
Thin	1	4,327	346,018,440	7,726,229,360 *	.0853	215,465
Error(a)	3	282,682	1,583,338,102	404,723,513	.0667	218,974
Management	2	1,337,195 *	605,944,116	94,276,704	.4223 +	372,407 *
Separation	4	395,882	343,135,526	40,815,555	.0653	138,068
Thin * Management	2	571,943	1,564,616,315 +	94,276,704	.1263	92,485
Thin * Separation	4	129,257	429,846,058	40,276,704	.2437	18,068
Mgm't * Separation	8	193,563	531,683,315	82,128,757	.1298	51,103
Thin * Mgm't * Sep	8	241,274	572,756,273	82,128,757	.2397	86,536
Error(b)	84	337,363	537,789,971	55,108,783	.1661	87,973

+ Significant at 10%.
* Significant at 5%.
** Significant at 1%.

Appendix Table 2. Analyses of variance of yield and yield-components, Manhattan, 1985.

Source	df	Mean Squares				
		Yield (kg/ha)	Heads/Ha	Plants/Ha	1000 Seed Weight (g)	Seed/Head
Rep	3	129,634	803,709,797	89,187,323	1.4314 **	647,068 *
Thin	1	896,196	5,209,856,410 +	3,855,486,967 **	1.1603	464,456 *
Error(a)	3	223,533	742,756,737	87,608,583	.6537	32,776
Management	2	303,183 +	51,341,713	3,414,881	.0703	218,145
Separation	4	136,390	1,287,830,735 +	45,532,941	.6171	222,037
Thin * Management	2	282,148 +	85,256,316	360,364	.6903	24,132
Thin * Separation	4	25,096	142,403,991	50,425,272	.4395	184,647
Mgm't * Separation	8	130,299	580,963,143	58,348,998	.2187	127,332
Thin * Mgm't * Sep	8	174,962	408,237,066	37,490,765	.3220	138,761
Error(b)	84	121,126	562,836,855	48,917,216	.3073	174,813

+ Significant at 10%.
* Significant at 5%.
** Significant at 1%.

EMERGENCE, YIELD, AND YIELD-COMPONENTS RESPONSES TO SIZE AND DENSITY SEPARATIONS OF PEARL MILLET SEED PRODUCED BY THREE MANAGEMENT PRACTICES

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Pearl millet, Pennisetum americanum (L.) Leeke, is one of the most important food crops in the semi-arid regions of Africa and Asia due to its ability to tolerate the harsh environment of low irregular rainfall and high temperatures. Suboptimal plant stands are thought to be one of the major problems in the production of pearl millet. Part of the problem is the small size of millet seed. Nutrient reserves within a small seed are minimal so very quickly the seed is dependent on the environment for its nutrient uptake.

In pearl millet seed production the management practices of head cutting and spikelet removal have shown the improved seed characteristics of larger, heavier, and denser seed. The objective of this study was to see if size and density separations on management produced seed had any effect on subsequent establishment, yield, and yield-components.

Seed used in this study was a Senegal Bulk population. In 1984 the management practices control, spikelet removal, and head cut were applied to get three management classes of seed with the spikelet removal and head cut showing improved seed characteristics. Each of these three management classes was separated into the five separation classes of control, large (>0.24 cm), dense (>1.265 g/cc), bold (>0.24 cm and >1.265 g/cc), and wet control (to test the effect of soaking seeds in density separations).

Field trials were conducted in 1985 at Manhattan and St. John, Kansas. With regards to establishment, large and bold separation classes were significantly better than control at Manhattan and the dense class was better at St. John. Except for germination, where the spikelet removal class was better than control, neither the spikelet removal or head cut classes showed a significant advantage over control.

Possible reasons for not getting more differences were 1) seed characteristics of management class seeds were different but they were not large differences, 2) the growing season was not stressful enough to bring out differences, and 3) the compensating capacity of millet was sufficient under this years growing conditions.