RESPONSE OF SEMIDWARF HARD WINTER WHEATS TO SEVERAL ENVIRONMENTS IN KANSAS

by

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INTRODUCTION

The introduction of Norin wheats (Triticum aestivum L. em. Thell.) from Japan and Seu Seun from Korea provided basic germplasm for breeding semidwarf wheats in the United States. The term "semidwarf" is used in the present study to describe short statured, agronomically useful wheat selections. Outstanding performance of cultivars such as the winter wheat 'Gaines' and Mexican spring wheats 'Pitic 62' and 'Siete Cerros' have given semidwarfs a reputation for high yield, disease resistance, and lodging resistance. About ten percent of world wheat plantings involve Mexican semidwarf spring wheats (CIMMYT Review, 1975).

In the United States many semidwarf wheat cultivars have been produced and evaluated (Heyne and Campbell, 1971; Johnson, Schmidt, and Mekasha, 1966; McNeal et al., 1960; Porter et al., 1964; Vogel et al., 1956, 1963). Briggle and Vogel (1968) extensively reviewed characteristics of semidwarf wheats and reported that most semidwarf wheats now grown in the United States have greater yield potential in their area of adaptation than standard commercial cultivars. Part of this yield advantage is inherent, part is due to performance under higher fertility levels and resistance to lodging.

Research on semidwarf wheats began in Kansas in 1949 using 'Norin 10', PI 156641, and 'Norin 66', PI 155276 (Heyne and Campbell, 1971). Later, other sources of short germplasm were crossed with adapted cultivars. Under Kansas conditions Reddi, Heyne, and Liang (1969) and Mallott (1970) found one-gene semidwarfs and especially two-gene semidwarfs had larger number of kernels and lower test weight than standard height segregates from crosses of Norin 10 backcrossed to 'Kaw' and 'Pawnee' three to five times. These segregates tended to lodge by straw breakage at the top node at or just before combine-ripe. Thus breeding for semidwarf wheats in this backcross program under Kansas climatic conditions was not promising. Semidwarf lines isolated from direct crosses involving CIMMYT semidwarfs gave more promise. These semidwarf lines have performed well since 1971 and have been encouraging in that acceptable kernel type and standability have been combined with good yields (Heyne, 1974).

The continental climate of Kansas fluctuates greatly from year to year and within seasons. Wheat production is highly variable with highly variable environmental conditions. In Kansas the success of a new cultivar is as dependent on its capacity for performing well over a range of environments as on its yield potential. Therefore, the goal of the wheat breeding program is to develop cultivars that produce stable high yields in a wide range of environments. One of the objectives of this study was to determine if these newly developed semidwarf lines were more responsive to nitrogen application than the older and taller standard cultivars. Another objective was to determine if any of the components of yield were associated with grain yield.

LITERATURE REVIEW

Agronomically useful dwarfing genes were not available to shorten tall cultivars until 1946, when S.C. Salmon brought seeds of the Japanese cultivar, Norin 10, into the United States (Reitz and Salmon, 1968). At present many plant breeding programs are concentrating on development of semidwarf selection with only one gene. Two major independent genes, sd_1 and sd_2, control semidwarf culm length in wheat and singly produce very similar culm length phenotypes (Allan and Pritchett, 1973). They also reported that semidwarf lines that carry both the sd_1 and sd_2 genes, in general, have not been successfully exploited in the United States.

Most semidwarf wheats now grown in the United States have greater yield potential in their area of adaptation than standard commercial cultivars (Briggle and Vogel, 1968). Vogel et al. (1956) showed that semidwarf wheats from the cross 'Norin 10 Brevor' produced higher yields. Vogel et al. (1963) further concluded that the general plant pattern of these efficiently producing cultivars appeared to be a combination of characters consisting of high tillering capacity, early spring recovery of growth, lodging and shattering resistance, coarse awns, medium semidwarf plant height, medium culm diameter and head size, and medium to small length and width of leaf.

Semidwarf selections have been developed and tested in the Southern Plains States but have not proved superior to standard cultivars (Heyne and Campbell, 1971; Johnson et al., 1966; Stickler and Pauli, 1961) except under irrigation or in areas of high rainfall (Porter et al., 1964). Porter et al. (1964) reported that short stature winter wheats yielded more than taller commercial cultivars in irrigated trials and on dryland in a 35 inches rainfall area but about the same or less on dryland in areas having 25 and 30 inches of annual rainfall. Hard red winter semidwarf cultivars 'Sturdy' and 'TAM W-101' were released in Texas but are restricted to areas of favorable rainfall or to irrigated land. McNeal et al. (1960), working in Montana with spring wheats, found high grain yield with short strains derived from crosses of 'Centena' and 'Thatcher' with strains of Norin 10 Brevor and observed no differential response to fertility levels. Johnson et al. (1966) working in Nebraska also found the short statured cultivars 'CI 13678' and 'CI 13677' were more productive on the average than the taller cultivars, Pawnee and 'Cheyenne'. The highest yielding cultivars, CI 13678, consistently produced more kernels per spike, but its kernel weight and spike number were less than the other cultivars. Stickler and Pauli (1961) compared seven Kansas developed semidwarf winter wheats with Pawnee and 'Triumph' for yield and individual components of yield (heads per unit area, kernels per head, and kernel weight). Only one semidwarf line outyielded Pawnee and no semidwarf line outyielded Triumph. One semidwarf line outyielded both Pawnee and Parker the second year and yield superiority was attributed to a greater number of seeds per head and to greater seed weight.

Problems with semidwarf wheats in Kansas were lower kernel weight and straw breakage at the top node. However, the most recently selected semidwarf lines from single crosses have been encouraging in that acceptable kernel type and standability have been combined with good yields (Heyne, 1974). There were 43 semidwarf breeding lines selected from 160 for evaluation in 1974. Heyne (1974) further reported that in replicated tests at Hutchinson and Manhattan these 43 semidwarf lines averaged 120 percent of the standards at Hutchinson with and without added nitrogen in the spring.

At Manhattan, without added nitrogen in the spring the 43 lines yielded 121 percent of the standards but with extra nitrogen yielded only 112 percent.

Effect of Nitrogen

Available soil nitrogen has been shown to be an important factor limiting wheat yields in many parts of the world (McNeal and Davis, 1954; Rankin, 1947; Wahhab and Hussain, 1957). The efficiency of nitrogen applications in increasing wheat yields is largely dependent upon the available soil moisture supply during the growing season (Fernandez and Laird, 1952). Rankin (1947) found in North Carolina that when nitrogen was applied at the proper time, increases in yield resulted from increases in kernels per spike, kernel weight, and tillering. Lewis, Procter, and Trevains (1938) found grain yield increased significantly with spring application of nitrogen in twenty-five out of twenty-eight experiments. Their data indicated that the increase in yield of grain due to spring application of nitrogen was usually due to an increase in number of grains, but not an increase in kernel weight. The yield of straw was significantly increased by spring application of nitrogen in all the experiments. Johnson et al. (1973) also found significant yield response to fertilizers; yield responses of both cultivars were non-linear. They also reported significant protein response to nitrogen fertilizer in all trials. There was highly consistent positive, linear response to nitrogen fertilizer and a consistent cultivaral relationship for grain protein content. Thorne (1962) found grain weight increased by increasing the number of grains per ear and number of ears with early nitrogen application. Williams and Smith (1954) working with winter wheat at Manhattan, Kansas, found that nitrogen alone did not increase the yield of wheat significantly except at the 50 pound per acre level. Hobbs (1953) found that nitrogen fertilization increased yield in eastern Kansas when adequate phosphate fertilizer was applied. The increase in yield was caused by an increase in tillering and an increase in the number of kernels per head. No increase in kernel weight was observed. Heyne and Campbell (1971) found depressed yield, test weight, and kernel weight in both parents (Kaw and Pawnee) and semidwarf lines (Kaw derivatives and Pawnee derivatives) when heavy nitrogen applications were made in the spring.

Reitz and Myers (1944), also working with winter wheats at Manhattan, Kansas, pointed out that cultivars of similar adaptation could be expected to exhibit equal response to fertilizer, but when cultivars differed greatly, differential response would be more likely. Worzella (1943) found a strong tendency for cultivar X fertilizer interaction in wheat grain yields. Lamb and Salter (1936) also obtained a cultivar X fertilizer interaction in a five-year study with eleven cultivars in Ohio. But, none of the cultivars were superior only at high or at low fertility level. Pendleton and Dungan (1960) concluded that four cultivars of winter wheat tested in Illinois did not react the same in grain yield to the different nitrogen applications. Whereas, McNeal et al. (1971), working with different height cultivars of spring wheat, found no cultivar X fertilizer interaction for yield, indicating that the short and medium height types did not respond differently to nitrogen fertilizer than the standard height types, But, they found significantly increased grain protein percentage. Terman et al. (1969) showed that the effect of nitrogen with adequate water was to increase yield while under severe water deficits protein content increased.

Yield Components

Kiesselbach and Sprague (1926) and Schlehuber and Tucker (1967) pointed out wheat grain yields vary as a result of the combined effects of yield components (number of ears per unit area, number of kernels per ear, and average kernel weight). These yield components vary widely with moisture supply, soil fertility level and other growth limiting factors. Many investigators have reported that nitrogen increased various yield components and resultant total grain yields. Grafius (1956) developed a geometric interpretation in working with yield components in oats and suggested that it might be easier to increase yield by increasing the smallest yield component of an otherwise good cultivar. Adams (1967) discussed yield component compensation in crop plants and concluded that yield tended to stabilize by compensation among yield components. However, the compensation is not necessarily complete. Thus a genetic increase in one component may well result in an increase in yield. Rasmusson and Cannell (1970) concluded that kernel size is the only yield component which should be kept near its genetic maximum. Whereas, Quisenberry (1926) concluded that the correlation between yield and seed weight was too low for seed weight to be an important factor in grain yield of wheat. In central Europe winter wheats with high kernel weight were needed for regions with high precipitation, and cultivars with higher grain number per heads for more arid areas (Foltyn, 1973).

In an experiment with five cultivars of hard red winter wheat and seven fertilizer treatments in Oklahoma, a significant increase in the number of heads occurred when both nitrogen and phosphorus were high, but there was no significant increase when either element was added alone (Moore, 1962). The number of seeds per head significantly increased when nitrogen was high. On the other hand, average seed weight decreased significantly when nitrogen was high and increased when phosphorus was high (Moore, 1962). Stickler and Pauli (1964) found heads per unit area were significantly higher in five trials seeds per head were significantly higher in three trials; and seed weight was significantly lower in six trials with the addition of nitrogen, in seven trials at two locations in Kansas (1959 to 1963). Tucker and Schlehuber (1968) in a three-year trial with addition of nitrogen found the number of fertile heads per unit area increased as well as the number of kernels per head. McNeal (1960) found that heads per plant and kernels per head were most closely associated with yield, but later McNeal et al. (1974) and Hsu and Walton (1971) found heads per unit area was the most important component in determining yield.

There have been many previous yield correlation studies since Engledow and Wadhem (1923) first divided the yield of cereals into various components. Frequently, high correlations of yield with its components, ears per unit area grains per ear, and 1000 kernel weight have been obtained but have little application outside their own experiments. Reddi, Heyne, and Liang (1969) reported that culm length and kernel weight were positively associated in the F_3 and F_4 of crosses of Norin 10 by Kaw and Pawnee. Correlation between the height of the semidwarf and test weight and kernel weight were positive (Heyne and Campbell, 1971). They also found plant height and yield were positively correlated in the semidwarfs, i.e., the taller semidwarfs had higher yields. Johnson et al. (1966) also found plant height to be highly correlated with kernel weight, grain yield, and spike length. Joppa (1973) in durum wheat found test weight and kernel weight highly correlated. Tall lines always had higher test weight and had equal or higher kernel weight than semidwarfs. Knott and Talukdar (1971) found highly significant correlation between 1000 kernel weight and yield per plot. The number of kernels per spike showed a high negative correlation with the number of spikes per plot.

Borojevic (1968), in a study of spikes and kernel characters of dwarf and semidwarf wheat lines, found the length of spike, number and weight of kernel had similar mean values. No correlations between stalk height and these characters were found. In a similar study, Borojevic and Mikic (1965), working with dwarf progenies from 30-50 cm. in plant height, found little, if any, correlation between plant height and spike length, number of kernels per spike, and number of spikelets per spike. Those authors stated that considerable shortening of stalk need not lead to a decreased genetic capacity for yield in short or dwarf wheats.

MATERIALS AND METHODS

Eight semidwarf winter wheat lines were selected at random from 43 promising lines from the cross Pitic 62/ Chris Sib/2* Sonora 64/3/ Klein Rendilor /4/ Scout (referred to as CIMMYT/Scout) in 1973.

Disease response

Sel. No.	Plant ht.	Leaf Rust	Stem Rust	Soil Borne Mosaic Virus
KS73105	99 cm	R	MR	MS
KS73151	95	MR+	-	R
KS73164	98	MR	Seg	MS
KS73189	92	MR	-	R
KS73202	98	MR-	-	MS
KS73211	96	MR-	MS	R
KS73198	99	MR	-	R
KS73278	93	R	MS	S

Two Kansas standard height cultivars, Parker, CI 13285, and Eagle, CI 15068, and two Texas semidwarf cultivars, Sturdy, CI 13684, and TAM W 101, CI 15324, were chosen as checks. They were studied in detail in 1974 and 1975 for grain yield and components of yield (number of ears per square meter, number of seeds per ear, and kernel weight in grams per 1000 kernels). The material was grown in 1974 and 1975 at Manhattan in Northeast Kansas, and Hutchinson in Southcentral Kansas under four levels of nitrogen. These two locations years were considered as four environments. Nitrogen (0, 50, 100, 150 pounds per acre) was applied in early spring (March 21) on top of the recommended 30 pounds of nitrogen and 40 pounds of P_2O_5 per acre at seeding. There were four replications in a split plot design using fertilizer levels as subplots. The seeded plot area was four rows 13 feet long spaced 12 inches apart and the seedrate was 75 pounds per acre at Manhattan and 60 pounds per acre at Hutchinson. The area harvested in 1974 was 19.2 square feet from the center two rows and the entire plot of 38.4 square feet in 1975.

The data were analyzed statistically by analysis of variance. Grain yield and components of grain yield were analyzed separately. Simple correlation coefficients were computed in each environment separately between yield and yield components (number of ears per square meter, number of seeds per ear, and kernel weight).

Measurement Procedures

Grain Yield:- In 1974 the harvested area was 19.2 square feet and 38.4 square feet in 1975 for yield measurement. The grain yield was converted to grams per square meter in all four environments.

Number of Ears per Square Meter:- A random sample of two feet was harvested from each plot before harvest. The number of ears were determined by counting the number of tillers with productive ears (bearing grains) and later transformed to number of ears per square meter.

Number of Seeds per Ear:- Ten good ears were chosen from each two square feet sample. The total number of seeds in ten ears was counted and the average number of seeds per ear was recorded.

Kernel Weight:- A five-gram sample was taken from each plot and the kernels were counted. This figure was converted to weight of 1000 kernels in grams.

Climatological Data

Temperature data for the period September through June for years 1973-74 and 1974-75 for Manhattan and Hutchinson experimental farms are shown in Table 1. Table 2 contains precipitation data for the period, September through June for 1973-74 and 1974-75, for both locations.

In 1973-74, there was adequate moisture at both locations for the period September through December as well as above average precipitation for the period March through May at Hutchinson. Precipitation was low in June. Hot, dry air along with moisture stress occurred during the ripening period. At Manhattan, precipitation for the period March through June was average but high temperatures around June 20 hastened maturity at that location. The average temperature for the period February through May was above normal at both locations.

In 1974-75, precipitation was slightly below average for the period September through early May at both locations. But, after the middle of May moisture supply was excellent at both locations. Temperature for the period February through April was below average at both locations.

Table 1:- Average air temperature (°F) September through June for the years 1973-74 and 1974-75 at Manhattan and Hutchinson, Kansas.

		Manhattan			Hutchinson		
Months	Years	Maximum	Minimum	Average	Maximum	Minimum	Average
September	1973	75.4	59.3	67.4	77.7	57.9	67.8
	1974	74.9	51.2	63.1	75.5	50.4	63.0
October	1973	73.0	50.2	61.6	74.3	49.4	61.9
	1974	70.1	48.8	59.5	71.4	49.5	60.5
November	1973	55.9	36.3	46.1	57.4	36.7	47.1
	1974	53.8	34.5	44.1	54.0	33.8	43.9
December	1973	38.9	22.1	30.5	41.1	24.3	32.7
	1974	44.0	24.8	34.4	45.7	24.9	35.3
January	1974	34.3	16.8	25.6	36.3	16.3	26.3
	1975	41.2	21.4	31.3	44.5	24.5	34.5
February	1974	49.8	26.0	37.9	54.5	27.1	40.8
	1975	36.6	21.0	28.8	38.9	19.7	29.3
March	1974	59.7	36.6	48.2	61.7	36.4	49.1
	1975	47.6	27.5	37.6	50.8	30.4	40.6
April	1974	69.0	45.3	57.2	69.4	44.7	57.1
	1975	65.6	43.0	54.4	67.4	42.6	55.0
May	1974	79.6	55.9	67.8	80.7	55.8	68.3
	1975	79.1	54.8	67.0	76.7	52.2	64.5
June	1974	83.2	60.6	71.9	88.4	60.0	74.2
	1975	84.5	63.4	74.0	85.2	60.6	72.9

Source:- Climatological Data, Kansas,
U.S. Department of Commerce,
National Oceanic and Atmospheric Administration,
Environmental Data Service.

Table 2:- Precipitation (inches) September through June for the years 1973-74 and 1974-75 at Manhattan and Hutchinson.

	1973-1974			1974-1975		
	Manhattan		Hutchinson	Manhattan		Hutchinson
Months	Total	Departure	Total	Total	Departure	Total
September	9.89	6.18	9.96	1.61	-2.35	1.63
October	6.49	4.17	4.87	3.97	1.25	2.08
November	1.15	-0.09	0.61	1.49	0.51	1.10
December	3.40	2.46	2.12	0.83	-0.23	1.72
Sept.-Dec.	20.93		17.56	7.90		6.53
January	0.61	-0.25	0.25	1.41	0.55	1.08
February	0.64	-0.28	0.13	1.70	0.78	2.20
March	1.39	-0.46	2.48	1.55	-0.30	1.46
Jan.-Mar.	2.64		2.86	4.66		4.74
April	5.64	2.64	8.30	2.23	-0.77	1.33
May	2.17	-2.18	6.63	3.56	-0.79	4.80
June	5.84	0.00	1.92	9.07	3.23	8.48

Source:- Climatological Data, Kansas,
U.S. Department of Commerce,
National Oceanic and Atmospheric Administration,
Environmental Data Service.

RESULTS

Mean values of grain yield and components of yield of twelve winter wheat cultivars grown at four environments under four nitrogen levels are given in Table 3. The mean grain yield ranged from 305 grams per square meter in Parker to 407 grams per square meter in the semidwarf line KS73164. On the average each of the eight semidwarf lines yielded significantly higher than the standard checks. They yielded 17 to 33 percent higher than Parker or Eagle. The semidwarf line KS73164 was significantly the highest yielding of all the cultivars. TAM W-101 was the lowest yielding cultivar.

Average number of ears per square meter for different cultivars varied from 604 in KS73189 to 759 in Parker. Semidwarf lines produced significantly fewer ears per m^2 and Parker produced the highest number. The semidwarf lines produced nine to twenty percent less ears per m^2 than Parker.

Average number of seeds per ear varied from 23 seeds in TAM W-101 to 34 seeds per ear in KS73164. The eight semidwarf lines produced 14 to 36 percent more seeds per ear than Parker or Eagle. The semidwarf lines KS73164, KS73278, KS73189, KS73105, and KS73211 produced significantly more seeds per head.

Kernel weight varied significantly among cultivars. Parker had the lowest kernel weight, 25.7 grams per 1000 kernels, and the semidwarf line KS73198 had the highest, 33.3 grams per 1000 kernels.

Response to Environment

There was significant environmental effect on grain yield as well as on components of yield as shown in Table 4. The mean yield was highest at

Table 3:- Grain yield and components of yield of twelve winter wheat cultivars (mean of all environments and nitrogen levels) and relative production in comparison to Parker.

	Grain yield		Number of ears		Number of seeds		Kernel weight	
Cultivar	g/m^2	% Parker	Ears/ m^2	% Parker	Seeds/ Ear	% Parker	g/1000	% Parker
Parker	305	100	759	100	25.0	100	25.7	100
Eagle	305	100	701	92	24.4	97	30.0	116
TAM W-101	300	98	670	88	23.1	92	30.5	118
Sturdy	336	110	651	86	31.9	127	28.1	109
KS73105	355	117	680	90	33.4	133	27.2	106
KS73151	370	121	690	91	32.4	130	28.8	112
KS73164	407	133	668	88	34.1	136	28.3	110
KS73189	366	120	604	80	33.4	134	29.2	113
KS73202	377	124	683	90	31.5	126	27.4	107
KS73211	362	119	691	91	33.2	133	26.1	102
KS73198	379	124	637	84	28.5	114	33.3	130
KS73278	383	125	656	86	33.5	134	27.8	108
LSD .05	15	-	30	-	1.4	-	.6	-
.01	20	-	39	-	1.8	-	.8	-

Table 4:- Grain yield and components of yield at four environments (mean of twelve cultivars under four nitrogen levels).

Environments	Grain yield g/m^2	Number of ears $Ears/m^2$	Number of seeds Seeds/ear	Kernel weight g/1000 seeds
Manhattan 1974	341	806	28.8	29.4
Hutchinson 1974	326	748	30.6	24.0
Manhattan 1975	398	562	32.3	30.8
Hutchinson 1975	350	582	29.8	29.8
LSD .05	17.5	45	0.7	1.0
.01	24.4	63	1.0	1.2

Manhattan in 1975, followed by Hutchinson in 1975, Manhattan in 1974, and Hutchinson in 1974.

Large environmental differences in number of ears per square meter were observed in this study. At Manhattan in 1974 a significantly higher number of ears per square meter was produced and in 1975 the fewest number of ears per m^2. In general, 1974 was more favorable for a larger number of tillers per m^2 than 1975.

The number of seeds per ear was significantly higher at Manhattan in 1975 while at Manhattan in 1974 there was fewer number of seeds per ear.

Kernel weight was significantly higher at Manhattan in 1975, 30.8 grams per 1000 kernels, followed by Hutchinson in 1975, Manhattan in 1974, and significantly the lowest at Hutchinson in 1974, 24.0 grams per 1000 kernels.

Cultivaral performance at different environments is given in Table 5. The variety X environment interaction for grain yield as well as for components of yield was significant indicating that the genotypes responded differently in different environments. Most of the cultivars yielded significantly higher at Manhattan in 1975 and lower in Hutchinson in 1974 except the cultivars KS73198 and Sturdy. Most of the cultivars were not significantly different for grain yield in the other two environments. At Manhattan in 1974, the yield ranged from 285 to 401 grams per m^2 and semidwarf lines yielded 99 to 121% of Parker. At Hutchinson in 1974, the yield ranged from 220 to 378 grams per m^2 and semidwarf lines yielded 147 to 172% of Parker. At Manhattan in 1975, the yield ranged from 338 to 477 grams per m^2 and semidwarf lines yielded 111 to 141% of Parker. At Hutchinson in 1975, the yield ranged from 287 to 405 grams per m^2 and semidwarf lines yielded 101 to 122% of Parker. Although the genotypes showed significant

Table 5:- Effect of four environments on grain yield of twelve winter wheat cultivars (mean of four nitrogen levels).

	Manhattan 1974		Hutchinson 1974		Manhattan 1975		Hutchinson 1975	
Cultivar	g/m^2	% Parker	g/m^2	% Parker	g/m^2	% Parker	g/m^2	% Parker
Parker	331	100	220	100	339	100	332	100
Eagle	301	91	231	105	354	105	333	100
TAM W-101	285	86	267	122	360	106	287	87
Sturdy	291	88	355	162	361	107	337	102
KS73105	351	106	352	160	385	114	333	101
KS73151	365	110	355	162	421	125	340	102
KS73164	372	113	372	169	477	141	405	122
KS73189	350	106	338	154	402	119	376	113
KS73202	367	111	345	157	436	129	361	109
KS73211	326	99	322	147	445	132	353	107
KS73198	401	121	375	171	377	111	365	110
KS73278	355	108	378	172	422	125	375	113

Cultivaral difference

	LSD .05	LSD .01
within same environment	31	41
among environments	33	44

yield difference between environments, the semidwarf lines KS73164 and KS73278 were significantly higher in yield than all four check cultivars at all the four environments (Table 5).

Almost all the varieties produced significantly higher number of ears per m^2 in 1974 and fewer ears for m^2 in 1975 at Manhattan (Table 6). Parker produced significantly more ears per m^2 in all environments except in Manhattan in 1975 and semidwarf line KS73189 produced fewer ears per m^2 in all four environments. The semidwarf lines produced 75 to 95%, 74 to 84%, 92 to 105%, and 87 to 98% as many ears as Parker at Manhattan in 1974, at Hutchinson in 1974, at Manhattan in 1975, and at Hutchinson in 1975, respectively.

Most of the cultivars produced significantly more seeds per ear in 1975 and fewer seeds per ear in 1974 at Manhattan (Table 7). At Manhattan in 1974 the number of seeds per ear ranged from 22 in Eagle to 35 in KS73105. The semidwarf lines produced 118 to 148% as many seeds per ear as Parker. The number of seeds per ear ranged from 22 to 37, 25 to 36, and 24 to 35 and the semidwarf lines had 118 to 151%, 102 to 131%, and 108 to 145% as many seeds per ear as Parker at Hutchinson in 1974, at Manhattan in 1975, and at Hutchinson in 1975 respectively. Therefore, the range in number of seeds per ear was higher in the low yielding environment and lower in the high yielding environment (Table 7).

Without exception, kernel weight was significantly lower at Hutchinson in 1974 for all the cultivars and higher at Manhattan in 1975. Although there was significant environmental variation for all the cultivars, the semidwarf line KS73198 significantly had the highest kernel weight in all four environments. Kernel weight ranged from 27 to 34, 21 to 30, 27 to 34, and 28 to 34 grams per 1000 kernels and the semidwarf lines had 100 to 126%,

Table 6:- Effect of four environments on number of ears per square meter of twelve winter wheat cultivars (mean of four nitrogen levels).

Cultivar	Manhattan 1974		Hutchinson 1974		Manhattan 1975		Hutchinson 1975	
	ears/ m^2	% Parker	ears/ m^2	% Parker	ears/ m^2	% Parker	ears/ m^2	% Parker
Parker	935	100	911	100	563	100	627	100
Eagle	882	94	761	83	559	99	604	96
TAM W-101	826	88	560	83	556	99	539	86
Sturdy	764	82	765	84	549	97	526	84
KS73105	813	87	723	79	590	105	597	95
KS73151	890	95	754	83	572	102	545	87
KS73164	743	79	763	84	569	101	599	96
KS73189	704	75	623	68	520	92	570	91
KS73202	776	83	754	83	591	105	611	97
KS73211	850	91	750	82	553	98	613	98
KS73198	755	81	672	74	555	98	567	90
KS73278	729	78	740	81	569	101	589	94

Cultivaral difference

	LSD .05	LSD .01
within same environment	28	37
among environments	33	44

Table 7:- Effect of four environments on number of seeds per ear of twelve winter wheat cultivars (mean of four nitrogen levels).

Cultivar	Manhattan 1974		Hutchinson 1974		Manhattan 1975		Hutchinson 1975	
	seeds/ ear	% Parker	seeds/ ear	% Parker	seeds/ ear	% Parker	seeds/ ear	% Parker
Parker	23.6	100	24.3	100	27.9	100	24.4	100
Eagle	22.1	94	22.8	94	26.4	95	26.3	108
TAM W-101	22.2	94	21.6	89	24.9	89	23.6	97
Sturdy	31.9	135	30.8	126	34.3	123	30.7	126
KS73105	34.9	148	34.8	143	34.5	124	29.4	120
KS73151	31.1	132	34.4	142	31.9	114	32.4	133
KS73164	31.3	133	33.4	137	36.5	131	35.3	145
KS73189	34.5	146	34.6	142	35.4	127	29.3	120
KS73202	27.9	118	28.7	118	36.3	130	33.3	136
KS73211	28.3	120	34.4	142	35.4	127	34.7	142
KS73198	28.6	121	30.5	125	28.5	102	26.3	108
KS73278	29.5	125	36.8	151	35.1	126	32.4	133

Cultivaral difference

	LSD .05	LSD .01
within same environment	2.4	3.0
among environments	2.8	3.7

100 to 144%, 106 to 126%, and 98 to 124% of Parker at Manhattan in 1974, at Hutchinson in 1974, at Manhattan in 1975, and at Hutchinson in 1975, respectively (Table 8).

Response to Nitrogen

Grain yield, grams per square meter, was significantly influenced by nitrogen application. Average grain yield and components of yield at four nitrogen levels are given in Table 9. On the average grain yields responded only up to 50 pounds of nitrogen per acre. However, the effect of nitrogen varied among genotypes (Table 10). Parker, Eagle, TAM W-101, KS73105, and KS73211 grain yield did not respond to nitrogen, whereas, the semidwarf lines KS73164 and KS73198 responded to nitrogen up to 150 pounds per acre and the yield was increased up to 115 percent. In the semidwarf lines KS73278, KS73189, and KS73202 and in Sturdy, nitrogen was effective only up to 100 pounds per acre. However the semidwarf lines KS73164, KS73278, KS73202, KS73198, and KS73189 were significantly higher in yield than all four check varieties at all four nitrogen levels (Table 10). The eight semidwarf lines yielded 115 to 125%, 113 to 127%, 120 to 140%, and 118 to 141% of Parker at 0, 50, 100, and 150 pounds of nitrogen per acre, respectively.

Number of ears per square meter was affected little by nitrogen application except at the 50 pounds per acre rate (Table 9). Parker produced significantly more ears per m^2 under all the nitrogen levels and KS73189 produced the fewest ears per m^2. The response to nitrogen of number of ears per m^2 was non-significant in Parker, Eagle, KS73105, KS73151, and KS73164, whereas, the response was variable in other cultivars (Table 11).

Table 8:- Effect of four environments on kernel weight of twelve winter wheat cultivars (mean of four nitrogen levels).

Cultivar	Manhattan 1974		Hutchinson 1974		Manhattan 1975		Hutchinson 1975	
	g/1000	% Parker	g/1000	% Parker	g/1000	% Parker	g/1000	% Parker
Parker	26.8	100	20.9	100	27.4	100	27.8	100
Eagle	30.2	113	25.7	123	31.8	116	32.1	115
TAM W-101	33.1	123	24.2	116	33.1	121	31.6	114
Sturdy	29.0	108	24.9	119	28.9	105	29.5	106
KS73105	28.1	105	24.3	116	29.0	106	27.3	98
KS73151	29.9	112	25.4	122	31.1	113	28.8	104
KS73164	29.3	109	23.2	111	30.9	113	29.6	106
KS73189	28.8	107	23.3	111	33.0	120	31.7	114
KS73202	28.0	104	22.8	109	30.2	110	28.4	102
KS73211	26.9	100	20.9	100	29.1	106	27.6	99
KS73198	33.9	126	30.1	144	34.5	126	34.6	124
KS73278	29.0	108	22.5	108	30.6	112	29.0	104

Cultivaral difference

	LSD .05	LSD .01
within same environment	1.3	1.7
among environments	1.5	1.9

Table 9:- Grain yield and components of yield at four nitrogen levels (mean of twelve cultivars grown at four environments).

Nitrogen lbs/acre	Grain yield		Number of ears		Number of seeds		Kernel weight	
	g/m^2	% O-N.	$Ears/m^2$	% O-N.	Seeds/ear	% O-N.	g/1000	% O-N.
0	341	100	647	100	28.3	100	29.7	100
50	360	105	684	106	30.1	106	28.8	97
100	357	104	686	106	31.3	111	28.0	94
150	357	104	681	105	31.9	113	27.7	93
LSD .05	5.1		14.3		0.7		0.2	
.01	6.7		18.8		0.9		0.26	

Table 10:- Grain yield of twelve winter wheat cultivars at four nitrogen levels (mean of four environments).

Cultivar	Nitrogen added pounds per acre						
	Zero lbs	50 lbs	% zero N.	100 lbs	% zero N.	150 lbs	% zero N.
	g/m^2						
Parker	302	316	105	300	99	302	100
Eagle	308	306	99	307	100	299	97
Tam W-101	308	308	100	290	94	293	95
Sturdy	314	338	108	344	110	348	111
KS73105	348	358	103	358	103	357	103
KS73151	350	388	111	376	108	366	105
KS73164	379	403	106	419	111	425	112
KS73189	350	369	106	376	108	370	106
KS73202	364	383	106	392	108	370	102
KS73211	359	373	104	353	98	361	101
KS73198	350	388	111	375	107	405	116
KS73278	367	388	106	394	108	381	104

Cultivaral difference

	LSD .05	LSD .01
within same nitrogen level	21.5	28.5
among nitrogen levels	17.6	23.2

Table 11:- Number of ears per square meter of twelve winter wheat cultivars at four nitrogen levels (mean of four environments).

Cultivar	Nitrogen added pounds per acre						
	Zero lbs	50 lbs	% zero N.	100 lbs	% zero N.	150 lbs	% zero N.
	ear number/m^2						
Parker	737	740	100	779	106	779	106
Eagle	704	688	98	719	102	695	99
TAM W-101	620	697	112	671	108	693	112
Sturdy	603	669	111	684	113	647	107
KS73105	693	669	97	692	100	669	97
KS73151	664	706	106	700	105	690	104
KS73164	658	677	103	671	102	668	102
KS73189	536	624	116	608	113	650	121
KS73202	660	719	109	689	104	665	101
KS73211	652	694	106	718	110	702	108
KS73198	606	658	109	650	107	634	105
KS73278	628	664	106	655	104	678	108

Cultivaral difference

	LSD .05	LSD .01
within same nitrogen level	52	69
among nitrogen levels	50	65

Number of seeds per ear, increased with increased nitrogen application (Table 9). The effect of nitrogen on number of seeds per ear varied among genotypes. Nitrogen application had no significant effect on number of seeds per ear in Parker, Eagle, and TAM W-101, whereas, in the semidwarf lines KS73164, KS73278, KS73211, and KS73198 nitrogen application stimulated the number of seeds per ear up to 150 pounds per acre and produced up to 24% more seeds per ear. In the semidwarf lines KS73105, KS73202, KS73151, and Sturdy, added nitrogen stimulated number of seeds per ear only up to 100 pounds per acre. Semidwarf lines produced significantly more seeds per ear at all four nitrogen levels than the standard check cultivars (Table 12).

Effect of nitrogen application on kernel weight was significant in negative linear pattern (Table 9). Heavier nitrogen application depressed the kernel weight up to seven percent. However, the genotypes responded differently to added nitrogen. Heavier nitrogen application depressed the kernel weight from three to four percent in KS73198, KS73164 and Sturdy and to ten percent in KS73189 and TAM W-101. The semidwarf line KS73198 had significantly higher kernel weight in all the four nitrogen levels and Parker had the lower (Table 13).

The effect of nitrogen on mean grain yield and on components of yield of 12 cultivars was significantly different in different environments. At Manhattan in 1975 there was a positive yield response to all nitrogen applications. At Hutchinson in 1975 and at Manhattan in 1974 the response was only up to 50 pounds of nitrogen per acre, whereas, at Hutchinson in 1974 added nitrogen depressed yield (Table 14).

The nitrogen X environment interaction for number of ears per m^2 was non-significant indicating similar response in all the environments.

Table 12:- Number of seeds per ear of twelve winter wheat cultivars at four nitrogen levels (mean of four environments).

Cultivar	Nitrogen added pounds per acre						
	Zero lbs	50 lbs	% zero N.	100 lbs	% zero N.	150 lbs	% zero N.
	seeds/ear						
Parker	24.7	24.6	100	25.1	102	25.7	104
Eagle	22.9	24.4	107	25.3	111	24.9	109
TAM W-101	21.9	23.3	106	23.5	107	23.6	108
Sturdy	29.8	31.9	107	33.0	111	32.9	110
KS73105	31.2	32.2	103	36.4	117	33.8	108
KS73151	30.7	32.1	105	33.4	109	33.6	110
KS73164	30.2	33.4	111	35.5	118	37.4	124
KS73189	31.4	34.4	110	33.8	108	34.2	109
KS73202	29.3	30.9	106	33.1	113	32.8	112
KS73211	31.2	32.2	103	33.6	108	35.9	115
KS73198	26.2	28.6	109	28.0	107	31.2	119
KS73278	29.5	32.8	111	35.4	120	36.2	123

Cultivaral difference

	LSD .05	LSD .01
within same nitrogen level	2.5	3.3
among nitrogen level	2.0	2.7

Table 13:- Kernel weight of twelve winter wheat cultivars at four nitrogen levels (mean of four environments).

Cultivar	Nitrogen added pounds per acre						
	Zero lbs	50 lbs	% zero N.	100 lbs	% zero N.	150 lbs	% zero N.
	g/1000 kernels						
Parker	26.6	26.0	98	25.4	96	25.0	94
Eagle	30.9	30.4	98	29.5	96	28.9	94
TAM W-101	32.6	30.8	95	29.4	90	29.3	90
Sturdy	28.9	28.1	97	27.7	96	27.5	95
KS73105	28.4	26.6	94	26.7	94	26.9	95
KS73151	29.9	29.3	98	28.0	94	28.0	94
KS73164	29.0	28.5	98	27.9	96	27.6	95
KS73189	31.2	29.3	94	28.3	91	28.1	90
KS73202	28.4	28.0	99	27.1	95	26.0	92
KS73211	27.1	26.5	98	26.0	96	24.9	92
KS73198	34.0	33.4	98	32.9	97	32.8	97
KS73278	29.0	28.0	97	27.0	93	27.1	93

Cultivaral difference

	LSD .05	LSD .01
within same nitrogen level	0.9	1.2
among nitrogen level	0.7	0.9

Table 14:- Effect of nitrogen application on mean yield and components of yield of twelve winter wheat cultivars grown at four environments.

Environment	N.lbs/acre	Grain yield		Number of ears		Number of seeds		Kernel weight	
		g/m^2	% O-N.	$Ears/m^2$	% O-N.	Seeds/ear	% O-N.	g/1000	% O-N.
Manhattan	0	334	100	765	100	27.6	100	30.6	100
1974	50	350	105	819	107	29.0	105	29.8	97
	100	342	102	814	106	29.4	107	28.8	94
	150	338	101	824	108	29.4	107	28.5	93
Hutchinson	0	336	100	720	100	29.1	100	25.0	100
1974	50	329	98	750	104	30.9	106	24.1	96
	100	321	96	772	107	31.1	107	23.6	94
	150	318	95	748	104	31.3	108	23.4	94
Manhattan	0	352	100	527	100	28.3	100	32.0	100
1975	50	403	114	577	109	31.1	110	31.2	97
	100	416	118	578	110	33.5	118	30.3	95
	150	422	120	565	107	36.1	128	29.8	93
Hutchinson	0	344	100	574	100	28.1	100	31.2	100
1975	50	357	104	588	102	29.2	104	29.8	95
	100	349	101	580	101	31.3	111	29.2	94
	150	347	101	586	102	30.7	109	29.1	93
LSD .05		10		28.6		1.4		0.4	
.01		13.4		37.6		1.8		0.5	

The nitrogen X environment interaction for number of seeds per ear was significant as the response to nitrogen was different by environments. Seeds per ear at Manhattan in 1975 increased with increased nitrogen up to 150 pounds per acre whereas at Hutchinsin in 1974 there was an increase only up to 50 pounds per acre. At Manhattan in 1974 and at Hutchinson in 1975 there was a positive response up to 100 pounds per acre for seeds per ear (Table 14).

The nitrogen X environment interaction for kernel weight was non-significant indicating the similar depressing effect of nitrogen application in all four environments.

The genotypes responded differently to added nitrogen in different environments as shown in Table 15. Grain yield of the semidwarf line, KS73164, responded to nitrogen application up to 150 pounds per acre at Manhattan in 1975, 100 pounds per acre at Manhattan in 1974 and at Hutchinson in 1975 and had low or no response at Hutchinson in 1974. Whereas, yields of KS73278, responded to nitrogen application up to 100 pounds per acre at Manhattan in 1975, up to 50 pounds per acre at Manhattan in 1974, but did not respond at Hutchinson in 1974 and 1975.

Correlations

Phenotypic correlations between grain yield and its components at four environments are given in Table 16. In 1974, kernel weight and number of seeds per ear were positively correlated with yield and number of ears per m^2 and yield were negatively associated. In 1975, number of seeds per ear and number of ears per m^2 were positively associated with yield. The correlations between yield components were negative. The correlations between number of seeds per ear and kernel weight were negative and significant

Table 15:- Response of Parker, KS73164, KS73202, and KS73278 to added nitrogen in different environments on grain yield.

Environments	N. lbs per acre	Parker	KS73164	KS73202	KS73278
		----------- grams per m^2 -----------			
Manhattan 1974	0	325	339	370	332
	50	337	373	364	384
	100	336	397	371	357
	150	325	379	360	347
Hutchinson 1974	0	233	369	354	381
	50	231	367	351	380
	100	202	373	343	385
	150	213	381	334	367
Manhattan 1975	0	323	428	367	380
	50	361	460	445	410
	100	330	487	479	452
	150	339	535	454	444
Hutchinson 1975	0	329	380	363	373
	50	335	414	373	378
	100	331	421	375	382
	150	332	406	334	367
LSD .05	10				
.01	13				

Table 16:- Phenotypic correlations between yield and its components and between the components at four environments (mean of twelve cultivars grown under four nitrogen levels).

	Environments	Grain yield	Kernel weight	# Seeds per ear
Kernel weight	Manhattan 1974	0.2034**		
	Hutchinson 1974	0.3235**		
	Manhattan 1975	-0.1152		
	Hutchinson 1975	0.0154		
# Seeds per ear	Manhattan 1974	0.2241**	-0.2503**	
	Hutchinson 1974	0.6341**	-0.0998	
	Manhattan 1975	0.5268**	-0.2685**	
	Hutchinson 1975	0.3195**	-0.4795**	
# Ears per m^2	Manhattan 1974	-0.0514	-0.1538*	-0.3248**
	Hutchinson 1974	-0.3389**	-0.3015**	-0.2642**
	Manhattan 1975	0.1527*	-0.1381	-0.0372
	Hutchinson 1975	0.1932**	-0.1551*	-0.0120

*Significant at 5% level.

**Significant at 1% level.

except at Hutchinson in 1974. Negative and significant associations between number of ears per m^2 and kernel weight were observed except at Manhattan in 1975. The association between number of seeds per ear and number of ears per m^2 was negative and significant in 1974 and non-significant in 1975.

DISCUSSION AND CONCLUSIONS

Eight semidwarf lines with Parker, Eagle, TAM W-101, and Sturdy as checks were studied in 1974 and 1975 at Manhattan and Hutchinson under four nitrogen levels. These newly developed semidwarf lines were selected to determine their response to different nitrogen applications and if components of yield were associated with grain yield.

The mean grain yield of eight semidwarf lines was 123 percent of the check cultivars. The semidwarf lines also yielded significantly higher at all four environments although there was significant yield difference among environments. These newly developed semidwarf lines have shown high yielding ability. The data (Table 3) indicated that the component of yield most closely associated with grain yield was the number of seeds per ear. Seeds per ear rapidly increased with improvement of the environment. Yield superiority of the semidwarf lines resulted mainly from increased seeds per ear under the four environments.

The components of grain yield in wheat were determined at different stages of growth. Number of ears per m^2 was determined at an early stage. Ear number was almost a direct function of tiller number. Number of spikelets was determined at the time of floral initiation but variation in number of florets per spikelet can occur later (Bonnett, 1966). For wheat, in general, failure of grain set due to lack of pollination is rare because of selfing and abundance of pollen. Therefore, the upper limit of kernel number was determined before anthesis. The terminal process, grain filling (when grain weight progressively increases), had an upper limit to grain size and rate of grain filling. Since yield components were determined at different times, the yield components were differentially affected by variation in the environment.

Yield differences in the different environments in this study probably were due to variation in amount of moisture, nutrients availability, and temperature stress occurring at different times.

The first component of yield, number of ears per m^2, was higher in 1974 because there was an adequate water supply at the early development stage and the air temperature was above the average in early spring.

Number of seeds per ear was higher at Manhattan in 1975 mainly because of good moisture conditions and low temperature. Friend (1965) found that at low temperatures, number of spikelets and length of the ear were in general greater than at higher temperatures at all stages of development, from double ridge formation to anthesis. Aspinall et al. (1964) found the number of seeds per ear reduced in barley by a moisture stress between stamen initiation and anthesis.

Kernel weight was associated with the lower yield at Hutchinson in 1974. Moisture stress and hot dry wind during the grain filling stage presumably reduced kernel weight by more than 20 percent at Hutchinson in 1974. Moisture stress along with hot dry air might affect photosynthesis in the ears and upper leaves, hastened maturation, and lowered grain weight. Thorne (1963) and Carr and Wardlaw (1965) reported that the greatest contribution to grain filling was usually from photosynthesis after anthesis by the ear, leaves, and stem. This was also supported by Aspinall (1965) in that reduced photosynthesis at any point of the post-anthesis stage may have effects on grain weight. There is no doubt, however, that water stress and temperature stress at different stages of development will affect yield in different ways.

This study supports the contention that the organ which is growing most rapidly at the time of a stress is the one most affected.

I was also interested in learning if the newly developed better performing semidwarf lines reacted differently than the older and taller standard cultivars when fertilized with nitrogen. The data (Table 10) clearly showed that the newly developed semidwarf lines KS73164, KS73198, KS73278 and KS73202 responded better to nitrogen applications than Parker and Eagle. The results also suggested that much of the grain yield increase from top-dressed nitrogen was associated with an increase in the number of seeds per ear and by an increase in the number of ears per square meter (Tables 12 and 11). This was similar to Murata's (1969) report on rice in that heavy nitrogen applications increased the formation of yield containers (grains) more than the accumulation and translocation of yield contents (filling of the grains). Another reason may be lack of sufficient phosphorus and potassium. Hobbs (1953) found increased kernel weight with fall application of phosphorus and potassium.

The effect of nitrogen on yield components was considered useful in explaining cultivaral differences in response of grain yield to nitrogen application.

KS73278 produced high relative grain yield increases because both number of seeds per ear and number of ears per m^2 were stimulated (Tables 12 and 11), whereas, KS73164 produced high relative grain yield increases mainly because of the stimulation of nitrogen on number of seeds per ear. In contrast, Parker and Eagle responded to little nitrogen applications in either relative grain yield or any of the yield components (Tables 10, 11, 12 and 13).

The differential manner in which the semidwarf lines responded to nitrogen application through yield components suggested that some wheat strains would be more flexible in adjusting to adverse or optimum environmental conditions than others.

In 1974, both at Manhattan and at Hutchinson grain filling was the limiting factor for grain yield, therefore, yield was correlated with kernel weight.

Grain yield was closely associated with number of seeds per ear in all four environments, therefore, the grain yield was correlated with number of seeds per ear.

In 1974, when number of ears per m^2 was higher and grain yield was lower, yield was negatively correlated with number of ears per m^2. In 1975, when number of ears per m^2 was lower and grain yield was higher, yield was positively correlated with number of ears per m^2.

The negative association between yield components agreed with Adams (1967) report on compensation effects. The correlation data (Table 16) add further support to the hypothesis of significant environmental control of components relationships.

These data showed that the increased yield of the semidwarfs over the taller standard cultivars was mainly due to an increase in number of seeds per ear.

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RESPONSE OF SEMIDWARF HARD WINTER WHEATS TO SEVERAL ENVIRONMENTS IN KANSAS

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Eight newly developed semidwarf wheat (Triticum aestivum L.) lines were studied in 1974 and 1975 at Manhattan and Hutchinson, Kansas. Zero, 50, 100, 150 pounds of nitrogen were applied per acre. The components of yield, number of ears per m^2, number of seeds per ear, and kernel weight were determined. Parker and Eagle, standard height cultivars, and TAM W-101 and Sturdy, semidwarf cultivars, were used as checks.

The mean grain yield of all semidwarf lines was 123 percent of the mean grain yield of the checks. All eight semidwarf lines were significantly higher in yield than the standard check cultivars. They yielded 17 to 33 percent higher than Parker or Eagle. Semidwarf lines also yielded significantly higher in all the four environments although there was significant yield difference among environments.

Response to nitrogen application was significant for grain yield and yield components. The semidwarf lines KS73164, KS73189, KS73278, and KS73202 were more responsive to nitrogen application than the standard check cultivars.

The component, number of ears per m^2, was affected little by added nitrogen except at the 50 pounds per acre rate. On the average semidwarf lines had significantly fewer ears as compared to standard checks.

The second component, number of seeds per ear, increased with increased nitrogen applications and was strongly affected by cultivar. The semidwarf lines on the average produced 32 percent more seeds per ear than the check cultivars. Number of seeds per ear was closely associated with grain yield and increased with the improvement of the environment.

The third component, kernel weight, was significantly affected by cultivar. Parker, significantly, had the lowest kernel weight and KS73198 the highest kernel weight. Kernel weight consistently decreased with increased nitrogen applications.

The advantage of semidwarf lines in number of seeds per ear and kernel weight were partially offset by less ears. The greater yield of the semidwarf lines seemed to be a result of the greater number of seeds per ear. Much of the yield increase from topdressed nitrogen was associated with an increase in the number of seeds per ear and by an increase in the number of ears; kernel weight had little effect.

Cultivars responded differently to nitrogen applications. KS73278 produced high grain yield increases because both number of seeds per ear and number of ears were stimulated by nitrogen, whereas, KS73164 responded only in number of seeds per ear. In contrast, Parker and Eagle produced little response to nitrogen in either grain yield or any of the yield components.

The components of grain yield in wheat are determined at different stages and environmental stress at different stages of development affect yield in different ways.

Correlation data (phenotypic correlation coefficient) among components of yield in these experiments add further support to the hypothesis of significant environmental control of component relationships.