PHOTOSYNTHETIC AREA DURATION IN WINTER WHEAT (*TRITICUM AESTIVUM* L.) AND ITS INFLUENCE ON GRAIN YIELD AND YIELD COMPONENTS

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CHAPTER I

INTRODUCTION

The growth of plant is a complex process governed by the genetic make-up of the plant, and the environment limits the expression of this genetic potential. Breeding efforts on wheat have been concentrated on the development of varieties with higher yield potential. Recently it has been realized that working with yield per se may not be the most efficient method of increasing yield. Grain yield is a complex character controlled by many genes and as such is very difficult to manipulate. In research programs designed to achieve increased yields, a knowledge of the photosynthetic area, yield components and their relationships to yield in response to environment, fertility level, and plant density should be of assistance to crop physiologists and plant breeders.

Nitrogen fertilization has contributed greatly to improving wheat yields in nitrogen deficient soils, and there are numerous reports supporting this fact. Nitrogen is a constituent of enzymes and nucleoproteins, which plays a major role in plant growth processes. Varieties differ from each other in morphological characters and yield components (8); and there are differential varietal responses to nitrogen (83). Studies with applied fertilizers have shown that an increase in yield can be obtained with fertilizer application; however, application rates higher than the plants can utilize effectively can result in reduction in yield. Plant density has long been thought to be a primary factor in the determination of yield. Grain yield increases with increase in seed rate up to a point beyond which a decline in yield occurs, due to inter-plant and intra-plant competition (21) for growth factors.

In cereals the yield components are determined sequentially in the development of plants and there is compensation among these components based on available environmental resources. The concept of an 'ideotype' plant (20) for wheat has pinpointed the importance of the flag leaf and photosynthesizing structures above the flag leaf in producing higher grain yields. Most of the present high yielding varieties have narrow upright leaves exposing greater leaf area to sunlight for higher rates of dry matter accumulation (86).

The purpose of this study was:

1. To determine the relative importance and relationship of photosynthetic area duration with grain yield and yield components.
2. To investigate the response of five winter wheat varieties to various nitrogen and seed rate treatment combinations higher than the levels now being used for present grain production.

CHAPTER II

REVIEW OF LITERATURE

The growth of crop science in recent years has been enormous and as a result, there is a rapid increase in volume of published literature. In the following pages relevant literature will be reviewed.

Effect of Nitrogen and Seed Rate on Grain Yield

The supply of nitrogen in many soils is not sufficient for optimum crop yields, as such nitrogen has been subjected to the greatest amount of study and still receives much attention. There is generally a big gap between the amount of nitrogen a soil can supply and the amount withdrawn annually by crops. Nitrogen fertilization has contributed greatly to improving wheat yields in many nitrogen deficient soils around the world (3,15,22,37,40,48,49,62). Nitrogen is a constituent of enzymes and nucleoproteins and an adequate supply of nitrogen is necessary for vigorous plant growth (41,49), and applied nitrogen can increase grain protein content (36,58,85). When compared to other nutrients in the soil, nitrogen is most vulnerable to leaching losses and more sensitive to moisture stress with regard to uptake by the plant (79). When the soil moisture is limited or leaching has occurred from excess moisture during the tillering or flower initiation stages of growth, no significant differences are observed in wheat yield due to nitrogen fertilization (79). Similar conclusions were drawn by Alhagi (4), and Klein (53) working with wheat in Oklahoma. Johnson et al. (47) found a positive non-linear yield response to nitrogen fertilizer with a second degree polynomial providing a good fit for the data, and a positive linear response for protein to nitrogen fertilizer. Stone and Tucker (84) found a negative linear relationship between nitrogen fraction in the grain and the quantity of water applied to soil surface.

Varieties differ from each other in morphological characters and yield components (8), and as such there are differences in yields of varieties. Because of these differences in plant characters, there are differential varietal responses to nitrogen as reported by Stickler and Pauli (83). Dwarf and semi-dwarf varieties are more resistant to lodging at higher nitrogen levels compared to the traditional tall varieties. Johnson et al. (46) concluded that short-statured varieties were more productive than tall varieties.

The yield of any variety or genotype in a given environment may be influenced to a large extent by the number of plants per unit area. At low densities competition among inflorescences on an intraplant basis is high, thereby reducing the efficiency of seed production in the individual inflorescence. In moderately dense stands, interplant competition becomes operative at the time of flower initiation. The number of floral primordia on each plant are reduced and the seeds per inflorescence and seeds per unit area achieves maximum values. Donald (21) suggested that the greater seed weight and number of seeds per inflorescence at intermediate densities are due to the timing of interplant and intraplant competition. In extremely dense stands the competition at the time of laying down of floral primordia is intense and plants in such dense communities are subjected to both interplant and intraplant competition. Nelson (68) reported that increasing the density of Gaines wheat from 8 to 25 plants per square feet reduced tillers per plant from 3.72 to 3.37. Spring application of nitrogen to winter wheat increased tillering which increased the grain yield. Higher seed rate (112 kg/ha) and higher nitrogen level (112 kg/ha) gave higher yields (85) but there was no significant interaction between nitrogen and plant population (38,85); an increase in nitrogen rate resulted in an increase in the total number of tillers and in the percentage of ear producing tillers (38). Similar results were reported by Ishaq and Taha (42) working with wheat in Sudan.

Yield and Yield Components

The yield components responsible for total grain yield in cereals were identified in the 1920's as tillers per unit area, kernels per head, and weight per kernel (25,50). Mitchell (66) suggested that final grain yield was a product of the following equation:

$$\text{Yield} = f\left(\frac{\text{plants}}{\text{area}} \times \frac{\text{heads}}{\text{plant}} \times \frac{\text{seed}}{\text{head}} \times \frac{\text{weight}}{\text{seed}}\right)$$

Grafius (34) considered heads per unit area, average number of kernels per head and average kernel weight as the edges of a rectangular parallelepiped with yield as the volume of this parallelepiped. The greatest rate of change in volume occurs with changes in the shortest edge and he suggested that from plant breeding standpoint, it might be easiest to increase yield by increasing the short edge for an otherwise good variety. Hsu and Walton (39) working with winter wheat concluded that for each variety there is one primary yield component responsible for changes in yield, thus different varieties may have the same yield potential, but the effects of the yield components may be different. In cereals the yield components are determined sequentially in the development of plants and the later components can compensate for reductions in earlier ones. Similar conclusions about yield component compensation were shown by Adams (1) for field beans. Adams and Grafius (2) suggested that yield component balance among crop plants is achieved primarily through the oscillatory response of sequential components to limited resources. Each variety reaches a compromise in the utilization of available environmental resources and strong linkages would not permit the required flexibility in order to respond to limitations of environmental resources (2). In wheat inflorescence the lower mid-part of the ear has the greatest number of grains and florets per spikelet and heaviest grains of the ear (51) and this is true for most cereal plants. McNeal (64) studied the yield components in Lemhi x Thatcher wheat cross and found heads per plant and kernels per head more closely associated with yield per plant than was kernel weight. In another study Knott and Talukdar (54) found weight per seed was positively correlated with yield and a negative correlation between weight per seed and number of kernels per plot. The number of kernels per spike were negatively correlated with the number of spikes per plot (54). Fonseca and Patterson (31) studied the yield component heretabilities and interrelationships in winter wheat and found a negative correlation between number of spikes and kernels per spike and between kernel weight and kernels per head. They also found yield was positively correlated with kernel weight, number of spikes and negatively correlated with kernels per spike. In a study for determining characters for yield in spring wheat, Nass (67) found that yield per ear and number of ears per plant were negatively correlated. Jain et al. (43) reported that grain yield was positively correlated with number of tillers per plant, number of grains per ear, and number of days to flowering. They also found a positive correlation between number of grains per ear and number of spikelets per ear. Johnson et al. (46) studied the yield components of winter wheat varieties differing in plant height and found that the variety which was highest yielding produced more kernels per spike but its kernel weight and spike number were less than the other varieties. There is an influence of nitrogen fertilizer on yield components and Easton and Clements (23) reported that nitrogen increased the number of ears per square meter and number of grain per ear but decreased 1000-grain weight. Khadr and Kassem (48) studied the response of wheat yield and yield components to nitrogen and found a linear increase in yield per ear, ear number and 100-grain weight with increase in applied nitrogen. The effect of nitrogen is more at certain stages of the reproductive phase and according to Langer and Liew (57) the spikelet number was increased by increasing nitrogen at the double-ridge stage and the number of grains per spikelet also responded to additional nitrogen during the same period. If nitrogen supply was high until ear emergence, the effect was more pronounced in increased number of spikelets and grains per spikelet (57).

Photosynthetic Area Above Flag Leaf and Its Influence on Grain Yield and Yield Components

Donald (20) introduced the concept of an 'ideotype' plant for wheat, and breeding programs in many cereal crops have attempted to develop plant types having the desirable characters of an ideotype plant.

According to Donald (29) an ideotype plant for England is one which has short, strong stems, few small erect leaves, a large ear and erect ear with awns, and a single culm. The recent trend in breeding field crops is toward a dwarf plant which is resistant to lodging with erect or angular leaves to trap more light energy. Lupton (61) suggested that greater yield of semi-dwarf selection might be due to rapid photosynthesis, despite less photosynthetic surfaces of leaves and ears as compared to conventional varieties. He also indicated that selection for erect leaves may lead to further increases in ,yield. Work on similar lines was reported by Gardner *et al*. (33) working with barley in Ontario, Canada. They found that the main difference between varieties for yield was leaf type with high yielding varieties having narrow upright leaves while low yielding varieties had wide floppy leaves. Also high yielding varieties had greater leaf area exposed to sunlight and a higher rate of dry matter production. Similar conclusions were drawn by Tanner *et al*. (86) and suggested that upright leaf types should be planted in narrower drill rows or broadcast for full utilization of radiant energy for crop growth instead of weed growth. Berdahl et al. (14) found that in barley large leaves favor higher kernel weights and small leaves favor production of more culms. Leaf area below or above the optimum will result in lower yields. In the first case there is not enough leaf area for optimal growth and assimilation of photosynthate and in the latter case due to excessive leaf area the lower leaves on the plant become parasitic and thereby reduce the net assimilation rate (98,99). This aspect of crop production was pinpointed by Niciporovic (69) who suggested that optimal leaf area index (LAI) of 3.0 to 3.5 be established early in season and remain active till the end of the growing season to give higher yields.

Much work has been done on barley, rice, sorghum, and corn in an effort to find a method for measuring the leaf area, and the general recommended method is:

$A = C\,(LW)$ where

A = estimated leaf area

C = Regression constant

LW = Product of length of leaf and maximum width of the leaf.

Palaniswamy and Gomez (70) reported the constant (C) for dry season rice to be 0.73 and 0.75 for wet season rice. Rao et al. (75) reported 0.876 as constant for Mexican dwarf wheat.

The importance of leaf area duration after the flowering was pointed out by Welbank et al. (101) and Fisher and Kohn (30) who found that varieties which had a longer leaf area duration produced higher yields. Quinlan and Sagar (74) and Khalifa (49) reported that nitrogen application increased leaf area duration.

Walpole and Morgan (95) studied the grain filling in three barley varieties and found that there are three distinct phases in grain filling in the main shoot ears of barley. Phase I lasted for a week after anthesis and was characterized by grains in the center of the ear showing the highest absolute rates of growth. Phase II lasted 14 to 21 days when basal grains had the highest absolute growth rates. Phase III lasted 7 to 14 days during which all grains lost weight. This implies that it takes about four to five weeks after flowering for the ear to be physiologically mature and this period of grain filling is controlled to a large extent by the environmental conditions.

Many investigations with cereal crops concerned with flag leaf and photosynthetic area above flag leaf such as peduncle, leaf sheath, awns and glumes have indicated the importance of these structures in increasing grain yields (13,39,60,67,81,88,89,92,100,105). Voldeng and Simpson (94) suggested that large flag leaf and a large ear area were indexes for selecting high yielding individuals from a mixture of genotypes. Long awns increase the chlorophyll containing area on a spike and possess a greater number of stomata which increase the gaseous exchange and transpiration rate of the spike, and as a result awns can function in dissipating excess heat energy from the barley spikes (52). Similar conclusions about the importance of awns in the yield of cereal crops were drawn by Patterson et al. (71), Faris (29) and Rastogi and Singh (76). Johnson et al. (45) concluded that differences in the amount of awn among genotypes could be described best by dry weight than awn number or awn length. McKenzie (63) working with wheat in southern Alberta for four years found an adverse influence of awns, and concluded that awnless cultivars were superior to the awned types in grain yield. He reported slight differences among kernels per spike between awned and awnless and the number of spikes per unit area was greater for awnless than for awned lines. Walpole and Morgan (96) studied the physiology of grain filling in barley and found that photosynthate assimilated by the awn goes primarily to the grain which it subtends.

The photosynthetic assimilate moves to all parts of the plant and is translocated preferentially to the sink closest to the assimilating leaf. Rawson and Hofstra (77) found each wheat leaf exported substances in a specific direction with the lower leaves exporting downwards to the tillers and roots, and the upper leaves supplying the stem and ear. They also found that tillers never became completely independent from the main stem and a significant amount of ^{14}C moved from the lower leaves of the main stem and was incorporated in ears of the tillers.

Evans _et al_. (28) reported that ^{14}C assimilated by the ears was most important to the economy of the upper spikelets and distal florets in each spikelet, whereas flag leaf assimilate went mainly to the spikelets in the lower half of the ear and to the proximal florets.

Many experiments have been done to estimate the contribution of the flag leaf, peduncle, leaf sheath, ear, awns and glumes to yield (16,19,26,27,35,52,55,78,90,91,97,98) and the results reported do not agree. These differences could be attributed to many factors such as techniques used, varietal effect, the compound of photosynthesis analyzed, stage of plant growth, time of sampling and environmental differences. Similar conclusions were drawn by Lupton and Ali (59) and

Buttrose and May (18) and they emphasized the need of more refined techniques.

Genotype and Environment Relationship

Plant growth at any time is determined by the environmental conditions at that time and by the genetic constitution of the plant. The knowledge of genotype by environment interaction is important to the plant breeder, if this interaction is not significant, the breeding program can be directed toward developing varieties suitable for larger areas. When the genotype by environment interaction is significant, the breeder has to develop varieties suitable for specific areas. McNeal et al. (65) reported that cultivars accounted for most of the variation among plant height and yield component comparisons. Eck and Tucker (24) summarizing the results of 104 field trials on 41 soil types in western Oklahoma concluded that soil moisture at sowing, rainfall during the season, temperature during ripening, soil moisture in spring and rainfall in the spring were significantly and positively correlated with grain yield and with yield response to nitrogen.

Hutcheon and Paul (41) reported that moderate moisture stress resulted in maximum efficiency of water use by wheat in Canada. Moisture stress during flower initiation results in the death of some upper spikelets in ears of wheat and a few hours of stress 4 or 5 days before ear emergence could result in similar damage (104). In a growth chamber study Johnson et al. (44) found that leaf water potential fell as low as -33 bars when water was withheld for 7 days, starting 7 days after spike emerged from the flag leaf sheath. They also found that rates of net photosynthesis and transpiration of both flag leaves and awned spikes decreased linearly with decreasing flag leaf water potential.

The organ which is growing most rapidly at the time of stress is the one most affected. Grain number per ear were seriously affected by stress occurring prior to anthesis, grain size was reduced by stress at anthesis and elongation of the internodes was reduced mostly by stress at or just before earing (11). According to Aspinall _et al_. (11) tillering was suppressed during a drought cycle but rewatering stimulated tillering later. Taylor _et al_. (87) working with wheat in Australia reported that seasonal rainfall was the major source of yield variation.

Langer (56) quoting the work of Blair and Morrison (17), indicated that exposure of wheat plants to frost during and following anthesis can cause severe sterility and shrivelling of grain. Grain yield of Australian and Indian wheats declined by 16 percent when the day temperature was raised from 25^{o} to 31^{o}C. as reported by Asana and Williams (10). Ishaq and Taha (42) working with wheat in Sudan concluded that higher air temperatures (33^{o}C. by day and 18^{o}C. by night) prevailing during the growth period resulted in mortality of tillers. Asana and Saini (9) reported that high temperatures (27.5^{o}C.) during the early stages of grain filling increased the rate of grain filling. This enhanced the yellowing of ear and stem, (loss of photosynthetic area), resulting in loss of stem sugars during later stage which reduced final grain weight. Peters _et al_. (72) reported that high night temperatures (15.3, 26.5^{o}C.) markedly reduced grain yields in wheat, and because of higher night temperatures, senescence and maturity was earlier which reduced the grain filling period. The number of spikelets on the differentiating inflorescence and the ear at anthesis was highest at high light intensities (2500 ft.C.) and at low temperatures (10 ^{o}C.) as reported by Friend (32).

CHAPTER III

MATERIAL AND METHODS

The study was conducted on Kirkland silt loam soil in 1972-73 and 1973-74 crop season at the Agronomy Research Station, Oklahoma State University, Stillwater, Oklahoma. This station is located on 36° 07' north latitude and 97° 05' west longitude at an altitude of 273 m above sea level. The experimental area was uniform in soil characteristics with a surface gradient of one to two percent. Representative soil samples from the experimental area were collected for soil test and the results of soil test indicated that there was 119 kg/ha of available nitrogen in top 60 cm soil, 45 kg/ha of available phosphorus and 340 kg/ha of available potassium in top 30 cm of soil. The pH of soil was 5.7.

The 1972-73 (October, 1972 to June, 1973) growing season was characterized by above normal precipitation. Total seasonal rainfall was 23.20 cm above normal. The daily precipitation for 1972-73 season is given in Table I (5,6) and pattern shown in Figure 1. There were three months in this season which had below normal precipitation: February, May, and June with 0.38 cm, 3.60 cm, and 5.30 cm below normal, respectively. The daily minimum and maximum temperatures during the 1972-73 season are listed in Table II (5,6) and weekly averages are shown in Figure 2.

TABLE I

DAILY PRECIPITATION FOR 1972-73 CROP SEASON
STILLWATER, OKLAHOMA

Days	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1		3.05			1.80				
2		0.03			0.05	0.15			2.13
3				2.69			0.64		0.71
4				0.81		0.97			
5									0.41
6						1.93			
7		0.81		0.13	0.13	0.08		1.98	
8					0.61	0.79	1.17		
9						1.04	0.81		
10						2.57			
11						3.23			
12									
13		3.05	1.57						
14									0.05
15			0.51				0.64		0.33
16							3.86		
17									
18		0.36			0.46				
19		1.04					0.81		1.04
20							0.13		
21	2.13	0.41		1.09					
22	6.12	0.05		0.08					
23								1.98	
24						3.12			
25		0.79				1.83	0.69	0.94	
26				3.07		0.10			
27				0.03				0.43	
28				0.33		0.94			
29									
30	0.61		1.83		-	0.08		0.30	0.79
31	3.66	-			-	2.82	-	2.49	-
Total	12.52	9.57	3.91	8.22	3.04	19.63	8.73	8.12	5.46
Departure	+ 5.46	+ 4.87	+ 0.50	+ 5.28	- 0.38	+ 14.90	+ 1.47	- 3.60	- 5.30

TABLE II

DAILY TEMPERATURES (C^o) FOR 1972-73 CROP SEASON

	October 1972		November		December		January 1973		February		March		April		May		June 1973	
Days	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	23	7	8	5	10	-1	7	-6	16	3	15	6	12	7	23	19	24	16
2	29	12	13	5	14	-1	7	-4	7	2	12	9	18	6	28	6	26	17
3	28	11	16	2	17	-1	4	-5	12	-2	14	7	14	5	17	4	21	17
4	29	10	17	2	2	-7	6	-7	16	0	13	7	10	3	23	6	28	19
5	29	10	21	2	-1	-7	-6	-8	17	-2	11	6	13	0	25	13	29	15
6	29	12	19	8	-1	-13	-6	-10	14	-2	15	7	18	4	22	17	27	13
7	20	9	18	4	-7	-12	-6	-10	6	0	18	2	20	6	24	14	29	13
8	23	12	16	1	-1	-9	-7	-14	3	-7	19	2	13	2	26	9	30	14
9	28	14	18	4	0	-8	-8	-18	-1	-9	13	8	6	-1	27	12	31	15
10	22	11	18	6	-7	-11	-10	-17	5	-8	13	8	6	-2	28	15	28	19
11	31	18	12	1	-6	-11	-8	-14	7	-4	21	7	11	0	32	16	30	19
12	32	16	14	6	-1	-9	-7	-20	8	1	19	5	19	3	26	14	31	19
13	31	13	11	7	-1	-11	-1	-18	16	-1	26	8	23	9	24	8	29	20
14	28	13	9	1	0	-10	5	-6	9	-4	23	11	18	7	21	6	27	21
15	27	10	3	0	-2	-8	13	-5	3	-6	22	4	24	9	23	3	30	21
16	18	11	4	1	-1	-18	16	-1	2	-7	14	3	17	6	24	9	33	24
17	29	13	7	2	7	-6	17	6	2	-6	13	-1	14	4	25	4	33	18
18	30	9	4	1	8	-2	19	8	3	-3	16	3	22	8	26	7	30	21
19	13	-1	2	0	9	2	8	-2	4	-1	23	12	23	13	32	14	34	16
20	12	-1	2	-1	12	-2	18	-2	6	-4	21	4	24	13	33	12	24	12
21	11	7	3	-2	9	2	14	7	14	-3	9	-2	26	16	29	18	31	14
22	14	10	2	-3	8	-3	10	1	11	-4	16	2	27	12	33	18	33	17
23	18	8	7	-3	15	-3	5	-6	9	-4	17	11	22	9	28	15	34	18
24	9	5	12	0	10	1	9	-4	15	-2	20	11	26	14	25	14	34	23
25	13	0	5	3	3	-2	16	-2	13	1	13	5	24	13	29	12	34	21
26	16	3	9	-1	7	-2	11	-1	16	3	9	6	18	11	26	19	35	21
27	12	7	15	1	12	-1	9	5	7	-2	14	3	17	5	33	13	33	22
28	16	8	8	-4	18	2	7	-5	15	2	16	7	18	6	21	12	36	17
29	15	6	9	-4	14	6	-1	-9	-	-	19	6	22	14	26	12	30	20
30	16	9	7	-2	22	1	4	-8	-	-	16	9	25	18	26	11	26	22
31	16	5	-	-	5	-2	16	-2	-	-	18	6	-	-	24	14	-	-

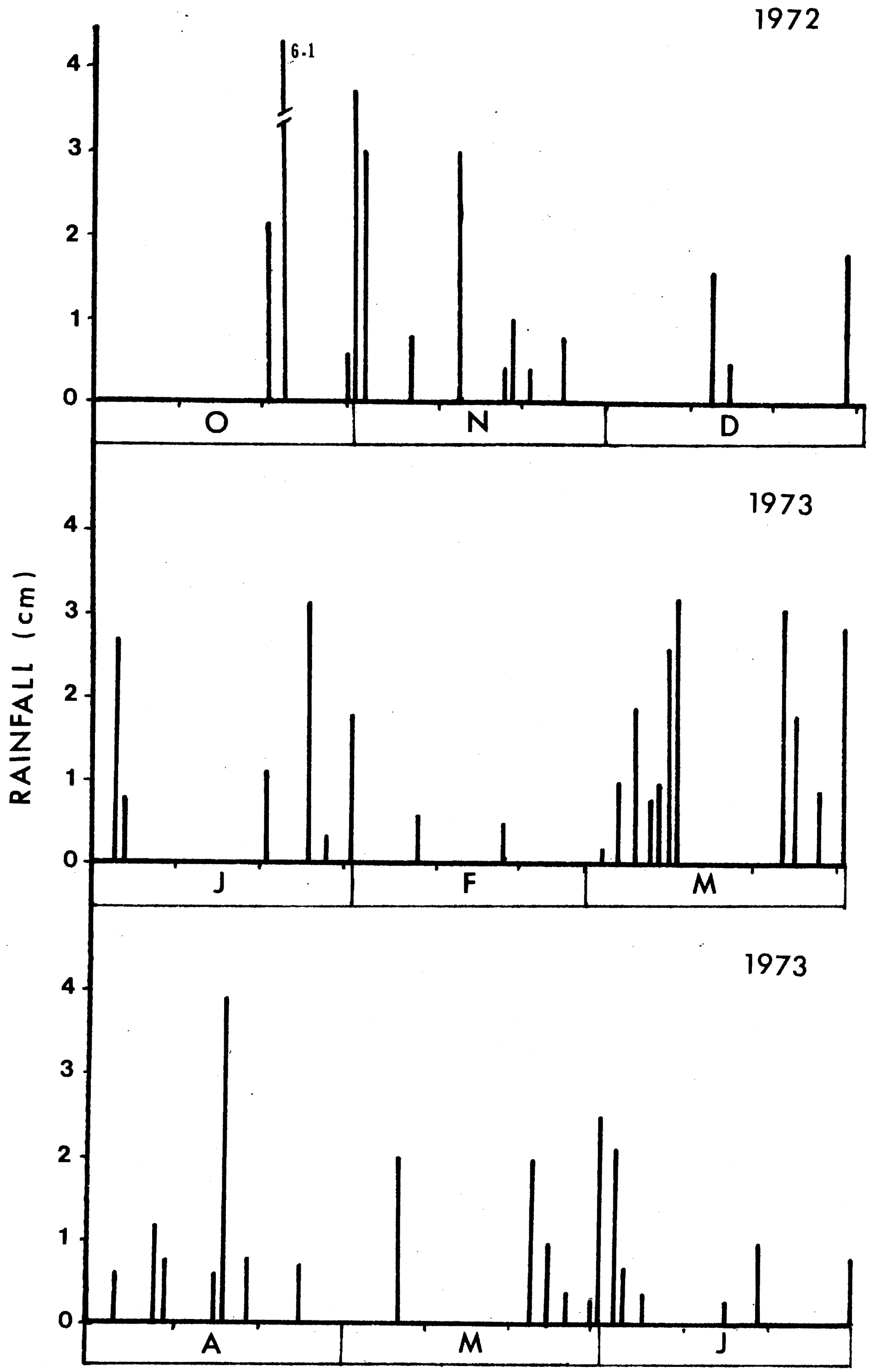

Figure 1. Rainfall Pattern in 1972-73 Crop Season, Stillwater, Oklahoma

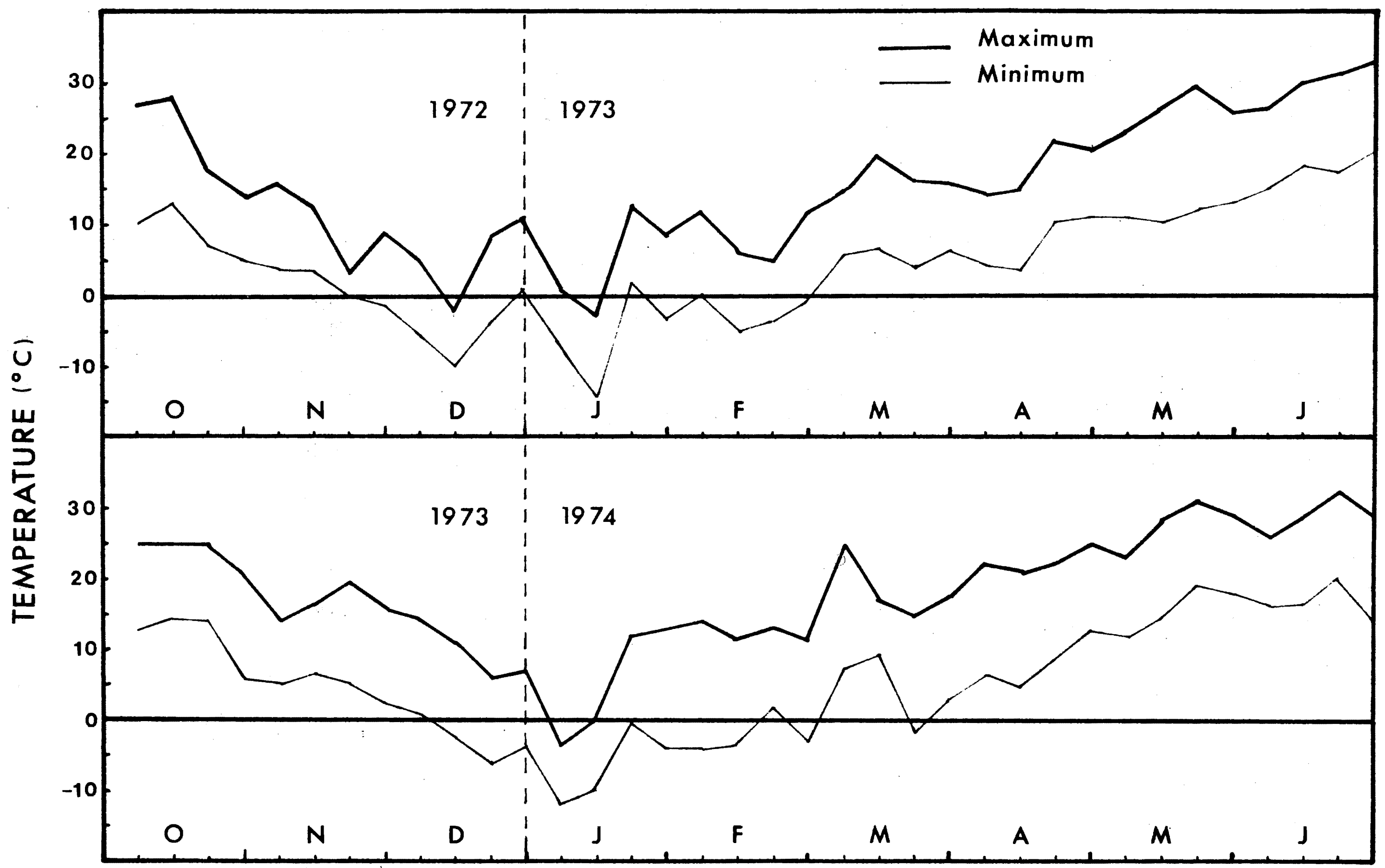

Figure 2. Temperature Pattern in 1972-73 and 1973-74 Crop Seasons, Stillwater, Oklahoma

The 1973-74 (October, 1973 to June, 1974) growing season had a little above normal precipitation, but the distribution of precipitation was not uniform during the growth of the crop. There were periods of reduced moisture in March, April, and May when the crop was in the flowering and grain filling stage. October, December, January, April, and June were below the normal by 0.86 cm, 0.73 cm, 1.11 cm, 1.14 cm, and 4.44 cm, respectively. Total seasonal rainfall was 2.79 cm above normal. The daily precipitation for 1973-74 is given in Table III (6,7) and pattern shown in Figure 3. The daily minimum and maximum temperatures during 1973-74 season are given in Table IV (6,7), and weekly averages are shown in Figure 2. The temperature shot up to 25^{o} C during the first week of March, by the middle of the second week the temperature was down to about 10^{o} C and even touched -2^{o} C on March 24, 1974. This drastic fluctuation in March and the freezing temperature of March 24, 1974, did result in damage to the flower initiating tillers. This winter injury was recorded on April 9, 1974, and some plots showed severe damage. The moderate temperature in April resulted in vigorous growth of late tillers and good development of yield-related characters.

Varieties Used

Five hard red winter wheat varieties were selected on the basis of their contrasting characters and a brief description of these varieties are presented below.

'Danne' named after Mr. Joseph Danne, a private wheat breeder, was developed by Oklahoma Agricultural Experiment Station (81). It is medium tall, early maturing and has a wide area of adaptation. Danne

TABLE III

DAILY PRECIPITATION FOR 1973-74 CROP SEASON
STILLWATER, OKLAHOMA

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1									
2								2.79	
3									0.08
4	1.04		2.54						
5			0.13						0.81
6	0.80								1.35
7									2.29
8									1.45
9						1.88			
10				1.17		1.93			
11	2.72					3.56	2.16		
12									
13	0.99								
14						0.13			
15					1.27				
16					0.51				
17									0.10
18									
19					0.79				
20		2.16							
21					2.06	0.53		0.13	
22					0.76		0.07	0.23	
23				0.13				0.81	
24		5.16						1.02	
25								5.26	
26								0.81	
27	1.17	0.33							
28		0.13							
29							1.78		
30					-		2.29		
31	0.20	-			-		-	3.61	-
Total	6.19	7.77	2.66	1.29	5.38	8.02	6.29	14.63	6.07
Departure	- 0.86	+ 3.07	- 0.73	- 1.11	+ 2.33	+ 3.47	- 1.14	+ 2.20	- 4.44

TABLE IV

DAILY TEMPERATURES (C^o) FOR 1973-74 CROP SEASON

	October 1973		November		December		January 1974		February		March		April		May		June 1974	
Days	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	21	11	21	6	22	1	-7	-13	15	-2	21	3	34	12	22	13	24	13
2	26	12	24	6	19	2	-10	-13	20	-3	24	7	22	9	18	13	24	14
3	31	17	15	4	20	13	-6	-12	12	-6	27	7	27	16	28	14	27	18
4	30	14	10	5	19	2	-4	-13	13	-7	26	18	16	3	21	8	29	18
5	20	9	9	4	3	-1	1	-12	19	-6	22	2	13	0	23	11	24	18
6	21	10	11	3	10	-4	6	-9	19	-1	24	3	18	0	22	9	28	17
7	23	16	9	4	4	-7	-4	-12	0	-6	28	12	25	6	26	11	27	16
8	28	18	11	8	9	-5	1	-8	-1	-9	26	18	24	6	27	13	26	16
9	28	21	9	1	13	3	6	-11	4	-4	24	16	22	2	30	17	29	13
10	27	20	11	-1	8	-4	-4	-11	4	-5	22	9	16	-1	32	18	27	12
11	29	17	11	3	10	-3	-7	-12	13	-4	13	7	18	4	29	16	29	16
12	19	9	16	7	15	-2	-6	-15	18	-6	19	3	23	8	26	8	30	13
13	17	12	23	11	18	-2	-2	-14	20	-4	9	4	23	12	28	14	27	15
14	26	9	23	16	8	-2	5	-5	21	2	12	4	26	6	32	17	29	19
15	27	10	26	8	6	-4	3	-2	13	2	16	7	16	1	24	9	33	20
16	24	10	19	1	1	-8	16	-1	5	2	15	-1	21	2	31	13	33	14
17	19	5	19	4	1	-5	18	1	14	1	11	1	16	3	32	24	26	16
18	22	4	21	8	11	-2	18	-1	20	4	21	3	22	5	32	22	27	18
19	27	10	23	10	16	-4	6	-1	12	0	27	3	26	9	30	20	35	20
20	29	9	24	10	-4	-11	3	1	12	1	11	2	25	14	32	21	35	22
21	26	10	11	1	-1	-11	13	-1	20	4	7	-9	21	17	31	17	35	24
22	27	13	17	2	9	-4	18	0	6	-1	11	-8	26	11	29	17	36	23
23	27	11	19	7	13	-2	3	-2	8	-1	17	-5	22	5	30	17	34	15
24	28	11	22	6	16	2	8	-6	13	-7	-2	-6	25	8	31	17	27	13
25	24	6	9	1	3	-2	13	-6	1	-8	4	-4	25	13	25	16	27	10
26	23	6	11	2	7	-3	15	-6	12	-7	9	-2	25	12	24	15	27	14
27	27	10	18	4	7	-4	15	-3	17	1	22	8	26	14	26	13	27	10
28	18	6	11	-1	8	-4	9	-1	18	3	27	8	23	16	29	19	28	14
29	14	-1	13	-1	14	-3	13	-4	-	-	28	7	28	16	33	22	29	17
30	17	7	22	2	1	-3	14	-4	-	-	23	3	23	14	33	22	34	21
31	16	4	-	-	2	-13	18	-3	-	-	27	10	-	-	32	17	-	-

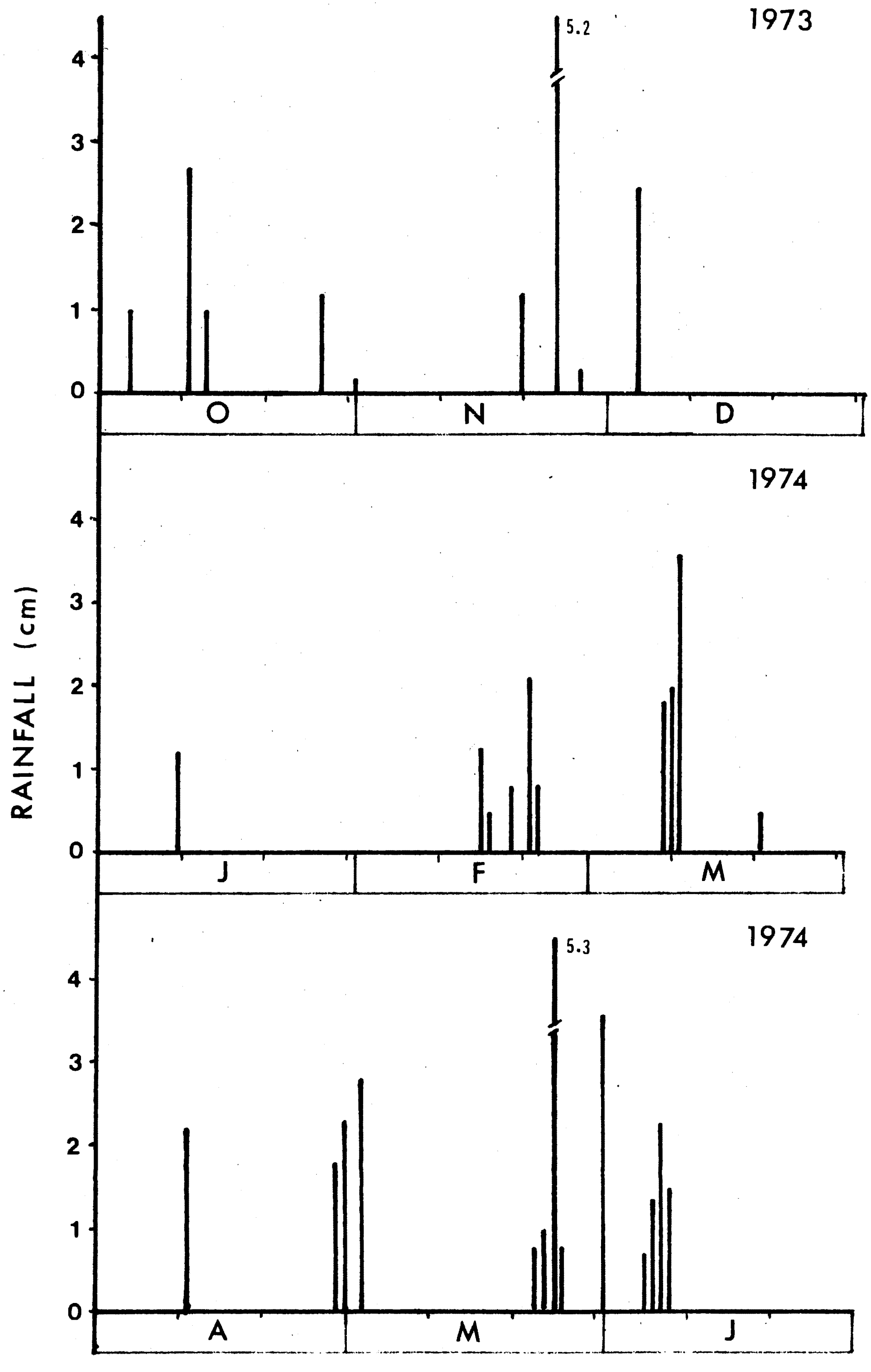

Figure 3. Rainfall Pattern in 1973-74 Crop Season, Stillwater, Oklahoma

is considered to be well balanced with regard to yield components.

'Centurk' was developed by the Nebraska Agricultural Experiment Station in cooperation with the Agricultural Research Service, USDA was released in 1971 by several agencies including Oklahoma (79). It is medium tall, has high tillering capacity, and short kernels.

'Palo Duro' was developed by Dekalb AgResearch Incorporated (99). It is a semi-dwarf variety and under Oklahoma conditions, it is considered to be medium to medium-late in maturity. Palo Duro has a high yield potential under above average fertility and moisture conditions due to a high tillering capacity. It has a high test weight.

'Tam W-101' was released in 1971 by the Texas Agricultural Experiment Station (72). It is short statured, early maturing variety and has a greater tolerance to moisture stress. It has upright juvenile growth with wide, erect leaves.

'Caprock' was released by Texas Agricultural Experiment Station (12), and is a sister strain of 'Sturdy' wheat. It has short straw, broad moderately upright leaves, early maturing and performs better under irrigation. It is less cold tolerant than 'Triumph'.

The Field Layout

The study was designed in a split-split plot design. Nitrogen levels comprised the main plot, varieties comprised the subplots and sub-subplots consisted of seeding rates. The main plots were randomized within each replication and sub-plots within main plots and sub-subplots occurred at random within the subplots. There were four replications of each treatment. A plot consisted of four 3.6 m long rows, 30.5 cm apart. Both years the experiment was planted with a tractor-mounted four row belt seeder and harvested manually using sickles. In 1972-73 the experiment was planted on October 13, 1972 and harvested on June 13, 1973. In 1973-74, the experiment was planted on October 10, 1973 and harvested on June 11, 1974.

Variety by seeding rate combination are shown in Table V. The three nitrogen levels were 67, 134, and 202 kg/ha. Nitrogen was applied as a topdressing with a small hand-powered garden fertilizer spreader and the source of nitrogen was ammonium nitrate. In 1972-73, the topdressing was done on March 16, 1973 and in 1973-74 the topdressing was done on February 5, 1974. The three seeding rates selected for the study were 67, 100, and 134 kg/ha.

Variables Evaluated and Sampling Procedures

The variables evaluated were: a) grain yield, b) straw yield, c) dry forage yield, d) plant height, e) leaf nitrate, f) straw nitrogen, g) grain protein, h) tiller number, i) kernels per spike, j) 200-kernel weight, and k) chaff weight.

There were eleven derived variables which were analyzed statistically. These were: 1) peduncle area, 2) flag leaf area, 3) total photosynthetic area, 4) peduncle area duration, 5) flag leaf area duration, 6) total photosynthetic area duration, 7) straw nitrogen recovery, 8) grain nitrogen recovery, 9) total nitrogen recovery, 10) protein yield, and 11) grain:straw ratio.

In addition to these, field notes were taken on 50 percent flowering, physiological maturity, lodging and winter injury, but these traits were not analyzed statistically.

TABLE V

NITROGEN, VARIETY BY SEED RATE TREATMENT COMBINATIONS

N_1	T	(S_1, S_2, S_3)
	PD	(S_1, S_2, S_3)
	D	(S_1, S_2, S_3)
	CK	(S_1, S_2, S_3)
	CP	(S_1, S_2, S_3)
N_2	T	(S_1, S_2, S_3)
	PD	(S_1, S_2, S_3)
	D	(S_1, S_2, S_3)
	CK	(S_1, S_2, S_3)
	CP	(S_1, S_2, S_3)
N_3	T	(S_1, S_2, S_3)
	PD	(S_1, S_2, S_3)
	D	(S_1, S_2, S_3)
	CK	(S_1, S_2, S_3)
	CP	(S_1, S_2, S_3)

N_1 = 67 kg N/ha
N_2 = 134 kg N/ha
N_3 = 202 kg N/ha
T = Tam W 101
PD = Palo Duro
D = Danne
CK = Centurk
CP = Caprock
S_1 = Seed rate 67 kg/ha
S_2 = Seed rate 100 kg/ha
S_3 = Seed rate 134 kg/ha

Grain Yield

Grain yield was determined by harvesting 2.4 m length of the two center rows which were prepared by cutting 0.6 m from each end. The harvested area per plot was 1.46 m^2 and the yield of threshed and clean grain was converted to kilograms per hectare.

Straw Yield

Straw yield was determined by taking the difference of the bundle weight from 1.46 m^2 area and the yield of grain for each plot. Later the straw yield was converted to kilograms per hectare.

Dry Forage Yield

Dry forage yield was measured by clipping two 30.5 cm sections, one from the first row and the second from the fourth row of each plot. The samples were dried in dryer at a temperature of 60^o C for 96 hours. After drying, the dry weights were recorded. The dry forage yield were recorded in grams and later converted to kilograms per hectare. In 1972-73 samples were taken on April 12 and 13, and in 1973-74 samples were taken on April 9 and 10.

Plant Height

Plant height was measured in centimeters as the distance from the ground surface to the tip of terminal spike excluding awns. Four readings were taken at random from the two center rows and the average of these four readings was taken as the average plant height of the plot.

Leaf Nitrate

Samples for leaf nitrate were collected while taking samples for dry forage yield. The samples were stored in the freezer at -8^{o} C and leaf nitrate was determined later by the method of Wooley et al. (103) and was reported as µg nitrate per gram fresh weight.

Straw Nitrogen

Straw samples after harvest were oven dried at 60^{o} C for 48 hours and were ground in a mill. The ground straw (0.2 g) was used to determine nitrogen content by the micro-kjeldahl procedure, and the results are reported as percent nitrogen.

Grain Protein

Whole grain flour was used to determine grain protein by Udy colorimetric method (93), and expressed as percent protein.

Tiller Number

Tiller number was determined by counting the number of grain-bearing tillers in a 30.5 cm section, two readings were made at random in the two center rows. The average of these readings was expressed as number of tillers per 930 cm^2.

Kernels Per Spike

Heads of 10 randomly selected tillers were hand threshed and the number of kernels were counted after separating the chaff. The average of 10 heads is reported as kernels per spike.

200-Kernel Weight

This was determined on a sample of 200 seeds taken at random from the grain harvested from each plot and was expressed as grams per 200 kernels.

Chaff Weight

The chaff weight was determined by taking the difference in weight of the 10 hand-threshed heads (chaff + seeds, excluding rachis) and the weight of seeds of 10 heads. It is reported as mg per spike. The chaff weight consisted of glumes, lemma, palea and awns.

Peduncle Area

Peduncle length was measured on 10 randomly selected tillers in each plot. The measurement was made in centimeters from the auricle to the base of the head, and the average was calculated. The 10 peduncles selected above were placed side by side on a smooth surface and the width of these 10 peduncles was measured in centimeters and the average was taken as the diameter of peduncle. The length and the diameter of the peduncle were used to calculate the peduncle area (m^2/ha) using the formula:

$$PA = \frac{\pi \, DL \times \text{Tillers/ha}}{1000}$$

where PA = peduncle area (m^2/ha)
D = diameter of peduncle
L = length of peduncle

Flag Leaf Area

In 1972-73, flag leaves from ten randomly selected tillers were taken in each plot and the length in centimeters was measured from base of leaf blade to the tip of the leaf. The width of leaf was measured in centimeters at the widest point perpendicular to the mid rib of the leaf. For calculating the flag leaf area a factor was determined using flag leaves from 375 tillers, selected at random from the experimental area, and their length and width were determined as described earlier. Then the actual area of these 375 leaves was determined by measuring the area of the traced leaves on paper using a planimeter. The length x width of the individual leaf was taken as an independent variable and planimeter area for the same leaf was taken as the dependent variable. A regression analysis was done for the first degree fit and after testing for zero intercept, the value of slope, 0.7351, was taken as a factor for calculating leaf area using the following equation:

$$A = 0.7351 \times LW$$

where A = leaf area in cm^2
LW = product of length and width of leaf (cm^2)

Leaf area for the 10 randomly selected flag leaves was calculated and the average was taken as the flag leaf area per tiller.

In 1973-74, flag leaves from 10 tillers were selected at random from each plot. The area of these 10 flag leaves was determined in laboratory using a Portable Area Meter (Model LI-3000, Lambda Instruments Corporation). The average of these 10 leaves was taken as the flag leaf area per tiller.

The flag leaf area (m^2/ha) was calculated as:

$$FA = \frac{\text{Flag leaf area per tiller x Tillers/ha}}{1000}$$

where FA = flag leaf area (m^2/ha)

Total Photosynthetic Area

Total photosynthetic area is the sum of flag leaf area and peduncle area.

$$TPA = PA + FA$$

where TPA = total photosynthetic area (m^2/ha)
PA = peduncle area (m^2/ha)
FA = flag leaf area (m^2/ha)

Peduncle Area Duration

Peduncle area duration was calculated by using the formula:

$$PAD = (MD - FD) \times \text{Peduncle area per tiller}$$

where PAD = peduncle area duration (cm^2 days)
MD = physiological maturity (days)
FD = 50 percent flowering (days)

Flag Leaf Area Duration

Flag leaf area duration was calculated by using the formula:

$$FAD = (MD - FD) \times \text{Flag leaf area per tiller}$$

where FAD = flag leaf area duration (cm^2 days)
MD = physiological maturity (days)
FD = 50 percent flowering (days)

Total Photosynthetic Area Duration

Total photosynthetic area duration is the sum of peduncle area duration and flag leaf area duration.

$$TPAD = PAD + FAD$$

where TPAD = total photosynthetic area duration (cm^2 days)
PAD = peduncle area duration (cm^2 days)
FAD = flag leaf area duration (cm^2 days)

Straw Nitrogen Recovery

Straw nitrogen recovery was calculated as follows:

$$SNR = \frac{\text{Straw Nitrogen x Straw Yield kg/ha}}{100}$$

where SNR = straw nitrogen recovery (kg/ha)

Grain Nitrogen Recovery

Grain nitrogen recovery was calculated as:

$$GNR = \frac{\text{Protein percent x Grain Yield kg/ha}}{5.7 \times 100}$$

where GNR = grain nitrogen recovery (kg/ha)

Total Nitrogen Recovery

Total nitrogen recovery is the sum of straw nitrogen recovery and grain nitrogen recovery.

$$TNR = SNR + GNR$$

where TNR = total nitrogen recovery (kg/ha)
SNR = straw nitrogen recovery (kg/ha)
GNR = grain nitrogen recovery (kg/ha)

Protein Yield

Protein yield was calculated as follows:

$$PY = \frac{\text{Grain Yield kg/ha x Protein Percent}}{100}$$

where PY = protein yield (kg/ha)

Grain:Straw Ratio

The grain:straw ratio was computed by dividing the grain yield (kg/ha) by the straw yield (kg/ha).

Fifty Percent Flowering

Fifty percent flowering was estimated as the date at which 50 percent of the tillers in the plot were in flower. Data on 50 percent flowering is reported as days from the date of planting.

Physiological Maturity

The physiological maturity was visually estimated as the number of days from the date of planting to the date when the plants appeared to be physiologically mature, i.e. when the peduncle and head turned yellow.

Lodging

This was estimated by a visual estimate of the percentage of the plot that was not standing erect. In 1973-74, there was no significant lodging.

Winter Injury

This was determined by an arbitrary visual rating scale, estimating the percentage of dead tillers in the plot. In 1972-73, there was no significant winter injury.

Statistical Analysis

The statistical analyses were done on an IBM 360/65 Computer at the Oklahoma State University Computer Center. Simple correlation coefficients were computed using treatment means averaged over replications for grain yield, yield components and the components of photosynthetic area. The correlation coefficient between two variables X and Y was determined using the formula:

$$r_{XY} = \frac{\Sigma xy}{\Sigma x^2 \Sigma y^2}$$

where r is the correlation coefficient, Σx^2 is the error sum of squares of the deviations of the variable X, Σy^2 is the error sum of squares of the deviations of the variable Y, and Σxy is the error sum of products of the deviations of X and Y.

CHAPTER IV

RESULTS AND DISCUSSION

The variables under study were analyzed with the years pooled in order to study any differences between years, year by nitrogen, year by variety and year by seed rate interaction. The mean squares from the pooled analysis of variance are presented in Tables VI, VII, VIII, and IX. The treatment means for the variables studied in this experiment are presented in Appendix Tables XII through XXXVI.

Grain Yield

There was a highly significant difference between years for grain yield, the first year (1972-73 crop season) being far superior to the second year (1973-74 crop season). The mean yield of all varieties averaged over nitrogen and seed rates was 2980 kg/ha in the first year and 1722 kg/ha in the second year. The reduction in yield in the second year could be due to the erratic rainfall distribution and late freeze. The first year had above normal rainfall well distributed throughout the growing season with good moisture during the tillering, flowering and grain filling stages of crop growth. During the second year, moisture stress in March, April, and May affected the three stages (tillering, flowering, and grain filling) of crop growth which are sensitive to moisture stress. These results are in general agreement with Adams (1) who also reported that under depleted soil moisture

TABLE VI

MEAN SQUARES FROM ANALYSIS OF DATA FOR GRAIN YIELD, STRAW YIELD, GRAIN:STRAW RATIO, DRY FORAGE YIELD AND PLANT HEIGHT

Source	d_f	Grain Yield	Straw Yield	Grain:Straw Ratio	Dry Forage Yield	Plant Height
Yr	1	142,515,082**	1,018,164,270**	.4857**	1,360	93,371.96**
Rep (Yr)	6	409,481	4,493,908	.0296	7,137,642	39.78
Nit	2	1,081,345	648,408	.0183	500,775	405.92*
Yr x Nit	2	471,870	249,116	.0125	1,528,186	53.66
Er(b)	12	685,846	3,145,354	.0121	2,521,584	96.22
Var	4	3,717,648**	9,626,384**	.2634**	2,988,078**	623.39**
Yr x Var	4	738,018**	1,054,937	.0120	4,656,015**	232.24**
Nit x Var	8	87,454	395,040	.0027	103,011	16.91
Yr x Nit x Var	8	93,767	467,350	.0052	482,316	34.41
Er(c)	72	144,777	518,578	.0064	460,681	49.33
Seed rate	2	547,535**	471,448	.0167*	3,581,125**	4.86
Yr x SR	2	105,472	1,132,111*	.0087	1,955,091**	5.59
Nit x SR	4	114,045	545,690	.0027	45,363	2.11
Yr x Nit x SR	4	37,749	214,896	.0059	427,565	2.42
Var x SR	8	104,371	269,057	.0042	424,505	8.15
Yr x Var x SR	8	132,863*	363,485	.0046	463,030	3.72
Nit x Var x SR	16	60,636	236,607	.0033	296,595	3.57
Yr x Nit x Var x SR	16	58,022	249,952	.0028	163,510	7.91
Er (d)	180	56,027	369,048	.0047	285,722	7.15

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

TABLE VII

MEAN SQUARES FROM AN ANALYSIS OF VARIANCE OF DATA FOR LEAF NITRATE, GRAIN PROTEIN, PROTEIN YIELD, STRAW NITROGEN, GRAIN NITROGEN RECOVERY, AND STRAW NITROGEN RECOVERY

Source	df	Leaf Nitrate	Grain Protein	Protein Yield	Straw Nitrogen	Grain Nitrogen Recovery	Straw Nitrogen Recovery
Yr	1	9,635	154.65**	2,246,908**	.2326	69,156.92**	6,806.60**
Rep (yr)	6	34,874	8.81	2,691	.1500	82.81	706.18
Nit	2	176,341*	76.61**	6,523	.2578*	200.78	563.00
Yr x Nit	2	18,109	0.12	10,328	.0093	317.89	114.09
Er(b)	12	32,478	7.47	6,513	.0659	200.47	748.70
Var	4	19,146	66.27**	127,627**	.4460**	3,928.21**	3,958.68**
Yr x Var	4	4,243	2.69	8,852**	.1564**	272.47**	750.02**
Nit x Var	8	34,786**	2.95*	1,716	.0199	52.81	116.39
Yr x Nit x Var	8	11,374	4.28**	1,074	.0098	33.06	72.33
Er(c)	72	12,510	1.22	2,398	.0155	73.81	88.03
Seed Rate	2	9,406	2.69**	7,003**	.0215	215.54**	165.07
Yr x SR	2	2,760	0.27	3,193	.0026	98.28	17.30
Nit x SR	4	14,490	0.39	1,757	.0050	54.09	70.47
Yr x Nit x SR	4	3,643	0.27	324	.0065	9.97	33.29
Var x SR	8	18,213*	0.29	1,614	.0095	49.68	66.24
Yr x Var x SR	8	4,664	1.13**	1,593	.0079	49.02	73.42
Nit x Var x SR	16	14,213	0.33	1,399	.0078	43.05	63.24
Yr x Nit x Var X SR	16	6,921	0.40	1,321	.0165*	40.65	87.66
Er(d)	180	8,747	0.43	1,173	.0086	36.11	73.36

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

TABLE VIII

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF DATA FOR TOTAL NITROGEN RECOVERY, TILLER NUMBER, KERNELS PER SPIKE, 200-KERNEL WEIGHT AND CHAFF WEIGHT

Source	d_f	Total Nitrogen Recovery	Tiller Number	Kernels Per Spike	200-Kernel Weight	Chaff Weight
Yr	1	274,431**	5,372.35*	1,402.65**	16.66**	11,972
Rep (Yr)	6	11,450	447.18	14.06	1.03	2,358
Nit	2	1,434	103.90	45.12	3.79	760
Yr x Nit	2	603	294.48	8.09	1.19	1,052
Er(b)	12	1,438	196.70	31.94	1.56	2,409
Var	4	7,365**	1,392.18**	587.27**	37.96**	21,207**
Yr x Var	4	505	819.12**	80.09**	2.38**	2,531*
Nit x Var	8	241	132.06*	5.20	0.15	350
Yr x Nit x Var	8	125	26.67	11.95	0.27	1,122
Er(c)	72	209	62.23	9.26	0.20	724
Seed Rate	2	758**	2,679.27**	63.54**	0.13	3,583**
Yr x SR	2	179	731.60**	6.47	0.38*	1,395*
Nit x SR	4	92	24.99	4.14	0.15	687
Yr x Nit x SR	4	24	24.32	3.71	0.01	177
Var x SR	8	132	70.37	6.97	0.38*	1,021*
Yr x Var x SR	8	132	56.03	3.18	0.14	489
Nit x Var x SR	16	149	75.55	6.73	0.13	884*
Yr x Nit x Var x SR	16	143	38.99	3.96	0.14	660
Er(d)	180	130	54.06	5.30	0.11	422

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

TABLE IX

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF DATA FOR PEDUNCLE AREA, FLAG LEAF AREA, TOTAL PHOTOSYNTHETIC AREA, PEDUNCLE AREA DURATION, FLAG LEAF AREA DURATION AND TOTAL PHOTOSYNTHETIC AREA DURATION

Source	df	Peduncle Area	Flag leaf Area	Total Photosynthetic Area	Peduncle Area Duration	Flag leaf Area Duration	Total Photosynthetic Area Duration
Yr	1	2,326,997,641**	6,454,757,364**	16,532,936,892**	3,337,262**	8,721,826**	22,849,272**
Rep (Yr)	6	2,593,307	36,287,105	39,899,670	4,287	7,051	3,950
Nit	2	9,678,872	6,237,608	25,368,631	10,053	6,711	13,612
Yr x Nit	2	2,153,352	7,695,906	6,717,119	6,483	2,196	7,749
Er (b)	12	5,724,003	47,230,849	75,541,033	8,126	26,884	51,203
Var	4	31,089,698**	164,680,215**	276,302,152**	50,825**	479,119**	744,173**
Yr x Var	4	4,387,643*	66,398,727**	87,483,465**	6,619*	67,617**	102,169**
Nit x Var	8	1,235,373	6,675,383	12,602,295	2,836	10,501	22,720
Yr x Nit x Var	8	3,051,501	4,490,765	10,634,515	4,620	17,360	30,926
Er (C)	72	1,553,264	7,758,438	12,151,321	2,301	9,808	15,230
Seed Rate	2	119,117,312**	79,487,685**	176,187,223**	15	12,350**	13,187**
Yr x SR	2	19,749,826**	34,280,900**	105,387,859**	1,006	6,193*	2,470
Nit x SR	4	612,252	992,173	1,490,847	1,077	1,434	2,276
Yr x Nit x SR	4	613,162	2,361,139	2,031,844	1,464*	2,041	1,346
Var x SR	8	426,017	3,698,532	5,436,119	222	420	493
Yr x Var x SR	8	1,247,325	1,813,009	4,903,020	894	1,760	905
Nit x Var x SR	16	1,484,889*	2,160,340	5,091,637	1,396**	1,470	2,082
Yr x Nit x Var x SR	16	1,041,218	3,665,353	6,548,696	913	2,729*	4,113**
Er (d)	180	786,647	3,907,280	6,881,707	555	1,334	1,942

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

conditions the yield components did not develop fully. In addition to this moisture stress effect, there could be the effect of warm temperatures in early March, 1974, and a freezing spell which occurred in the third week of March, 1974. The temperatures started warming up early in the first two weeks of March, 1974, initiating growth processes in plants. There was a freeze in the third week of March, 1974, which could have caused physiological imbalance resulting in low grain yields. After the freezing a visual observation estimated an overall 12.5% loss of tillers due to frost injury. Blair and Morrison (17) reported that wheat plants when exposed to frost during and following anthesis caused severe sterility and shrivelling of grain.

Grain yields were not increased by nitrogen levels. The soil test showed 119 kg/ha of available nitrogen in the top 60 cm of soil profile, which is sufficient for above average wheat yields. During the first year there was above normal precipitation which might have increased the possibility of leaching losses. The uptake of nitrogen is sensitive to moisture stress and the erratic distribution of rains in the second year could account for the lack of response to nitrogen fertilization.

Yield difference among varieties were highly significant. Also there was a highly significant year by variety interaction, indicating the presence of genotype by environment interaction as shown in Figure 4. The average yield of each variety was higher in the first year than the second, and the ranking of varieties for grain yield had similar patterns (Table X). Tam W 101 and Caprock were high yielding varieties in both years of the experiment. Danne appeared to be the most sensitive variety to environment as the yield in the second year

TABLE X

YIELD AND YIELD COMPONENTS FOR WHEAT VARIETIES AVERAGED OVER NITROGEN AND SEED RATE

Variety	Grain Yield (kg/ha)	Yield Components: Tiller Number	Kernels per Spike	200-Kernel Weight (gm)
		1972-73 Crop Season		
Caprock	3269 a	69.4 b	33 a	4.93 c
Tam W 101	3252 a	74.0 a	25 c	6.35 a
Centurk	2915 b	70.5 a	31 b	4.58 d
Danne	2815 bc	64.3 c	30 b	5.55 b
Palo Duro	2648 c	70.3 a	30 b	4.52 d
		1973-74 Crop Season		
Tam W 101	1937 a	61.3 c	23 d	5.74 a
Caprock	1897 ab	53.9 e	28 b	5.00 b
Palo Duro	1714 b	72.1 a	24 d	4.35 c
Centurk	1710 b	65.1 b	30 a	3.81 d
Danne	1368 c	57.5 d	26 c	4.88 d

Note: Those means not followed by the same letter are significantly different at .05 level of probability, means followed by the same letter are not significantly different at .05 level of probability.

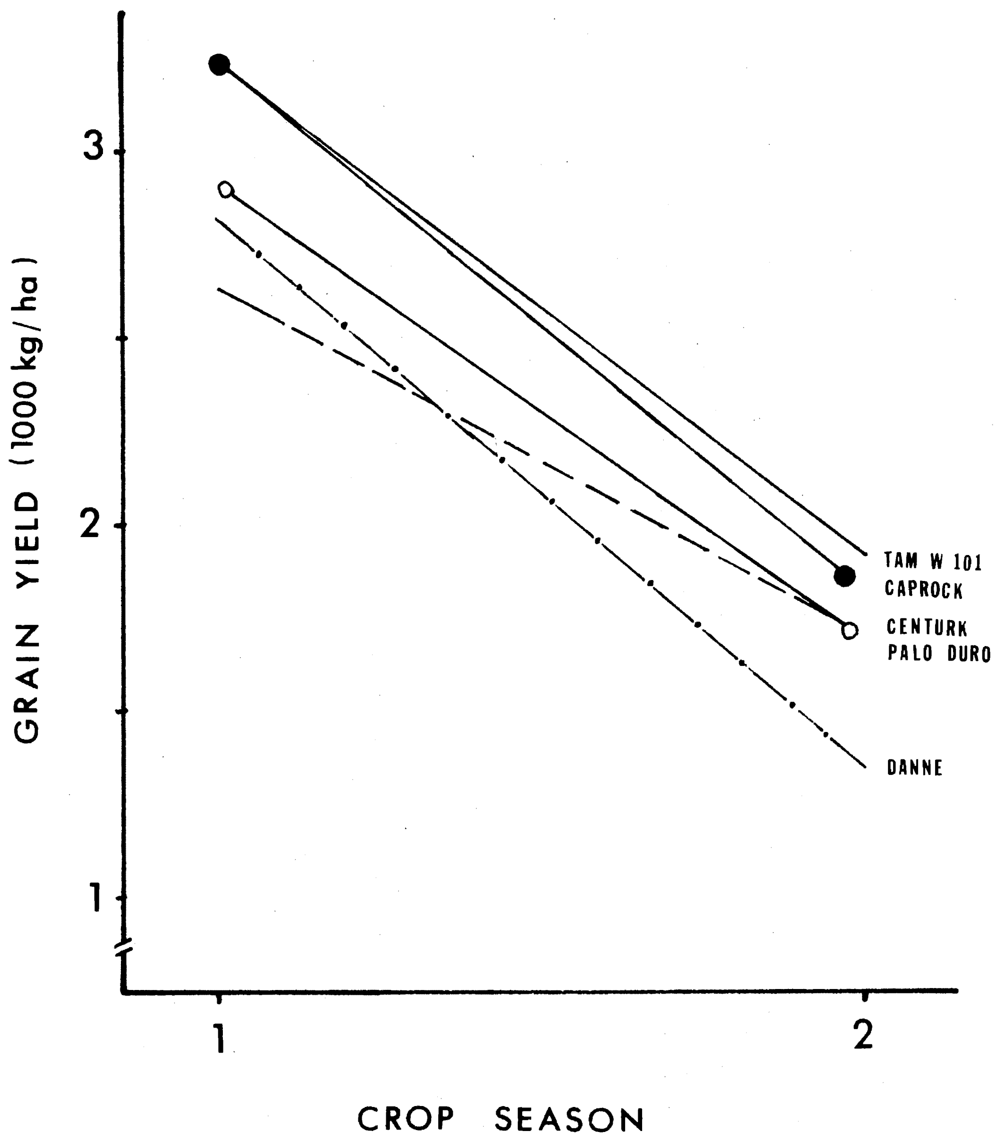

Figure 4. Grain Yield of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972--73 and 2=1973--74)

was reduced more than 50 percent compared to the first year. Yield differences due to seed rates were highly significant and a significant year by variety by seed rate interaction was observed. The nature of this interaction is shown in Figure 5. In the first year there was an increase in yield of Tam W 101, Caprock, Danne and Centurk when seed rate was increased from 67 kg/ha to 100 kg/ha, and the yield decreased when seed rate was further increased to 134 kg/ha. The yield of Palo Duro decreased with increase in seed rate from 67 to 100 kg/ha, and there was a slight increase in yield at 134 kg/ha (Figure 5a), but this increase was not significant. These results suggested that under adequate nitrogen and soil moisture, higher yields are obtained at seed rate of 100 kg/ha for Tam W 101, Caprock, Danne and Centurk. For Palo Duro the optimum seed rate was 67 kg/ha.

In the second year of the experiment higher yields were recorded at seed rate of 67 kg/ha for Caprock, Tam W 101, Centurk and Palo Duro. The yield of these varieties decreased with an increase in seed rate. For Danne the best seed rate was 100 kg/ha. The response of Danne in the second year indicated that it is less tolerant to environmental stress compared to the other four varieties.

In extremely dense stands the competition at the time of flower initiation is intense, and plants are subjected to both interplant and intraplant competition as proposed by Donald (21).

In general, the environmental conditions during the second year were not favorable for the varieties to express their yield potential. Treatment means for grain yield are presented in Appendix Table XII.

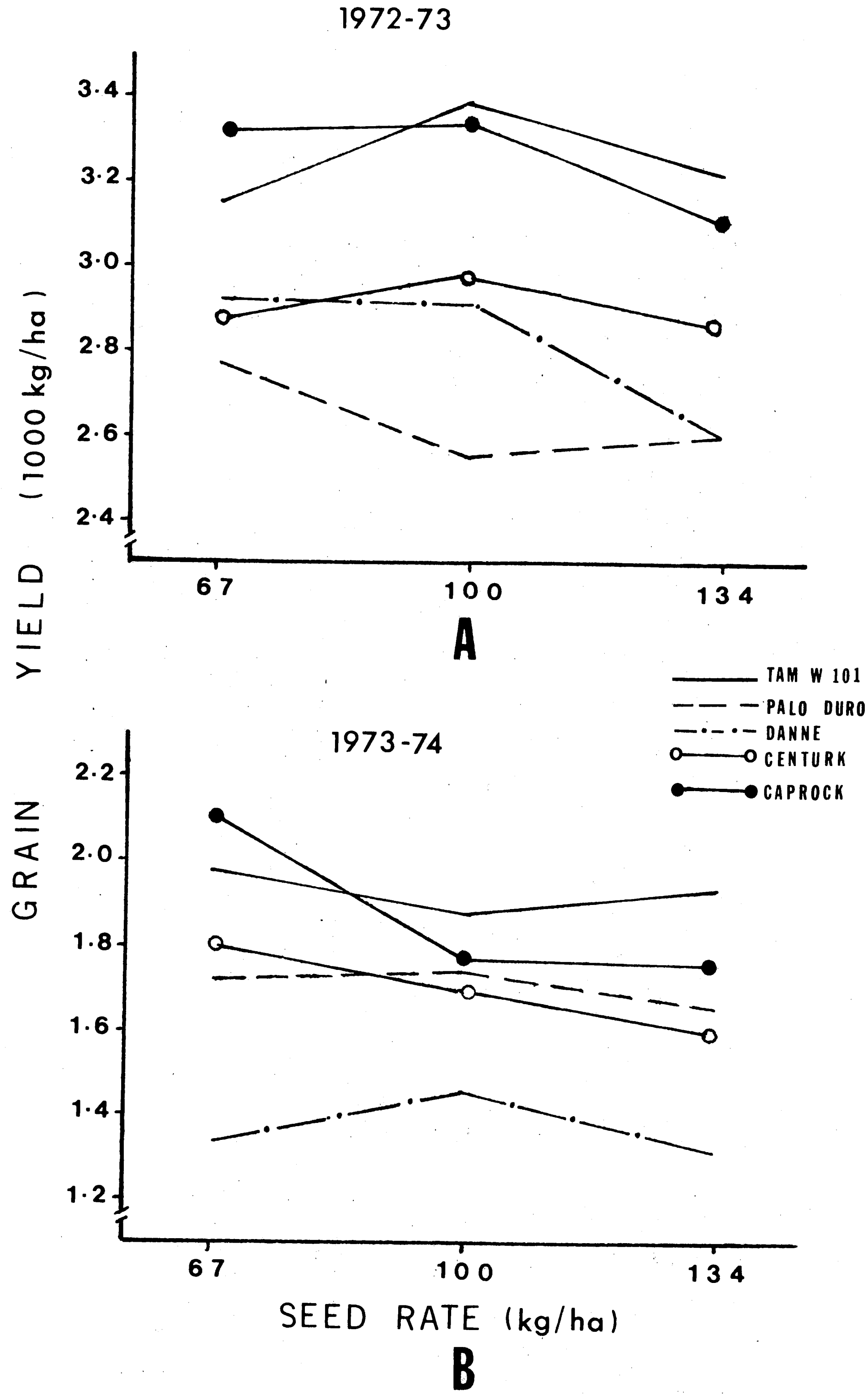

Figure 5. Grain Yield of the Five Winter Wheat Varieties at the Three Seed Rates in 1972-73 (A) and 1973-74 (B) Crop Seasons

Straw Yield

Differences between years were highly significant for straw yield. The average straw yield for all varieties averaged over nitrogen and seed rate was 6678 kg/ha in the first year and 3315 kg/ha in the second year. As mentioned in the grain yield discussion, the reduction in straw yield in the second year could be attributed to the unfavorable environmental conditions.

There were no significant differences for straw yields in response to nitrogen levels in both years. Straw yield differences among varieties were highly significant. The year by variety interaction (Figure 6) was not significant at .05 level of probability. In the first year, Tam W 101 recorded the highest straw yield and in the second year Palo Duro was the highest in straw yield. The differences among seed rates were not significant statistically; however, there was a significant year by seed rate interaction. In the first year of experiment the seed rate of 100 kg/ha gave the highest straw yield and in the second year the 67 kg/ha seed rate produced maximum straw yield. Treatment means for straw yield are presented in Appendix Table XIII.

Grain:Straw Ratio

Mean squares for grain:straw ratio were highly significant for differences between years. The average grain:straw ratio for the first year was 0.45 and it was smaller compared to the average value of 0.54 for the second year, indicating that the efficiency of grain production in the second year was higher than the first year. Differences among nitrogen levels were not significant for grain:straw ratio. There were

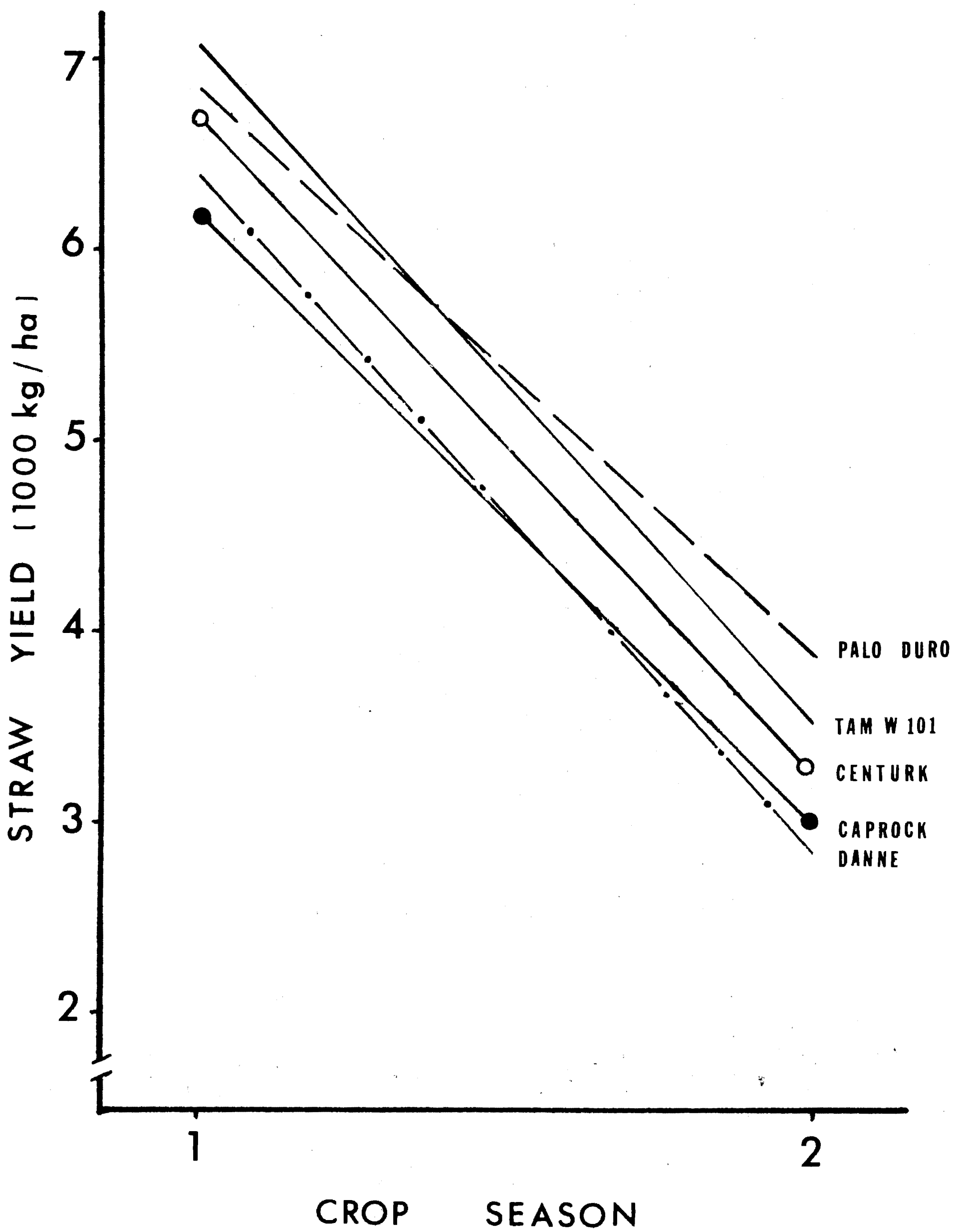

Figure 6. Straw Yield of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

highly significant differences among varieties for grain:straw ratio. Caprock had the highest ratio in both years (0.53 and 0.63 respectively) followed by Tam W 101 (0.47 and 0.55 respectively) and these two varieties had high grain yields in both the years. The mean squares for grain:straw ratio were significant for differences among seed rates. Low seed rate (67 kg/ha) had high grain:straw ratio compared to higher seed rates (100 and 134 kg/ha). Treatment means for grain: straw ratios are presented in Appendix Table XIV.

Dry Forage Yield

There was no significant difference between years for dry forage yield. The average dry weight in the first year was 2884 kg/ha and in the second year 2888 kg/ha. The dry weight in both years was recorded in the second week of April. Since there was no statistical difference in the dry forage yield for two years, and it implies that the growth rate was similar in both years until the early part of April. However, there were highly significant differences between years for grain yield and straw yield, the second year producing less grain and straw than the first.

Dry forage yield differences among nitrogen levels were not significant statistically. Differences among varieties were highly significant and a highly significant year by variety interaction was observed. The dry weight differences in response to seed rates were highly significant, and there was a highly significant year by seed rate interaction. The means for seed rate increased with increasing seed rate for the first year, whereas the dry weight means in the second year showed a slight decrease for the higher seed rates. This decrease could be due to the limited moisture and plant competition during the second year. The treatment means for the dry forage yield are presented in Appendix Table XV.

Plant Height

Mean squares for plant height were highly significant for differences between years. The mean plant height of all varieties averaged over nitrogen and seed rate was 92.4 cm in 1972-73 and 60.2 cm in 1973-74 crop season.

Differences among nitrogen levels and seed rates for plant height were not significant. The differences among varieties were highly significant for plant height and there was a highly significant year by variety interaction. The mean height for nitrogen varieties and seed rates are shown in Figure 7. Treatment means for plant height are presented in Appendix Table XVI.

Leaf Nitrate

Differences in leaf nitrate between years were not statistically significant. The differences among nitrogen levels were significant, the leaf nitrate content increased with an increase in applied nitrogen. There was a highly significant nitrogen by variety interaction and a significant variety by seed rate interaction. The leaf nitrate increased (Figure 8) with increasing nitrogen level for all varieties except for Tam W 101, which showed a drop at 134 kg nitrogen per hectare, and then an increase in leaf nitrate at 202 kg nitrogen per hectare. Treatment means for leaf nitrate are presented in Appendix Table XVII.

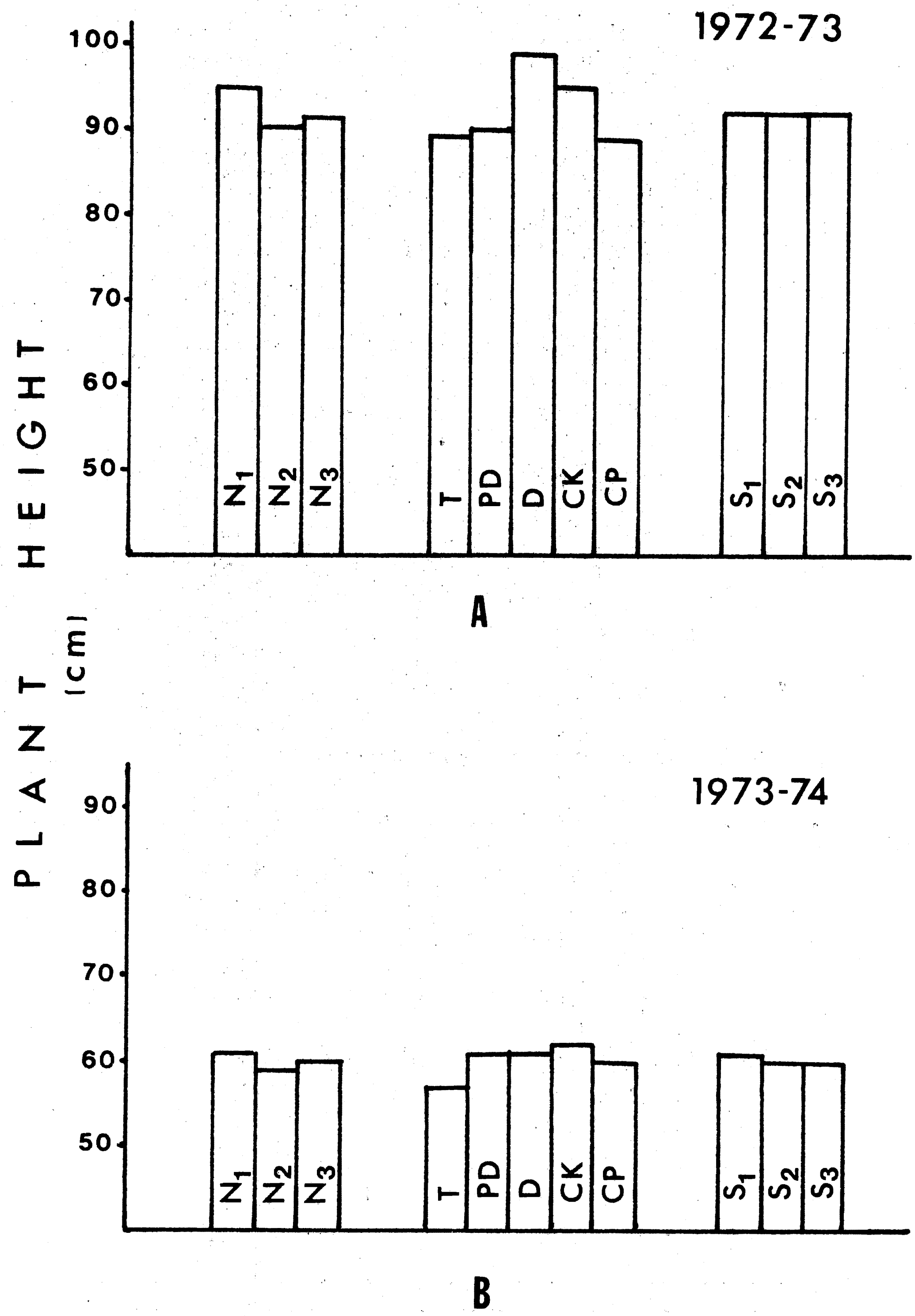

Figure 7. Plant Height for Nitrogen Levels, Varieties and Seed Rates in 1972-73 (A) and 1973-74 (B) Crop Seasons.

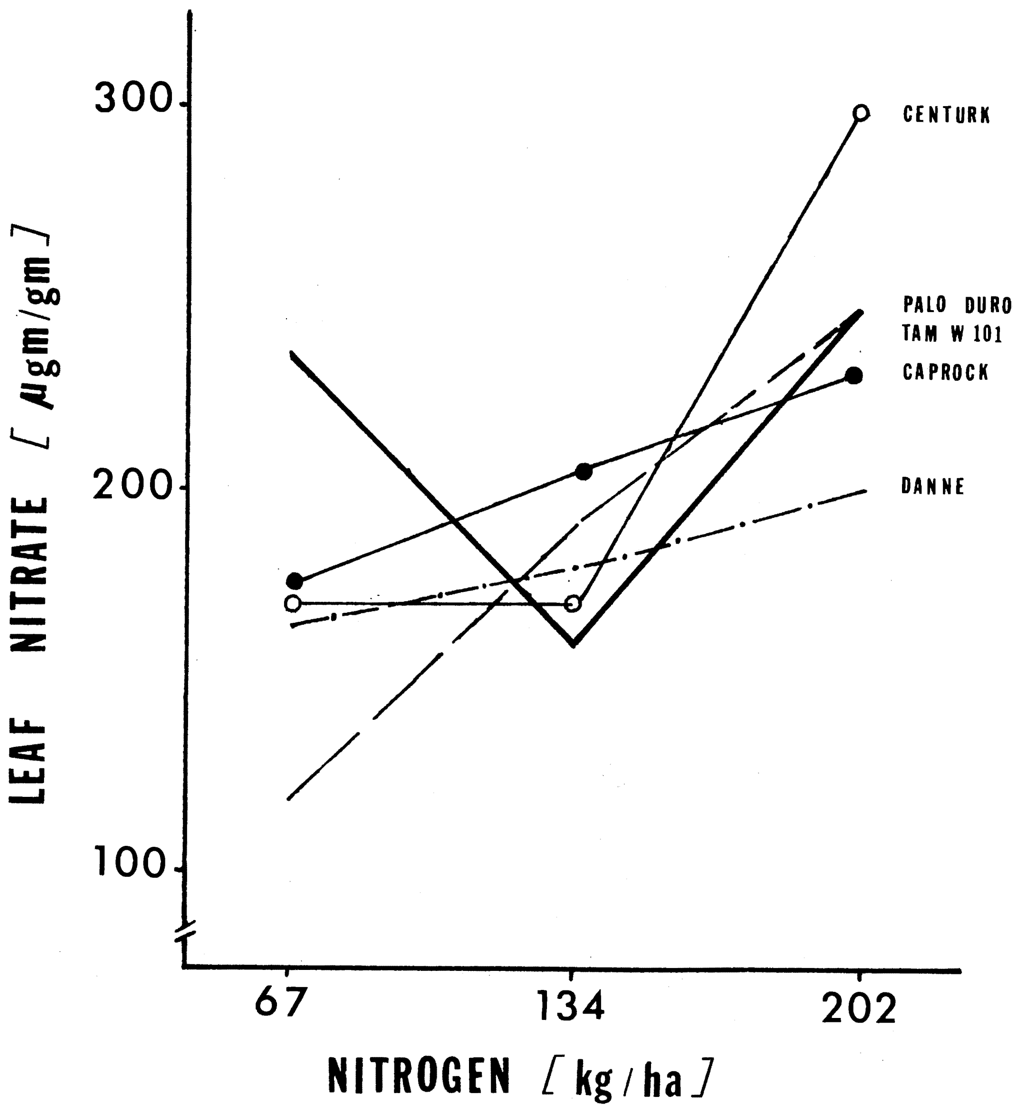

Figure 8. Leaf Nitrate of the Five Winter Wheat Varieties Averaged Over the Two Crop Seasons and Three Seed Rates

Grain Protein

Differences in grain protein were highly significant for the two years. The average protein content for the 1972-73 crop season was 14.5 percent and that for 1973-74 season was 15.9 percent. The results are in agreement with the general inverse relationship between protein content and grain yield.

Grain protein was increased with increasing levels of nitrogen. Similar results were reported by Johnson _et al_. (47) and Stone and Tucker (84). Grain protein was also influenced by varieties and seed rates as shown in Figure 9. Palo Duro and Centurk which had low grain yields recorded higher protein content in both years. Danne recorded the lowest protein percent in both years suggesting it may have a genetic ceiling for grain protein and is a low protein genotype. There were significant year by nitrogen, year by nitrogen by variety and year by variety by seed rate interactions, but the magnitude of the mean squares indicated that the differences among nitrogen, varieties and seed rates were of more importance than the two and three factor interactions. Treatment means for grain protein are presented in Appendix Table XVIII.

Protein Yield

For protein yield the mean squares were highly significant for differences between years. In the first year the mean protein yield was 430 kg/ha which was higher than the mean protein yield of 272 kg/ha recorded in second year. Protein yield was not significantly influenced by nitrogen levels. Protein yields were highly significant

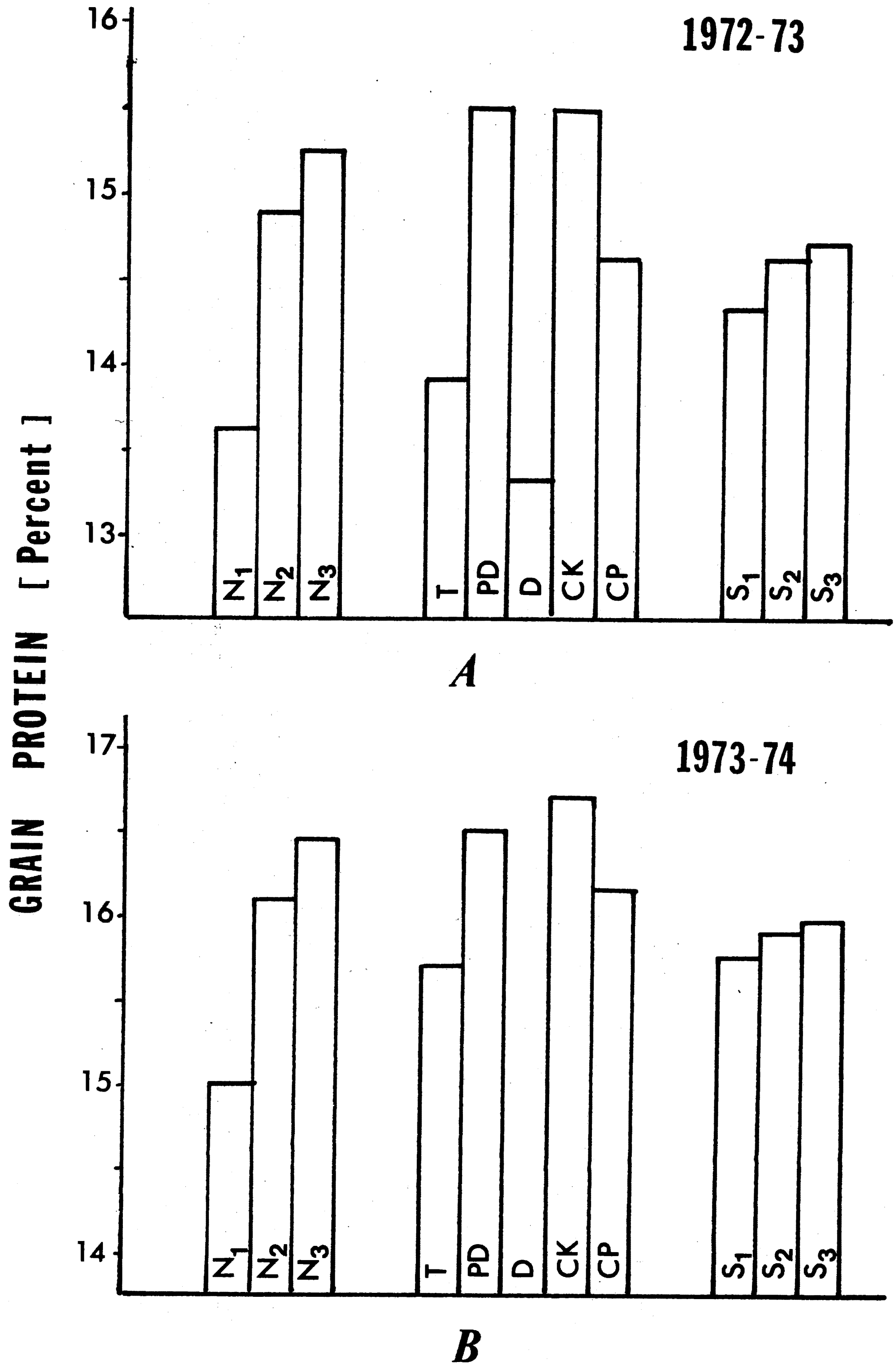

Figure 9. Grain Protein Percent for Nitrogen Levels, Varieties and Seed Rates in 1972-73 (A) and 1973-74 (B) Crop Seasons

for differences among varieties, and there was a highly significant year by variety interaction. Seed rates significantly affected protein yield at 0.05 level of probability. Treatment means for protein yield are presented in Appendix Table XIX.

Straw Nitrogen

There was no difference in straw nitrogen between the two years. The differences among nitrogen levels were significant at 0.05 level of probability. The mean squares for straw nitrogen were highly significant for differences among varieties, and there was a highly significant year by variety interaction. A significant four factor interaction indicated that straw nitrogen is a function of year, nitrogen level, variety and seed rate. The treatment means for straw nitrogen are presented in Appendix Table XX.

Grain Nitrogen Recovery

There were highly significant effects of years, varieties, seed rates and interaction between years and varieties. The differences among nitrogen levels were not significant. The average grain nitrogen recovery was higher in the first year (75.4 kg/ha) than the average nitrogen recovery in the second year (47.7 kg/ha). Figure 10 shows the year by variety interaction. Treatment means for grain nitrogen recovery are presented in Appendix Table XXI.

Straw Nitrogen Recovery

Straw nitrogen recovery was significantly different for the two years. The differences among nitrogen levels were not significant.

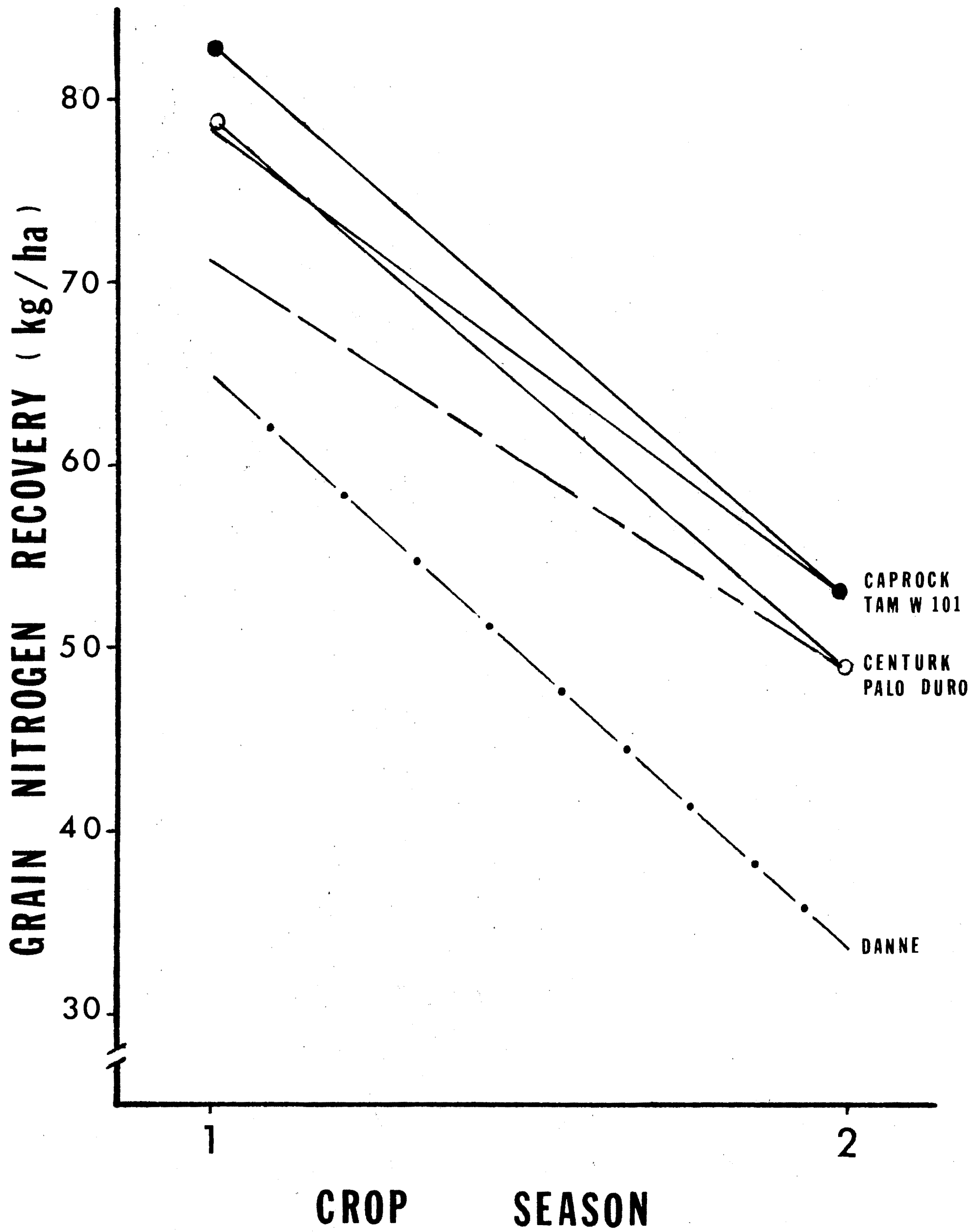

Figure 10. Grain Nitrogen Recovery of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

The mean squares for straw nitrogen recovery were highly significant for differences among varieties, and there was a highly significant year by variety interaction. Differences among seed rates were not significant. The first year of the experiment had a higher nitrogen recovery than the second year of the study. The treatment means for straw nitrogen recovery are presented in Appendix Table XXII.

Total Nitrogen Recovery

The differences in total nitrogen recovery were highly significant for the two years. Total nitrogen recovery was not significantly influenced by nitrogen levels. The mean squares for total nitrogen recovery were highly significant for differences among varieties and seed rates.

The total nitrogen recovered in the first year was higher than the amount recovered in the second year. The lower recovery in the second year is due to low grain and straw yield, since total nitrogen recovery is influenced by grain and straw yield. The total nitrogen recovery is shown in Figures 11 and 12. The average nitrogen application for the experiment was 134 kg/ha. It is interesting to note that the total nitrogen recovery in the first year was 133.4 kg/ha which is very close to the average fertilizer nitrogen application figure. In the second year the average nitrogen recovery was 78.2 kg/ha which is less than the average nitrogen applied. Since the treatment and experimental area were the same in both years of experiment, a possible explanation for this reduction in total nitrogen recovery is the environmental variation. The first year had a normal growing season with enough soil moisture at all critical stages of crop growth, whereas the

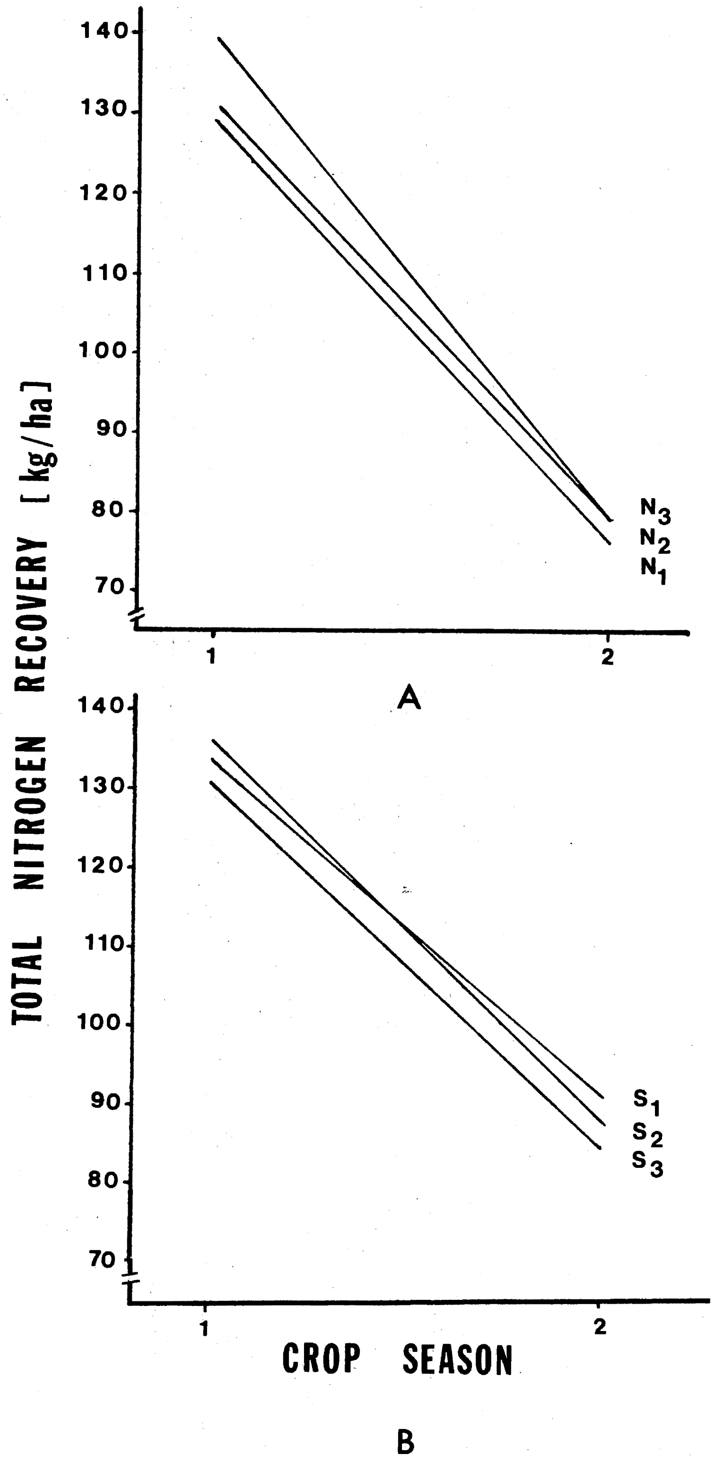

Figure 11. Total Nitrogen Recovery for Nitrogen Levels (A) and Seed Rates (B) for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

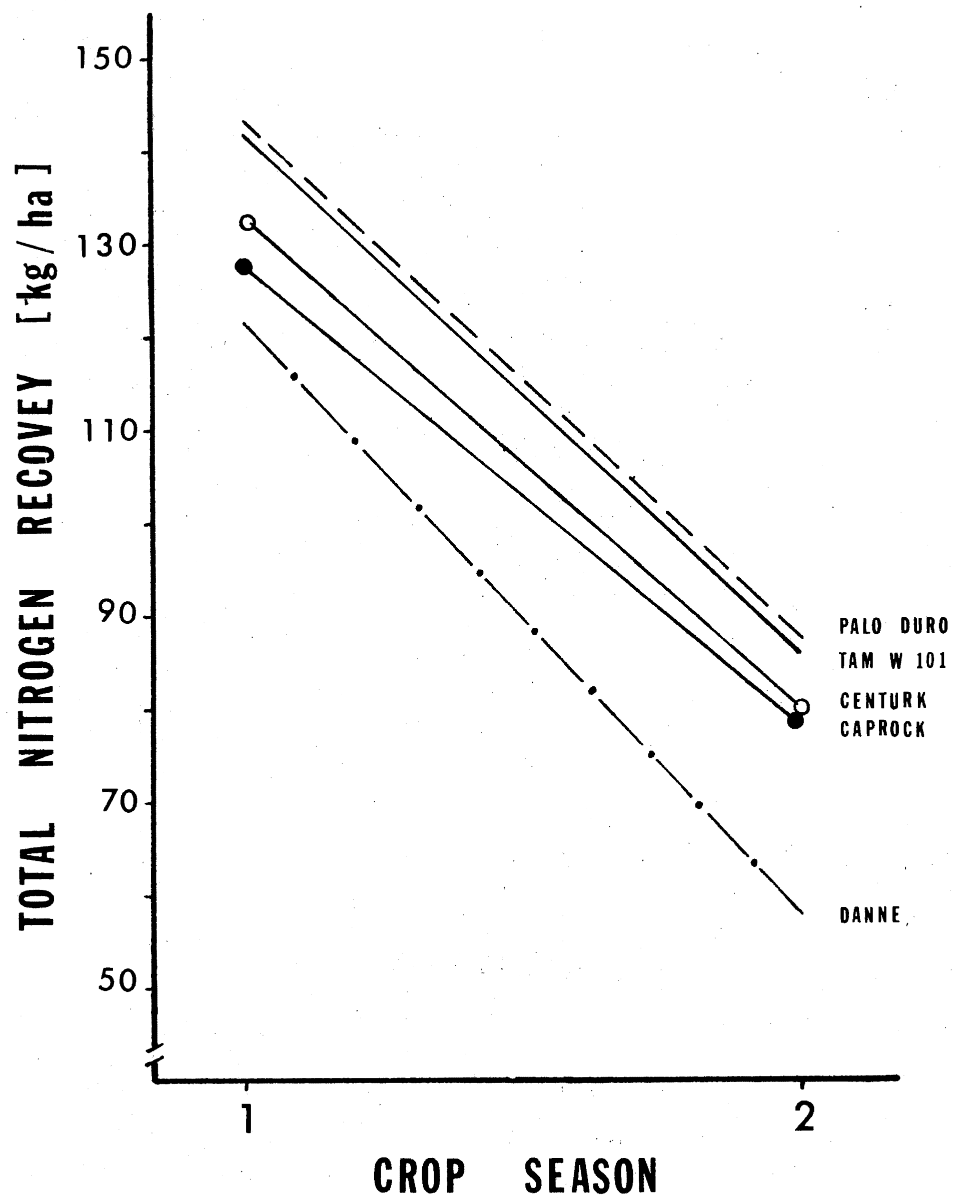

Figure 12. Total Nitrogen Recovery of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

second year had some dry periods during tillering, flowering and grain filling stages of crop growth. There was a genetic potential for higher yield but the environmental conditions of the second year were not favorable for that potential to be fully expressed. Treatment means for total nitrogen recovery are presented in Appendix Table XXIII.

Yield and Yield Components

There were highly significant differences in yield and yield components between the two years of this study. However, these differences among nitrogen levels were not significant. Varieties were highly significant for differences in yield and yield components, and agrees with the results of Asana and Mani (8), and there was a significant year by variety interaction for the yield components as shown in Table VIII. The year by variety interactions for yield components are shown in Figures 13, 14 and 15. The differences among seed rate were not significant for 200-kernel weight, and the variety by seed rate interaction was not significant for grain yield, tiller number and kernels per spike, the response of varieties was averaged over nitrogen and seed rate and presented in Table X. The years were separated because the year by variety interaction was highly significant for yield and yield components. Treatment means for yield components are presented in Appendix Tables XXIV, XXV and XXVI.

1972-73 Crop Season

For the variety Tam W 101, tiller number and 200-kernel weight seemed to be most closely associated with grain yield based on the

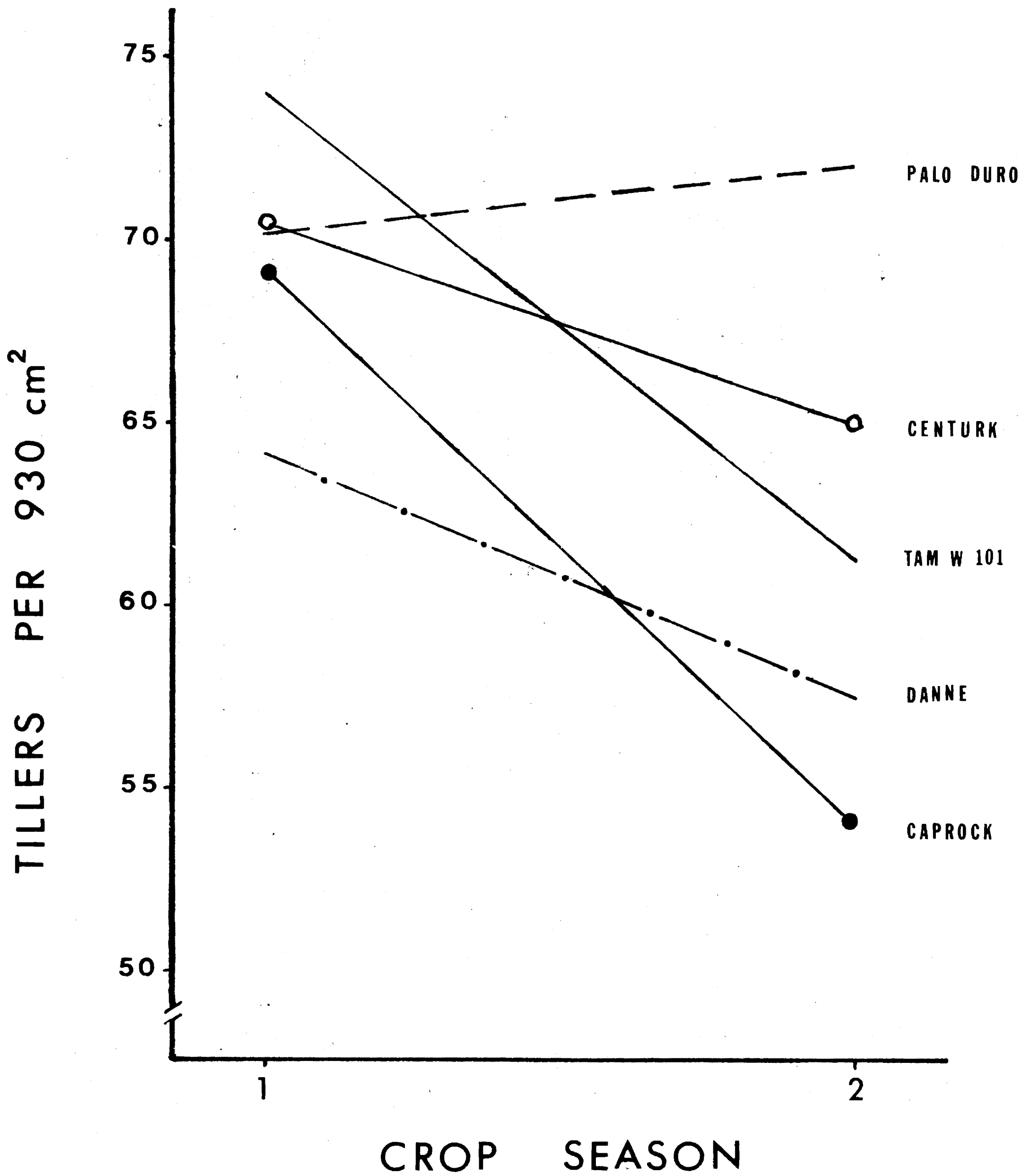

Figure 13. Tiller Number of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

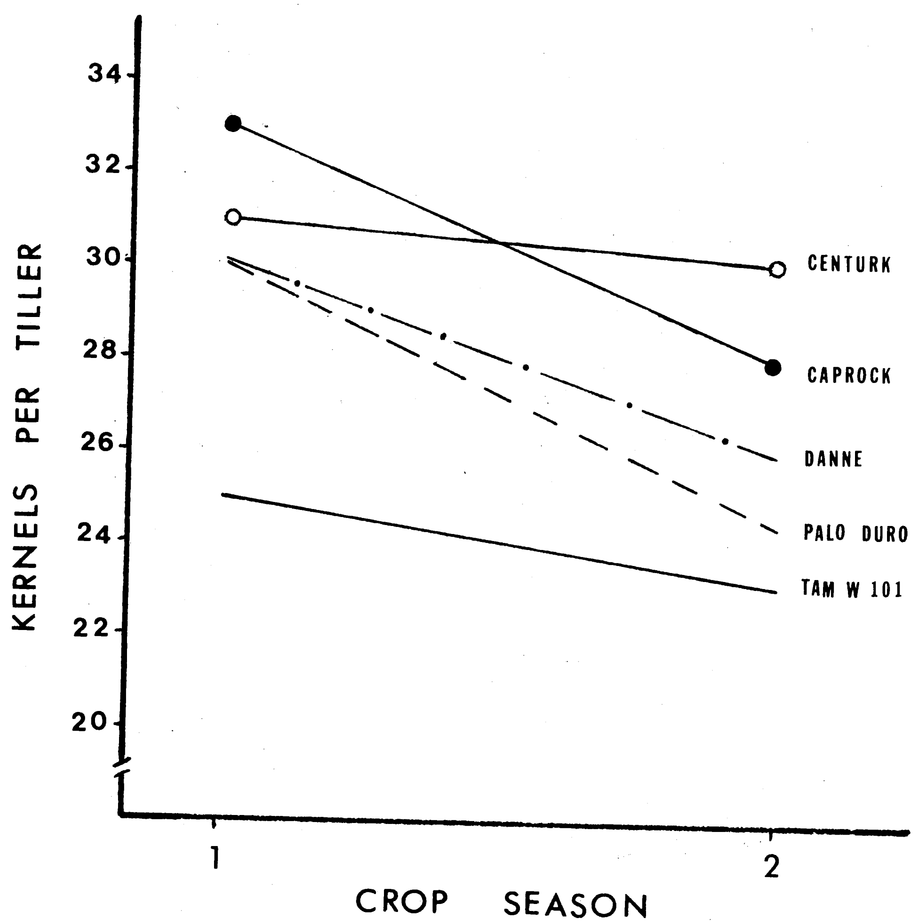

Figure 14. Kernels Per Spike of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

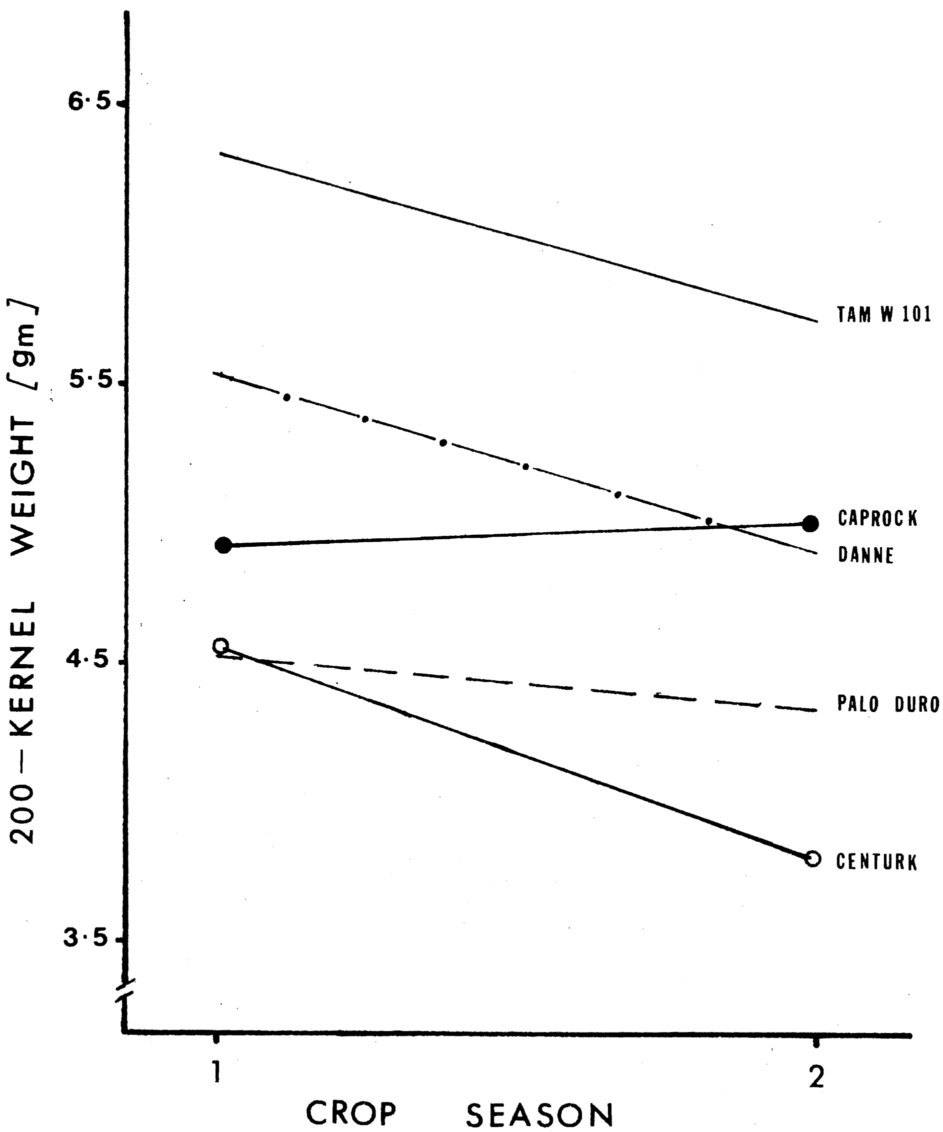

Figure 15. 200-Kernel Weight of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

ranks in Table X, and kernels per spike appeared to be less important. Tam W 101 gave the highest yield in 1972-73.

Caprock had the highest grain yield in 1972-73 crop season, and kernels per spike appeared to be most closely associated with yield, as it had the highest number of kernels per tiller. However, tiller number also seemed to be important in determining yield in this variety (Table X).

The variety, Palo Duro, gave the lowest yield even though it had a high tiller number, and was ranked second with respect to kernels per spike. The component that could account for this decrease is the 200-kernel weight (Table X).

For the variety Danne, kernels per spike and 200-kernel weight appeared to be most closely associated with yield (Table X), and this variety had the lowest tiller number in 1972-73.

For the variety Centurk, tiller number and kernels per spike seemed to be most closely associated with yield and the 200-kernel weight was ranked fourth as seen in Table XI.

1973-74 Crop Season

Tam W 101 was the highest in yield and the 200-kernel weight appeared to be most closely associated with yield. This variety had the lowest rank for kernels per spike and third rank for tiller number (Table X).

For the variety Caprock the 200-kernel weight and kernels per spike were more closely associated with grain yield. This variety was still a top yielder in 1973-74 season in spite of a considerable reduction in tiller number. There was a slight increase in 200-kernel weight in 1973-74 crop season which helped offset the reduction in tiller number.

For the variety Palo Duro 200-kernel weight appeared to be related to yield more than tiller number. This variety was the lowest yielder in 1972-73 season, but the yield improved in the 1973-74 season (second rank) and the yield component which appeared to help this is the 200-kernel weight, which showed an increase over the previous year. One fact that should be considered is that Palo Duro is a high tillering variety, and when all other varieties showed a decrease in tiller number in 1973-74 season, Palo Duro recorded a slight increase in tiller number (Figure 16).

For the variety Danne, kernels per spike seemed to be more closely associated with yield. This variety recorded the lowest yield in 1973-74 season. The only change was a reduction in number of kernels per tiller in 1973-74 season.

The variety Centurk showed that kernels per spike and tiller number were most closely associated with yield. The same components appeared to be closely associated with yield in the 1972-73 crop season. There was a reduction in grain yield in the second year compared to the first year of the experiment, but the pattern of association of yield components with yield was similar in both years for Centurk.

Thus, yield components develop sequentially in wheat and that the latter components tend to compensate for the reductions in earlier ones agrees with the results of Adams (1). For each variety there is one primary yield component responsible for increasing yield and the results were in agreement with the findings of Hsu and Walton (39).

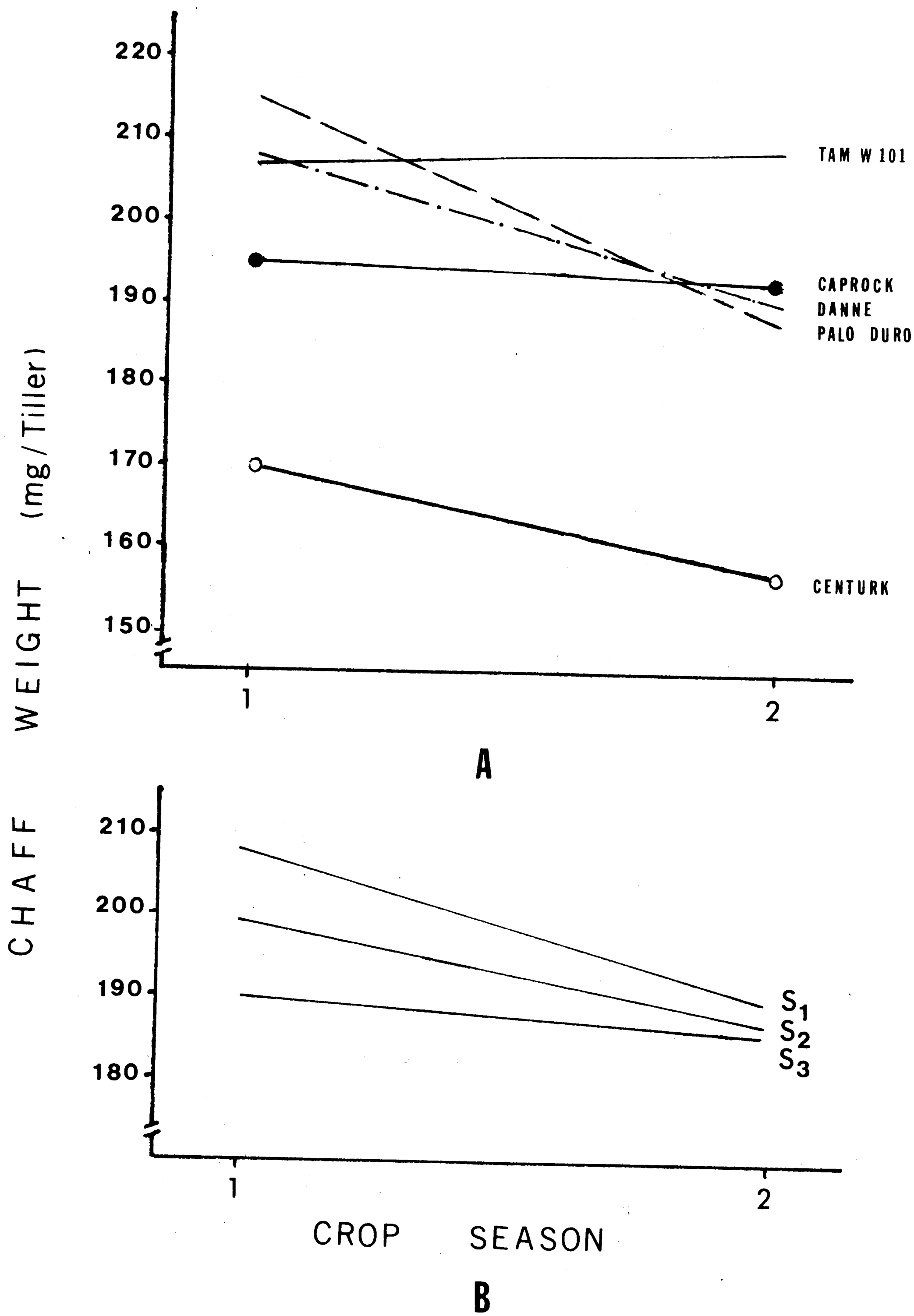

Figure 16. Chaff Weight of the Five Winter Wheat Varieties (A) and Chaff Weight for the Seed Rates (B) for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

Chaff Weight

The differences between years for chaff weight were not significant. There was no significant effect of nitrogen on chaff weight, the differences among varieties and seed rates were highly significant. The year by variety and year by seed rate interactions were significant at 0.05 level of probability and they are shown in Figure 16. Also the variety by seed rate and nitrogen by variety by seed rate interactions were significant at 0.05 level of probability. Treatment means for chaff weight are presented in Appendix XXVII.

Peduncle Area

The differences between years were highly significant. The differences among nitrogen levels were not significant, but there were highly significant differences among varieties and seed rates. The year by variety and year by seed rate interactions were significant at .05 and .01 levels of probability. The interactions are shown in Figure 17. There was a reduction in peduncle area of all varieties in the second year of the study with Tam W 101 recording higher area in both years. In the first year the peduncle area per hectare was higher for the higher seed rate (134 kg/ha) followed by 100 kg/ha and 67 kg/ha seed rates. In the second year of study there was no effect of seed rate on peduncle area per hectare. A significant nitrogen by variety by seed rate interaction was observed. The treatment means for peduncle area are presented in Appendix Table XXVIII.

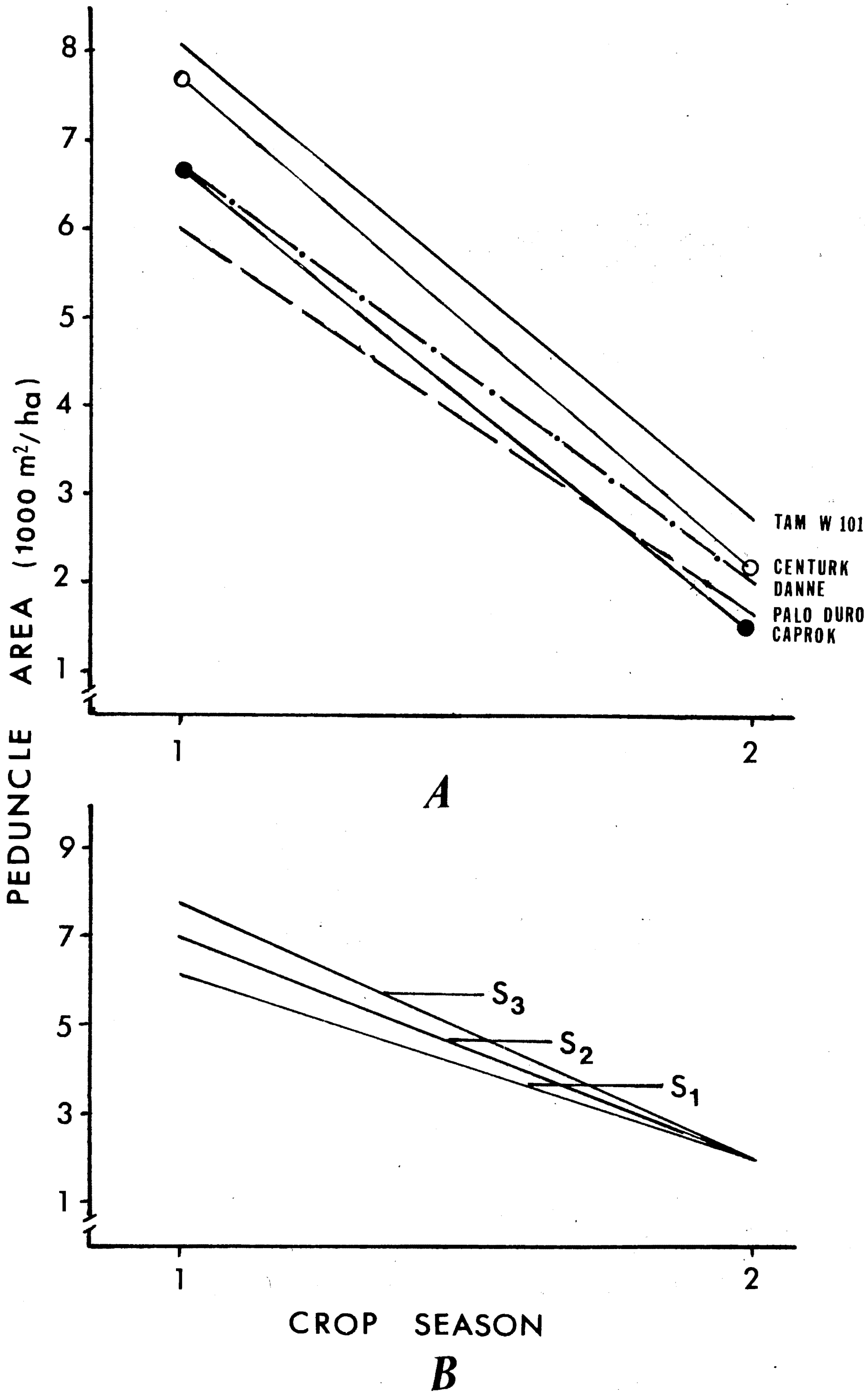

Figure 17. Peduncle Area of the Five Winter Wheat Varieties (A) and Peduncle Area for the Seed Rates (B) for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

Flag Leaf Area

The mean squares for flag leaf area were highly significant for differences between years. The mean flag leaf area of all varieties averaged over nitrogen and seed rate was 17692 m^2/ha in 1972-73 and 9223 m^2/ha in 1973-74. This reduction could be attributed to the different growing conditions in the two crop seasons. The differences among nitrogen levels were not significant, but there were highly significant differences among varieties and seed rates. The mean squares for year by variety and year by seed rate were highly significant, and the nature of these interactions is shown in Figures 18 and 19. In the first year Tam W 101 recorded the highest flag leaf area (21288 m^2/ha) followed by Palo Duro, Caprock, Centurk and Danne. In the second year Palo Duro produced the highest flag leaf area (10195 m^2/ha) followed by Tam W 101, Centurk, Danne and Caprock. The highest seed rate (134 kg/ha) produced the highest flag leaf area in 1972-73, and in 1973-74 seed rates of 134 and 100 kg/ha recorded higher leaf areas. The treatment means for flag leaf area are presented in Appendix Table XXVII.

Total Photosynthetic Area

The differences between years were highly significant, but the mean squares for differences among nitrogen levels were not significant. The mean photosynthetic area for varieties averaged over nitrogen and seed rate was 24764 m^2ha for 1972-73 and 11211 m^2/ha for 1973-74, suggesting that in the first year, growing conditions were more favorable than the second year. The varieties were highly significant

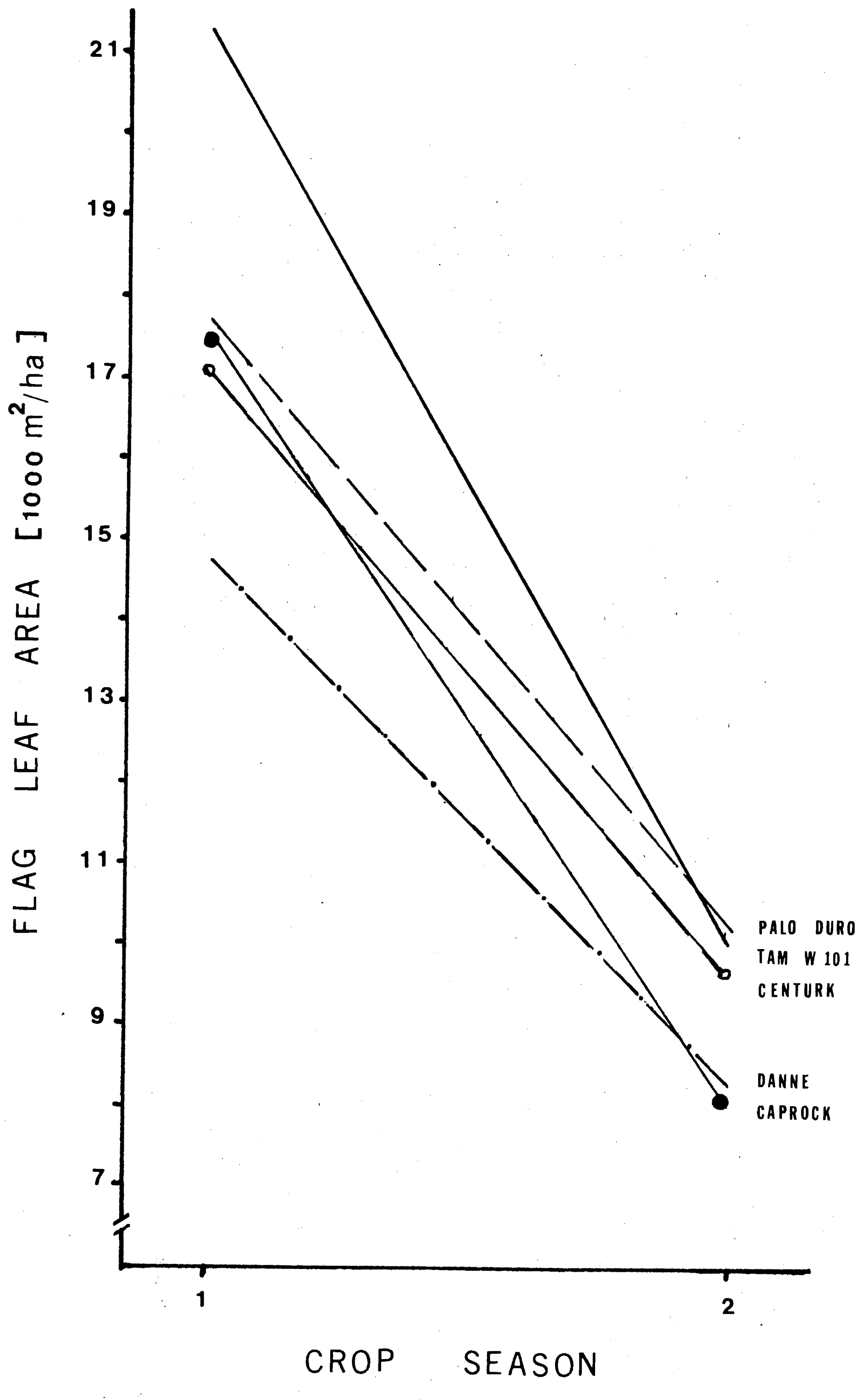

Figure 18. Flag Leaf Area of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

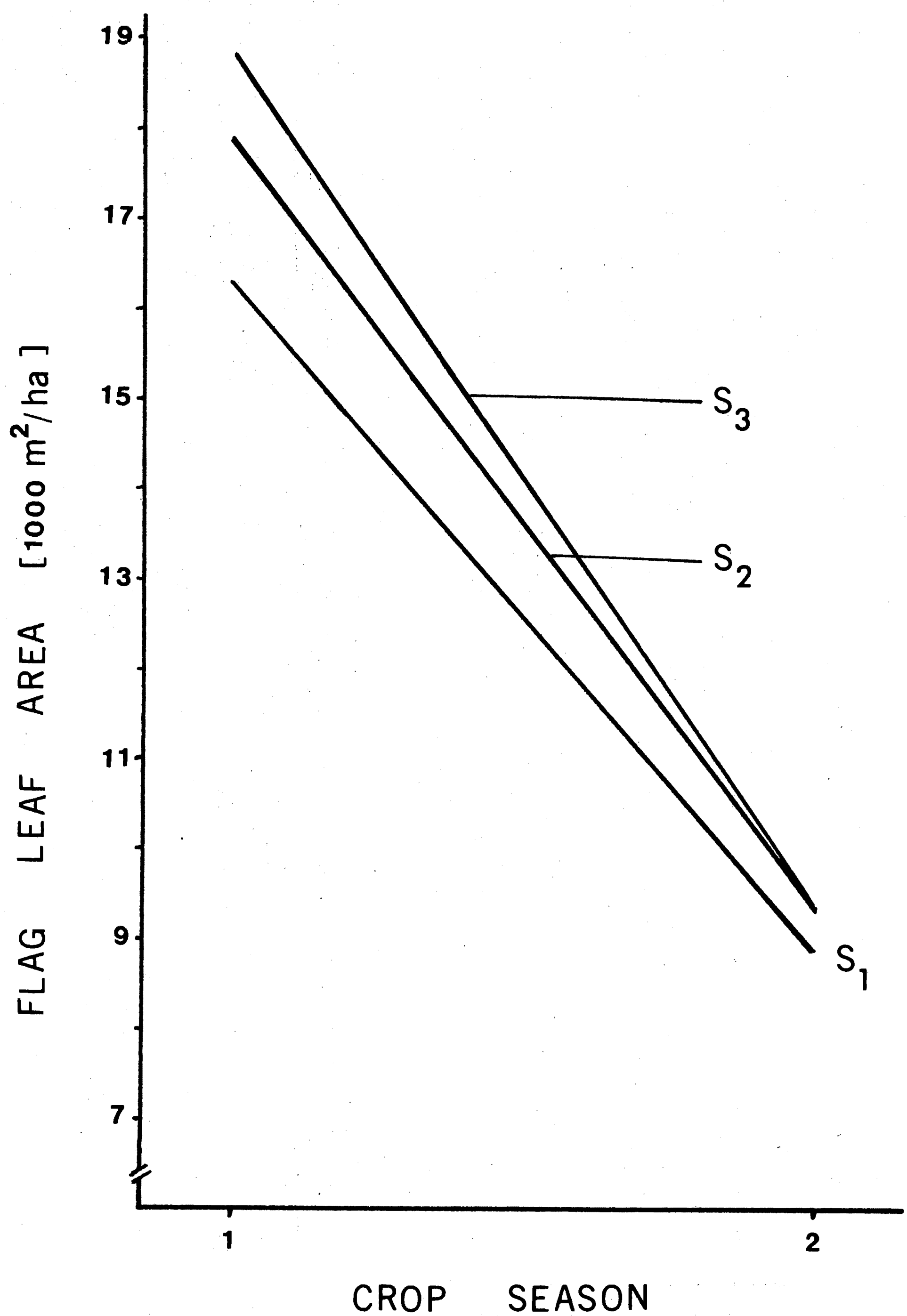

Figure 19. Flag Leaf Area for the Three Seed Rates in the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

and year by variety interaction was also highly significant. The nature of the interaction is shown in Figure 20. The response pattern of varieties was similar in both years, except for Caprock. Caprock recorded the lowest photosynthetic area in the second year; however, there was no significant difference in yield between Caprock and Tam W 101. Tam W 101 had the highest photosynthetic area in both years and was ranked first with regard to grain yield. The high yields in Tam W 101 could be attributed to better light utilization for dry matter accumulation, and agrees with the results reported by Tanner et al. (86). The high yields in Caprock could be attributed to an efficient physiological system suggesting the need for more extensive research. The differences among seed rates were highly significant and the year by seed rate interaction (Figure 21) was also highly significant. In the first year the photosynthetic area increased with increasing seed rate from 67 to 134 kg/ha. In the second year there was a small increase in photosynthetic area with the increase in seed rate from 67 to 100 kg/ha, but there was no difference between 100 and 134 kg/ha seed rate. The treatment means for total photosynthetic area are presented in Appendix Table XXIX.

Peduncle Area Duration

There was a highly significant difference between years for peduncle area duration. The mean peduncle area duration of all varieties averaged over nitrogen and seed rate was 274 cm^2days in 1972-73 and 81 cm^2days in 1973-74. Differences among nitrogen levels and seed rates were not significant for peduncle area duration. The differences among varieties were highly significant, and there was a year by

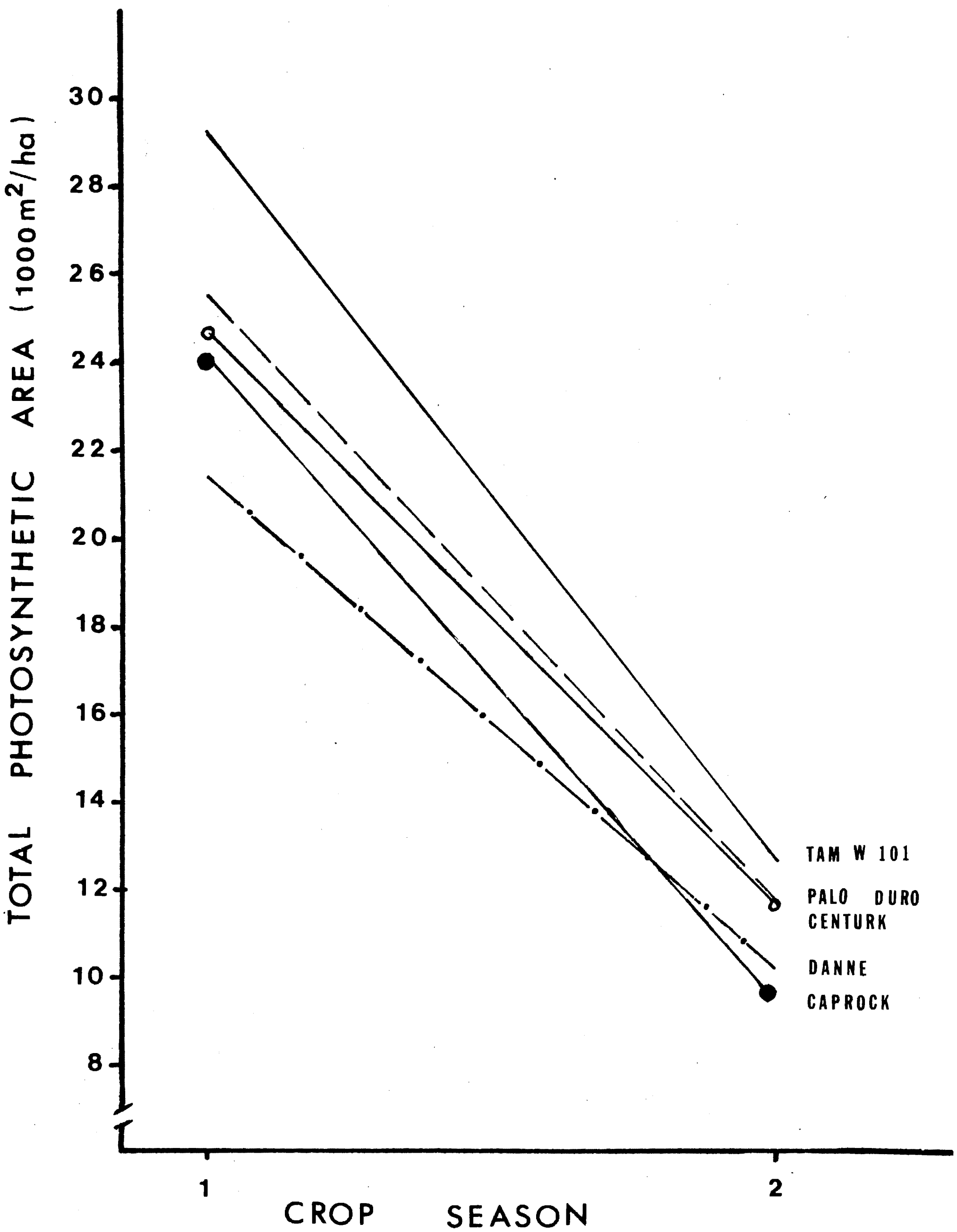

Figure 20. Total Photosynthetic Area of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

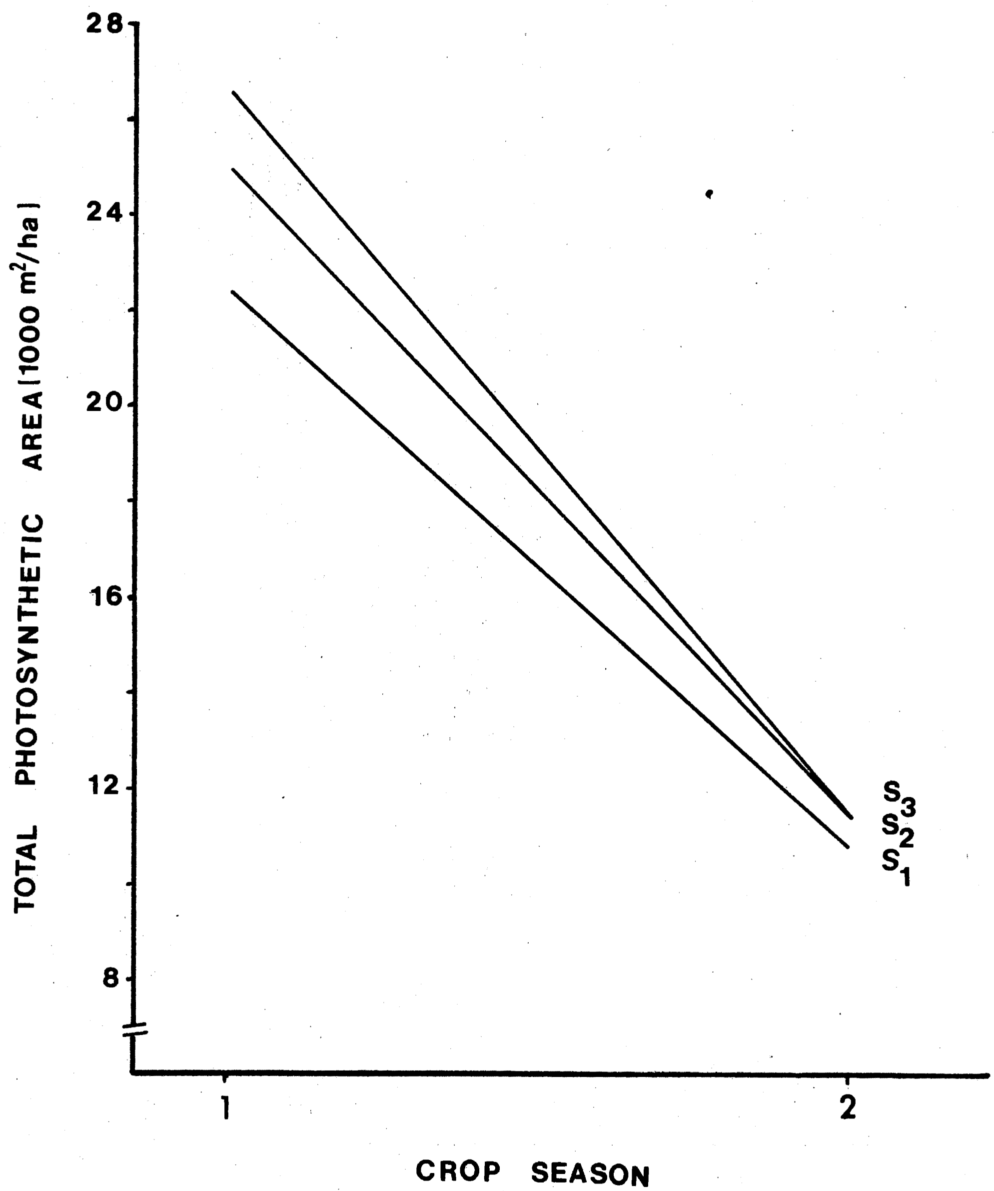

Figure 21. Total Photosynthetic Area for the Three Seed Rates in the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

variety interaction. The nature of this interaction is shown in Figure 22. The year by nitrogen by seed rate interaction was significant, and there was a highly significant nitrogen by variety by seed rate interaction. Treatment means for peduncle area duration are presented in Appendix Table XXX.

Flag Leaf Area Duration

Differences in flag leaf area duration were highly significant for the two years of study. The average flag leaf area duration for 1972-73 crop season was 687 cm^2days and that for 1973-74 crop season was 375 cm^2days. Flag leaf area duration was not significantly influenced by nitrogen levels. The differences among varieties and seed rates were highly significant for flag leaf area duration. There was a highly significant year by variety interaction and a significant year by seed rate interaction. There was a significant four factor interaction but the magnitude of the mean squares was small. The year by variety interaction is shown in Figure 23. Treatment means for flag leaf area duration are presented in Appendix Table XXXI.

Total Photosynthetic Area Duration

For total photosynthetic area duration the mean squares were highly significant for differences between years. In the first year the mean total photosynthetic area duration was 961 cm^2days, which was higher than the mean total photosynthetic area duration of 457 cm^2days for the second year. There was no significant effect of nitrogen on the total photosynthetic area duration; the differences among varieties and seed rates were highly significant. The year by variety interaction

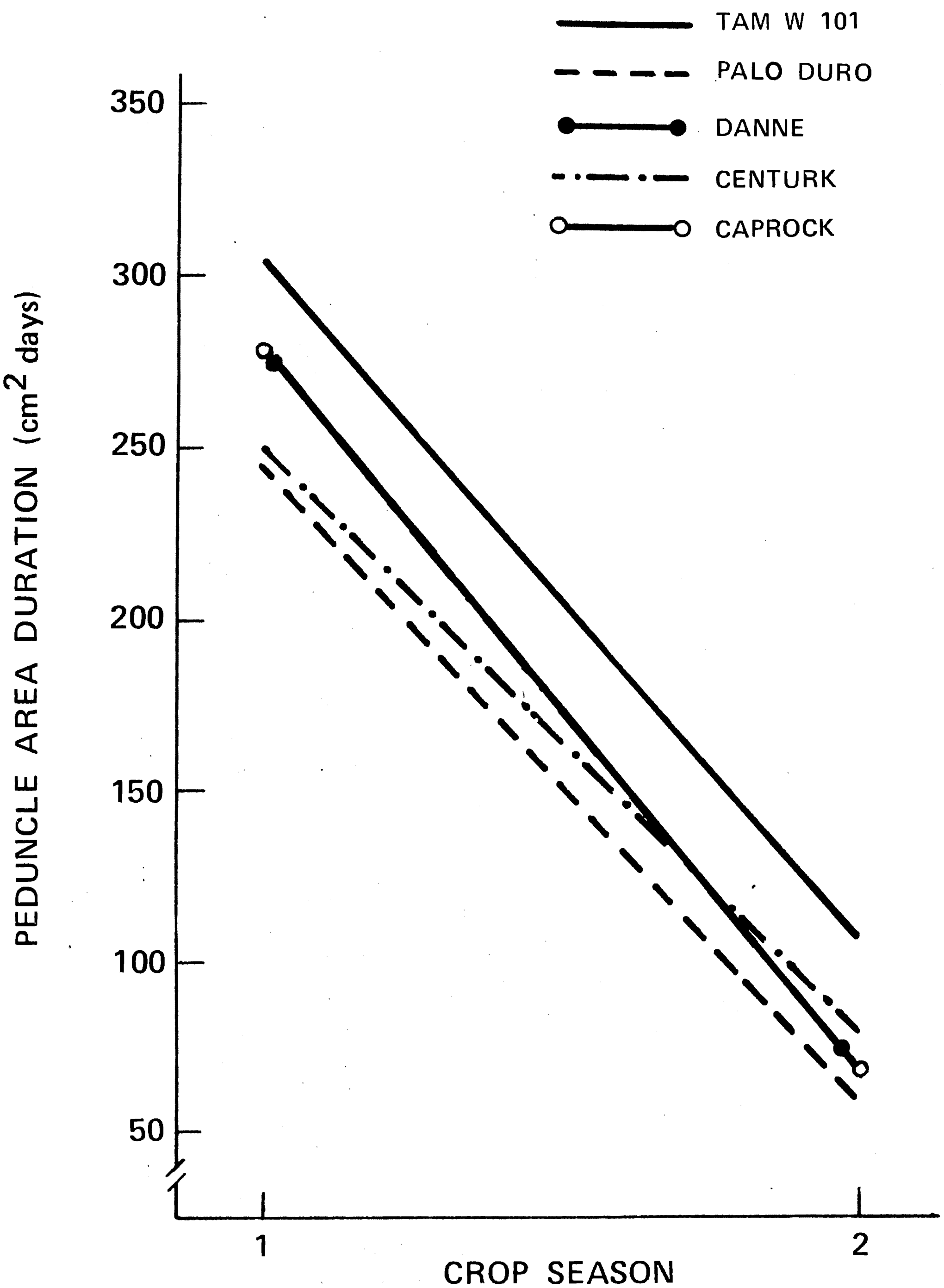

Figure 22. Peduncle Area Duration of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

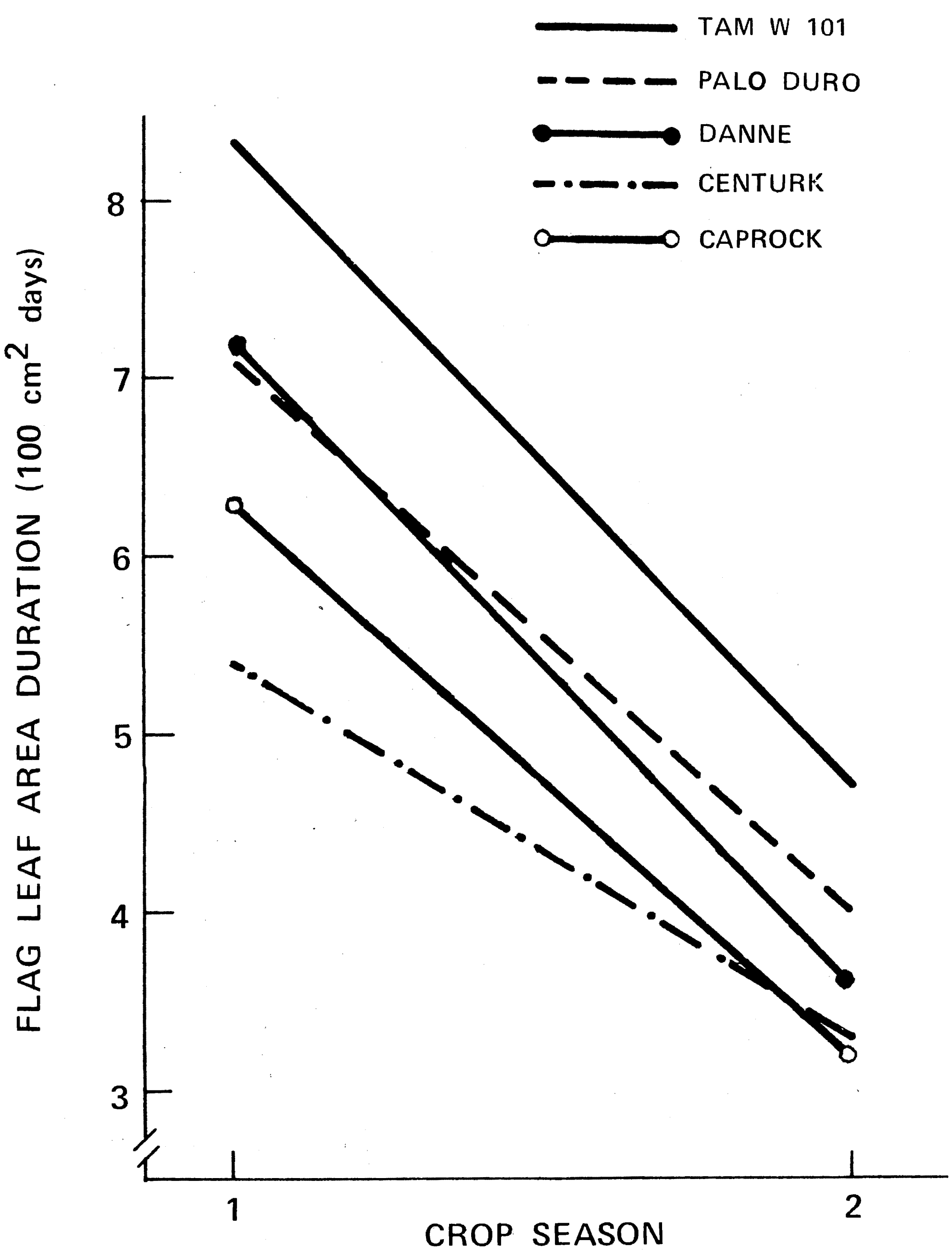

Figure 23. Flag Leaf Area Duration of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

was highly significant, and there was a highly significant year by nitrogen by variety by seed rate interaction. The nature of year by variety interaction is shown in Figure 24. Treatment means for total photosynthetic area duration are presented in Appendix Table XXXII.

Influence of Photosynthetic Components on Grain Yield and Yield Components

The years were highly significant for grain yield, yield components and photosynthetic area components, as such the years were separated in the computation of simple correlations. The correlation coefficients are presented in Table XI.

1972-73 Crop Season

Grain yield was positively correlated with 200-kernel weight, peduncle area, flag leaf area, total photosynthetic area, peduncle area duration, flag leaf area duration and total photosynthetic area duration. The relationship between grain yield and total photosynthetic area duration is shown in Figure 25. Of the two high yielding varieties, Tam W 101 had greater duration and Caprock had an intermediate total photosynthetic area duration.

There was a negative correlation between tiller number and kernels per spike. The relationship between tiller number and peduncle area duration was positive. Kernels per spike were negatively correlated with 200-kernel weight and photosynthetic components. The relationship between kernels per spike and total photosynthetic area duration is shown in Figure 26. The 200-kernel weight was positively correlated with photosynthetic components. The relationship between 200-kernel

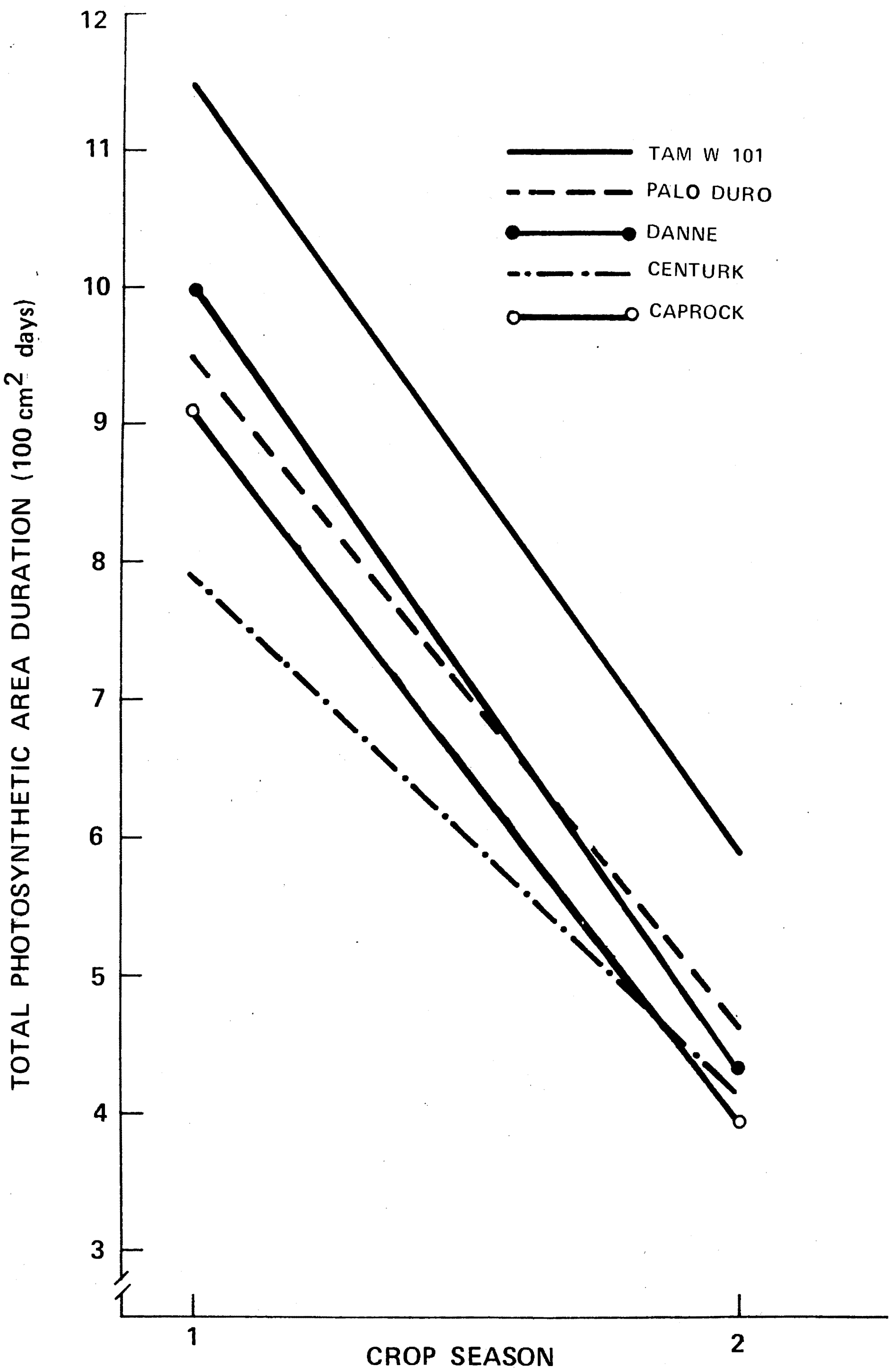

Figure 24. Total Photosynthetic Area Duration of the Five Winter Wheat Varieties for the Two Crop Seasons (Crop Season 1=1972-73 and 2=1973-74)

TABLE XI

SIMPLE CORRELATION COEFFICIENTS FOR PHOTOSYNTHETIC COMPONENTS, YIELD AND YIELD COMPONENTS

	Grain Yield	Tiller Number	Kernels/ Spike	200-Kernel Weight	Peduncle Area	Flag Leaf Area	Total Photo- synthetic Area	Peduncle Area Duration	Flag Leaf Area Duration	Total Photo- synthetic Area Duration
					1972-73 Crop Season					
Grain Yield		.179	-.146	.443**	.364*	.387**	.416**	.588**	.441**	.530**
Tiller Number			-.426**	.018	.725**	.787**	.839**	.322*	.213	.267
Kernels/Spike				-.678**	-.430**	-.612**	-.605**	-.331*	-.393**	-.417**
200-Kernel Weight					.353*	.344*	.380**	.490**	.355*	.431**
					1973-74 Crop Season					
Grain Yield		.003	-.069	.291*	.300*	.207	.284	.406**	.468**	.493**
Tiller Number			-.222	-.385**	.063	.802**	.644**	-.151	.029	-.033
Kernels/Spike				-.615**	-.207	-.342*	-.350*	-.380**	-.673**	-.636**
200-Kernel Weight					.374**	-.077	.098	.613**	.624**	.683**

*,**Significantly different from zero at the .05 and .01 level of probability respectively (44 d.f.).

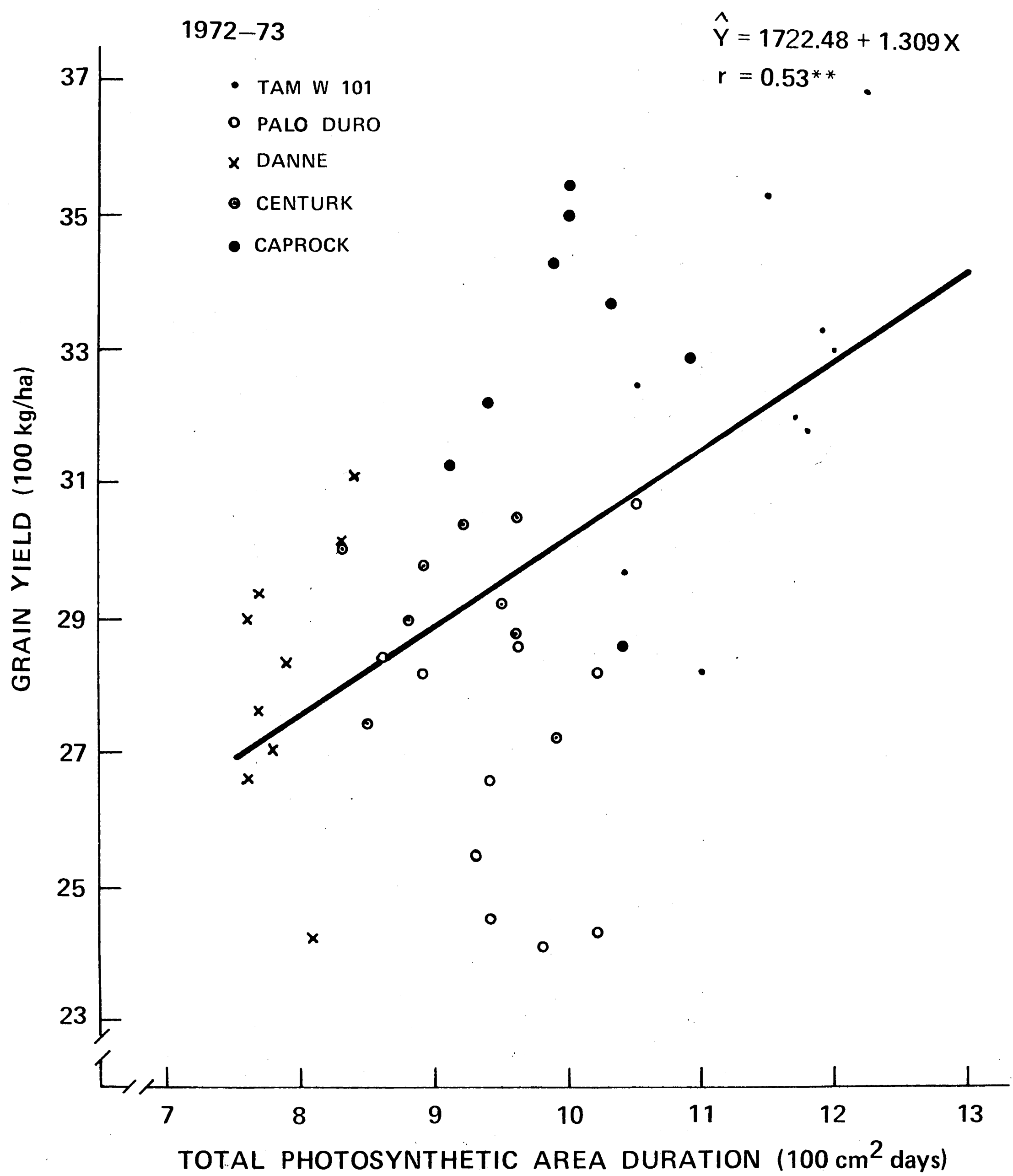

Figure 25. The Influence of Total Photosynthetic Area Duration on Grain Yield of the Five Winter Wheat Varieties for 1972-73 Crop Season

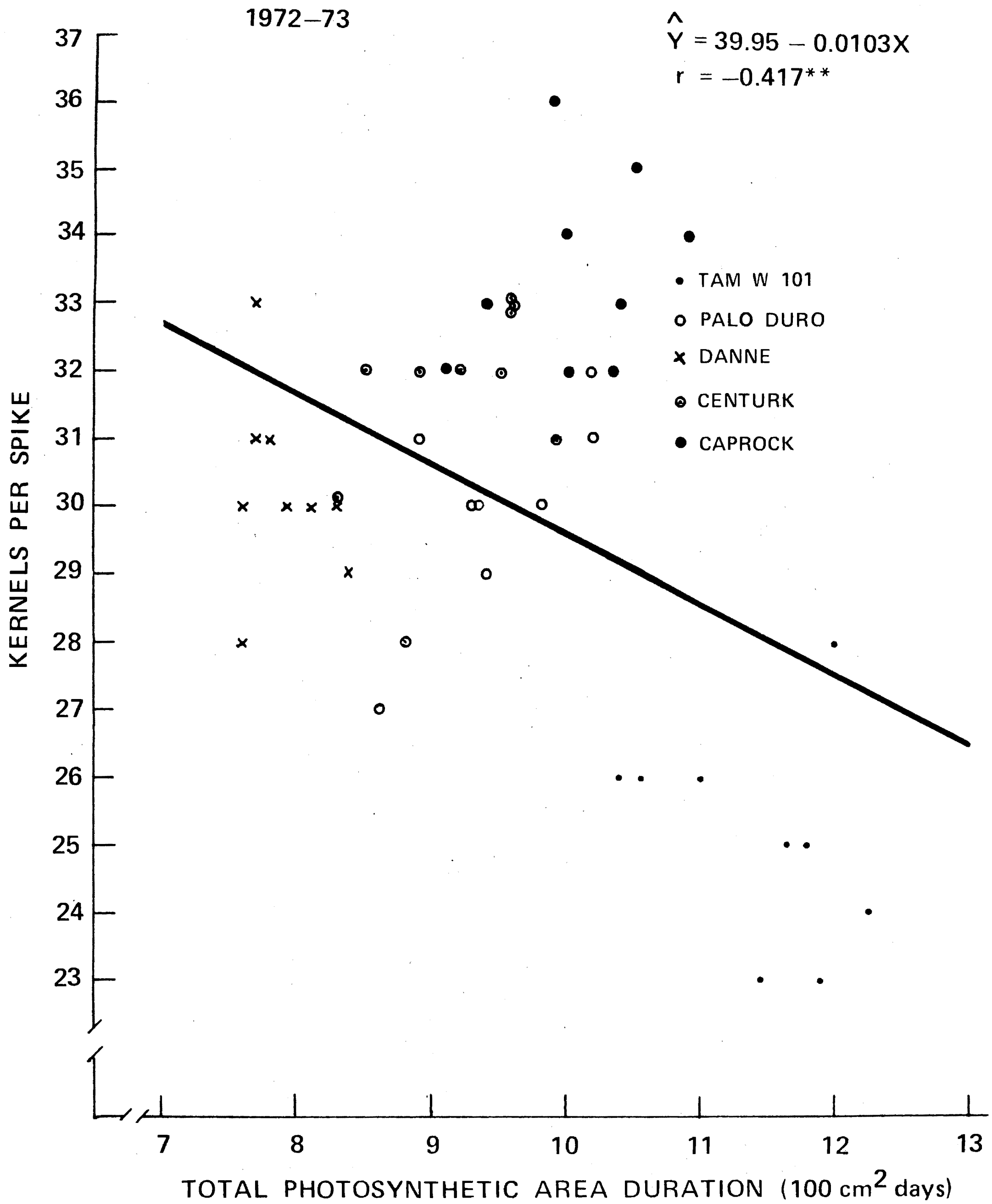

Figure 26. The Influence of Total Photosynthetic Area Duration on Kernels Per Spike of the Five Winter Wheat Varieties for 1972-73 Crop Season

weight and total photosynthetic area duration is shown in Figure 27.

1973-74 Crop Season

The relationship between grain yield and 200-kernel weight was positive. Grain yield was also positively correlated with peduncle area, peduncle area duration, flag leaf area duration and total photosynthetic area duration. The relationship between grain yield and total photosynthetic area duration is shown in Figure 28. Tam W 101 and Caprock were both high yielding varieties, however Tam W 101 had longer duration than Caprock. Tiller number was negatively correlated with 200-kernel weight. There was a highly negative correlation between kernels per spike and 200-kernel weight. Kernels per spike were also negatively correlated with the photosynthetic components; however, the relationship with peduncle area was not significant. The relationship between kernels per spike and total photosynthetic area duration is shown in Figure 29. The 200-kernel weight was positively correlated with peduncle area, peduncle area duration, flag leaf area duration and total photosynthetic area duration. The relationship between 200-kernel weight and total photosynthetic area duration is shown in Figure 30.

In both years grain yield was positively correlated with 200-kernel weight and agrees with the results of Fonseca and Patterson (31) and Knott and Talukdar (54). Total photosynthetic area duration was positively correlated with grain yield in both years of the study and the results tend to agree with reports of Fisher and Kohn (30) and Welbank et al. (101), who stated that varieties which had a longer leaf area duration produced higher yields. There was a negative relationship

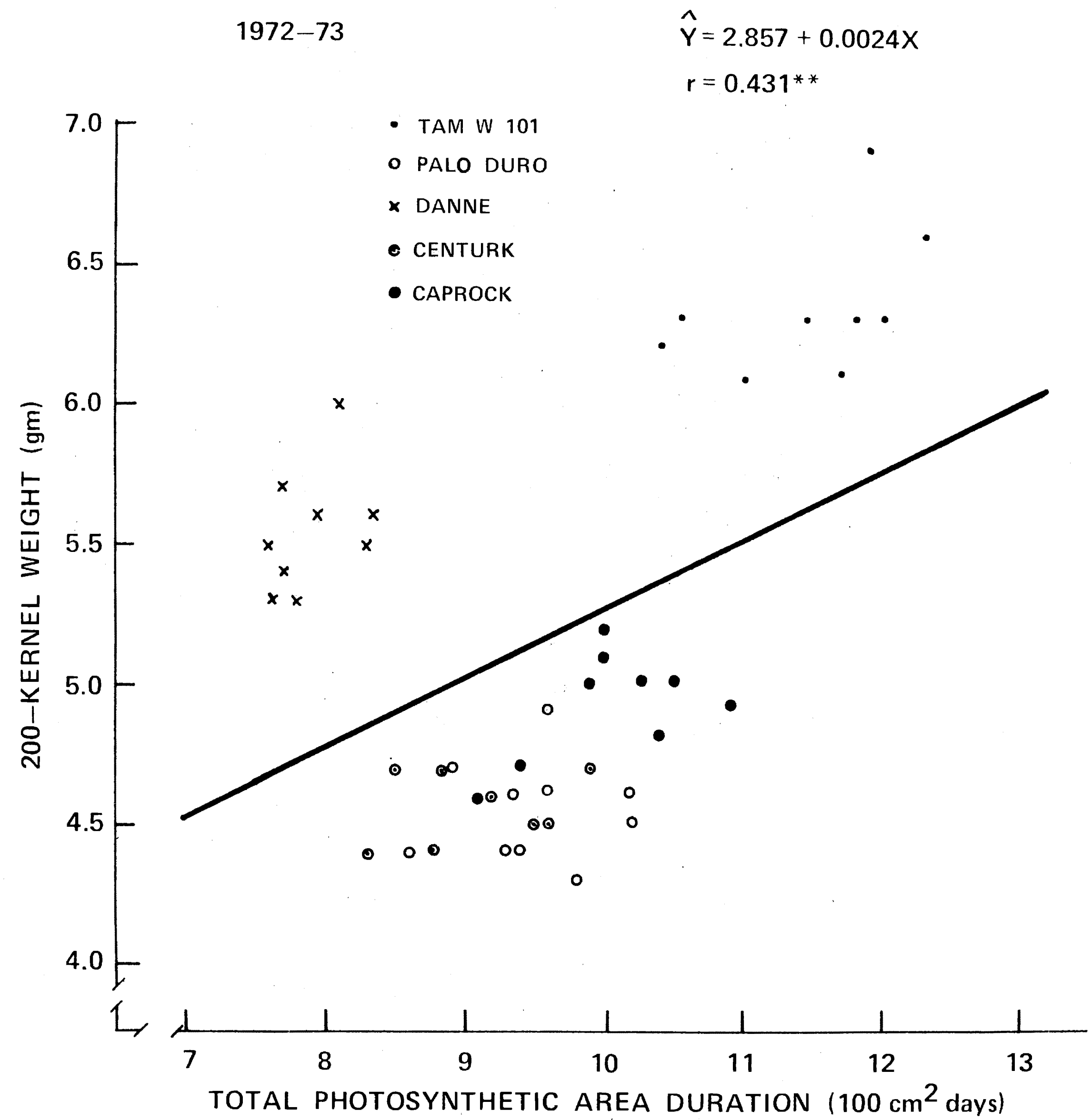

Figure 27. The Influence of Total Photosynthetic Area Duration on 200-Kernel Weight of the Five Winter Wheat Varieties for 1972-73 Crop Season

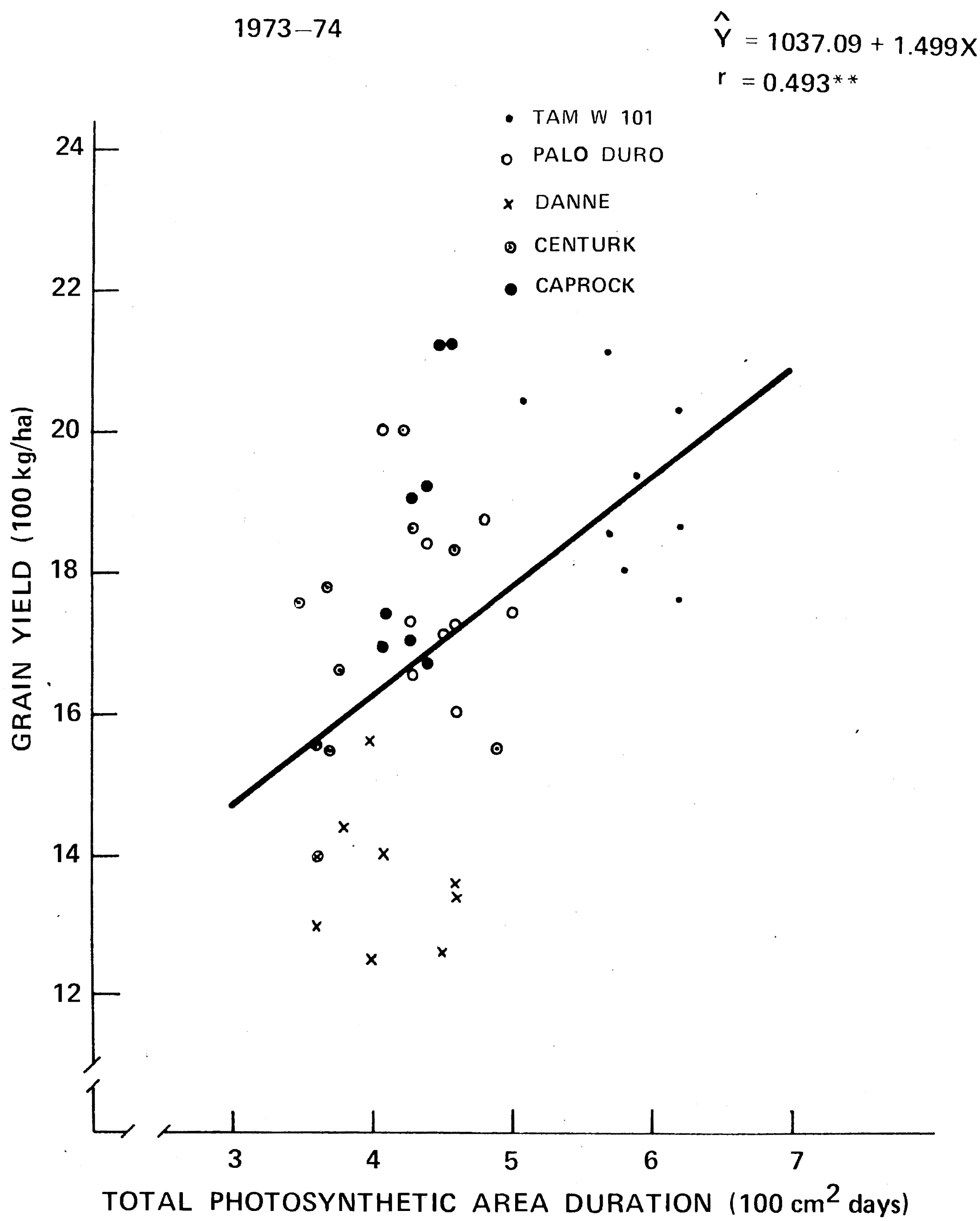

Figure 28. The Influence of Total Photosynthetic Area Duration on Grain Yield of the Five Winter Wheat Varieties for 1973-74 Crop Season

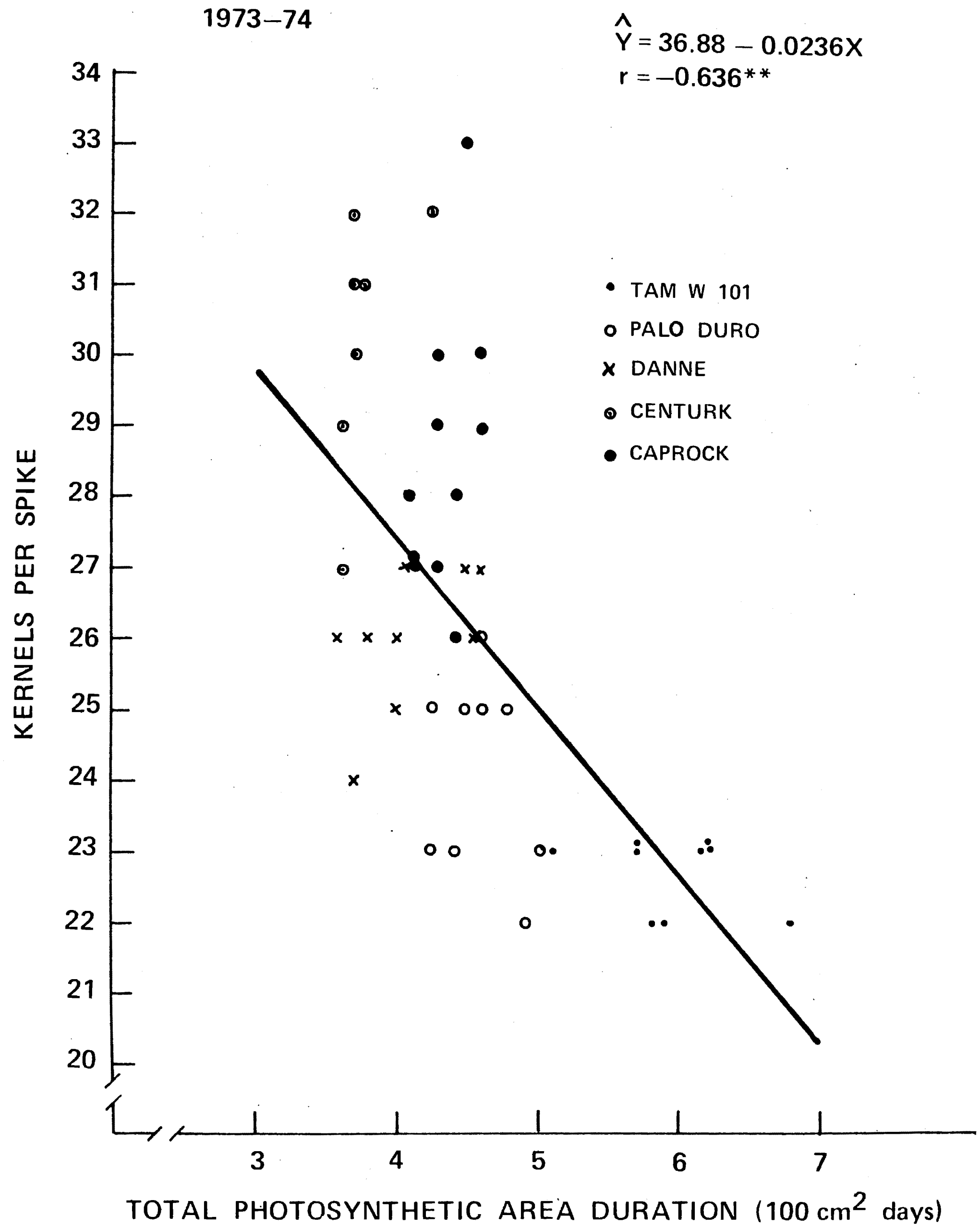

Figure 29. The Influence of Total Photosynthetic Area Duration on Kernels Per Spike of the Five Winter Wheat Varieties for 1973-74 Crop Season

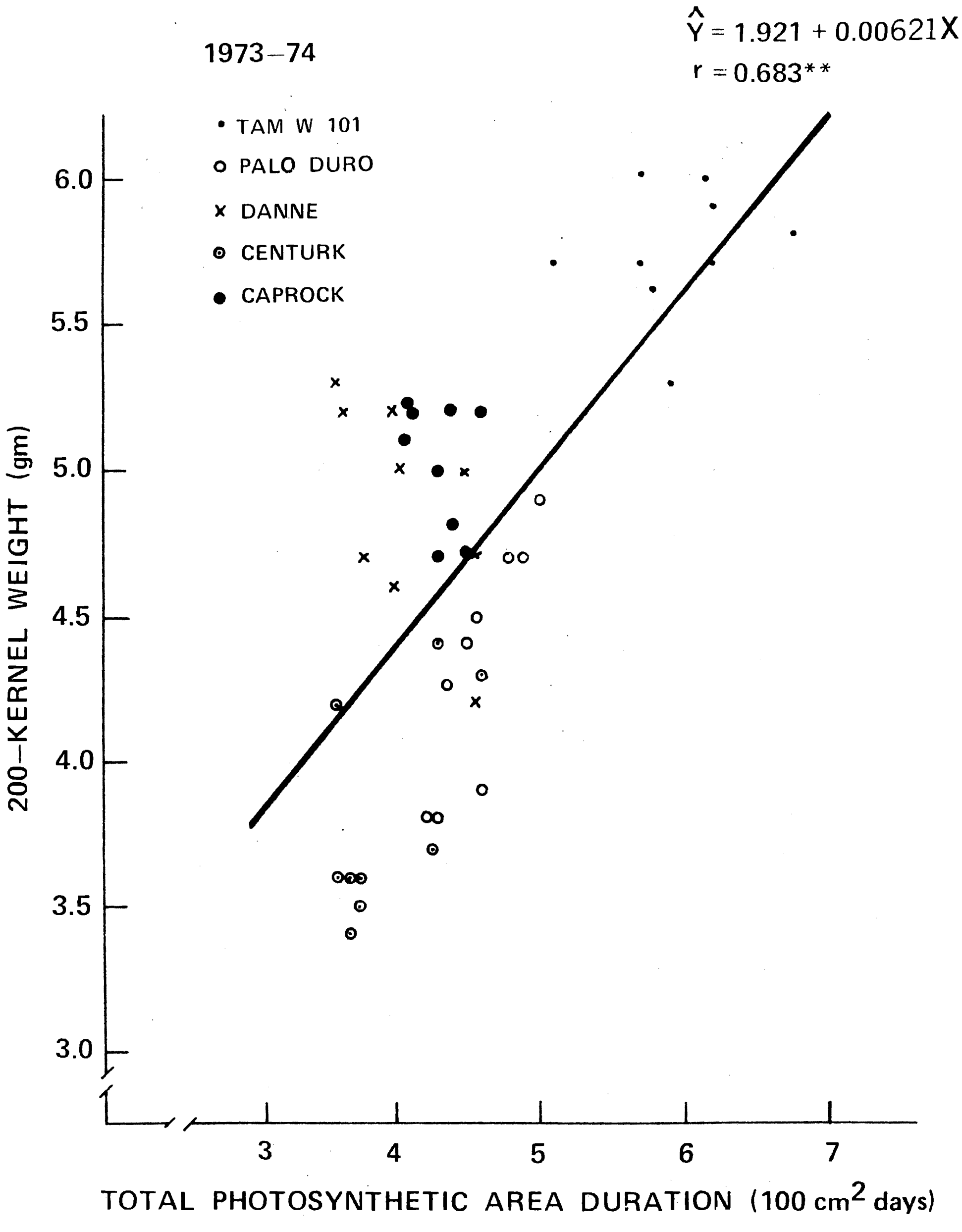

Figure 30. The Influence of Total Photosynthetic Area Duration on 200-Kernel Weight of the Five Winter Wheat Varieties for 1973-74 Crop Season

between grain yield and kernels per spike in both years of study, however this relationship was not significant statistically.

There was a negative correlation between tiller number and kernels per spike in both the years of study, however the correlation coefficient for the second year was not significant. Fonseca and Patterson (31) and Knott and Talukdar (54) also reported a negative correlation between number of spikes per plot and number of kernels per spike.

Kernels per spike were negatively correlated with 200-kernel weight in both years of this study and similar results were reported by Fonseca and Patterson (31) and Knott and Talukdar (54). There was negative relationship between kernels per spike and photosynthetic components in both years of the study, however the negative correlation between kernels per spike and peduncle area was not significant in the second year for study.

The 200-kernel weight was positively correlated with all the photosynthetic components in the first year of study. In the second year of the study 200-kernel weight was positively correlated with peduncle area, peduncle area duration, flag leaf area duration and total photosynthetic area duration.

The total photosynthetic area duration was negatively correlated with kernels per spike and positively correlated with kernel weight in both years of the study, suggesting the possibility that photosynthetic assimilate after flowering was preferentially utilized in kernel development rather than kernel number in the head of plant. The positive correlation between 200-kernel weight and grain yield in both years of the study also supports such a possibility.

Fifty Percent Flowering

The days to 50 percent flowering was estimated by a visual observation as such an analysis of variance was not conducted. The visual observation indicated that the average number of days for 50 percent flowering for all varieties averaged over nitrogen and seed rate were 208 in the first year (1972-73) and 202 days in the second (1973-74) year of experiment. The warmer temperatures and dry spells in March and April 1974 may have induced early flowering. Visual differences for 50 percent flowering were not observed among nitrogen levels and seed rates, but there were noticeable differences among varieties. Treatment means for days to 50 percent flowering are presented in Appendix Table XXXIV.

Physiological Maturity

Due to the fact that physiological maturity was estimated by a visual observation, an analysis of variance was not conducted. The average days for maturity were 237 days in the first year of experiment and in the second year the crop took 229 days for physiological maturity. There were no visual differences in maturity days among nitrogen and seed rates. However, the differences for maturity days were noticeable among varieties. In both years, Danne and Caprock matured early followed by Centurk, Tam W 101 and Palo Duro. Treatment means for days to maturity are presented in Appendix Table XXXV.

Lodging

Lodging was measured as percent by visual estimation and as such an analysis of variance was not conducted. The lodging was noticeable in the first year of experiment and in the second year there was practically no lodging. Danne a medium tall variety had the highest lodging percent (7.2%). The average lodging for all varieties averaged over nitrogen and seed rate was 2.3 percent. Treatment means for lodging are presented in Appendix Table XXXVI.

Winter Injury

Winter injury occurred after the freezing temperature in March, 1974. The injury was measured as percent dead tillers by a visual estimation. An analysis of variance was not conducted. The average winter injury for all varieties averaged over nitrogen and seed rate was 12.5 percent. The differences among nitrogen, varieties and seed rates were not that noticeable. The average winter injury for Palo Duro was less compared to the other four varieties and as stated earlier Palo Duro is a high tillering variety, and the visual damage was less compared to other varieties. Treatment means for winter injury are presented in Appendix Table XXXVI.

CHAPTER V

SUMMARY AND CONCLUSIONS

A two year study was conducted in 1972-73 and 1973-74 crop seasons at the Agronomy Research Station, Oklahoma State University, Stillwater, Oklahoma, to determine the relationship of photosynthetic area duration to yield and yield components, and to study the varietal response to nitrogen and seed rate treatment combinations higher than the levels now being used for present grain production. A split-split plot design with four replications was used for the study. Nitrogen levels comprised main-plots, varieties were sub-plots and seed rates were sub-subplots. The levels of nitrogen were 67, 134 and 202 kg/ha, and the seed rates were 67, 100 and 134 kg/ha. The varieties were Tam W 101, Palo Duro, Danne, Centurk and Caprock. The varieties were selected on the basis of their contrasting characters and as well as their present and potential use as varieties and/or breeding stock. In both years the experiment was planted with a tractor-mounted four row belt seeder and harvested by hand. In the first year the experiment was planted on October 13, 1972, and harvested on June 13, 1973. In the second year, the experiment was planted on October 10, 1973 and harvested on June 11, 1974. In both years nitrogen was applied as top dressing. The experimental plot consisted of four rows 3.6 m long, 30.5 cm apart.

The characters analyzed were grain yield, straw yield, dry forage yield, plant height, leaf nitrate, grain protein, protein yield, straw nitrogen, grain nitrogen recovery, straw nitrogen recovery, total nitrogen recovery, tiller number, kernels per spike, 200-kernel weight, chaff weight, peduncle area, flag leaf area, total photosynthetic area, peduncle area duration, flag leaf area duration and total photosynthetic area duration. An analysis of variance was conducted for each character to provide information on differences between years, among nitrogen levels, varieties, seed rates and interactions. In addition to these, field notes were taken on 50 percent flowering, physiological maturity, winter injury and lodging, but these traits were not analyzed statistically. Treatment means averaged over replications were used for calculating simple correlations for selecting characters.

There was a significant difference between the years for grain yield; the first year 1972-73 was superior to the second year 1973-74 of the experiment. The differences between years were significant for all characters studied except for dry forage yield, leaf nitrate, straw nitrogen recovery and chaff weight.

The differences among nitrogen levels were significant for plant height, leaf nitrate, grain protein and straw nitrogen. There was no effect of nitrogen on the other characters studied. The possible reasons for lack of response could be the high amount of available soil nitrogen and the high level of the lowest rate, leaching losses due to excess moisture in the first year or poor utilization of absorbed nitrogen due to unfavorable environmental conditions in the second year.

There were highly significant differences among varieties for all characters studied except for leaf nitrate. The year by variety interaction was significant for almost all the characters studied except for straw yield, grain:straw ratio, leaf nitrate, grain protein and total nitrogen recovery, suggesting the presence of genotype by environment interaction. In both years of the experiment Tam W 101 and Caprock were high yielding varieties. The grain yield of all the varieties in the second year was low compared to the first year. Though there was a higher genetic potential present for yield in the varieties, the growing conditions in the second year were not favorable.

The differences among seed rates were highly significant for grain yield, grain:straw ratio, dry forage yield, grain protein, protein yield, grain nitrogen recovery, total nitrogen recovery, tiller number, kernels per spike, chaff weight, peduncle area, flag leaf area, total photosynthetic area, flag leaf area duration and total photosynthetic area duration. In the first year the best seed rate was 100 kg/ha and in the second year higher yields were obtained with seed rate of 67 kg/ha.

Simple correlations among yield, yield components and total photosynthetic area duration indicated that grain yield was positively correlated with 200-kernel weight and total photosynthetic area duration. There was a negative relationship between grain yield and kernels per spike in both years of the study, however this relationship was not significant statistically. Tiller counts were high and there was no significant relationship between tiller number and total photosynthetic area duration. Total photosynthetic area duration was negatively correlated with kernels per spike and positively correlated with 200-kernel weight in both years of the study.

The total photosynthetic area duration showed positive relationship with yield and 200-kernel weight in both years, even though the growing conditions were different. Tam W 101 (high photosynthetic area duration, high kernel weight) and Caprock (medium photosynthetic area duration, medium kernel weight) were the two high yielding varieties. These data are very encouraging for the use of kernel weight as a factor for increasing grain yields. The data also supports the use of photosynthetic area duration as a selection criteria for higher yields. Research should now be conducted emphasizing these characters in efforts to improve grain yields.

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APPENDIX

TABLE XII

MEANS* FOR GRAIN YIELD (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	3339	3675	3532	2817	3254	2969	3296	3204	3179	3252
Palo Duro	2859	2817	2842	2657	2447	2548	2817	2430	2413	2648
Danne	3111	3027	2421	2699	2893	2657	2935	7834	2758	2815
Centurk	3053	3044	2893	2876	2918	2725	2741	2977	3011	2915
Caprock	3498	3549	3372	3069	3288	2859	3431	3221	3137	3269
Avg.	3172	3222	3012	2824	2960	2752	3044	2933	2900	2980
					1973-74 Crop Season					
Tam W 101	1858	1853	2110	2043	2033	1796	2040	1758	2936	1937
Palo Duro	1741	1869	1551	1712	1724	1842	1729	1655	1601	1714
Danne	1250	1443	1401	1408	1564	1292	1357	1340	1260	1368
Centurk	2006	1825	1860	1779	1766	1551	1655	1546	1403	1710
Caprock	2180	1917	1897	1998	1690	1742	2121	1694	1672	1879
Avg.	1807	1781	1764	1788	1756	1645	1780	1598	1574	1722

*Averaged over replications.

TABLE XIII

MEANS* FOR STRAW YIELD (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	7039	7678	7308	6425	7274	6643	7249	7064	7291	7108
Palo Duro	6475	7173	7182	6828	7551	6887	6727	6433	6534	6866
Danne	6164	6500	6660	7190	6198	6021	6114	6845	6029	6414
Centurk	6677	6711	6946	6484	6610	6610	6963	6795	6971	6752
Caprock	6098	6416	7022	5929	6181	5878	5895	6383	6458	6251
Avg.	6491	6896	7023	6571	6763	6408	6590	6704	6657	6678
					1973-74 Crop Season					
Tam W 101	3507	3688	3717	3179	3761	3182	3636	3809	3539	3558
Palo Duro	3793	3655	3604	4006	3759	3885	4107	4013	4016	3871
Danne	2585	3005	2955	2730	2893	2678	3024	2948	2642	2829
Centurk	3729	3414	3270	3670	3490	3007	3407	2962	2970	3324
Caprock	3370	2910	2820	3132	2826	2757	3253	3024	2827	2991
Avg.	3397	3334	3273	3343	3346	3102	3486	3351	3199	3315

*Averaged over replications.

TABLE XIV

MEANS* FOR GRAIN:STRAW RATIO

Variety	N_1 S_1	N_1 S_2	N_1 S_3	N_2 S_1	N_2 S_2	N_2 S_3	N_3 S_1	N_3 S_2	N_3 S_3	Avg.
					1972-73 Crop Season					
Tam W 101	.56	.48	.48	.45	.45	.45	.46	.46	.44	.47
Palo Duro	.44	.39	.39	.39	.33	.37	.42	.38	.37	.39
Danne	.51	.47	.37	.41	.46	.44	.48	.42	.47	.45
Centurk	.46	.45	.42	.44	.44	.41	.41	.44	.43	.43
Caprock	.57	.55	.48	.53	.53	.49	.58	.51	.49	.53
Avg.	.51	.47	.43	.45	.44	.43	.47	.44	.44	.45
					1973-74 Crop Season					
Tam W 101	.53	.50	.57	.64	.54	.56	.57	.48	.55	.55
Palo Duro	.46	.51	.43	.43	.46	.47	.42	.42	.40	.46
Danne	.47	.48	.47	.52	.54	.48	.46	.46	.49	.49
Centurk	.54	.53	.57	.49	.51	.52	.51	.53	.48	.52
Caprock	.65	.66	.67	.64	.60	.64	.66	.57	.60	.63
Avg.	.53	.54	.54	.54	.53	.53	.52	.49	.50	.53

*Averaged over replications.

TABLE XV

MEANS* FOR DRY FORAGE YIELD (KG/HA)

Variety	N_1 S_1	N_1 S_2	N_1 S_3	N_2 S_1	N_2 S_2	N_2 S_3	N_3 S_1	N_3 S_2	N_3 S_3	Avg.
					1972-73 Crop Season					
Tam W 101	2758	2974	3579	2556	2826	3256	2893	3512	2498	3095
Palo Duro	2368	2624	2570	2355	2476	2906	2233	2570	2879	2553
Danne	3189	3283	4010	2570	3000	3068	3014	3700	3740	3286
Centurk	2395	2166	2866	1884	2153	2516	2328	2610	2906	2425
Caprock	3377	2678	3431	2395	3175	3256	2799	2879	3552	3060
Avg.	2817	2745	3291	2352	2726	3000	2653	3054	3315	2884
					1973-74 Crop Season					
Tam W 101	3041	2799	3391	2852	2852	3310	2610	2933	2826	2957
Palo Duro	3256	2664	2691	3175	2664	2799	3418	2530	3283	2942
Danne	1642	2503	2583	2826	2503	2503	2368	2718	2610	2473
Centurk	2503	3525	2583	2583	3229	3041	2772	2852	2530	2846
Caprock	2987	3122	2826	3310	3310	3391	3122	3391	3525	3220
Avg.	2686	2922	2815	2949	2912	3009	2858	2885	2955	2888

*Averaged over replications.

TABLE XVI

MEANS* FOR PLANT HEIGHT (CM)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				1972-73 Crop Season						
Tam W 101	92	93	92	85	86	82	91	89	90	89
Palo Duro	91	93	93	88	87	89	92	90	91	90
Danne	103	102	102	98	98	99	97	95	97	99
Centurk	99	95	97	94	94	94	92	93	94	95
Caprock	91	91	94	86	89	88	87	87	88	89
Avg.	95	95	95	90	91	91	92	91	92	92
				1973-74 Crop Season						
Tam W 101	57	56	58	56	59	57	58	57	56	57
Palo Duro	63	64	63	59	60	61	62	60	62	61
Danne	63	61	62	61	60	59	60	59	62	61
Centurk	65	65	64	61	57	59	65	62	61	62
Caprock	60	60	59	60	58	60	58	60	59	59
Avg.	62	61	61	59	59	59	61	60	60	60

*Averaged over replications.

TABLE XVII

MEANS* FOR LEAF NITRATE (μgm/gm FRESH WEIGHT)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	113	310	461	167	113	122	195	266	274	224
Palo Duro	118	175	56	191	187	146	270	226	199	174
Danne	213	175	145	116	261	174	188	184	173	181
Centurk	176	156	159	96	197	121	309	275	367	206
Caprock	175	139	174	253	219	116	234	189	276	197
Avg.	159	191	199	165	195	136	239	228	258	197
					1973-74 Crop Season					
Tam W 101	166	192	219	209	178	173	218	253	185	211
Palo Duro	102	159	102	187	281	157	276	265	255	198
Danne	161	161	152	151	221	166	221	270	174	186
Centurk	195	153	207	178	231	221	329	291	247	228
Caprock	217	169	189	271	232	157	187	229	250	211
Avg.	168	167	174	199	229	175	246	262	242	207

*Averaged over replications.

TABLE XVIII

MEANS* FOR GRAIN PROTEIN (PERCENT)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	12.7	12.4	12.8	14.4	14.4	14.2	14.7	14.7	14.4	13.9
Palo Duro	14.0	14.5	14.0	16.0	16.4	16.5	15.6	16.2	16.0	15.5
Danne	11.8	12.8	12.8	13.1	13.2	13.3	13.5	14.4	14.8	13.3
Centurk	14.9	14.9	14.5	15.1	15.8	15.6	16.0	16.3	16.2	15.5
Caprock	13.8	13.6	14.6	14.4	14.6	15.4	14.8	15.1	15.2	14.6
Avg.	13.4	13.7	13.7	14.6	14.9	15.0	14.9	15.3	15.3	14.5
					1973-74 Crop Season					
Tam W 101	15.1	15.7	15.0	16.1	15.9	16.6	15.5	15.7	15.9	15.7
Palo Duro	15.9	15.5	15.6	16.6	16.2	16.7	17.0	17.2	17.6	16.5
Danne	14.2	13.2	14.3	14.0	14.0	14.2	14.9	14.7	14.6	14.2
Centurk	14.4	15.2	14.0	17.0	17.8	17.9	17.6	17.9	18.5	16.7
Caprock	15.4	15.9	15.3	16.1	16.7	16.4	16.2	16.9	16.4	16.1
Avg.	15.0	15.1	14.8	16.0	16.1	16.4	16.2	16.5	16.6	15.9

*Averaged over replications.

TABLE XIX

MEANS* FOR PROTEIN YIELD (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	423	454	450	405	468	421	482	471	455	448
Palo Duro	399	408	396	424	397	418	440	395	386	407
Danne	365	384	308	352	373	353	395	403	405	371
Centurk	454	452	420	434	459	426	440	484	485	450
Caprock	479	481	487	441	476	436	508	486	474	474
Avg.	424	436	412	411	435	411	453	448	441	430
					1973-74 Crop Season					
Tam W 101	281	289	317	329	322	298	315	278	307	304
Palo Duro	276	285	237	284	278	305	293	284	281	280
Danne	171	185	197	198	216	182	201	196	183	192
Centurk	286	276	259	302	313	277	291	274	259	282
Caprock	332	303	285	322	282	286	345	285	274	301
Avg.	269	268	259	287	282	270	289	263	261	272

*Averaged over replications.

TABLE XX

MEANS* FOR STRAW NITROGEN (PERCENT)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	0.75	0.75	0.93	0.95	0.88	0.98	0.93	0.95	0.88	0.89
Palo Duro	0.98	1.03	0.80	1.08	1.08	0.98	1.20	1.13	1.15	1.04
Danne	0.88	0.80	0.83	0.95	0.93	0.80	0.83	0.93	0.93	0.87
Centurk	0.83	0.68	0.70	0.83	0.73	0.80	0.83	0.88	0.85	0.79
Caprock	0.73	0.68	0.75	0.70	0.68	0.68	0.78	0.80	0.70	0.72
Avg.	0.83	0.79	0.80	0.90	0.86	0.85	0.91	0.94	0.90	0.86
					1973-74 Crop Season					
Tam W 101	0.86	0.95	0.86	0.91	0.91	0.90	0.96	0.94	0.96	0.92
Palo Duro	0.93	0.88	0.93	1.00	1.00	0.99	1.07	1.05	0.99	0.98
Danne	0.82	0.87	0.85	0.89	0.85	0.85	0.94	0.94	0.82	0.87
Centurk	0.87	0.86	0.85	0.96	1.00	0.87	0.92	0.91	1.01	0.91
Caprock	0.88	0.86	0.85	0.90	0.86	0.86	0.92	0.91	0.90	0.88
Avg.	0.87	0.88	0.87	0.93	0.92	0.89	0.96	0.95	0.93	0.91

*Averaged over replications.

TABLE XXI

MEANS* FOR GRAIN NITROGEN RECOVERY (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				1972-73 Crop Season						
Tam W 101	74	80	79	71	82	74	85	83	80	79
Palo Duro	70	72	69	74	70	73	77	69	68	71
Danne	64	67	54	62	65	62	69	71	71	65
Centurk	80	79	74	76	81	75	77	85	85	79
Caprock	84	84	85	77	84	77	89	85	83	83
Avg.	74	76	72	72	76	72	79	79	77	75
				1973-74 Crop Season						
Tam W 101	49	51	56	58	57	52	55	49	54	53
Palo Duro	49	50	42	50	49	54	51	50	49	49
Danne	30	33	35	35	38	32	35	34	32	34
Centurk	50	48	45	53	55	49	51	48	45	50
Caprock	58	53	50	56	49	50	60	50	48	53
Avg.	47	47	45	50	50	47	51	46	46	48

*Averaged over replications.

TABLE XXII

MEANS* FOR STRAW NITROGEN RECOVERY (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	55	58	68	60	64	64	68	67	63	63
Palo Duro	63	73	58	74	82	68	81	73	76	72
Danne	54	52	55	71	57	48	51	64	56	57
Centurk	55	46	48	54	48	53	58	60	59	54
Caprock	44	44	53	41	41	39	46	52	45	45
Avg.	54	55	56	60	58	55	61	63	60	58
					1973-74 Crop Season					
Tam W 101	31	36	33	29	34	28	35	36	34	33
Palo Duro	36	32	34	40	37	38	44	42	40	38
Danne	22	26	25	24	25	23	28	28	21	25
Centurk	33	30	28	35	35	30	31	27	30	30
Caprock	29	25	24	28	25	24	30	28	25	26
Avg.	30	30	29	31	31	28	34	32	30	31

*Averaged over replications.

TABLE XXIII

MEANS* FOR TOTAL NITROGEN RECOVERY (KG/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				1972-73 Crop Season						
Tam W 101	130	138	147	131	146	138	152	150	143	142
Palo Duro	133	145	127	148	151	141	158	142	143	143
Danne	119	120	109	133	123	110	120	135	127	122
Centurk	135	125	122	130	129	128	136	145	145	133
Caprock	128	128	138	119	125	116	135	137	129	128
Avg.	129	131	129	132	135	127	140	142	137	133
				1973-74 Crop Season						
Tam W 101	80	86	88	87	91	81	90	85	88	86
Palo Duro	84	82	76	90	86	92	95	92	89	87
Danne	52	59	60	59	63	55	64	62	53	58
Centurk	83	78	73	89	90	74	82	75	75	80
Caprock	88	78	74	85	74	74	90	78	73	79
Avg.	77	77	74	82	81	75	84	78	76	78

*Averaged over replications.

TABLE XXIV

MEANS* FOR TILLERS PER 930 CM^2

Variety	N_1 S_1	N_1 S_2	N_1 S_3	N_2 S_1	N_2 S_2	N_2 S_3	N_3 S_1	N_3 S_2	N_3 S_3	Avg.
					1972-73 Crop Season					
Tam W 101	63.0	76.0	86.2	66.0	73.1	77.4	68.8	73.1	82.3	74.0
Palo Duro	61.1	70.1	84.1	65.3	70.9	79.9	62.8	65.1	73.3	70.3
Danne	60.7	68.5	68.4	56.9	63.0	67.4	54.8	70.8	68.6	64.3
Centurk	65.7	71.2	73.6	59.4	75.1	75.5	59.3	72.9	81.5	70.5
Caprock	68.1	74.4	81.4	62.3	63.6	71.5	59.9	66.0	77.4	69.4
Avg.	63.7	72.1	78.7	62.0	69.2	74.3	61.1	69.6	76.6	69.7
					1973-74 Crop Season					
Tam W 101	58.0	63.8	64.0	60.9	62.6	61.8	59.4	58.9	62.0	61.3
Palo Duro	58.6	69.0	76.6	65.3	86.2	83.7	72.1	67.0	70.0	72.1
Danne	55.1	61.0	58.8	58.9	62.3	58.6	49.6	56.4	56.6	57.5
Centurk	59.8	62.1	64.5	69.6	65.3	66.4	66.3	65.4	66.6	65.1
Caprock	54.3	58.0	54.8	53.3	50.8	58.3	49.0	52.9	54.0	53.9
Avg.	57.2	62.8	63.7	61.6	65.4	65.8	59.3	60.1	61.9	62.0

*Averaged over replications.

TABLE XXV

MEANS* FOR KERNELS/SPIKE

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				1972-73 Crop Season						
Tam W 101	22.8	23.6	23.1	26.1	25.8	26.4	27.7	24.7	24.5	25.0
Palo Duro	32.6	31.4	27.4	29.3	30.2	29.5	32.1	31.0	30.1	30.4
Danne	29.3	29.8	29.7	30.6	29.8	28.4	32.7	29.9	30.7	30.1
Centurk	32.6	31.9	27.5	32.6	31.6	31.0	31.9	32.4	30.2	31.3
Caprock	33.5	32.4	32.4	35.0	33.5	33.1	36.2	32.7	32.3	33.4
Avg.	30.2	29.8	28.0	30.7	30.2	29.7	32.1	30.1	29.5	30.0
				1973-74 Crop Season						
Tam W 101	22.5	22.9	22.5	22.9	23.2	22.0	21.7	23.4	22.2	22.6
Palo Duro	23.1	24.7	22.3	24.8	24.6	22.9	25.3	23.2	25.7	24.1
Danne	24.7	26.2	24.1	26.9	25.7	26.1	25.9	26.6	26.9	25.9
Centurk	31.9	30.4	29.6	29.8	26.5	28.5	30.7	32.2	30.5	30.0
Caprock	28.5	25.9	27.0	27.6	26.6	26.6	32.7	28.8	27.5	27.9
Avg.	26.1	26.0	25.1	26.4	25.3	25.2	27.3	26.8	26.5	26.1

*Averaged over replications.

TABLE XXVI

MEANS* FOR 200-KERNEL WEIGHT (GM)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	6.9	6.6	6.3	6.1	6.3	6.2	6.3	6.1	6.3	6.3
Palo Duro	4.9	4.7	4.4	4.4	4.6	4.4	4.5	4.6	4.3	4.5
Danne	5.6	5.5	6.0	5.3	5.3	5.5	5.7	5.6	5.4	5.6
Centurk	4.5	4.6	4.4	4.6	4.5	4.7	4.7	4.7	4.4	4.6
Caprock	5.2	5.1	5.0	5.0	4.9	4.8	5.0	4.7	4.6	4.9
Avg.	5.4	5.3	5.2	5.1	5.1	5.1	5.2	5.1	5.0	5.2
					1973-74 Crop Season					
Tam W 101	6.0	5.7	6.0	5.7	5.9	5.6	5.8	5.7	5.3	5.7
Palo Duro	4.9	4.7	4.7	4.4	4.5	4.3	3.8	3.8	3.9	4.3
Danne	5.2	4.7	5.2	5.0	4.6	5.3	4.7	4.2	5.0	4.9
Centurk	3.7	4.3	4.4	3.5	3.6	4.2	3.6	3.6	3.4	3.8
Caprock	5.2	5.2	5.0	5.1	5.2	5.2	4.7	4.7	4.8	5.0
Avg.	5.0	4.9	5.1	4.7	4.7	4.9	4.5	4.4	4.5	4.8

*Averaged over replications.

TABLE XXVII

MEANS* FOR CHAFF WEIGHT (MG/SPIKE)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				1972-73 Crop Season						
Tam W 101	202	207	194	223	221	208	230	179	205	207
Palo Duro	233	224	189	208	221	214	227	214	209	215
Danne	208	204	209	213	202	198	232	201	206	208
Centurk	172	155	143	174	172	170	171	220	155	170
Caprock	197	187	181	215	195	200	219	186	178	195
Avg.	203	195	183	207	202	198	216	200	191	199
				1973-74 Crop Season						
Tam W 101	215	209	218	203	212	202	208	215	205	210
Palo Duro	174	202	166	194	193	175	201	191	198	188
Danne	181	200	170	202	179	200	187	183	212	190
Centurk	171	172	179	137	136	163	155	159	153	158
Caprock	197	184	189	203	183	195	228	186	171	193
Avg.	188	193	184	188	181	187	196	187	188	188

*Averaged over replications.

TABLE XXVIII

MEANS* FOR PEDUNCLE AREA (M^2/HA)

Variety	N_1 S_1	N_1 S_2	N_1 S_3	N_2 S_1	N_2 S_2	N_2 S_3	N_3 S_1	N_3 S_2	N_3 S_3	Avg.
					1972-73 Crop Season					
Tam W 101	6516	9199	10075	6714	7940	8702	7843	7546	8848	8154
Palo Duro	5837	6336	6780	4835	5683	6991	5531	5625	6583	6022
Danne	6764	7168	8174	5578	6517	6715	5609	6793	7155	6719
Centurk	7606	8304	6886	6238	8831	9516	5740	8033	8645	7755
Caprock	6746	8037	8485	6269	6029	7233	5422	5785	6417	6714
Avg.	6694	7809	8080	5927	7000	7831	6029	6756	7529	7073
					1973-74 Crop Season					
Tam W 101	2455	2589	2845	2440	2833	1915	4075	2647	2778	2731
Palo Duro	1364	1550	1896	1548	1873	1925	1304	1481	1558	1611
Danne	1812	2213	2159	2356	1980	1825	1371	1941	1970	1959
Centurk	2618	3149	3019	1739	1346	1456	2296	1621	1974	2135
Caprock	1780	1822	1566	1250	1111	1522	1573	1504	1410	1504
Avg.	2006	2265	2297	1867	1829	1729	2124	1839	1938	1988

*Averaged over replications.

TABLE XXIX

MEANS* FOR FLAG LEAF AREA (M^2/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	18674	22223	22944	19622	19833	20148	21103	21986	25062	21288
Palo Duro	15635	16506	19652	17151	17816	19386	16644	17611	19000	17711
Danne	14605	16927	15502	12802	13413	14709	12550	16970	15653	14792
Centurk	16221	16596	17340	14924	17920	18319	14891	18503	19147	17096
Caprock	17066	18246	20546	16099	17299	17837	16079	16256	18716	17572
Avg.	16440	18100	19197	16120	17256	18080	16253	18265	19515	17692
					1973-74 Crop Season					
Tam W 101	9910	10208	9939	8539	10819	10723	9942	10016	9991	10010
Palo Duro	9189	10557	11600	8915	11969	10959	9744	8801	10023	10195
Danne	8124	8510	7603	8298	9191	7618	7922	8733	8687	8298
Centurk	9136	9864	9585	9990	8996	9288	9688	9833	9833	9579
Caprock	8487	8781	8293	7642	7468	8190	7288	7833	8316	8033
Avg.	8969	9584	9404	8677	9689	9356	8917	9043	9370	9223

*Averaged over replications.

TABLE XXX

MEANS* FOR TOTAL PHOTOSYNTHETIC AREA (M^2/HA)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	25190	31422	33018	26335	27773	28850	28946	29532	33909	29442
Palo Duro	21472	22842	26432	21986	23499	26376	22174	23235	25582	23734
Danne	21368	24095	23676	18379	19929	21423	18159	23762	22808	21511
Centurk	23826	24899	24226	21162	26751	27835	20630	26535	27791	24851
Caprock	23812	26282	29031	22368	23328	25070	21501	22041	25132	24285
Avg.	23134	25909	27277	22047	24256	25911	22282	25021	27045	24765
					1973-74 Crop Season					
Tam W 101	12364	12797	12783	10979	13652	12638	14017	12663	12769	12741
Palo Duro	10552	12107	13495	10463	13841	12884	11047	10282	11581	11806
Danne	9935	10722	9761	10653	11170	9443	9293	10673	10656	10257
Centurk	11753	13012	12604	11728	10342	10743	11984	11454	11806	11715
Captock	10266	10603	9859	8892	8579	9712	8860	9336	9726	9537
Avg.	10975	11849	11701	10544	11517	11084	11041	10882	11308	11211

*Averaged over replications.

TABLE XXXI

MEANS* FOR PEDUNCLE AREA DURATION
(CM^2 DAYS)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	311	360	348	281	303	314	325	299	310	317
Palo Duro	264	247	225	210	226	247	256	243	250	241
Danne	270	249	280	237	247	238	239	227	243	248
Centurk	313	304	249	282	312	336	240	271	258	285
Caprock	288	311	299	297	284	304	252	243	233	279
Avg.	289	294	280	262	275	288	262	257	259	274
					1973-74 Crop Season					
Tam W 101	120	112	126	112	130	87	193	127	128	126
Palo Duro	66	63	71	66	62	65	51	62	62	63
Danne	73	82	80	90	72	70	66	83	84	78
Centurk	97	113	104	56	48	50	71	54	61	73
Caprock	79	74	68	57	52	64	79	69	64	67
Avg.	87	89	90	76	73	67	92	79	80	81

*Averaged over replications.

TABLE XXXII

MEANS* FOR FLAG LEAF AREA DURATION (CM^2 DAYS)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	882	867	800	821	752	727	877	869	874	830
Palo Duro	695	645	636	729	709	682	760	773	732	707
Danne	565	582	531	540	513	522	534	567	530	543
Centurk	646	616	627	674	640	650	614	621	576	629
Caprock	711	690	727	753	802	734	734	693	680	725
Avg.	700	680	664	703	683	663	704	705	678	687
					1973-74 Crop Season					
Tam W 101	495	456	445	397	493	496	482	492	464	469
Palo Duro	437	416	420	383	394	374	374	364	396	395
Danne	325	302	286	315	330	291	389	374	370	331
Centurk	328	348	325	319	311	310	305	317	307	319
Caprock	381	367	361	350	360	349	366	359	373	363
Avg.	393	378	367	353	377	364	383	381	382	375

*Averaged over replications.

TABLE XXXIII

MEANS* FOR TOTAL PHOTOSYNTHETIC AREA DURATION (CM^2 DAYS)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	1193	1226	1145	1103	1056	1041	1202	1167	1184	1146
Palo Duro	959	892	861	939	935	929	1017	1016	982	948
Danne	835	831	812	777	761	760	773	794	773	790
Centurk	958	920	876	956	952	986	854	892	834	914
Caprock	999	1002	1027	1051	1086	1037	986	936	913	1004
Avg.	989	974	944	965	958	951	966	961	937	961
					1973-74 Crop Season					
Tam W 101	615	568	571	510	623	583	675	619	591	595
Palo Duro	502	479	491	449	456	438	425	426	458	458
Danne	398	384	366	405	401	361	455	456	454	409
Centurk	425	461	429	374	358	360	376	371	368	391
Caprock	460	440	428	407	412	413	445	428	437	430
Avg.	480	466	457	429	450	431	475	460	462	457

*Averaged over replications.

TABLE XXXIV

MEANS* FOR 50 PERCENT FLOWERING (DAYS)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	208	208	208	210	210	210	211	211	211	210
Palo Duro	210	210	210	211	211	211	212	212	212	211
Danne	205	205	205	204	204	204	205	205	205	205
Centurk	209	209	209	211	211	211	210	210	210	210
Caprock	205	205	205	205	205	205	205	205	205	205
Avg.	207	207	207	208	208	208	208	208	208	208
					1973-74 Crop Season					
Tam W 101	202	202	202	202	202	202	203	203	203	202
Palo Duro	202	202	202	202	202	202	204	204	204	203
Danne	201	201	201	200	200	200	200	200	200	200
Centurk	202	202	202	202	202	202	204	204	204	203
Caprock	199	199	199	199	199	199	200	200	200	199
Avg.	201	201	201	201	201	201	202	202	202	201

*Averaged over replications.

TABLE XXXV

MEANS* FOR PHYSIOLOGICAL MATURITY
(DAYS)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
					1972-73 Crop Season					
Tam W 101	240	240	240	240	240	240	242	242	242	241
Palo Duro	240	240	240	241	241	241	242	242	242	241
Danne	230	230	230	230	230	230	230	230	230	230
Centurk	238	238	238	239	239	239	237	237	237	238
Caprock	235	235	235	237	237	237	235	235	235	236
Avg.	237	237	237	238	238	238	237	237	237	237
					1973-74 Crop Season					
Tam W 101	233	233	233	233	233	233	234	234	234	233
Palo Duro	225	225	225	224	224	224	226	226	226	233
Danne	226	226	226	226	226	226	226	226	226	225
Centurk	226	226	226	226	226	226	226	226	226	226
Caprock	233	233	233	234	234	234	226	226	226	226
Avg.	228	228	228	228	228	228	229	229	229	229

*Averaged over replications.

TABLE XXXVI

MEANS* FOR LODGING (PERCENT), WINTER INJURY (PERCENT)

Variety	N_1			N_2			N_3			Avg.
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
				Lodging - 1972-73 Crop Season						
Tam W 101	12.5	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Palo Duro	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.8	0.0	0.7
Danne	8.8	12.5	17.5	0.0	1.3	2.5	2.5	7.5	12.5	7.2
Centurk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.4
Caprock	1.3	1.3	1.3	0.0	0.0	0.0	0.0	0.0	1.3	0.6
Avg.	4.5	3.8	4.8	0.0	0.3	0.5	1.0	2.3	3.5	2.3
				Winter Injury - 1973-74 Crop Season						
Tam W 101	12.0	12.0	12.0	13.8	11.8	16.3	9.0	12.5	9.5	12.1
Palo Duro	7.5	7.0	13.8	7.5	8.8	7.8	8.3	7.5	8.8	8.5
Danne	17.5	14.5	15.0	12.5	12.5	15.5	13.3	13.3	11.3	13.9
Centurk	9.5	12.0	11.0	13.8	16.3	21.3	15.0	17.5	16.3	14.7
Caprock	12.0	15.0	16.3	11.3	15.0	14.3	12.0	10.8	13.8	13.4
Avg.	11.7	12.1	13.6	11.8	12.9	15.0	11.5	12.3	11.9	12.5

*Averaged over replications.

VITA

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