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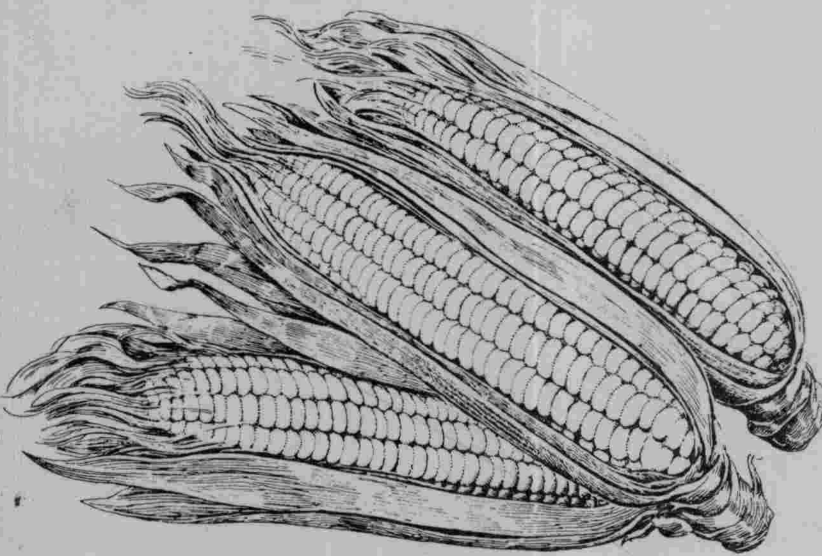

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Introduction

A farmer's total enterprise is based on solar energy converters. Every crop uses solar energy and each plant is a solar energy converter. Among the cultivated row crops that farmers produce, corn is the better solar energy converter, and it is only about 5% efficient under desirable conditions.

Corn has what may be called an open canopy, as much of the sunlight reaching the surface of a growing corn crop penetrates the corn canopy. In many cases, 50% or more of the incoming radiation reaches the soil surface. In comparison, narrow-row soybeans have a closed canopy; less than 1% of the incoming radiation reaches the soil surface. Incoming radiation that reaches the soil surface increases the soil temperature, germinates weed seeds, and causes loss of soil moisture through evaporation.

Plant growth and development depends on four main inputs: sunlight, water, carbon dioxide, and plant nutrients (from fertilizers and from the soil). The average carbon dioxide concentration in the atmosphere is now about 330 ppm, an increase of about 10% over the last 30 years. So, any attempt to obtain higher corn yields must consider the plant canopy and the incoming radiation distribution with the canopy. It has been reported that more than 90% of the incoming radiation reaches the soil surface in 40-inch row corn in early July. In 20-inch row corn of the same age, the amount of radiation reaching the soil surface may range from 45 to 65 percent of the total incoming radiation (Aubertin and Peters, 1961). However, planting corn in a 12- by 14-inch diamond pattern, which tends to maximize the amount of radiation intercepted by the corn canopy, has resulted in a 3-year average yield of 312 bushels per acre (Flannery, 1892-3).

Evapotranspiration experiments have shown that transpiration accounts for only 30 to 50 percent of the water loss by a corn crop (Peters and Russell, 1959). Under normal field conditions, corn yields per inch of water loss by evapotranspiration range from 6 to 9 bushels per acre (Peters and Russell, 1959; Parks and Smith, 1962; Yao and Shaw, 1964). However, when water loss through evaporation is eliminated through the use of plastic-covered soil surfaces, this water-use efficiency may range from 14 to more than 20 bushels per acre inch of water (Peters and Russell, 1959).

Materials and Methods

In an effort to increase corn yields and production efficiency, a series of experiments involving corn row spacing, plant population, nitrogen application, and different corn varieties was conducted at the Plant Sciences Unit, Knoxville. The objective was to determine which corn row spacing, plant population, and variety combination would produce higher yields of corn. The soil pH was maintained between 6.1 and 6.6, and fertilizer was applied annually at 0-100-100 pounds per acre. In experiments for which nitrogen was not a variable, it was applied at a rate of 200 or 250 pounds per acre. The corn was mechanically planted with a 4-row planter and mechanically harvested with a combine fitted with a 4-row, 20-inch corn header. The corn was not irrigated in experiments conducted prior to 1983; however, starting with the 1983 crop year, the corn was irrigated. After the corn reached a height of about 5 feet, it received 2.5 inches of water (rainfall + irrigation) per week. Irrigation continued until the ear reached maturity. Weights of each plot from a split plot randomized block experimental design were obtained and yields adjusted to the standard 15.5 percent moisture.

Results

Table 1 shows the April through September monthly rainfall at the Plant Sciences Unit, Knoxville, over a 6-year period. Table 1 also provides a 6-year average and a 33-year average. The rainfall during the first 3 years (1982-84) ranged from 24 and 31 inches, but ranged from 17 to 20 inches during the last 3 years (1985-87). The year of the lowest rainfall (1986) was also the year of the highest corn yield. This was probably due to the July, August, and September rainfalls in 1986, which were 3.63, 3.75, and 3.42 inches, respectively. This amount of rainfall would supply more than half of the moisture needed for the corn and would also aid in reducing the peaks in air temperature during the day. These two factors, along with increased incoming radiation due to less cloud cover during low rainfall years, would contribute to higher yields in irrigated corn.

Table 1. The April through September monthly rainfall at the Plant Science Farm, Knoxville over a 6-year period, with 6- and 33-year averages.

Month	1982	1983	1984	1985	1986	1987	6 Yr Av	33 Yr Av
	Inches Rainfall							
April	2.90	6.95	3.84	2.81	1.94	2.89	3.69	4.22
May	5.88	7.13	9.79	1.57	2.77	1.67	4.59	3.93
June	3.12	3.05	2.77	3.07	1.60	5.00	3.10	4.22
July	10.59	3.07	11.31	3.55	3.63	3.68	5.05	4.70
August	6.69	2.89	2.21	6.80	3.75	3.01	3.73	3.90
September	1.82	1.36	1.19	0.43	3.42	3.98	2.08	2.60

Figure 1 (located at the end of the text) shows average corn yields obtained at different row spacings and plant populations for 12 varieties, evaluated over a 13-year period. This shows that 164 Bu/A corn yield may be obtained in 10- to 20-inch row spacings with 18 thousand to 21 thousand plants per acres. In 30- to 40-inch row spacings, the same 164 Bu/A corn yield may be obtained over a wide range of 18 thousand to 34 thousand plants per acre. A yield of 180 Bu/A was obtained in row spacings ranging from 10 to 23 inches with plant populations ranging from 23 thousand to 34 thousand plants per acre. Yields above 200 Bu/A were obtained at row spacings of 10 to 13 inches with plant populations of more than 30.4 thousand plants per acre. These values cover many corn varieties, and varieties may differ in the plant population required for maximum yield.

Figures 2 through 6 (located at the end of the text) show the corn yields of 5 varieties at different row spacing and plant population combinations. Figures 2 and 3 show the yields of DeKalb 394 and Pioneer Brand 3145 grown at different row spacings and plant populations over 4- and 6-year periods, respectively. The corn was grown on a Sequatchie loam soil and was not irrigated. The yield differences among the row spacing and plant populations for the two varieties were 12 Bu/A for DeKalb 394 and 7.5 Bu/A for Pioneer Brand 3145. This essentially means that for corn yields of 155 Bu/A or less on a soil well-adapted for corn, neither the range of row spacing nor the plant population had a dominating effect on the resulting corn yield of these 2 varieties. The yield isoquants for the 2 varieties were quite different, with DeKalb 394 having its highest yield of 153 Bu/A at 20- to 24-inch row spacing and 25 thousand to 26 thousand plants per acre, and Pioneer Brand 3145 reaching its highest yield at row spacings of 20 to 32 inches with plant populations of 20 thousand to 24.5 thousand plants per acre.

Figures 4 and 5 show the yield isoquants of Pioneer Brands 3184 and 3147. The yield results for these 2 varieties are somewhat similar at yield levels above 170 Bu/A, but differ at the lower yield levels. At high plant populations and wide row spacings, the yield of Pioneer Brand 3147 drops considerably and equals that of narrow rows and 18 thousand to 20 thousand plants per acre. However, the yield of both varieties was highest in narrow rows with high plant population.

Figure 6 shows the yield isoquants of DeKalb 789, with irrigation, over a 5-year period and illustrates the relationship between row spacing and plant population for irrigated corn. Yields of 200 Bu/A were obtained at 18- to 24-inch row spacings over a wide range of plant populations. Yields decreased as row spacing increased above 24 inches at all plant populations and also decreased at row spacings below 18 inches as plant populations decreased.

While these results indicate that narrow spacing will increase corn yields in years of above-average rainfall, the yield increases are not as dramatic as those obtained in narrow-row soybeans. This is probably because corn, even in narrow rows, is still an open canopy and much of the incoming radiation reaches the soil surface. This results in evaporation of much-needed water from the soil surface and increases the temperature within the plant canopy. This combination of moisture and temperature stress during the ear development stages may greatly reduce corn yields in dense corn populations. This is a resultant yield relationship that does not happen in soybean production.

Tables 2 and 3 (located at the end of the text) show the corn yields of five varieties obtained for different row spacings and plant populations during 1982-84 and 1985-87. In the 1982-85 years, row spacing significantly affected corn yield in only 1 of 14 year-variety situations, while plant population significantly affected yield in 5 of 14 year-variety situations. In the 1985-87 crop years, row spacing significantly affected yield in 9 of the 15 possible year-variety situations, while plant population significantly affected yield in only 4 of the possible 15 year-variety situations.

Summary

These results show a wide range in corn yields among the varieties, row spacings, and plant populations evaluated. The cumulative effect of this is that the corn plant responds to its environment. Corn varieties differ in their capacity to withstand stress relative to moisture, plant population, fertility, and temperature during the growing season. The capacity of the farmer to control these production factors eventually determines the maximum yields possible under any given situation.

The corn plant is very responsive to the treatment that it receives. It is capable of withstanding considerable moisture and temperature stress during the first 60 to 65 days after planting. However, during the pollination and ear development stages, the resultant corn yield is greatly affected by the moisture and temperature conditions. The normal soil moisture use by corn during this stage of development may vary from 0.20 to 0.35 (or more) inches per day. Excessive temperature and soil moisture stress during this period greatly reduces corn yields. It is for this reason that corn is generally found on soils having the highest available moisture-holding capacity, and that it is planted at plant populations consistent with average rainfall expectations.

The highest corn yields are obtained in planting patterns that permit the greatest plant interception of incoming radiation, as long as moisture does not become limited. High corn yields are typical with irrigation or a crop year during which adequate rainfall and sunlight are well-distributed over the pollination and ear development stages of growth. Years with excessive cloudy weather and higher rainfall may not always produce the highest possible corn yield because dense cloud cover reduces the amount of incoming radiation necessary for maximum corn yield.

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Figure 1. Average corn yields (Bu/A) obtained at different row spacings and plant populations for 12 varieties evaluated over a 13-year period (1975-1987)

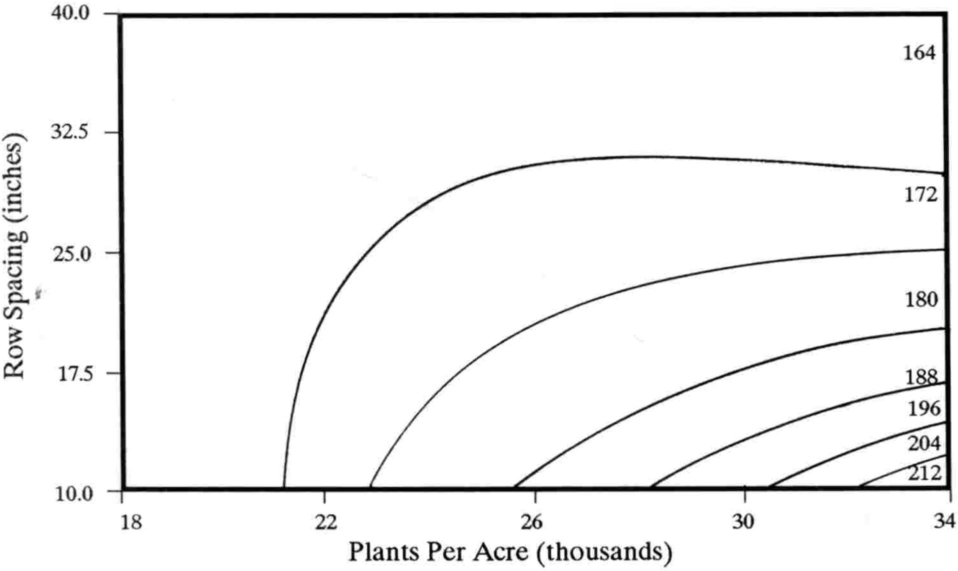

Figure 2. Average corn yields (Bu/A) obtained for DeKalb 394 at different row spacings and plant populations over a 4-year period (1977-1980)

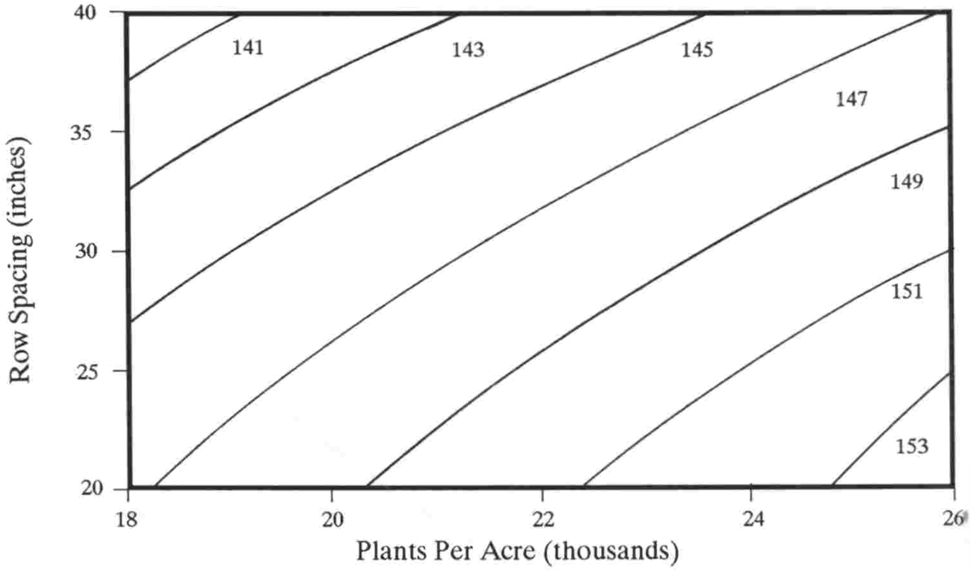

Figure 3. Average corn yields (Bu/A) obtained for Pioneer Brand 3145 at different row spacings and plant populations over a 6-year period (1975-1980)

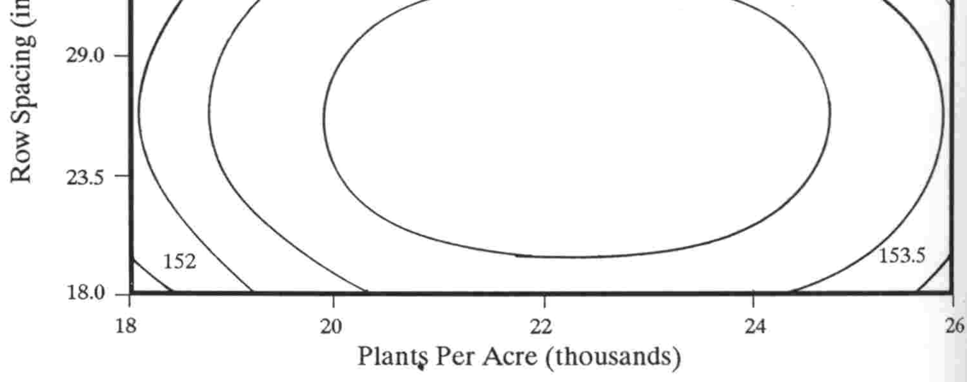

Figure 4. Average corn yields (Bu/A) obtained for Pioneer Brand 3147 at different row spacings and plant populations over a 13-year period (1975-1987)

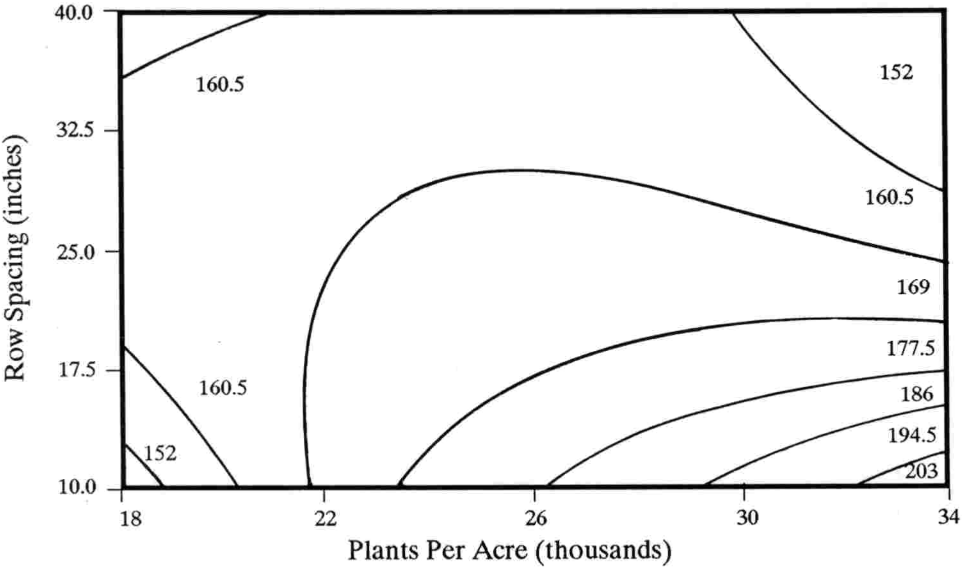

Figure 5. Average corn yields (Bu/A) obtained for Pioneer Brand 3184 at different row spacings and plant populations over a 9-year period (1978-1981, 1983-1987)

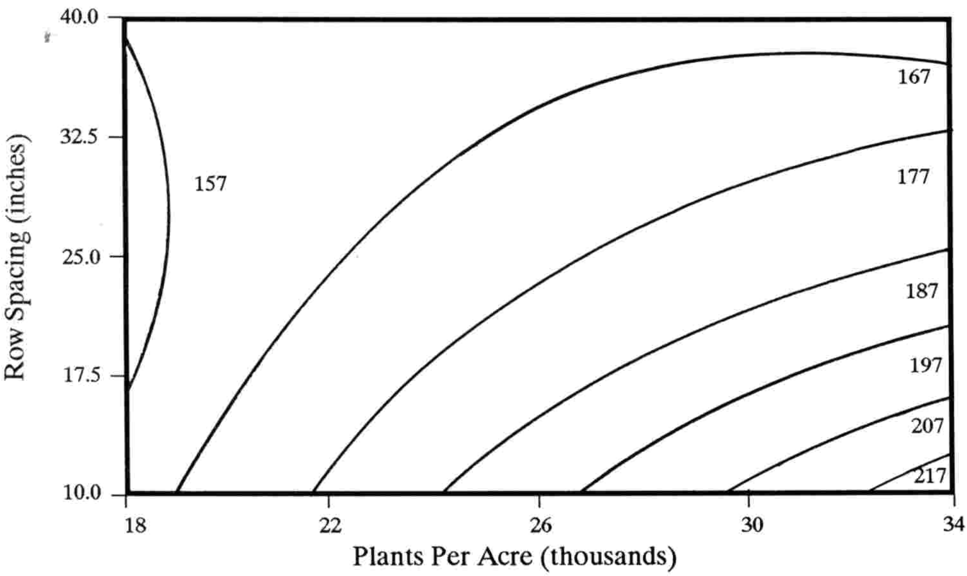

Figure 6. Average corn yields (Bu/A) obtained for DeKalb 789 at different row spacings and plant populations over a 5-year period (1983-1987)

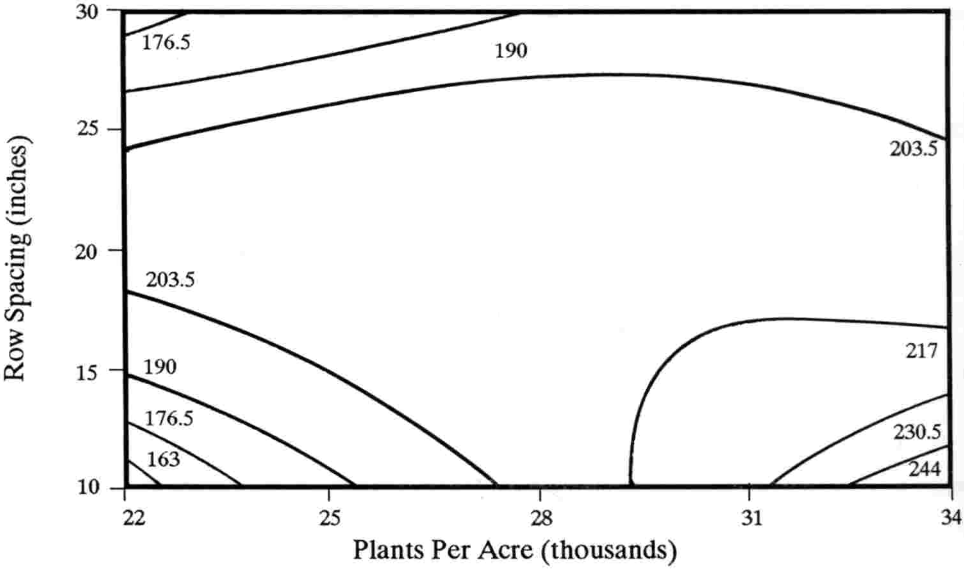

Table 2. Irrigated Corn Yields at Three Row Spacings and Four Populations

RS In.	PPA 1,000	Variety: DK789 1982	1983	1984	2 Yr. Avg.
		Bu/A			
30	22		146	186	166
30	26		170	165	168
30	30		165	188	177
30	34		180	172	176
24	22		181	205	193
24	26		191	197	194
24	30		187	182	185
24	34		192	198	195
20	22		171	204	188
20	26		189	210	200
20	30		192	210	201
20	34		199	218	209
RS (Inches)		Row Spacing Means			
30			165	178	172
24			188	196	192
20			188	210	199
LSD	(.05)		NS	18	22
PPA (1,000)		Plant Population Means			
22			166	198	182
26			183	191	187
30			181	193	187
34			190	196	193
LSD	(.05)		15	NS	NS

Table 2. (continued)

RS In.	PPA 1,000	Variety: DK747 1982	1983	1984	3 Yr. Avg.
		Bu/A			
30	22	194	145	201	180
30	26	191	166	180	179
30	30	185	132	183	167
30	34	205	144	178	176
24	22	206	157	186	183
24	26	211	177	198	195
24	30	207	160	216	194
24	34	229	187	191	202
20	22	213	167	192	191
20	26	241	179	207	209
20	30	226	170	207	201
20	34	225	187	214	209
RS (Inches)		Row Spacing Means			
30		194	147	185	175
24		213	170	198	194
20		226	176	205	202
LSD	(.05)	NS	NS	NS	9
PPA (1,000)		Plant Population Means			
22		204	157	193	185
26		214	174	195	194
30		206	154	202	187
34		219	179	194	196
LSD	(.05)	NS	11	NS	NS

Table 2. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3160 1982	1983	1984	3 Yr. Avg.
		Bu/A			
30	22	194	169	181	181
30	26	198	183	185	189
30	30	192	184	188	188
30	34	197	187	182	189
24	22	180	175	188	181
24	26	201	185	185	190
24	30	202	186	198	195
24	34	191	209	214	205
20	22	198	171	192	187
20	26	196	173	188	186
20	30	208	172	209	196
20	34	206	188	187	194
RS (Inches)		Row Spacing Means			
30		197	181	184	187
24		194	189	196	193
20		202	176	194	191
LSD	(.05)	NS	NS	NS	NS
PPA (1,000)		Plant Population Means			
22		190	172	187	183
26		198	180	185	188
30		201	181	198	193
34		198	195	194	196
LSD	(.05)	NS	14	NS	8

Table 2. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3184			
		1982	1983	1984	3 Yr. Avg.
		Bu/A			
30	22	148	143	188	160
30	26	144	157	163	155
30	30	157	140	193	163
30	34	135	145	196	159
24	22	160	143	189	164
24	26	150	153	152	152
24	30	142	143	188	158
24	34	144	160	206	170
20	22	148	148	204	167
20	26	177	152	190	173
20	30	146	147	214	169
20	34	130	162	239	177
RS (Inches)		Row Spacing Means			
30		146	146	185	159
24		149	150	183	161
20		150	152	212	171
LSD	(.05)	NS	NS	NS	NS
PPA (1,000)		Plant Population Means			
22		152	145	194	164
26		157	154	169	160
30		148	144	198	163
34		136	156	214	169
LSD	(.05)	NS	NS	15	NS

Table 2. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3147			
		1982	1983	1984	3 Yr. Avg.
		Bu/A			
30	22	180	162	163	168
30	26	151	164	155	157
30	30	166	170	140	159
30	34	159	165	148	157
24	22	180	173	161	171
24	26	183	184	169	179
24	30	176	168	151	165
24	34	169	178	141	163
20	22	179	181	167	176
20	26	186	183	160	176
20	30	198	186	149	178
20	34	187	200	124	170
RS (Inches)		Row Spacing Means			
30		164	166	151	160
24		177	176	156	170
20		187	187	150	175
LSD	(.05)	NS	NS	NS	NS
PPA (1,000)		Plant Population Means			
22		180	172	164	172
26		173	177	161	170
30		180	175	147	167
34		172	181	138	164
LSD	(.05)	NS	NS	20	NS

Table 3. Irrigated Corn Yields at Four Row Spacings and Two Plant Populations

RS In.	PPA 1,000	Variety: DK789 1985	1986	1987	3 Yr. Avg.
		Bu/A			
30	30	173	232	201	202
30	34	170	240	230	213
20	30	214	272	214	233
20	34	186	237	190	204
15	30	176	248	229	218
15	34	288	261	198	249
10	30	201	256	239	232
10	34	239	302	239	260
RS (Inches)		Row Spacing Means			
30		172	236	216	208
20		200	255	202	219
15		192	254	213	220
10		219	279	239	246
LSD	(.05)	9	9	NS	NS
PPA (1,000)		Plant Population Means			
30		191	252	221	221
34		201	260	214	225
LSD	(.05)	8	6	NS	NS

Table 3. (continued)

RS In.	PPA 1,000	Variety: DK689 1985	1986	1987	3 Yr. Avg.
		Bu/A			
30	30	172	219	204	198
30	34	198	237	186	207
20	30	180	256	226	221
20	34	177	227	200	201
15	30	210	273	246	243
15	34	181	243	199	208
10	30	185	236	201	207
10	34	180	288	243	237
RS (Inches)		Row Spacing Means			
30		185	228	195	203
20		178	241	213	211
15		196	262	222	225
10		183	262	222	222
LSD	(.05)	NS	10	10	21
PPA (1,000)		Plant Population Means			
30		187	246	219	217
34		184	248	207	213
LSD	(.05)	NS	NS	NS	NS

Table 3. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3165 1985	1986	1987	3 Yr. Avg.
		Bu/A			
30	30	190	222	201	204
30	34	187	248	220	218
20	30	181	272	224	226
20	34	198	260	230	229
15	30	193	276	220	230
15	34	198	246	235	226
10	30	217	274	222	238
10	34	235	287	277	266
RS (Inches)		Row Spacing Means			
30		188	235	211	211
20		189	266	227	227
15		196	261	227	228
10		226	281	249	252
LSD	(.05)	NS	NS	NS	17
PPA (1,000)		Plant Population Means			
30		195	261	217	224
34		205	260	240	235
LSD	(.05)	NS	NS	NS	NS

Table 3. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3184 1985	1986	1987	3 Yr. Avg.
		Bu/A			
30	30	141	235	136	171
30	34	122	225	148	165
20	30	181	265	144	197
20	34	160	237	160	186
15	30	142	233	183	186
15	34	170	254	164	196
10	30	163	246	169	193
10	34	188	296	193	226
RS (Inches)		Row Spacing Means			
30		132	230	142	168
20		171	251	152	191
15		156	242	174	191
10		176	271	181	209
LSD	(.05)	23	11	14	23
PPA (1,000)		PPA Population Means			
30		157	244	158	186
34		160	253	166	193
LSD	(.05)	NS	8	NS	NS

Table 3. (continued)

RS In.	PPA 1,000	Variety: Pioneer Brand 3147			
		1985	1986	1987	3 Yr. Avg.
		Bu/A			
30	30	132	195	120	149
30	34	146	242	128	172
20	30	196	244	178	206
20	34	146	236	132	171
15	30	171	257	154	194
15	34	141	200	150	164
10	30	163	226	171	187
10	34	212	269	179	220
RS (Inches)		Row Spacing Means			
30		139	218	124	160
20		171	240	155	189
15		156	229	152	179
10		187	247	174	203
LSD	(.05)	15	NS	25	15
PPA (1,000)		Plant Population Means			
30		166	230	156	184
34		161	237	147	182
LSD	(.05)	NS	NS	8	NS

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