ANALYSIS OF GROWTH AND YIELD OF WHEAT, BARLEY AND TRITICALE IN A SEMI-ARID ENVIRONMENT

by

EMMANUEL R. MORRIS

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INTRODUCTION

Recommended production practices for new wheat plant types and, to a large degree, for barley and triticale, are based on those for old "standard" wheat cultivars. The need for more current agronomic data is obvious if producers are to realize the full agronomic potentials of semi-dwarf wheat varieties, barley, and triticale.

The three species and their cultivars differ in many physiological and morphological traits. Those traits determine the agronomic responses of cereals to different production practices. Seeding and nitrogen fertilization rates are among the most easily manipulated agronomic practices and the most important determinants of grain yield. Optimum seed and fertilizer rates for the new wheat, barley, and triticale varieties must be tailored to their unique requirements for maximum yields.

Detailed examination of plant growth and development and yield components gives more information than measuring yield alone. We obtained this detailed information for the three cereals during their most critical growth stage - grain filling - under different seeding and nitrogen fertilizer rates. It is hoped that the information will assist formulation of improved recommendations for production of these cereals.

REVIEW OF LITERATURE

Plant Growth

Most experiments examining the response of plant characters to nitrogen and seeding rate were conducted before the advent of short-straw wheat and barley varieties and high fertilizer usage. In some investigations, variation in grain yield of wheat and barley mainly reflected the effects of applied nitrogen and seeding rates on leaf area and its duration (Luebs et al., 1967; Lupton et al., 1974; Fischer et al., 1976; Spiertz et al., 1978a; Pearman et al., 1978, 1979).

Studies in Eastern Kansas and elsewhere showed that well fertilized wheat, barley and triticale had most dry weight and high nitrogen content at heading, and that grain production depended more on transfer of nutrients from other parts to developing grain than on further absorption from the soil (Miller, 1930; Daigger et al., 1976; Bidinger et al., 1977; Lal et al., 1978; Austin et al., 1980; Karlen et al., 1980). Thus early nitrogen application and optimum seeding rates were known to contribute significantly to yield of winter cereals provided that sufficient green area was maintained to allow dry matter accumulation in the growing spikes (Khalifa, 1973; Fischer et al., 1976; Thorne et al., 1976; Spiertz et al., 1976). Elsewhere, Metivier et al. (1977) reported that early application of nitrate nitrogen to spring barley cultivars produced healthy potted plants which demonstrated rapid uptake of nitrogen. They showed that inadequate nitrogen supply lead to considerable reductions in absolute and relative growth rates, particularly in the shoot. Simpson (1968) and

Williams et al. (1979) reported that maintenance of sufficient green area above the flagleaf node before anthesis allowed full genetic expression of kernel size and number in barley and wheat.

Intermittent drying of seed beds, late season heat, and drought frequently limited winter cereal production more than agronomic practices of seeding rates and nitrogen fertilization in the great plains (Laude et al., 1955; Brengle, 1960; Smith, 1979, 1980). Thus, yield responses to high nitrogen fertilization or high seeding rates were marginal or nonexistent (Laude et al., 1955; Harlod et al., 1968; Lundiquist, 1979). When water and nitrogen rapidly failed elsewhere as in the trials of Puckridge (1971) and Fischer et al. (1976), anthesis of wheat was preceded by maximum leaf area index that declined before grain setting. Several workers (Watson et al., 1958; Khalifa, 1973; Evans, 1975; Mohiuddin et al., 1980) demonstrated that the size and duration of the flagleaf determined the yield of most wheats and barley cultivars, particularly in semi-arid climates where the growing season is brief.

Tanner et al. (1966) in Canada reported that vertical leaves gave a significant yield advantage to wheat, oats and barley. Angus (1972) in Australia found that crop photosynthesis was greater with erect leaves as was yield at high sowing densities in wheat. But, a lax-leafed cultivar at low seeding rate produced the highest grain yield of all stands. Grafius et al. (1980) reported that barley leaf canopy integrated over time (leaf area duration) was significantly related to both fertile tiller number and seeds per head and had no significant correlation with yield. Berdah et al. (1972) in Minnesota reported that large-leafed barley lines had higher kernel weight but comparatively lower yield than small-leafed lines. They postulated that large leaves in barley favored higher kernel weights and that small leaves favored more culms. Evans et al. (1970) reported that in the course of evolution, wheat leaf and grain size increased while the photosynthetic rate per unit area decreased. Angus et al. (1972) reported that other effects of leaf inclination probably counteracted benefical effects of light distribution.

Luebs et al. (1965) and Pearman et al. (1976) reported that greater transpiring leaf area as a result of nitrogen fertilization caused dryland barley and winter wheat yields to decline as water stress increased after anthesis. Several workers (Luebs, 1965; Ramig et al., 1963; Pearman et al., 1979) reported that Nitrogen was inefficient in producing grain yield becuase it decreased the harvest index of dryland barley and both short and tall straw winter wheats under dry conditions. Donald et al. (1976) reported that harvest index of winter wheat was positively correlated with grain but negatively correlated with weight of vegetative plant parts, particularly the stems and leaves, and with plant height. They also found that drought decreased the harvest index of wheat except when it decreased vegetative growth. Pearman et al. (1978a) reported that nitrogen decreased the harvest index of both the tall and short-straw wheat varieties, not only the tall ones as reported by Vogel et al. (1963). Pearman et al. (1978a) found that without nitrogen, the harvest index was less in a drought year, but with nitrogen the harvest index increased because drought restricted luxurious vegetative growth. Spiertz et al. (1978a) suggested that high nitrogen levels restricted vegetative crop development and prolonged duration of root activity so that photosynthesis and grain growth after anthesis would considerably favor grain yield in winter wheat. However, several workers (Watson et al., 1963; Pearman et al., 1978b; Thorne et al., 1976; Spiertz et al., 1978b; Luebs, 1965) reported that nitrogen fertilization increased green leaf area relatively more than grain yield in winter wheat and barley when late-season heat and water stress was less severe. Earlier, Pendleton (1960) reported that yield response of short and tall-straw winter wheat to nitrogen was not correlated to varietal characteristics. He suggested that varietal selection controlled the agronomic characteristics more than either nitrogen level or seeding rates. The apparent inefficiency of grain production by wheat and barley leaves given ample nitrogen was caused by increased leaf area at a time when photosynthetic efficiency was already diminished by age (Khalifa, 1973; Thorne et al., 1976; Luebs et al., 1965). Anderson et al., (1975) reported that the decline of dry matter production in barley at higher nitrogen levels was due to reduced grain size. Byles et al. (1978) reported that grains of winter wheat frequently became smaller and shriveled as nitrogen level increased. Muratal (1969) and Anderson et al. (1975) suggested that heavy nitorgen fertilization increased the formation of, "yield containers," i.e., the grains, more than filling of the grains. Pearman et al. (1978a) wondered whether small seeds in cereals given ample nitrogen were a consequence or a cause of the inefficiency of leaves in grain production.

Niffenger et al. (1965) suggested that establishing an optimum plant density from a minimum number of seed was the main objective for seeding efficiency in wheat. Elsewhere, several workers (Fischer et al., 1976; Willey et al., 1971) reported that low plant densities of short-straw wheats and barley were limited by light interception and, consequently, reduced dry matter production. Willey et al. (1971) reported that rapid leaf scenescence, increased barrenness, and consequently decreased harvest index were associated with overcrowding of barley plants and caused inefficiency of high seeding rates in grain production. Fischer et al. (1976) explained the decline in harvest index in over-crowded short-straw wheats by the observation that maximum grain yield was reached before most dry matter was produced. MacFadden (1970) reported that higher seeding rates decreased the number of days to maturity of winter barley. Fischer et al., (1976) observed that the delay in 50 percent anthesis helped low plant densities to reach maximum grain yield in wheat. Kirkby (1967) reported that increasing plant density depressed the relative growth rate of barley. Luebs et al. (1976) and Kinra (1960) reported that selecting proper row spacing distance was important for dryland barley and winter wheat production. Bishnoi et al. (1974) reported that higher seeding rates increased straw weight but not grain yield in triticale.

Yield and Yield Components

Johnson et al. (1973) stated that significant increases in yield of winter wheat from nitrogen applications above 67.5 kg per ha seldom occur under dryland production conditions in the Great Plains. Further increases in yield levels of winter wheat, barley, and triticale were progressively more difficult because yield components were greatly influenced by environment, showed compensating effects, and were negatively correlated to each other (McNeal et al., 1978; Knott et al., 1971; Johnson et al., 1973). Nitrogen and seeding rate were earlier known to influence the numbers of spikes per acre, kernels per spike, and average kernel weight in wheat, oats, and barley (Kieselbatch, 1926; Gruitard, 1961; Scheulber, 1967). Several workers (Hobbs, 1954; McNeal et al., 1963; Johnson et al., 1973; Bishnoi et al., 1980; Zubriski, 1970) reported that nitrogen increased yield of wheat, barley and triticale. Mugwira et al. (1980) stated that the growing triticale required modifications in agronomic practices used for wheat production. Zillinsky (1974) cited literature which showed that triticale was generally less responsive to nitrogen than bread wheat. He reported that the response of triticale to nitrogen varied from place to place depending on the variety and residual nitrogen in soils. Sapra et al. (1971) reported that triticale generally yielded less, had lower test weight, and poorer grain quality than 'scout' wheat. Bishnoi et al. (1979) reported that the lower test weight of triticale than wheat and rye was caused partly by its large seed size and greater shriveling of the kernel. Hobbs (1959), Kinra et al. (1960), and McNeal (1963) reported that test weight and often kernel weight were not significantly affected by nitrogen application in winter wheat. Conversely, Rhode (1964) reported that nitrogen significantly decreased kernel weight in only four of the twelve tested wheat varieties. Johnson et al. (1973) reported that test weight responses to nitrogen fertilizer were negative and linear in winter wheat. They reported that the test weight of 'Lancer' was reduced from 79.1 kg/hl with no nitrogen application to 77.7 kg/hl at 135 kg nitrogen per ha. Knott et al. (1971) reported that weight per seed was positively correlated with grain yield but negatively correlated with the number of kernels per plot in wheat. Van Dobben (1966) suggested that additional dressing with small amounts of nitrogen may promote shorter and stiffer straw and increased kernel weight in small grains. But, Mienzan et al. (1977) reported that ripening, yield, and test weight did not change with late nitrogen application. Bishnoi et al. (1980) reported that nitrogen application did not influence the number of spikes per plant and test weight of triticale. However, Isabe et al. (1977) reported that nitrogen-fertilized plants derived from large kernels produced more spikes and had higher kernel weights while fertilized plants derived from small seeds had relatively more protein in the grain. Ruffing et al. (1980) reported that nitrogen up to 100 kg N per ha increased barley yields. Higher fertilizer rates decreased plumb kernels and promoted lodging. Several workers (Finker et al., 1971; Lupton et al., 1974) reported that nitrogen increased spike populations in wheat and barley by promoting tillering. Pearman et al. (1978) and Kirkby (1967) reported that nitrogen increased tiller size and reduced tiller mortality in winter wheat and barley. Darwinkel (1978) reported that low plant densities promoted tillering in wheat. Larter et al. (1975) reported that higher seeding rates reduced the kernel, weight of triticale and wheat. Middleton et al. (1963) reported that low seeding rates decreased the number of fertile heads per unit area but increased the number of seeds per head in winter barley. Mariam et al. (1979) reported that 1000-kernel weight, kernel number per spike, and number of fertile spikes per plant exhibited a highly significant linear decrease with increased plant density in wheat and triticale. Zeven (1972) stated that plant density had no effect on the expression of heterosis for yield and its components in wheat, meaning that the effects of plant density could be buffered by the genetic background of the species. Riverland et al. (1979) recommended that seeding rates of different wheat types should compensate for kernel size variation. They suggested using 1000-kernel weight of the seed to determine optimum seeding rate of wheat. Larter et al. (1971) reported that plant density had no influence on protein in triticale. Hunter et al. (1973) reported that applying nitrogen fertilizer beyond the rate required for maximum yield increased the protein content of winter wheat. When fertilizer nitrogen was applied to a growing crop near blooming time, the grain protein content was increased but yields were not greatly affected (Finney et al., 1957; Miezan et al., 1977). Miezen et al. (1977) and Cochran et al. (1978) suggested that applying excessive nitrogen to increase protein content is not economical or safe because of diseases (e.g., Fusarium) (Smiley et al., 1972) and pollution of underground water. Terman (1979) reported that protein concentration in winter wheat was inversely related to grain and straw yield. Oplinger et al. (1975) reported that the protein percentage was higher in triticale grain than in wheat, oats, and barley. But with the higher grain yields of wheat, oats and barley, their total protein production per unit area was greater than for triticale. However, Morey et al. (1979) found no large differences in total protein production among wheat, oats, barley, rye, and triticale.

Photosynthetic efficiency and grain filling characteristics

Earlier research showed that the supply of assimilate to the grains of wheat and barley depended on activity and duration of photosynthesis, mainly in the leaves (Rawson et al., 1965; Friend, 1965; Welbank et al., 1965). However, Thorne et al. (1979) found that the relationship between grain yield and LAI at anthesis (or LAD at anthesis to maturity) was not always as close as reported by Welbank et al. (1968). They found that increases in LAI above 8 gave small increases of wheat grain yield. Although plant breeders used leaf area duration as one of the visible yield-determining characteristics, selection for large persistent green leaf area did not always give high yielding wheat types (Groeneugen, 1979).

Friend (1965) emphasized that grain yield of wheat was mainly determined in the post floral period by the rate and duration of grain growth. However, Austin et al. (1980) found that pre-anthesis assimilation of 24 barley cultivars contributed about 44 percent of the grain dry weight in 1976, a drier year, but only 1 percent in 1977, a wetter, cooler year. Similarly, Bidinger et al. (1977) in Northwest Mexico estimated an increase in pre-anthesis assimilation of 14 and 5 percent to final grain weight in droughted wheat and barley, respectively.

The apparent photosynthetic efficiency of leaves was often measured by green leaf area ratios to give yield responses of different cultivars of wheat (Watson et al., 1963; Langer et al., 1973; Brojevic et al., 1980) and barley (Watson et al., 1958) with the assumption that photosynthate production limits grain yield. Earlier work by Watson (1958) showed that the grain-weight-to-leaf-area-duration (from anthesis to maturity) ratio was an approximation of NAR after ear emergence in barley. However, the contribution of NAR by the wheat leaves after flowering was difficult to measure since other green parts (e.g., awns, leaf, sheaths, glumes) were actively photosynthesizing (Watson, 1963). Brojevic (1980) found that semidwarf wheats had greater grain weight to leaf area ratio and hence were more efficient than tall ones in accumulating dry matter to the grain. Langer et al. (1973) found that nitrogen increased the persistence of green leaf area (LAD) but depressed the grain/leaf ratio. Thomas et al. (1979) and Fischer et al. (1965) proposed that LAD was a less useful indicator of grain yield in cases where grain yield is limited by the number of grain set, a direct measure of sink size. Brojevic et al. (1980) found it was difficult to determine the principles governing the effect of green area attributes on grain yield partly because of the differences in yield compensation with wheat cultivars and cultivar year interactions.

Many workers attributed genetypic variation in grain weight to differences in the rate of grain growth (Spiertz and van de Harr, 1978) and the duration of grain filling (Sofield et al., 1977) in wheat. Keim et al. (1981) found that a winter wheat, "Yamhill," cultivar was drought resistant by demonstrating a high growth rate during flowering and high kernel weight while the drought resistance of "Lancer" was related to internal water stress by maintaining a large number of tillers through development to harvest. Sappo et al. (1978) found that shriveled lines of triticale exhibited a lower grain growth rate and shorter filling period than the plump ones. De Wit (1977) postulated that extension of grain filling period by improved crop sanitary measures (e.g., disease, weed control, etc.) accounted for much of the recent yield increases in Western Europe. Wiegand (1980) in Texas found that the apparent average grain filling rate in the Northern Plains of the U.S. was 1.1 mg/kernel/day for wheat during 1978-79. Sofield et al. (1977) found that genetic factors dominate the rate of grain filling and environmental factors (e.g., temperature) dominate the duration of grain filling. Wiegand (1980) found that higher temperatures during the post floral period paced plant senescence in wheat and ripening of the kernels, but shortened the duration of grain filling in wheat and thereby caused low kernel weights. Daynard et al. (1971) found positive correlations between the actual filling period duration and effective filling period duration (i.e., final kernel weight to average filling rate during the linear period of grain formation) in corn. Spiertz (1979) suggested that selection for an extended grain filling period could increase grain yield in wheat. However, the use of effective grain filling period concept was limited by the recognition of cessation of growth rate in small grains. Also, exceptions in crop species and cultivars indicated the relationship between filling period and grain yield was only indirect rather than direct. For example, cultivars with higher growth rate had a higher yield but relatively shorter effective kernel filling period (Austin et al., 1976). Selection for long filling duration in small grains meant selection for greater leaf longevity (i.e., increased time when leaves are active) since the two variables were positively correlated (Khalifa, 1973; Mohiuddin et al., 1980). Experience showed, however, that genotype that remained green for a longer time often had a poor rate of grain growth (Kramer, 1979). That made it possible for green area after flowering to become a competitive sink (Atsmon, 1979). The physiology of grain filling suffers from lack of standardized nomenclature and operational methods apart from the little but scanty information that was documented.

Varieties

Triticale (X Triticosecale Wittmack) is a new plant species produced by crossing tetraplois wheat (Triticum Durum Desf.) with diploid rye (Secale Cereale L.) following by doubling the chromosome number of the sterile hybrid to produce a fertile and productive polyploid type (Jenkins, 1969). Sapra et al. (1973) reported that low grain yield in triticale was due to its inherent cytological instability. The genetics of high test weight in triticale is not yet understood. The frequency of recovering lines of comparable test weight from crosses between two lines of high test weight is low (Cimmyt, 1977). Zillinsky (1974) reported that visual selection for plumb kernels tended strongly to eliminate all selections having the dwarfing genes of Norin 10 origin. Thus, kernel shriveling may be affected by plant height. Selecting desirable parents or identifying superior progenies is a major problem (Salmon et al. 1977). Also, small numbers of uniform cultivars are available compared to other crops. Interest in semidwarf character in barley resulted from a desire to reduce lodging and increase grain yield. Allan (1980) stated that probably 50 percent of area in the world sown to wheat is now occupied by semidwarf wheats which trace their origin to Japanese semidwarf sources. Several workers (Seiken et al., 1965; Sunderman, 1964; Heyne et al., 1971) reported that poor plant establishment was a serious problem associated with semidwarf wheat varieties. Although most semidwarf wheats show some yield advantages compared with the 'standard' cultivars, their milling and baking quality and winter hardiness are often inferior (Powers et al., 1978). Oplinger et al. (1975)

reported that triticale cultivars were later in maturity than wheats and oats.

MATERIALS AND METHODS

Experiments were conducted on summer fallowed sites on a Tully silt clay loam soil at Manhattan in Northeast Kansas and on a Harney silt loam soild at Minneola in Southeast Kansas during the 1979 and 1980 crop years. Soil characteristics at the respective sites were pH 6.7 and 6.1, 1.3 and 0.7% organic matter, 8.1 and 5.6 ppm available No_3-N, 6.5 and 5.3 ppm available NH_4^+-N, 28 and 52 kg per ha available P, and 467 and 362 kg per ha exchangeable K. A uniform application of 30 kg per ha P as triple super-phosphate (0-46-0) was made before the experiment was initiated.

A split-split-plot factorial design with four cultivars as main plots, three nitrogen fertilizer rates as subplots, and three seeding rates as sub-subplots in four replications was used. Four cultivars -- 'Newton' and 'Sage' wheats, 'Kanby' barley, and '368A' triticale were seeded at rates of 0.43, 0.87, and 1.3 hl per ha (0.5, 1.0, and 1.5 bu per acre) for wheat; 27, 54 and 81 kg per ha (24, 48, and 72 lbs per acre) for barley; and 31, 63, and 94 kg per ha (28, 56, and 84 lbs per acre) for triticale. The low, medium and high seeding rates were equivalent to approximately 1.2, 2.4, and 3.6 million seeds per ha for each cultivar. Nitrogen rates of 0, 50, and 100 kg N per ha (0, 45, and 90 lbs per acre) as ammonium nitrate were topdressed during early spring. Each sub-subplot was 1.2m wide and 10m long and contained six rows sowed 20cm apart. We applied 2, 4 D Amine salt at 0.34 kg a.i. per ha in 90 litres spray per ha when plants were fully stooled during late April 1979. Bromoxynil and 2, 4 D Amine salt were applied at 0.22 kg a.i. per ha each in 130 litres spray per ha on 11 May 1980, at Manhattan. The experiment at Minneola was destroyed by hail in 1980. Winter survival, late season weed infestation, and lodging were determined by visual ratings. Plant heading dates were recorded in each subplot. Mean plant height was determined from three measurements taken randomly in each sub-subplot. An area of 9.6 m^2 in each sub-subplot was harvested by a plot combine at maturity at both locations in early July of each year. Moisture content of the grain was determined with an electronic moisture meter. Grain yield and test weights were adjusted to 14% moisture content. Samples for 1000-kernel weight were dried at approximately 60 C for 7 days before 100 kernels per plot sample were counted and weighed. Protein content of grain was determined by infra-red reflectance and expressed on a 14% moisture basis.

A growth analysis study was conducted on a separate but similar, adjacent experiment at Manhattan in 1980. During spring, the plots were regularly examined to determine emergence and at least weekly to assign a growth stage on each observation date. Plant growth stages were defined according to the "Feekes" growth stage published by Large (1954). The beginning of flowering indicated by the phenological stage 10.5.1 on Feeds-Large Scale was used to indicate the start of grain filling. The physiological maturity of grain was taken as a stage 11.2, when kernels were soft but dry (i.e., mealy ripe) with about 35 percent moisture content.

Two individual plant samples of 0.25-m row length were harvested with a hand sickle from two center rows of each sub-subplot 19 May, 29 May, 9 June, 19 June, and at harvest. Also, plant samples were taken at the 50% flowering date for each tested cultivar. Total and flag leaf area was determined with a photoelectric area meter (Hartfield et al. 1976). Tillers in each sample were counted and leaves and stems were dried at 60 C for leaf, spike and total dry matter determinations. Mean specific leaf weight, $\overline{SLW}$, was computed as gm dry weight per dm^2 leaf area for each harvested plant sample.

The mean leaf area and flag leaf area indices (i.e., $\overline{LAI}$ and $\overline{FLAI}$ respectively), were computed as described by Hunter (1979) and Radford (1972), using formulae: $\overline{LAI}_{1-2} = \frac{{}_2LA - {}_1LA}{P}$ cm^2/cm^2...........(1)

where ${}_1LA$ and ${}_2LA$ were leaf areas in cm^2 from effective plot area of P cm^2 at ${}_1t$ and ${}_2t$ sampling dates.

$$\overline{FLAI} = \frac{{}_2FLA - {}_1FLA}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where ${}_2FLA$ and ${}_1FLA$ are flag leaf areas obtained at ${}_2t$ and ${}_1t$ respective dates of sampling. The mean leaf area duration, $\overline{LAD}$, was computed on the basis of LAI, leaf area (dm^2) and flag leaf area (dm^2) to obtain comparisons of the magnitude of leaf area and its persistence during the crop growth period.

$$LAD_{1-2} = \frac{({}_1LAI + {}_2LAI)({}_2t - {}_1t)}{2} = \text{days}\ldots(3)$$

where, ${}_1LAI$ and ${}_2LAI$ were leaf area indices at respective ${}_1t$ and ${}_2t$ sampling dates.

$$LADA = \frac{({}_2LA + {}_1LA)({}_2t - {}_1t)}{2} = dm^2 \text{ days}\ldots(4)$$

where ${}_1LA$ and ${}_2LA$ were leaf areas in dm^2 atindividual ${}_1t$ and ${}_2t$ sampling dates.

$$FLAD = \frac{({}_2FLA + {}_1FLA)({}_2t - {}_1t)}{2} = dm^2 \text{ days}\ldots(5)$$

where ${}_1FLA$ and ${}_2FLA$ were flag leaf areas in dm^2 at ${}_1t$ and ${}_2t$ respective sampling dates.

The mean leaf area ratio, $\overline{LAR}$, was computed as the ratio of total leaf area, to whole plant dry weight i.e.:

$$\overline{LAR}_{1-2} = \frac{({}_1LA/W) + ({}_2LA/W)}{2} \; dm^2/gm ....(6)$$

where ${}_1W$ and ${}_2W$ were respective whole plant dry weights (gm) per plot at ${}_2t$ and ${}_1t$ respective sampling dates. Formulae (6) was used on assumption that $\overline{LAR}$ is linear related to time (Ondok 1971).

The mean leaf weight ratio, $\overline{LWR}$, was calculated to measure the degree of leafiness for plants from each cultivar on a dry weight basis, i.e.:

$$\overline{LWR} = \frac{({}_1LW/W) + ({}_2LW/{}_2W)}{2} \; {}^{gm}/_{gm} ....(7)$$

where ${}_1LW$ and ${}_2LW$ indicated leaf dry weights (gm) from plant samples at ${}_1t$ and ${}_2t$ dates of sampling. The mean crop growth rate, $\overline{CGR}$, was used to measure the rate of dry matter production per P m^2 land area, i.e.:

$$\overline{CGR}_{1-2} = \frac{1}{P} \times \frac{{}_2W - {}_1W}{{}_2t - {}_1t} \; gm/m^2/day...........(8)$$

Measurement on the efficiency or relative increase of dry matter production by plants employed the use of mean relative growth rate, $\overline{RGR}$, formula:

$$\overline{RGR}_{1-2} = \frac{\log_{e_2} W - \log_{e_1} W}{{}_2t - {}_1t} \quad \text{reported as: } mg/gm/day......(9)$$

The relative increase in leaf area percent per day was calculated as:

$$\overline{RILA}\ \%\ \text{per day} = \frac{\log_{e_2} LA - \log_{e_2} LA}{{}_2t - {}_1t} \times 100...(10)$$

for the sampling intervals from 29 May to 19 June, 1980.

The final spike weight and kernels per 0.2m^2 plot sample were obtained from the last harvest after maturity. Kernel weight was determined directly from threshed spikes per plot sample after oven drying the grain at 65° C.

The spike and kernel filling rate, $\overline{SFR}$ and $\overline{KFR}$ in, was calculated as:

$$\overline{SFR}_{1-2} = \frac{{}_1WP - {}_2WP}{{}_2t - {}_1t} \times \frac{1}{NSP} = \text{mg/spike/day} \ldots\ldots\ldots (11)$$

where, ${}_1WP$ and ${}_2WP$ were spike dry weights per $0.2m^2$ plot area obtained at ${}_1t$ and ${}_2t$ sampling dates. NSP was the number of spikes per $0.2m^2$. Kernel filling rate was calculated as:

$$\overline{KFR}_{1-2} = \frac{{}_2WK - {}_1WK}{{}_2t - {}_1t} \times \frac{1}{KPA} = \text{mg/kernel/day} \ldots\ldots\ldots (12)$$

where ${}_1WK$ and ${}_2WK$ were average kernel weights per spike at sampling dates, ${}_1t$ and ${}_2t$. KPS was the average number of kernels per spike at a sampling interval, ${}_2t - {}_1t$. The mean relative filling rate was calculated as:

$$\overline{RFR}\ \%\ \text{per day}, = \frac{\log_{e_2} WK - \log_{e_2} WK}{{}_2t - {}_1t} \times 100 \ldots\ldots\ldots (13)$$

The mean effective filling period, EFP, was calculated as:

$$EFP = \frac{{}_nWK}{\frac{d}{dt} WK_e} \text{days} \ldots\ldots\ldots (14)$$

to give the relative measure of the duration of grain filling. ${}_nWK$ was the final grain weight; $\frac{d}{dt} WK_e$ was the kernel filling rate during the linear phase of growth. (Danyard et al., 1971).

The apparent efficiency of the leaves after heading in providing dry matter for the ear or the grain was estimated as (i) the increment in dry weight of ears WP, mg/dm^2 between flowering and final harvest in relation to green leaf area duration LADA, dm^2 days for the same period ($\Delta WP/LADA$ reported in $mg/dm^2/day$); (ii) the grain weight to leaf area duration from flowering to maturity W/LADA in $mg/dm^2/day$; and (iii) the grain weight to leaf area index at flowering.

The final spike weight and kernels per spike per plot sample were obtained at maturity from an area of $0.2m^2$. Analysis of variance was computed for each character relative to nitrogen and seeding rates. Correlations among important variables in the study were determined.

Noteworthy weather conditions were prolonged cool spring at both locations and frequent late season rains at Manhattan in July, 1979, dry seed beds for planting in October 1979, and late season drought and high temperatures from May to maturity in 1980.

RESULTS

The growth calendars for wheat, barley and triticale cultivars are shown in Table I. All cultivars generally grew 7 to 11 days faster to heading at Minneola and, consequently, were harvested 8 days earlier there than at Manhattan. Statistical analysis of the data showed that the season and location had greater effects than seeding rate and nitrogen, respectively. Since this study was to study effects of different levels of management on growth and yield of the cereal cultivars in semi-arid environment, less emphasis was given to climatic effects than to management effects.

The means for vegetative characters of the cultivars are indicated in Table II. Kanby barley had significantly higher mean leaf area index ($\overline{LAI}$) during 29 May, mean leaf area ratio (LAR) but lower mean flag leaf area ($\overline{FLAI}$) than 368A triticale and the wheats. The triticale had significantly higher mean green leaf area duration (LAD) from heading to maturity, crop growth rate ($\overline{CGR}$), relative crop growth rate ($\overline{RCGR}$), and accumulated total dry matter (DM) during 29th May than the two wheats and barley. No significant differences in those morphological characters were found among the two wheats and Kanby barley. Mean relative growth rate of leaf area per day ($\overline{RILA}$) was negative for all cultivars; it declined significantly faster in the two wheats than in barley and triticale. Mean leaf weight ratio ($\overline{LWR}$) was similar for all cultivars.

Nitrogen fertilizer significantly increased $\overline{LAI}$, LAD, $\overline{CGR}$, $\overline{RCGR}$, DM and decreased the rate of loss of leaf area (i.e., negative $\overline{RILA}$), but decreased $\overline{SLW}$ in wheat and triticale. Seeding rate significantly increased

Table 1. Growth calendar of wheat, barley and triticale cultivars at Manhattan and Minneola, Kansas during 1979 and 1980.

			Growth Stages								
Specie	Cultivar	Seeding	Early Dormancy	Growth Initiation	Jointing	Flag Leaf	Heading	Milk	Dough	Maturity+	Harvesting
		month/day									
Manhattan (1979)											
Wheat	Sage	10/18	-----	3/21	4/22	5/12	5/23	6/9	6/19	6/22	6/28
Wheat	Newton	10/18	-----	3/21	4/21	5/11	5/21	6/8	6/19	6/21	6/28
Barley	Kanby	10/18	-----	3/23	4/19	5/11	5/18	6/3	6/12	6/16	6/28
Triticale	368A	10/18	-----	3/23	4/27	5/14	5/25	6/13	6/23	6/27	6/28
Manhattan (1980)											
Wheat	Sage	9/16	11/24	3/19	4/21	5/13	5/22	6/8	6/17	6/21	6/29
Wheat	Newton	9/16	11/24	3/19	4/21	5/12	5/21	6/8	6/17	6/19	6/29
Barley	Kanby	9/16	11/24	3/21	4/16	5/11	5/17	6/3	6/10	6/16	6/29
Triticale	368A	9/16	11/24	3/21	4/26	5/14	5/24	6/12	6/23	6/27	6/29
Minneola (1979)											
Wheat	Sage	10/3	-----	----	4/16	----	5/18	----	----	----	6/22
Wheat	Newton	10/3	-----	----	4/16	----	5/16	----	----	----	6/22
Barley	Kanby	10/3	-----	----	4/12	----	5/13	----	----	----	6/22
Triticale	368A	10/3	-----	----	----	----	5/21	----	----	----	6/22

+Maturity taken as if mealy ripe, contents of kernel soft but dry.

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TABLE 2. Vegetative characters of wheat, barley and triticale cultivars under nitrogen dressings and seeding rates at Manhattan, Kansas, 1980.

Specie	Cultivar		LAI	$\overline{FLAI}$	$\overline{LAI}$	LAD	$\overline{LAR}$	$\overline{LWR}$	$\overline{SLW}$	$\overline{CGR}$	$\overline{RCGR}$	$\overline{RLLA}$	DM	LAP
			cm/cm	cm/cm	cm/cm	days	dm^2/gm	gm/gm	mg/dm^2	$gm/m^2/day$	mg/gm/day	% per day	gm/m^2	
		Nitrogen Rate kg/ha	mean											
Wheat	Sage	0	1.43	0.37	1.36	19	0.11	0.23	561	20.51	59	-4.2	425	2.53
		50	2.49	0.47	1.56	21	0.13	0.24	484	23.83	68	-4.2	593	3.12
		100	3.13	0.57	1.88	25	0.14	0.26	434	27.96	71	-2.0	698	3.64
	Mean		2.35b	0.47ab	1.61b	22c	0.13b	0.24a	491a	24.09b	65b	-3.5a	572b	3.12a
Wheat	Newton	0	1.92	0.52	1.76	22	0.13	0.22	573	21.02	59	-5.0	407	2.86
		50	2.76	0.54	2.00	26	0.14	0.24	467	23.91	58	-4.0	628	3.36
		100	3.11	0.60	1.97	28	0.15	0.25	392	26.78	63	-3.5	684	2.75
	Mean		2.60b	0.55a	1.91ab	25bc	0.14b	0.24a	477a	23.89b	60b	-4.2a	573b	3.36a
Barley	Kanby	0	2.52	0.20	1.93	23	0.16	0.20	371	20.93	59	-4.0	467	3.20
		50	3.62	0.21	2.40	28	0.17	0.34	340	24.53	68	-1.1	607	3.57
		100	3.99	0.23	2.60	33	0.17	0.21	339	26.81	57	-2.2	671	5.78
	Mean		3.38a	0.21c	2.32a	28b	0.17a	0.25a	349b	23.68b	62b	-2.4b	582b	4.00a
Triticale	368A	0	1.52	0.37	1.66	26	0.12	0.18	453	26.84	68	-2.5	583	2.16
		50	2.64	0.38	2.00	28	0.14	0.20	398	29.96	70	-1.7	674	2.80
		100	3.60	0.47	2.46	35	0.17	0.22	358	37.04	78	-1.4	732	3.74
	Mean		2.59b	0.41b	2.04a	32a	0.14b	0.20a	403ab	31.27a	71a	1.4b	663a	2.80b
		Seeding Rate 10^6 seeds/ha												
Wheat	Sage	1.2	1.33	0.45	1.52	22	0.13	0.27	507	22.08	63	-1.9	462	3.51
		2.4	2.85	0.53	1.65	22	0.12	0.22	492	20.43	67	-4.3	583	2.64
		3.6	2.89	0.42	1.65	21	0.13	0.24	475	29.79	67	-4.4	651	3.12
	Mean		2.35b	0.47ab	1.61b	22c	0.13b	0.24a	491a	24.10b	65b	-3.5a	572b	3.12a
Wheat	Newton	1.2	1.51	0.56	1.79	24	0.14	0.21	447	18.93	56	-3.3	513	3.50
		2.4	3.01	0.55	1.88	25	0.14	0.24	552	21.66	64	-4.1	595	3.36
		3.6	3.27	0.55	2.06	26	0.16	0.25	431	31.10	59	-4.6	613	3.36
	Mean		2.60b	0.55a	1.91ab	25bc	0.14b	0.24a	477a	23.89b	60b	-4.0a	573b	3.36a
Barley	Kanby	1.2	2.65	0.24	2.29	28	0.16	0.33	391	17.78	70	-1.4	514	5.28
		2.4	3.74	0.20	2.32	29	0.16	0.22	365	28.19	75	-2.6	596	3.52
		3.6	3.80	0.21	2.37	27	0.17	0.20	292	24.97	68	-3.1	638	3.40
	Mean		3.38a	0.21c	2.32a	28b	0.16a	0.25a	349b	23.68b	62b	-2.4b	582b	4.00a
Triticale	368A	1.2	1.77	0.36	2.05	32	0.14	0.19	453	31.35	78	-1.3	605	2.66
		2.4	2.52	0.46	2.04	32	0.15	0.20	398	32.34	70	-0.8	652	3.00
		3.6	3.58	0.40	2.05	31	0.14	0.20	358	34.93	66	-2.3	734	2.80
	Mean		2.59b	0.41b	2.04a	32a	0.14b	0.20a	4.03ab	31.27a	71a	-1.4b	663a	2.80b

Column means for cultivars with the same letter are not significantly different at $P_{.05}$ level.

Column means within each cultivar underscored with the same line are not significantly different at $P_{.05}$ level.

LAI = leaf area index during 29th May; $\overline{LAI}$ = mean leaf area index from 19th May to 29th June; $\overline{FLAI}$ = flag leaf area index during 29th May; LAD = leaf area duration; $\overline{LAR}$ = mean leaf area ratio; $\overline{LWR}$ = mean leaf weight ratio; $\overline{SLW}$ = mean specific leaf weight; $\overline{CGR}$ = mean crop growth rate; $\overline{RCGR}$ = mean relative crop growth rate; RLGR = relative leaf growth rate; DM = accumulated dry matter up to 29th May (mean of total dry matter found from 19 and 29th May samples); $\overline{RLLA}$ = relative leaf growth rate; LAP = leaf area weight ratio.

$\overline{\text{LAI}}$, $\overline{\text{CGR}}$ and DM, but significantly lowered $\overline{\text{RILA}}$. Seeding rate above 2.4 million seeds per ha gave no significant increases in LAI, LAD and DM for wheat and barley. $\overline{\text{LAR}}$ and $\overline{\text{LWR}}$ were nearly constant for each cultivar over the useful life of leaves irrespective of nitrogen or seeding rate treatment, but that observation may not hold for individual plant leaves.

The simple correlations of vegetative characters of wheat, barley and triticale cultivars with nitrogen fertilizer and seeding rate are shown in Table 3. Significant and positive correlations of nitrogen rate with LAI and LAD were found in all tested species' cultivars. Positive and significant correlations between flag leaf area duration and nitrogen were found in wheat and triticale. Seeding rate was positively correlated with $\overline{\text{CGR}}$ and $\overline{\text{LWR}}$ in Newton wheat and barley. Nitrogen rate was negatively correlated with $\overline{\text{SLW}}$ in both wheats and triticale. Conversely, positive correlation was found between $\overline{\text{SLW}}$ and seeding rate in Newton wheat and triticale.

Grain filling characteristics and related yield components of wheat, barley and triticale cultivars are shown in Table 4. Both barley and triticale had significantly higher spike weight, kernels per spike and mean spike and kernel filling rates than the two wheat cultivars during 1980. However, kernel weights of the two wheats were significantly higher than that of triticale and similar to that of barley. The wheats had significantly higher mean effective filling period, EKFP, than triticale and barley. Barley headed three to five days earlier than wheat. Nitrogen significantly increased mean spike filling rates of all cultivars. However, nitrogen nor seeding rate influenced the kernel filling rate or relative filling rate of all tested cultivars.

TABLE 3. Simple correlations of vegetative characters of wheat, barley and triticale cultivars with nitrogen and seeding rate at Manhattan, Kansas, 1980.

Specie	Cultivar	LA	LAD	FLA	FLAD	$\overline{LAR}$	$\overline{LWR}$	$\overline{SLW}$	$\overline{CGR}$	$\overline{RGR}$	Grain Leaf Ratio
Nitrogen						r					
Wheat	Sage	0.6341**	0.5168**	0.2453	0.3520*	0.2510	0.2133	-0.4844**	0.1661	0.3102	0.2745
Wheat	Newton	0.4554**	0.4559**	0.0831	0.3132*	0.2114	-0.2579	-0.2336	0.1330	0.2000	-0.4775**
Barley	Kanby	0.4401**	0.4203*	0.0816	0.1349	0.0023	0.0171	-0.4473**	0.1080	0.0303	-0.1376
Triticale	368A	0.5696**	0.6364**	0.3091	0.4042**	0.4596**	0.3290*	-0.4533**	0.4433**	0.4858*	-0.3546*
Seeding Rate											
Wheat	Sage	0.2388	-0.2475	0.1234	-0.0937	-0.2377	-0.2853	-0.1130	0.2475	0.2392	-0.3812*
Wheat	Newton	0.2261	0.3289*	-0.0374	-0.3196*	0.2068	0.4977**	0.5993**	0.4873**	0.3568*	-0.1734
Barley	Kanby	0.1159	-0.2337	0.0039	-0.1284	-0.2406	0.4614**	0.0104	0.6419**	0.3625*	-0.1810
Triticale	368A	0.2322	0.1646	0.0422	0.2178	-0.3670	0.1544	0.4108*	0.3249*	0.1377	-0.1275

*, ** significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

LA - leaf area index; LAD = leaf area duration (days); FLA = flag leaf area (dm^2); FLAD = flag leaf area duration (days); $\overline{LAR}$ = mean leaf area ration; $\overline{LWR}$ = mean leaf weight ration; $\overline{SLW}$ = mean specific leaf weight; $\overline{CGR}$ = mean crop growth rate (mg/gm/day); $\overline{RGR}$ = mean relative growth rate.

TABLE 4. Headed tillers and grain filling characters of wheat, barley and triticale cultivars under nitrogen dressings and seeding rates at Manhattan, Kansas, 1980. (Experiment B)

Specie	Cultivar	Rate	Headed	Tillers	Spike+ Weight	Kernels	Kernel++ Weight	Mean Rate Spike	Filling Per Kernel	RKFR	EKFP
			no/m row	%	mg/spike	no/spike	mg/kernel	---mg/day---		% days	days
		Nitrogen Rate kg/ha	------	------	------	------	---mean---	------	------	------	------
Wheat	Sage	0	106	55	756	19	27.8	23.5	1.19	9	23
		50	135	50	865	22	30.4	30.6	1.35	10	21
		100	147	46	952	23	29.2	33.6	1.42	12	21
	Mean		129a	50b	858d	21b	29.1a	29.2d	1.32b	10b	22a
Wheat	Newton	0	107	55	883	22	28.1	27.3	1.20	9	23
		50	128	53	970	23	30.3	35.7	1.43	12	20
		100	151	49	991	25	29.6	32.4	1.37	10	20
	Mean		128a	52ab	948c	23b	29.3a	31.8c	1.33b	10b	21ab
Barley	Kanby	0	96	53	1047	28	28.7	39.3	1.41	12	20
		50	126	44	1199	29	29.3	46.3	1.56	14	19
		100	132	48	1193	32	29.6	50.7	1.58	14	19
	Mean		118a	48b	1146b	30a	29.2a	45.4b	1.52a	13ab	19b
Triticale	368A	0	79	54	1365	29	27.9	49.5	1.67	14	17
		50	82	59	1432	33	29.1	60.4	1.75	15	16
		100	107	52	1500	35	28.4	58.9	1.70	15	16
	Mean		89b	55a	1432a	32a	28.6b	56.3a	1.71a	15a	16c
		Seeding Rate kg/ha									
Wheat	Sage	1.2	117	56	831	21	28.9	27.6	1.26	10	22
		2.4	131	48	890	21	29.8	31.5	1.38	11	21
		3.6	139	46	853	22	28.7	28.4	1.31	10	22
	Mean		129a	50b	858d	21b	29.1a	29.2d	1.32b	10b	22a
Wheat	Newton	1.2	110	60	863	24	29.5	32.4	1.34	10	21
		2.4	130	48	995	23	29.7	33.1	1.37	11	21
		3.6	145	48	987	23	28.6	29.9	1.29	9	20
	Mean		128a	52ab	948c	23b	29.3a	31.8c	1.33b	10b	21ab
Barley	Kanby	1.2	103	51	1141	28	29.6	44.5	1.55	13	19
		2.4	120	46	1154	29	29.7	48.1	1.57	13	19
		3.6	131	49	1142	29	28.3	44.7	1.44	12	18
	Mean		118a	48b	1146b	29a	29.2a	45.8b	1.52a	13ab	19b
Triticale	368A	1.2	76	58	1482	33	28.8	57.1	1.72	15	17
		2.4	89	59	1471	33	28.4	57.7	1.71	15	15
		3.6	103	52	1343	31	28.3	54.0	1.70	14	15
	Mean		89b	55a	1432a	32a	28.6b	56.3a	1.71a	15a	16c

Column means for varieties with the same letter are not significantly different at $P_{.05}$ level.

Column means within each varity underscored by same line are not significantly different at $P_{.05}$ level.

+ mg spike at harvesting. RKFR = relative kernel filling rate.

++ mg kernel at harvesting. EKFP = effective kernel filling period duration.

Considering each cultivar, higher rate of kernel filling was usually associated with shorter effective filling duration, EKFP, so kernel weight at harvest was only slightly affected.

Correlations among grain filling characters are listed in Table 5. Sage and Newton wheats showed positive and significant correlations between nitrogen rate and spike weight. Seeding rate was negatively correlated with mean kernel and relative filling rate of triticale. Strong negative correlations were found between seeding rate and effective filling duration, EKFP, in Newton wheat and barley. Similarly, nitrogen had strong negative correlations with EKFP in Sage wheat and triticale. However, strong positive correlations were found in all cultivars between effective filling duration, mean and relative filling rates, MKFR and MRFR (Table 6). The kernel weight of Sage wheat and triticale was not strongly correlated with spike weight. Effective filling duration, EKFP, was negatively correlated with spike and kernel weight in Sage wheat and triticale.

Apparently efficiency of leaves in providing dry matter for the grain after heading is indicated in Table 7. Triticale had a significantly higher increment in spike weight and leaf area duration, LADA, from flowering to maturity, but had lower kernel and total grain weight per dm^2 land area than the two wheats. Triticale also had significantly fewer headed tillers per m row than the wheats (Table 7). No significant differences were found among cultivars in number of kernels per dm^2 leaf area, KN/LA. The two wheats had significantly higher grain to leaf area duration, W/LADA, and grain to leaf area index, W/LAI, ratios in spite of their lower leaf area durations, LADA, from flowering to maturity than barley and triticale. Barley had significantly lower flag leaf area duration, but field observations showed that its second uppermost leaf persisted longer than the flag leaf of the two wheats.

TABLE 5. Simple correlations of grain filling attributes for wheat, barley and triticale cultivars with nitrogen and seeding rate at Manhattan, Kansas, 1980.

Specie	Cultivar	SPWT+	FSPWT	KWT	Mean Kernel Filling Date	Mean Relative Filling Rate	Spike to Stem Ratio	HI	HD	EKFP
Nitrogen		r								
Wheat	Sage	-0.1358	0.6578**	-0.3354*	-0.1839	-0.0084	-0.2433	0.0437	0.7179**	-0.4275*
Wheat	Newton	0.5347**	0.5535**	-0.2585*	0.2743	0.3068*	-0.3089*	0.4638*	0.5087**	-0.2465
Barley	Kanby	-0.0510	0.2114	-0.2669	-0.2069	-0.0769	-0.0063	0.4733*	0.1491	-0.2465
Triticale	368A	0.6251**	0.0346	0.3649*	0.1962	0.2211	0.2104	-0.1442	0.6369**	-0.3960*
Seeding Rate										
Wheat	Sage	-0.3104	-0.3017	0.0868	-0.0742	0.1524	0.2289	-0.2765	-0.4271*	0.0050
Wheat	Newton	-0.2239	0.3121	0.2300	0.2453	-0.1538	0.0459	-0.0828	-0.1454	-0.4483*
Barley	Kanby	-0.0387	-0.1701	-0.2168	-0.2373	-0.1479	0.2326	-0.0322	-0.0852	-0.4827*
Triticale	368A	-0.2897	-0.1918	0.0777	-0.3888*	-0.3971*	-0.1905	-0.1983	0.1447	0.1428

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

SPWT -Spike weight at 29th May; FSPWT - spike weight at final harvesting (29th June); KWT - final kernel weight (mg); HI - harvest index; HD - days to heading; EKFP - effective filling period (days).

TABLE 6. Simple correlations among grain filling characters of wheat, barley and triticale cultivars at Manhattan, Kansas, 1980.

Specie	Cultivar	Spike Weight FSPWT	Kernel Weight KWT	Mean Filling Rate MKFR	Mean Relative Filling Rate MRFR	Effective Filling Period EKFP	Filling Duration KFD	Flag Leaf Area Duration FLAD
Wheat	Sage							
	HI	0.041	0.037	0.182	0.102	0.156	-0.321**	-0.145
	FLAD	-0.123	0.162	0.369*	0.107	-0.366*	-0.262	
	KFD	0.614*	0.617*	0.138	0.595**	0.393*		
	EKFP	-0.571*	-0.104	-0.396*	0.267			
	MRFR	0.719**	0.700**	0.426				
	MKFR	0.348*	0.386*					
	KWT	0.266						
Wheat	Newton							
	HI	0.045	0.276	0.255	0.237	0.176	0.203	0.189
	FLAD	0.132	0.252	0.359*	0.248	0.185	0.141	
	KFD	0.401*	0.343*	0.884**	0.912**	0.830**		
	EKFP	0.633*	-0.608**	-0.655**	0.461**			
	MRFR	0.795**	0.504**	0.325**				
	MKFR	0.933**	0.475*					
	KWT	0.434*						
Barley	Kanby							
	HI	0.146	0.134	0.102	0.077	0.135	-0.234	0.185
	FLAD	0.129	0.120	0.203	0.028	0.021	0.154	
	KFD	0.477*	0.503**	0.425**	0.387*	0.479*		
	EKFP	-0.471**	-0.469**	-0.489*	0.325*			
	MRFR	0.440**	0.339**	0.485*				
	MKFR	0.452**	0.344*					
	KWT	0.398*						
Triticale	368A							
	HI	0.206	0.207	0.274	0.174	0.096	-0.065	0.065
	FLAD	0.331*	0.303*	0.106	0.194	0.404	0.112	
	KFD	0.673**	0.732**	-0.367*	0.249	0.542**		
	EKFP	-0.704**	-0.404*	0.581**	0.715**			
	MRFR	0.638**	0.491**					
	MKFR	0.750*	0.582*					
	KWT	0.216						

+Simple correlations for results from 50 Kg Nitrogen and 2.4 X 10^6 seeds per ha treatments.

*; ** - Signifiacnt, highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE 7. Photosynthetic efficiency by leaves of wheat, barley and triticale cultivars under nitrogen dressings and seeding rates at Manhattan, Kansas, 1980.

Specie	Cultivar	Nitrogen Rate kg/ha	ΔWP	KN	LADA	FLADA	W	LA	KN/LA	W/LADA	ΔWP/LADA
			mg/spike	Kernels/dm^2	---dm^2	days---	gm/dm^2	dm^2	kernels/dm^2	-----mg/dm^2	/day-----
			means								
Wheat	Sage	0	490	133	117	28	1.9	14.5	9.2	16.2	4.2
		50	578	147	159	35	2.7	25.3	5.8	16.9	3.6
		100	630	166	174	40	2.8	31.8	5.2	16.1	3.6
	Mean		566b	149a	150b	34b	2.5	23.9b	6.2a	16.4a	3.8a
Wheat	Newton	0	503	131	128	32	2.0	19.5	6.7	15.6	3.9
		50	673	149	175	36	2.8	28.0	5.3	16.0	3.8
		100	692	182	188	37	2.9	31.6	5.8	15.4	3.7
	Mean		623b	154a	163b	35b	2.6	26.4b	5.9a	15.7a	3.8a
Barley	Kanby	0	487	145	159	13	1.6	25.6	5.7	10.0	3.1
		50	125	176	224	16	1.8	36.8	4.8	8.0	2.6
		100	590	197	236	14	1.9	40.5	4.9	8.0	2.6
	Mean		567b	172a	706a	14c	1.8	34.3a	5.1a	8.7b	2.8b
Triticale	368A	0	696	112	184	32	1.1	25.4	7.3	8.9	3.4
		50	794	140	262	43	1.6	32.8	5.2	8.7	2.9
		100	799	154	287	45	1.7	36.6	4.2	7.8	2.5
	Mean		763a	135b	241a	40a	1.5b	26.5b	5.6a	8.4b	2.9b
		Seeding Rate Kg/ha	WP mg/spike	KN kernels/dm^2	LAI cm^2/cm^2	FLADA dm^2 days	W gm/dm^2	LA dm^2	KN/LA kernels/dm	W/LAI x10[1]	
Wheat	Sage	1.2	519	143	1.33	33	2.2	13.5	10.6	17	
		2.4	607	162	2.85	36	2.5	29.0	5.6	9	
		3.6	578	141	2.89	34	2.7	29.3	4.9	9	
	Mean		568b	149a	2.35b	34b	2.5	23.9b	6.2a	12a	
Wheat	Newton	1.2	564	140	1.51	36	2.2	15.3	7.6	15	
		2.4	616	155	3.01	36	2.7	30.6	5.1	9	
		3.6	678	167	3.27	34	2.8	33.2	5.0	9	
	Mean		623b	154a	2.60b	35b	2.6	26.4b	5.9a	11a	
Barley	Kanby	1.2	571	141	2.65	16	1.5	26.3	5.7	6	
		2.4	563	192	3.74	14	1.8	38.0	4.8	5	
		3.6	566	183	3.80	13	2.1	38.6	4.7	5	
	Mean		567b	172a	3.38a	14c	1.8	34.3a	5.1a	5b	
Triticale	368A	1.2	769	123	1.77	40	1.2	18.0	6.8	7	
		2.4	760	136	2.50	43	1.6	24.7	5.5	6	
		3.6	759	147	3.51	39	1.6	36.1	4.1	5	
	Mean		763a	135b	2.59b	40a	1.5	26.3b	5.6a	6b	

Column means with the same letter are not significantly different at $P_{.05}$ level.

ΔWP = change in spike weight (heading to maturity) mg; KN = kenrels/dm^2; LADA = leaf area duration-anthesis to maturity; FLADA = flag leaf area duration; W = gram weight (mg/dm^2); LA = leaf area at anthesis (dm^2); LAI = leaf area index at anthesis; W/LADA; ΔWP/LADA = estimates of grain/leaf area duration ratio; W/LAI = grain/leaf area ratio.

Nitrogen significantly prolonged longevity of total green leaf and flag leaf areas, LADA and FLADA, and increased grain weight per dm^2 land area in Sage and Newton wheats, but reduced the grain to leaf area duration in triticale and barley. Seeding rate increased leaf area, LA, but significantly reduced the grain to leaf area index ratio, W/LAI, in all cultivars. Both nitrogen and seeding rate increased kernels per dm^2 land area but decreased kernels per dm^2 leaf area and grain leaf ratios (i.e., W/LADA and W/LAI), respectively. However, increases in either nitrogen or seeding rate above 50 kg N or 2.4 million seeds per ha, respectively, had no effect on kernels per leaf area and grain leaf area ratios.

Grain yield and yield components for tested wheat, barley and triticale cultivars at Manhattan and Minneola were indicated in Tables 8 and 9, respectively. Yields of the two wheats were significantly higher than that of barley and triticale at both locations. Although triticale had a significantly higher number of kernels per spike, days to heading and plant height, it had significantly lower headed tillers per m row, kernel weight, test weight and harvest index than the wheats' (Table 8). Test weights of barley and triticale were comparable in spite of the significantly higher 1000-kernel weight of barley than of triticale at both locations. Barley had lower percent protein and days to heading but had higher lodging score than the wheats at both locations. The harvest indices of Newton wheat and barley were similar but significantly higher than that of triticale at Manhattan. Sage wheat and triticale were taller than barley and Newton wheat at Manhattan.

A summary of the means of yield components from the analysis of vaiance for nitrogen and seeding rate appears in Tables 8 and 9. Nitrogen fertilizer and seeding rate treatments significantly increased grain

TABLE 8. Yield and yield components, weed, lodging and survival scores of wheat, barley and triticale cultivars at Manhattan, Kansas, 1979-80.

Specie	Cultivar	Nitrogen kg/ha	Grain Yield	Kernel Weight	Test Weight	Kernels+	10^3 Kernels	Headed Tillers	Headed Tillers	Harvest Index+	Protein	Plant Height	Days to Heading	Weed[1] Score	Lodging[2] Score	Survival[3] Score
			kg/ha	gm/1000	kg/hl	no/spike	---no/m row---		-----%-----			cm	Julian	-----1-9-----		
			- - - - - - means - - - - - -													
Wheat	Sage	0	1890	28.0	75.6	25	2.4	96	72	43	12.7	105	142	3.4	4.0	---
		50	2316	28.3	76.2	26	3.5	136	69	42	12.9	109	142	3.6	4.0	---
		100	2408	27.9	75.3	27	3.8	142	63	42	13.4	110	144	3.7	4.9	---
	Mean		2205a	28.1a	75.7a	26b	3.2b	125a	68a	42a	13.0b	108b	143b	3.6b	4.3b	---
Wheat	Newton	0	1972	29.7	76.9	23	2.4	103	72	43	12.3	90	141	3.2	3.8	---
		50	2382	29.9	77.3	24	3.1	129	69	43	12.5	93	141	3.6	3.9	---
		100	2572	29.1	78.2	26	3.6	137	66	42	13.2	94	142	3.7	4.4	---
	Mean		2308a	29.6a	77.5a	24b	3.0b	123a	69a	43a	12.7b	92b	141b	3.5b	4.0b	---
Barley	Kanby	0	1312	27.3	65.9	29	2.9	100	57	45	11.4	87	138	3.6	6.8	---
		50	1607	28.4	67.5	31	4.0	128	51	44	12.1	94	138	4.0	7.9	---
		100	1743	28.0	64.8	33	4.6	139	43	42	12.3	96	139	4.1	8.8	---
	Mean		1554b	27.9b	66.0c	31a	3.8a	122a	50b	44a	11.9c	92b	138c	3.9ab	7.8a	---
Triticale	368A	0	1177	26.9	62.1	29	2.7	94	56	40	13.8	127	145	4.5	5.2	---
		50	1266	27.8	64.2	36	3.6	99	68	39	14.1	149	145	4.9	5.6	---
		100	1400	27.4	63.7	37	4.6	124	69	38	14.3	151	147	4.9	5.9	---
	Mean		1281c	27.3b	63.3c	34a	3.6a	.06b	64a	39b	14.1a	142a	146a	4.8a	5.6b	---
		Seeding Rate 10^6 seeds/ha														
Wheat	Sage	1.2	1914	28.4	76.1	26	2.6	101	67	42	13.2	107	143	3.8	4.2	6.5
		2.4	2265	28.0	75.8	27	3.5	130	68	42	13.3	109	143	3.7	4.2	6.1
		3.6	2436	28.0	75.2	25	3.6	144	69	41	12.5	108	142	3.4	4.5	4.7
	Mean		2205a	28.1a	75.7a	26b	3.2b	125a	68a	42b	13.0b	108b	143b	3.6b	4.3b	5.8b
Wheat	Newton	1.2	1920	29.8	77.5	25	2.6	103	67	43	12.6	92	142	3.9	3.8	6.5
		2.4	2457	29.5	77.0	24	3.1	130	69	44	12.7	93	141	3.4	4.0	6.2
		3.6	2548	29.2	76.8	24	3.4	142	70	42	12.7	93	140	3.2	4.3	4.9
	Mean		2308a	29.6a	77.1a	24b	3.0b	125a	69a	43b	12.7b	92b	141b	3.5b	4.0b	5.9b
Barley	Kanby	1.2	1264	28.2	66.5	34	3.2	108	50	45	11.8	92	139	4.1	6.9	8.6
		2.4	1627	27.9	66.2	33	4.1	129	55	44	12.0	93	138	4.0	8.2	8.3
		3.6	1771	27.5	65.6	33	4.3	133	45	42	11.9	94	138	3.6	8.4	6.9
	Mean		1554b	27.9b	66.1b	33a	3.8a	123a	50b	44a	11.9c	92b	138c	3.9ab	7.8a	7.9a
Triticale	368A	1.2	1113	27.3	63.4	34	3.1	91	59	40	14.2	147	146	4.9	5.3	8.1
		2.4	1313	27.7	63.6	34	3.7	109	69	39	14.1	140	146	4.8	5.6	7.7
		3.6	1417	26.9	62.9	33	3.9	119	67	39	14.1	139	146	4.7	5.8	6.5
	Mean		1281c	27.3b	63.3b	34a	3.6a	106b	68a	39b	14.1a	142a	146a	4.8a	5.6b	7.4a

+ From 1980 data only.

Column means with the same letter are not significantly different at $P_{.05}$ level.

Within cultivar means underscored by the same line are not significantly different at $P_{.05}$ level.

1. Rating scale of 1-9; 1 = no weeds, 9 = very weedy.
2. Rating scale of 1-9; 1 = no lodging, 9 = full lodging.
3. Rating scale of 1-9; 1 = high plant survival (i.e., >90%); 9 = no plant survival (i.e., <3%).

TABLE 9. Means for grain yield and yield components, weed, lodging and survival scores of wheat, barley and triticale cultivars at Minneola, Kansas, 1979.

Specie	Cultivar		Grain Yield kg/ha	Test Weight kg/hl	Kernel Weight gm/1000	Protein %	Days to Heading Julian	Headed Tillers no/m row	Lodging Score 1-9	Weed Score 1-9	Survival Score 1-9
		Nitrogen kg/ha									
Wheat	Sage	0	1107	77	28	12.7	137	89	2	4	---
		50	3472	77	28	12.9	137	131	2	5	---
		100	3506	76	27	13.6	138	141	3	6	---
	Mean		2695a	77a	28a	12.8b	138a	120a	2b	5b	---
Wheat	Newton	0	1009	78	29	11.4	135	94	1	5	---
		50	3579	79	29	12.7	136	110	3	5	---
		100	3738	77	28	13.2	136	137	3	4	---
	Mean		2775a	78a	29a	12.4b	136b	114a	2b	5b	---
Barley	Kanby	0	1081	67	27	11.6	132	82	7	7	---
		50	2111	67	27	11.7	133	100	7	7	---
		100	2243	66	28	11.7	134	102	7	7	---
	Mean		1812b	67b	27b	11.3c	133c	94ab	7a	7a	---
Triticale	368A	0	968	64	25	13.2	141	65	2	5	---
		50	1601	65	27	14.2	142	86	3	6	---
		100	1730	63	26	14.0	142	88	2	5	---
	Mean		1437c	64b	26b	13.8a	142a	80b	2b	5b	---
		Seeding Rate 10^6 seeds/ha									
Wheat	Sage	1.2	1874	78	29	13.0	138	119	2	7	7
		2.4	3926	77	28	12.8	139	122	2	4	5
		3.6	3386	76	28	12.6	136	120	3	4	3
	Mean		2695a	77a	28a	12.8b	137b	120a	2b	5b	5b
Wheat	Newton	1.2	1586	78	29	12.2	137	108	2	5	7
		2.4	3202	78	29	13.0	135	116	3	5	7
		3.6	3537	77	28	12.0	135	120	2	4	3
	Mean		2775a	78a	29a	12.4b	136b	114a	2b	5b	6b
Barley	Kanby	1.2	1002	68	28	12.0	133	79	7	9	9
		2.4	2196	67	27	12.2	134	93	7	7	8
		3.6	2240	67	26	11.6	132	112	7	4	6
	Mean		1812b	67b	27b	11.9c	133c	94ab	7a	7a	8a
Triticale	368a	1.2	1273	65	26	13.9	143	69	2	6	8
		2.4	1467	64	26	13.7	142	80	2	5	7
		3.6	1498	64	25	13.7	142	91	3	5	5
	Mean		1412c	64b	26b	13.8a	142a	80b	2b	5b	7a

Column means with the same letter are not significantly different at $P_{.05}$ level.

Within cultivar means underscored by the same line are not significantly different at $P_{.05}$ level.

TABLE 10. Simple correlations of grain yield and yield components of wheat, barley and triticale cultivars with nitrogen and seeding rate at Manhattan, Kansas, 1979 and 1980.

Specie	Cultivar	Grain Yield	10^3 Kernel Weight	Test Weight	Kernels Per Spike	Kernels Per m row	Headed Tillers Per m row	Total Dry Matter	Percent Protein	Harvest Index	Plant Height	Days to Heading	Lodging Score	Weed Score	Plant Survival
		r													
(a) Nitrogen															
Wheat	Sage	0.42276**	-0.01777	-0.0053	0.31622	0.2452	0.2965*	0.2492	0.0143	0.1153	0.3401**	0.7118**	0.1237	0.0137	-------
Wheat	Newton	0.3162**	-0.1589	-0.0216	0.3562*	0.3562**	0.0877	-0.3449*	0.2177	-0.0110	0.2294	0.5087**	0.0853	-0.1145	-------
Barley	Kanby	0.3676*	-0.0945	0.1543	0.3502**	0.4570**	0.2839*	0.3937*	0.0364	0.0685	0.2764	0.4010*	0.2102	0.0137	-------
Triticale	368A	0.3052*	-0.3677**	0.0406	0.2237*	0.4306*	0.3531*	0.3017*	0.4580*	-0.1442	0.2455*	0.4083*	0.1103	0.1674	-------
(b) Seeding Rate															
Wheat	Sage	0.3111*	-0.0330	-0.1413	-0.14072	0.1373	0.5331**	0.1819	0.3386	0.0024	0.0177	-0.0392	-0.7415	-0.2411	-0.7267**
Wheat	Newton	0.3295*	-0.2054	-0.3084	-0.0654	0.2519	0.6023**	-0.0063	0.2027	-0.2273	-0.0463	-0.2967	-0.1624	-0.0151	-0.3937*
Barley	Kanby	0.2697*	0.0406	-0.1255	-0.3288*	0.2031	0.5610**	0.6870*	0.0422	-0.1238	0.0844	-0.3038*	0.0340	-0.1373	-0.3860*
Triticale	368A	0.1159	0.0897	0.1388	-0.0396	0.3715*	0.6568**	0.5377*	0.1992	0.0863	0.2911*	0.0476	0.0306	-0.12431	-0.1632

*, ** - significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE 11a. Simple correlations among yield components of Sage and Newton wheats, respectively at Manhattan, Kansas, 1979 and 1980.

	Winter Survival	Days to Heading	% Headed Tillers	Harvest Index	Percent Protein	Lodging	Weed Score	Plant Height	Spikes Per m row	Kernels Per m row	Kernels Per Spike	Test Weight	Kernel Weight
Wheat - Sage						r+							
Grain Yield	0.622**	0.183	0.169	0.117	-0.247	-0.211	-0.335	-0.114	0.213	0.304*	0.359*	0.154	0.209
Kernel Weight	-0.419**	-0.163	-0.015	0.087	-0.173	-0.176	-0.019	0.081	-0.176	-0.984**	-0.289*	0.054	
Test Weight	0.210	-0.607**	-0.014	0.097	-0.035	-0.627**	-0.321	-0.452**	-0.143	-0.038	0.178		
Kernels/spike	0.447**	0.256	0.029	0.067	0.014	0.092	0.091	-0.114	-0.177	0.451**			
Kernels/m row	0.690**	0.252	0.160	0.108	0.399*	0.221	-0.031	-0.244	0.349**				
Spikes/m row	0.483**	0.359*	0.638**	0.188	-0.209	0.384*	0.092	0.143					
Plant Height	-0.305	-0.025	-0.056	-0.177	-0.121	0.356**	-0.273						
Weed Score	-0.037	0.397*	0.138	-0.121	-0.307	0.025							
Lodging	0.753**	0.766**	0.169	-0.077	0.245								
Percent Protein	0.244	0.040	-0.003	-0.198									
Harvest Index	0.041	-0.028	0.099										
Headed Tillers %	0.483**	0.076											
Days to Heading	-0.071												
Wheat-Newton													
Grain Yield	0.437*	0.447**	0.056	0.335**	-0.070	-0.055	-0.195	-0.064	0.417**	0.524**	0.051	0.129	0.047
Kernel Weight	-0.241	-0.572*	-0.419*	-0.140	0.064	-0.078	-0.093	-0.091	0.023	-0.612**	-0.639**	0.368**	
Test Weight	-0.694**	-0.603**	0.193	0.657*	-0.264	-0.583**	-0.110	-0.612**	0.223	0.131	-0.377**		
Kernel/spike	0.385*	0.462*	0.256	0.250	0.139	0.213	0.170	0.568**	-0.210	0.592**			
Kernel/m row	0.196	0.465*	0.165	0.155	0.041	0.061	0.070	0.256	0.202				
Spikes/m row	0.195	0.658*	0.590**	0.061	-0.151	0.517*	0.215	-0.257					
Plant Height	0.212	0.158	-0.146	-0.588**	0.122	0.381*	-0.141						
Weed Score	-0.369*	-0.116	-0.036	-0.184	0.022	0.207							
Lodging	0.397*	0.717**	-0.163	-0.496**	0.033								
Percent Protein	0.003	0.224	-0.174	-0.027									
Harvest Index	0.041	-0.172	0.055										
Headed Tillers %	0.371*	-0.091											
Days to Heading	-0.212												

+ - Correlation coefficients for plant treated with 50 k gN/ha and 2.4 x 10^6 seeds/ha treatments.

*, ** - Significant, highly significant at $P_{.05}$ and $P_{.01}$ levels, respectively.

TABLE 11b. Simple correlations among the yield components of barley and triticale cultivars at Manhattan, Kansas, 1979 and 1980.

	Winter Survival	Days to Heading	% Headed Tillers	Harvest Index	Percent Protein	Lodging	Weed Score	Plant Height	Spikes Per m row	Kernels Per m row	Kernels Per Spike	Test Weight	Kernel Weight
						r							
Barley - Kanby													
Grain Yield	0.454*	0.248	0.447**	0.322*	-0.322*	0.024	-0.161	0.014	0.455**	0.352**	0.107	0.072	0.131
Kernel Weight	0.115	0.119	-0.032	0.197	-0.199	-0.277	-0.034	0.028	0.342*	0.172	-0.156	0.207	
Test Weight	-0.251	-0.692**	0.129	0.061	-0.346**	-0.099	-0.350*	-0.221	0.049	-0.042	-0.327**		
Kernels/Spike	0.287	0.194	0.319**	0.149	0.078	0.261	0.108	0.032	0.294	0.437**			
Kernels/m row	0.108	0.165	0.208	0.041	-0.097	0.317	0.363*	-0.034	0.322*				
Spikes/m row	0.324*	0.091	0.609**	-0.044	0.130	0.304	0.081	0.285					
Plant Height	-0.224	0.126	0.269	-0.417*	0.301	0.474**	0.016						
Weed Score	-0.417*	-0.322	-0.110	-0.247	-0.643	-0.372*							
Lodging	0.257	0.665**	0.132	-0.223	-0.032								
Percent Protein	0.112	0.179	-0.018	-0.195									
Harvest Index	0.235	-0.364*	-0.219										
% Headed Tillers	0.189	0.183											
Days to Heading	-0.502*												
Triticale - 368A													
Grain Yield	0.184	0.192	0.339**	0.308*	0.061	-0.132	-0.429*	0.222	0.279*	0.065	-0.199	0.119	0.564**
Kernel Weight	-0.308*	-0.440**	0.058	0.203	0.049	-0.461**	-0.032	0.272	-0.180	-0.052	-0.097	0.375**	
Test Weight	-0.027	-0.697**	0.238	-0.014	-0.222	-0.676**	-0.512*	-0.592**	-0.360*	-0.099	-0.315*		
Kernels/spike	0.186	0.179	-0.227	0.382*	0.113	-0.407*	-0.303*	-0.134	-0.131	0.415**			
Kernesl/m row	0.195	0.228	-0.089	0.139	0.197	0.390*	0.146	-0.045	0.279*				
Spikes/m row	0.322*	0.135	0.321*	0.012	0.202	0.197	-0.322*	0.305*					
Plant Height	0.277	0.437*	0.240	-0.107	-0.113	0.448**	0.326*						
Weed Score	-0.292	0.283	0.002	-0.208	0.021	0.068							
Lodging	0.052	0.759*	-0.143	-0.209	0.399*								
Percent Protein	-0.172	0.040	0.087	0.118									
Harvest Index	-0.031	-0.123	-0.058										
% Headed Tillers	0.061	0.054											
Days to Heading	-0.152												

+ - Correlation coefficients for plants treated with 50 kgN/ha and 2-4 x 10^6 seeds/ha treatment.

*, ** - Significant, highly significant at $P_{.05}$ and $P_{.01}$ levels, respectively.

yield and headed tillers per m row in all cultivars at both locations. Nitrogen above 50 kg per ha significantly increased plant height and percent protein, but slightly decreased the harvest index of Newton wheat and barley. Percent protein of barley was not affected by nitrogen but the number of kernels per m row of barley increased with higher nitrogen at Manhattan. Significant reduction in percent headed tillers were associated with nitrogen rate and seeding rate above 50 kg and 2.4 million seed per ha, respectively, in Newton wheat and barley. However, nitrogen significantly increased the headed tillers in Sage wheat. Nitrogen above 50 kg per ha significantly extended the heading date two days in Sage wheat and triticale. High seeding rate significantly increased plant survival (i.e., low survival scores), but slightly reduced kernels per spike in all cultivars at Manhattan. Kernel and test weights were influenced little by plant density and nitrogen, although there was a trend towards relatively smaller and lighter seeds at rates above 50 kg nitrogen and 2.4 million seeds per ha, respectively.

Simple correlation coefficients between grain yield components and nitrogen and seeding rate treatments are shown in Table 10 for Manhattan. Grain yield, kernels per spike, kernels per m row, headed tillers and days to heading were positively correlated with nitrogen and seeding rate, respectively, in nearly all cultivars. Positive correlations were found between seeding rate and grain yield and winter survival in both wheats and barley.

Correlations among yield components of wheat, barley and triticale are shown in Tables 11a and 11b for Manhattan. Grain yield was positively correlated with spike number per m row and kernels per spike in all cultivars. Negative correlations were observed between grain yield and percent protein in barley. Kernel weight and test weight were negatively correlated with spikes and kernels per m row in Sage wheat and Kanby barley. Also correlations between test weight and lodging score were strongly negative in both wheats and triticale. Plant height was positively correlated with lodging in all cultivars, but was negatively correlated with harvest index in Sage wheat and triticale. Winter survival was positively correlated with grain yield in Sage wheat, barley and triticale. However, negative correlations were found between kernel weight and winter survival in Sage wheat and triticale (Tables 11a and 11b).

DISCUSSION

Analysis of growth:

A notable part of variation in accumulated dry matter was attributed to the effects of nitrogen and seeding rate treatments on leaf area index and leaf area duration. But, owing to post floral high temperatures and rapidly falling moisture levels, neither nitrogen nor seeding rate treatments raised the leaf area index above 4 at 50% flowering or thereafter in all cultivars. Alternatively, low values of LAI meant low leaf transpiring area.

Since the crop growing season after heading and, consequently, leaf area duration, were brief, accumulated dry matter was partly determined by the contribution of nitrogen and seeding rate treatments to early growth. The importance of pre-anthesis assimilation to the growth of the spike components was shown by several workers in wheat (Bidinger et al., 1977) and barley (Austin et al., 1980). Our results suggest that greater photosynthetic capacity can be achieved after flowering by increasing leaf longevity since that will not increase total vegetative growth (Bingham, 1966; Spiertz, 1978).

Nitrogen fertilization increased the leaf area index after heading by increasing the total number of headed tillers per m row and reducing the specific leaf weight. Also, the long persistence of realtively larger leaf areas in high nitrogen plots was mainly due to significant reduction in the relative rate of leaf area loss, $\overline{\text{RILA}}$, (i.e., negative relative rate of leaf area growth) and specific leaf weight (Bingham, 1966). However, low specific leaf weights of leaves at higher plant densities above 2-4 million seeds per ha were associated with small thin leaves of relatively lower leaf area per plant in all entries. Yet, the faster relative rate of loss of leaf area percent per day at high seeding rates was associated with non-significant reduction in leaf area duration because of higher leaf area indices at high plant densities. The greater leaf areas were found in high density treatments after heading. However, if the photosynthetic area of the spike was also considered, the apparent differences between treatments would be affected.

Increases in accumulated dry matter after heading were related to the increase in spike weight of the two wheats and barley, because the two measurements were similar (Watson et al., 1963). High crop growth rate and high relative growth rate percent per day accounted for increased accumulated dry matter with nitrogen fertilization (Brunori et al., 1980). Conversely, the marginal differences in accumulated dry matter with rates above 2.4 million seeds per ha were due to depressed relative growth rates at high plant densities (Kirkby, 1967). The leaf weight ratio indicated the proportion of photosynthetic to non-photosynthetic tissue (Hunt, 1978). Marginal differences in leaf weight ratio were observed, but the highest leaf weight ratios were found in the lowest seeding rate treatments (Kirkby, 1967). That indicated the relative increase in leaf thickness at low plant densities of Sage and Newton wheats and Kanby barley (Darwinkle, 1978a; Kirkby, 1967).

A wider variation in vegetative growth between wheat, barley and triticale cultivars after heading reflected differences in the duration of flower initiation, apical morphogenesis, leaf production and tillering. The relatively large leaf area per plant, higher crop growth rate, and, consequently, higher accumulated dry matter per m^2 indicated the potential of triticale to produce substantial amounts of vegetative mass and qualify as a fodder crop under intensive management. The long leaf area duration of barley was partly caused by its early heading. The two wheats developed relatively large leaf area index at flowering, but formed two compact a canopy thatlead to fast senescence of lower leaves. That consequently reduced leaf area index at the milk stage and caused shorter LAD than in triticale.

Tillering:

Contrasting tillering performance among cultivars was attributed to differences in tillering capacity and response to nitrogen and seeding rate treatments. Although barley had higher maximum tillering capacity than the wheats and triticale, it had significantly lower percent tillers that survived to maturity. The ability of Kanby barley to produce many tillers and their sensitivity to stress indicated the potential to adapt to a wide range of climatic conditions. Triticale had the lowest tillering capacity and headed tillers per m row, but it had the highest percent of stems initiated that produced kernels. To increase yield per unit area, continued breeding efforts of a short-straw triticale with tillering capacity similar to that of Newton wheat might be a worthwhile objective.

Variation in tiller number per m row indicated that the biomass distribution was affected by late season heat and water stress. The lower percentage headed tillers for 1980 than 1979 was due to severe reduction in tiller number with earlier onset of high temperatures and and water stress. Although Hurd (1971) argued that tillering may be an unwanted luxury in dry areas by wasting soil moisture, our study indicated that the final spike number per m row contributed significantly to the final yield per ha. Hence, the ability of wheat, barley and triticale to maintain a high number of kernel-bearing tillers until maturity was regarded as an important trait contributing to yield under intermittent late season heat and water stress in Kansas.

The percentage of shoots that survived and produced seeds was highest when no nitrogen fertilizer was applied or when seeding rate was low in all cultivars. The marginal but consistent effect of nitrogen fertilizer on reducing the percent headed tillers was considered an expression of increased competition between more numerous tillers for limited resources. Although increases in seeding rate increased the number of headed tillers by increasing the main culms that produced few tillers, the percent headed tillers was severely reduced by earlier competition and prolonged gradual tiller death in wheat and barley cultivars until maturity. Darwinkel (1978a) assumed that at higher densities tiller growth suffered because of increased competition for light.

Photosynthetic efficiency:

Because of the differences in grain/leaf ratios (W/LADA and W/LAI ΔWP/LADA) among species, higher grain yields of Newton and Sage wheats were caused, at least in part, by greater production of dry matter from the leaves during the pre or post floral periods (Watson et al., 1963; Kirkby, 1966; Brojevic et al., 1980). However, the comparatively lower grain leaf ratios of barley and triticale were caused by other factors. If photosynthate production limited grain yield, low grain/leaf ratio implied that the spikes of barley were not able to accomodate all the carbohydrate produced from relatively larger photosynthetic areas (Welbank, 1966: Langer et al., 1973). Like other six row barleys, the head of Kanby was commonly reduced in size with somewhat restricted glume capacity that probably aided in producing unacceptably small grains (Elliot et al., 1976). The largest spike capacity (i.e., high potential of grain size and numbers) of 368A triticale than Kanby barley and the two wheats, did not emphasize that view in spite of its 10-14 percent infertility. However, most workers (Sapra, 1973; Kaltsikes, 1979; Thomas et al., 1981) relate the inefficiency of triticale cultivars in producing high grain weight relative to their large leaf area to factors (i.e., shriveling and poor sink performance) not caused by poor supply nor incorporation of photosynthate into kernel dry matter. No distinction can be made between low rates of photosynthesis and a low rate of translocation in this study.

Differences in grain leaf ratio among cultivars were also related to their growth habits. Although Kanby barley produced large leaf area per m^2 and was shorter than 368A triticale and Sage wheat, early lodging perhaps made translocation of available photoassimilates to the grain proportionately lower to the photosynthetic potential (Brojevic et al., 1980). Also, the lack of lodging despite the higher plant height of 368A triticale than the wheats and barley cultivars, showed that part of the dry matter produced from the leaves was used for supporting tissue in the stems. Salminen et al. (1978) found that triticale showed an increase in weight of vegetative parts during seed maturation. That could partly explain why 368A triticale was most efficient in producing total dry matter per plant but was least efficient in producing economic yield. Lack of significant correlations between the final spike weight and kernel weight and significant correlations between leaf area and crop growth rate may also indicate the preferrential accumulation of the photosynthate into plant organs other than the kernels. Since Kanby barley had the lower percentage headed tillers but higher maximum tillering capacity than Newton and Sage wheats and triticale, the early rapid tiller death may not permit enough translocation of dry matter to the main shoot. Thus, rapid tiller removal was another sink for dry matter produced by Kanby barley leaves that contributed partly to its low grain leaf ratios. Senescence of leaves was postponed considerably more in triticale than in wheat and barley cultivars. It was likely under high temperatures and water stress that the rate of photosynthesis per unit leaf area after flowering of triticale was diminished by age. Thorne et al. (1975) reported low photosynthetic rates per unit leaf area in persistent wheat leaves. Differences among cultivars in leaf area duration and the number of headed tillers per m row may partly reflect relative efficiency of root systems to take up water and nutrients.

The study indicated the difficulty of showing the cause and effect relationship between green leaf area and grain yield in wheat, barley and triticale.

Nitrogen increased the number of kernels per dm^2 land area but decreased the number of kernels per leaf area indicating that nitrogen did not necessarily increase sink capacity relative to photosynthetic capacity. The increase in number of kernels per dm^2 land at high seeding rates was due to the increase in number of headed tillers per m row that compensated for a decrease in the number of kernels per spike in wheats and barley. Higher seeding rates above 2.4 million seeds per ha decreased the number of kernels per dm^2 leaf area, indicating the possibility that early leaf shading before flowering limited the genetic expression of kernel size and number.

Grain filling:

Our measurements of mean kernel filling rate of 1.3 mg $kernel^{-1}$ day^{-1} during May and June 1980 were slightly higher than the statistically predicted average of 1.1 mg $kernel^{-1}$ day^{-1} for wheat grown in the U. S. Great Plains during 1979 (Wiegand, 1981). Higher mean daily air temperatures of 23 C (i.e., 28.7 C and 16.9 maximum and minimum temp., respectively) during May and June 1980 as compared to 20.3 C (i.e., 26.9 C and 13.7 C maximum and minimum temp.) during 1979 for the same period possibly caused the faster initial filling rates (N.O.A.A. 1979, 1980) and hastened ripening of kernels. Wiegand et al. (1981) in Texas reported a 2.8 mg $kernel^{-1}$ decrease for one °C rise in air temperature.

Consequently, the depressed effective filling period duration hastened leaf senescence and prolonged gradual tiller death until maturity accounted for the lower final yield per ha during 1980 than during 1979 in all tested cultivars.

Lack of appreciable differences in kernel filling rate and effective filling period duration due to nitrogen fertilization or seeding rate indicated the limited contribution of those treatments to grain filling attributes. However, higher spike filling rates induced by high nitrogen fertilization were usually associated with depressed effective filling period and slightly reduced kernel weights. Since a negative correlation between grain yield and percent protein was demonstrated in all cultivars, it is logical that preferrential accumulation of nitrogen relative to starch with advancing stages of seed development slowed down the rate of dry matter accumulation in spite of higher initial filling rates and, consequently, depressed the effective kernel filling period duration and grain weight. Nitrogen fertilization increased the days to heading but decreased effective filling period duration by similar magnitudes. However, the association of low kernel weights of the two wheats and barley with low relative dry matter increments percent per day at higher seeding rates was a reflection of early competitive effects for substrates and nutrients. Because higher seeding rates depressed the harvest indices of those cultivars, it is not surprising that a greater proportion of the dry matter was accumulated in the straw and chaff. Limited translocation of the photosynthate also possibly disfavored the kernels. Lack of assimilates and nutrient uptake may not be the ultimate reason for cessation of kernel filling for all cultivars; genetic factors were possibly more important.

Significant differences in the mean filling rate and effective filling period duration among wheat, barley and triticale cultivars indicated that genetic effects on grain filling attributes should be expected. Since the cultivars differed significantly in days to 50% flowering, they experienced different regimes of water availability, temperature and other factors that partly contributed to the observed differences in the rate and effective duration in kernel filling. In the late flowering triticale, the grain filling period came during a time of high temperature that caused faster initial growth rates but very brief effective kernel filling period duration. That limited genetic potential for yield in triticale by further raising its percent protein (Spiertz, 1977, 1978) worsened the shirveling nature of the grain. The high kernel filling rate of barley was caused by early flowering and faster maturation. The shorter kernel filling period of barley than the two wheats can be explained by its rapid rate of dry matter accumulation. Thus, barley demonstrated that it may be advantageous to fill kernels at a maximum rate after attaining maximum spike capacity so that maturation and harvest can be completed early. Hence early flowering, rapid grain filling and short filling duration for barley may represent a better breeding objective in areas of short growing seasons. The effective filling duration of Newton and Sage wheats were relatively longer than those of triticale, which probably compensated for their lower kernel filling rates than triticale.

Comparing mean kernel filling rates and effective filling period duration of different cultivars was complicated by differences in average kernel size and maximum kernel weight, respectively. Differences in the spike filling rate among cultivars were partly influenced by kernel number per spike. A positive correlation between mean filling rate and effective filling period duration in Newton and Sage wheats showed the possibility of a positive interaction of the two features, and development of wheat cultivars of high mean filling rate and longer filling durations could be possible. However, Brunori and Mickle (1980) suggested that high rate and long filling duration may not combine easily in wheat. Difficulty was expressed in identifying grain maturity by Large-Feekes' scale because a frequent sampling during mealy ripe stage would have lead to a large number of harvested samples that were difficult to handle. Darwinkel (1980) suggested that the start of discolouration of chaff might be a useful indicator of cessation of kernel growth other than the loss of green area in other plant parts. Also, 50% flowering was found to be too early for the start of kernel filling although there was little ambiguity in its identification. Since effective filling period duration was a numberical function of the mean kernel filling rate, it is no wonder that individual observations were correlated. In correlating the means, however, some of the close numerical relationship was expected to be removed by averaging. There was scanty information on the physiological factors that controlled grain filling.

From correlation analyses, it is likely that physiological functions that determined kernel filling characteristics were, to some extent, independent of functions that controlled grain maturity. That should not preclude some genetic linkages.

Yield and yield components:

Differences in yield components among wheat, barley and triticale were sufficient to suggest that their tested cultivars had different patterns of attaining maximum yield. The two wheats, Newton and Sage, had more headed tillers per m row, higher kernel and test weight and winter survival; Kanby barley had more kernels per spike and headed tillers per m row but lowest percent protein; while 368A triticale had the highest kernels per spike and percent of shoots that survived and produced spikes.

The grain yield per ha of each cultivar highly depended on the expression of its predominating yield component. Thus, the yield of Newton and Sage wheats highly depended on the number of headed tillers per m row and 1000-kernels weight, and moderately depended on kernels per spike. Also, Pearman et al., (1978) found that semidwarf wheats had many kernels per spikelet. Grain yield of Kanby barley was dominated by the kernels per spike and kernels per m row. Yet, 368A triticale struggled to compensate for its lower winter survival, 1000-kernel weight and consequently low grain yield by retaining more of its produced shoots to produce larger spikes and higher kernel number per m row. However, comparisons for yield potential between wheats and triticale considered wheat as a long term end result of breeding and selection while 368A triticale was most recent and stemmed from newly synthesized species.

Close examination, however, showed that Sage wheat was less successful than Newton wheat at Manhattan because it was unable to maintain higher 1000-kernels and test weight of its large number of kernels per spike under the experimental conditions. As the growing season was more limiting late in the season, late determined yield components of percent headed tillers, 1000-kernels weight and test weight were strongly expressed in grain yield per ha apart from the early determined kernels per spike. The consistency in grain yield per ha of Newton and Sage wheat at Manhattan was possibly facilitated by their large and presistent flag leaves (i.e., considerably longer flag leaf area duration) and relatively longer effective kernel filling period duration because the yield components of 1000-kernel weight and test weight were likely to be influenced by the level and rate of dry matter supply. 1000-kernel weight and kernel number per spike were sometimes regarded as good characters for indirect selection for grain yield in wheat.

The realtively shorter straw and large grain weight contributed to large harvest indices of Newton wheat. However, the large harvest index of Kanby barley was mainly due to its shorter straw and large but compact head. The low grain yield of Kanby barley despite its high harvest index was mainly caused by early lodging. Negative correlations between test weight and lodging were found in Sage wheat, barley and triticale. Since the total dry matter did not change appreciably, it was possible for the developing spike to compete with the extending stem for assimilates and, consequently, produce large compact spikes on a less supporting, materially exhausted stem. Significant higher harvest indices of semidwarf wheat and barley suggested that they were better able to withstand disadvantageous changes in the environment.

The harvest index was positively correlated with grain yield and test weight for Newton wheat. The negative correlations between harvest index and plant height and lodgine, respectively, in 368A triticale and Kanby barley suggested that selection for stiff straw in Kanby barley and short in straw in 368A triticale may improve their grain straw ratios. The highest percent protein of the whole kernel of 368A triticale indicated its potential value as a feed grain irrespective of its characteristic shrunken kernels. In that regard, Thomas et al. (1980) suggested that maximum grain yield per ha was the most important breeding goal in triticale. That objective may be reached by increasing the number of headed tillers per m row, spikelet fertility and reduction in plant height of 368A triticale. However, Sage and Newton wheat may have produced higher total protein per ha because of their relatively higher number of kernels per m row and grain yield per ha than 368A triticale. The lower kernel weight and protein content of barley than the tested wheat cultivars suggested improvement of the feeding quality of the grain. While the notable increase in protein percent of Kanby barley with nitrogen fertilization would make it valuable for feeding ruminants. Although nitrogen increased the protein in wheat, barley and triticale cultivars, profitable use of nitrogen fertilizer may also require a price premium for portein.

Nitorgen had a strong positive association with grain yield, plant height and days to heading. Such associations were undesirable because correlations between grain yield and days to heading and plant height, respectively, were negative particularly in Newton wheat and 368A triticale. Lodging was negatively correlated to test weight and somewhat to kernel weight in all species' cultivars. Thus, nitrogen produced much kernels per m row of high protein percent but lower test weight especially in wheat and triticale. The fact that nitrogen increased the proportion of poorly filled grains in wheat was demonstrated by Bayles et al. (1978). The general effect of nitrogen fertilization in this study was to increase the number of headed tillers per m row and kernels per spike and to somewhat decrease the weight of the kernels in all entries especially during a more dry year, 1980. Increasing seeding rate from 2.4 to 3.6 million seeds per ha, however, resulted in little change in grain yield in spite of 3.6 million seeds per ha treatment produced the most dry matter per ha in all entries. That indicated the optimum grain yield was reached at seeding rates less than 3.6 million seeds per ha in all tested species' cultivars. Also, there was a trend towards smaller kernels at high seeding rates.

Generally seeding rate increased grain yield per ha by mainly increasing the number of headed tillers per m row in all species' cultivars. However, tillering was less important in 368A triticale than wheat and barley. The higher harvest index at low seeding rate did not sufficiently compensate for the low headed tillers per m row and grain yield per ha was low at low seeding rates.

Plant population differences resulting from the seeding rate treatments were not largely eliminated by the differences in plant survival in all species cultivars. Generally, Newton and Sage wheats had a higher yield potential than Kanby barley and triticale. Like other semidwarf wheats, however, Newton yielded grain of variable quality (test weight range 76.9 - 78.2, pretine percentage 12.2 - 13.1).

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APPENDIX

TABLE A1. Mean squares and their respective P values for F test for plant vegetative characters in wheat, barley and triticale at Manhattan, Kansas, 1980.

Source of Variation	Degrees of Freedom	LAI	LAR	LWR	SLA	SLW	LAD	CGR	RGR
		- - - - - - - - - - - -	- Mean Square and F Probability -					- - - - - - - - - - - -	
Block	2	0.1373	0.00007	0.0069	0.0007	595,254.5	4.5268	1107.6	0.0379
P		0.3053	0.9547	0.1054	0.9436	0.1896	0.3479	0.2009	0.0094
Cultivars Variety	3	3.4185	0.0027	0.1807	0.0620	987,547.6	106.8339	10,440.6	0.0645
P		0.0023	0.1727	0.0013	0.0028	0.0468	0.0001	0.0001	0.0001
Block X Variety	6	0.1393	0.0016	0.0103	0.0097	225,412.5	3.7176	459.1	0.0048
Nitrogen	2	0.7669	0.0037	0.0002	0.0672	1,320,033.5	30,395.0	3,411.4	0.0317
P		0.0001	0.1105	0.9519	0.0029	0.0289	0.0018	0.0097	0.0190
Variety X Nitrogen	6	0.2530	0.0007	0.0054	0.0923**	282,598.5	9.8500*	678.4	0.0499
P		0.0548	0.8652	0.1103	0.0001	0.5619	0.0452	0.4259	0.6678
Block X Variety X Nitrogen	16	0.0412	0.0013	0.0039	0.0076	321,345.8	1.37625	813.9	0.0096
Seeding Rate	2	0.0329	0.0022	0.0041	0.0334	99,706.8	1.01798	2,168.5	0.0308
P		0.7480	0.2644	0.2622	0.0674	0.7508	0.7855	0.0475	0.0212
Variety X Seeding Rate	6	0.1713	0.0011	0.0048	0.2102	1,616,209.3*	5.6672	484.5	0.0164
P		0.1925	0.6370	0.1620	0.1198	0.1228	0.2535	0.6306	0.9677
Nitrogen X Seeding Rate	4	0.1434	0.0005	0.0067	0.0261	334,870.3	1.5350	1,104.9	0.0054
P		0.2945	0.8516	0.0759	0.0798	0.4335	0.8316	0.1757	0.5729
Variety X Nitrogen X Seeding Rate	12	0.2136	0.0217	0.0539	0.02406*	566,375.6	8.7850*	737.0	0.0058
		0.0593	0.2087	0.0716	0.0389	0.1125	0.0354	0.3785	0.6625

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ levels, respectively.

TABLE A2. Mean tillers per m row for wheat, barley and triticale under different nitrogen levels at Manhattan, Kansas, 1980.

Specie	Cultivar	Nitrogen Rate	9 May	19 May	29 May	9 June	19 June	29 June	Mean Tillers	Headed Tillers
		kg/ha	- - - -	- - - -	- - - -	tillers/m row	- - - -	- - - -	- - - -	%
Wheat	Sage	0	176a	216a	132a	128a	121a	115a	118b	55a
		50	211a	236a	142a	146a	133a	100a	117b	50a
		100	214a	286a	150a	147a	137a	124a	131a	46b
Wheat	Newton	0	188b	209a	148a	129b	128a	99b	114b	55a
		50	205a	223ab	144a	140a	131a	105a	118b	53a
		100	208a	257a	154a	146a	138a	114a	126a	49b
Barley	Kanby	0	153b	179c	109b	100b	97b	84b	91c	59a
		50	160ab	181b	123a	109b	108b	86b	97b	54a
		100	196a	236a	122a	141a	122a	104a	113a	48b
Triticale	368A	0	118b	152c	81a	86b	78b	56c	67c	44b
		50	122b	166b	92a	89b	84ab	78b	81b	49b
		100	147a	189a	95a	100a	102a	94a	98a	52a

+Column means with the same letter are not significantly different at $P_{.05}$ level.

TABLE A3. Mean tillers per m row for wheat, barley and triticale under different seeding rates at Manhattan, Kansas, 1980.

Specie	Cultivar	Seeding Rate	9 May	19 May	29 May	9 June	19 June	29 June	Mean Tillers	Headed Tillers
		kg/ha	- - -	- - -	- - -	- - -	no/m row	- - -	- - -	%
Wheat	Sage	0	188b	202a	138a	127b	122a	103a	113b	56a
		50	188b	265a	143a	141ab	133a	122a	128a	48b
		100	225a	271a	144a	152a	137a	114a	126a	46b
Wheat	Newton	0	185a	188b	133a	129a	127a	99b	113c	60a
		50	205a	231ab	151a	142a	128a	102a	115b	48b
		100	209a	269a	162a	144a	142a	116a	129a	48b
Barley	Kanby	0	163a	181a	111a	110a	104a	84a	94b	51a
		50	164a	175a	113a	112a	102a	93a	98ab	56a
		100	170a	218a	118a	127a	115a	97a	106a	49b
Triticale	368A	0	116a	145a	81b	87a	79a	59b	69c	48b
		50	128a	169a	85b	90a	87a	76b	82b	49b
		100	142a	184a	101a	100a	98a	93a	96a	52a

Column means for each cultivar with the same letter are not significantly different at $P_{.05}$ level.

TABLE A4. Mean squares and probability for F test for leaf area, duration and its efficiency in grain production in kernel filling of wheat, barley and triticale at Manhattan, Kansas, 1980.

	Degrees of Freedom	LAA	LADA	W/LAA	W/LADA	KN/LAA	FLAA	FLADA	ΔW/FLAA	ΔW/FLADA	KN/FLAA	Effective Crop Growth Period
		- - - - - - Mean square and probability for F test - - - - - -										
Block	2	66.53	409.95	0.54	0.60	44.15	1.31	9.90	520.55*	0.85	32.06	56.50
P		0.2637	0.4972	0.6803	0.5823	0.2214	0.3556	0.3683	0.0047	0.7653	0.0573	0.1365
Variety	3	127.02*	1924.69*	22.26**	28.68**	309.01**	57.14**	105.75**	375.63*	5.93	124.87**	80.79*
P		0.0122	0.0272	0.0026	0.0065	0.0029	0.0037	0.0025	0.0088	0.3704	0.0001	0.0416
Block x variety	6	53.04	580.58	1.34	2.46	19.42	3.93	6.25	157.46	4.72	10.38	20.43
Nitrogen	2	300.02*	3599.86**	2.20**	8.20**	21.71**	9.81**	15.86**	36.95	18.35**	52.99**	8.11
P		0.0035	0.0029	0.0474	0.0067	0.0126	0.0178	0.0091	0.8279	0.0103	0.0122	0.9017
Variety x nitrogen	6	30.63	351.98	0.70	1.16	8.64	1.12	1.86	40.69	5.95	9.87	9.78
P		0.7061	0.5546	0.7983	0.3918	0.3997	0.4725	0.4392	0.8738	0.1217	0.4793	0.4054
Block x variety x nitrogen	16	36.43	417.07	0.59	1.18	7.79	1.93	2.48	51.41	2.97	14.36	29.30
Seed rate	2	33.47	258.97	8.01**	3.90*	28.17	1.76	1.66	83.85	20.02**	11.42	9.38
P		0.5090	0.6416	0.0056	0.0367	0.9967	0.2513	0.4168	0.3877	0.0046	0.3471	0.7111
Variety x seed rate	6	12.44	99.71	3.78*	4.72**	1.91	1.20	1.97	42.23	16.76**	9.89	23.99
P		0.9552	0.9830	0.0227	0.0016	0.3783	0.1491	0.3997	0.8148	0.0004	0.4771	0.5180
Nitrogen x seed rate	4	18.75	357.25	1.42	4.02*	19.72	0.22	0.33	36.06	5.37**	6.21	27.41
P		0.8201	0.6518	0.4049	0.0113	0.9987	0.9687	0.9479	0.7165	0.1864	0.6730	0.4151
Variety x nitrogen x seed rate	12	41.12	555.18	2.98*	2.71*	13.48	0.71	0.83	83.16	5.40	11.07	24.86
P		0.6065	0.4984	0.0302	0.0137	0.9197	0.7991	0.9347	0.4990	0.1169	0.4228	0.5440
Block x variety x nitrogen x seed rate	48	48.81	578.20	1.38	1.10	28.40	1.16	1.86	86.7	3.32	------	27.32

*, ** - Significant, highly significant at $P_{.05}$ and $P_{.01}$ levels, respectively. KN = kernels/m row; FLADA = flag leaf area duration from heading to maturity. LA = leaf area (dm^2/m row); LADA = leaf area duration from anthesis to maturity (days); ΔW = grain weight (mg/dm^2); W = change in spike weight from anthesis to maturity (mg); FLAA = flag leaf area at anthesis (dm^2). KN/LAA, W/LADA, ΔW/FLADA - grain/leaf area ratios.

TABLE A5. Mean square and probability for F test for grain filling characteristics of wheat, barley and triticale at Manhattan, Kansas, 1980.

Source of Variation	Degree of Variation	Final Weight (spike)	Weight at Anthesis (spike)	Mean Filling Rate (spike) mg/spike/day	Final Weight (kernel) mg/kernel	Mean Filling Rate (kernel) mg/kernel/day	Relative Filling Rate (kernel) mg/mg/day	Effective Filling Rate (kernel) days	Harvest Index
		Mean Square and F Probability							
Block	2	29447.51	2732.06	518.32	27.9	.02	.11	14.34	0.54
P		0.2915	0.1765	0.0632	0.7084	0.7594	0.7084	0.9496	0.0375
Variety	3	502174.63**	50145.18**	45,093.33**	2890.33**	5.15**	2.88**	4503.83**	3.50**
P		0.0001	0.0001	0.0001	0.0001	0.0015	0.0006	0.0001	0.0002
Block x variety	6	8115.71	1427.66	159.67	12.65	0.65	0.10	492.42	0.24
Nitrogen	2	305300.02**	793.39	1,131.95*	797.00**	0.35	0.30	1002.68*	0.05
P		0.0001	0.5965	0.0280	0.0001	0.6609	0.6169	0.0344	0.5437
Variety x nitrogen	6	27716.68*	1136.88	257.65	91.03*	0.84	0.22	363.15	0.11
P		0.0049	0.2321	0.2140	0.0014	0.3416	0.6592	0.2711	0.7164
Block x variety x nitrogen	16	5619.62	3723.05	276.56	14.29	0.83	0.43	465.96	0.27
Seeding rate	2	99439.50*	6347.89*	67.13	202.03	3.64*	1.83**	171.76	0.02
P		0.0196	0.0212	0.6866	0.0588	0.0107	0.0059	0.5425	0.8916
Varelty x seeding rate	6	66166.50*	3050.52	35.09	156.83		0.26	534.32	0.19
P		0.0189	0.6941	0.1235	0.0465	0.9738	0.5639	0.0955	0.3104
Nitrogen x seeding rate	4	164386.02**	6820.51	151.55	268.01**	0.34	0.10	423.99	0.20
P		0.0001	0.2350	0.4974	0.0005	0.7605	0.8616	0.2087	0.2743
Variety x nitrogen x seeding rate	59	102298.00**	3886.74	164.04	254.87**	0.61	0.32	407.27	0.20
P		0.0001	0.6282	0.5293	0.0005	0.6124	0.4609	0.1693	0.2376
Block x nitrogen x seeding rate	107	23280.72	1519.16	177.13	67.16	0.90	0.31	277.28	1.53

*, ** - Significant and highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE A6. Mean squares and probability, (P) values for F test for yield components at Manhattan, Kansas, 1979.

Source of Variation	Degrees of Freedom	Mean Square and Probability Values - Yield Components								
		Mean Squares and F Probability								
		Grain Yield Kg/Ha	Headed Tillers rs/m row	Test Weight Kg/HL	Kernel Weight gm	Plant Height cm	Heading Date Julien	Lodging	Weed Density	Winter Survival
Block	3	7,578,180.7	4,201.6	10.9	27.5	180.4	2.3	3.2	7.3	0.6
P		0.0001	0.0001	0.5451	0.0002	0.0137	0.0001	0.0001	0.0001	0.0088
Variety	3	17,001,652.0	21,383.5	2,186.6	128.9	23,334.3	370.4	46.4	30.5	47.1
P		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Block X Variety	9	377,626.7	205.4	20.2	9.5	134.0	2.5	5.7	4.5	0.3
Nitrogen	2	1,894,003.6	5,602.6	42.2	56.5	667.5	1.9	9.0	0.6	---
P		0.0001	0.0001	0.0682	0.0001	0.0001	0.0001	0.0001	0.2006	
Variety X Nitrogen	6	551,156.2	471.2	12.4	5.4	28.0	0.2	0.7	1.1	---
P		0.0120	0.2769	0.5556	0.1713	0.7375	0.1048	0.0215	0.0026	
Block X Variety X Nitrogen	24	239,678.9	530.8	45.4	3.4	36.2	0.2	0.6	1.8	
Seeding Rate	2	5,287,173.3	1,457.2	25.4	5.5	148.2	1.6	2.1	4.7	8.4
P		0.0001	0.0233	0.1948	0.2159	0.0501	0.0001	0.0011	0.0289	0.0001
Variety X Seeding Rate	6	167,093.6	158.9	5.3	1.1	108.5	0.1	0.6	1.7	0.1
P		0.5000	0.8552	0.9092	0.9325	0.0448	1.0000	0.0654	0.0551	0.4792
Nitrogen X Seeding Rate	4	187,378.9	186.7	29.5	3.1	8.8	1.0	0.1	0.3	---
P		0.4086	0.7302	0.1115	0.4777	0.9450	0.0001	0.9456	0.8035	
Variety X Nitrogen X Seeding Rate	12	115,048.0	305.8	13.6	4.9	34.7	0.1	0.7	0.9	---
P		0.8189	0.6180	0.5499	0.1867	0.7161	1.0000	0.0174	0.3403	
Block X Variety X Nitrogen X Seeding Rate	48	211,345.2	196.4	28.1	7.5	87.6	0.2	0.1	1.1	

TABLE A7. Mean grain yield, yield components, lodging and weed scores of wheat, barley, triticale under different nitrogen rates at Manhattan, Kansas, 1979.

Specie	Cultivar	Nitrogen kh/Ha	Grain Yield kg/Ha	Headed Tillers no./m row	Test Weight kg/HL	Kernel Weight gm/1000	Plant Height cm	Heading Date Julien	Lodging Score 1-9	Weed Density 1-9
Wheat	Sage	0	2,276.9 b+	93.9 b	72.8 a	30.4 a	106.4 b	143 b	6.2 a	3.8 a
		50	2,606.2 ab	114.6 ab	71.8 a	29.1 ab	113.1 ab	143 b	6.5 a	4.0 a
		100	2,818.8 a	127.2 a	71.8 a	27.9 b	114.6 a	144 a	7.1 a	3.2 a
Wheat	Newton	0	2,182.6 b	79.0 a	70.9 a	27.5 a	90.7 b	142 a	6.5 ba	3.9 a
		50	2,642.4 a	104.8 a	72.1 a	26.9 b	96.1 ab	142 a	6.3 b	3.3 a
		100	2,795.6 a	198.3 a	69.7 b	26.6 b	94.6 a	143 a	7.3.a	3.4 a
Barley	Kanby	0	1,257.6 b	66.4 a	57.1 a	32.1 a	92.6 b	140 a	9.0 ab	4.9 a
		50	1,942.5 a	84.5 a	57.8 a	31.9 a	102.9 a	140 a	8.7 b	5.0 a
		100	1,607.5 ab	82.6 a	59.4 a	30.5 a	98.0 ab	141 a	9.3 a	4.0 a
									0.4	3.7
Triticale	368A	0	1,261.9 a	49.9 b	57.8 a	27.6 ab	146.4 a	147 a	7.4 a	5.2 a
		50	1,124.3 a	59.8 a	60.2 a	28.0 a	150.6 a	147 a	6.4 b	5.6 a
		100	1,188.9 a	54.9 ab	56.9 a	25.7 b	152.4 b	149 b	7.6 a	5.6 a

+Means within the same column for each cultivar having the same letter are not significantly different at $P_{.05}$ level (New Duncan's Multiple Range Test).

TABLE A8. Mean grain yield and yield components, lodging, weed density and plant survival under different seeding rates at Manhattan, Kansas, 1979.

Specie	Cultivar	Seeding Rate 10^6 seeds/Ha	Grain Yield Kg/Ha	Headed Tillers no./m row	Test Weight Kg/HL	Kernel Weight gm/1000	Plant Height cm	Heading Date Julien	Lodging Score 1-9	Weed Score 1-9	Survival Score 1-9
Wheat	Sage	1.2	2,359.5 b	107.1 a	72.9 a	29.2 a	112.2 a	144 a	6.3 b	3.8 a	6.57 a
		2.4	2,555.4 ab	109.4 a	72.4 a	29.2 a	112.3 a	144 a	6.5 ab	4.0 a	6.20 a
		3.6	2,773.2 a	118.8 a	71.3 a	29.1 a	109.9 a	143 b	6.9 a	3.1 b	5.40 b
Wheat	Newton	1.2	1,988.8 b	87.2 a	71.5 a	27.4 a	93.7 a	143 a	6.3 b	3.9	6.5 b
		2.4	2,733.9 a	100.2 a	70.4 a	28.1 a	94.0 a	142 a	6.7 a	3.3	6.7 b
		3.6	2,830.6 a	193.8 a	69.4 a	27.4 a	93.7 a	142 a	6.8 a	3.4	6.9 a
Barley	Kanby	1.2	1,114.1 b	174.5 a	58.9 a	30.7 a	96.1 a	141 a	9.1 a	4.9 a	9.2 a
		2.4	1,853.3 a	178.4 a	57.8 a	31.9 a	97.6 a	140 b	8.9 a	5.0 a	8.7 b
		3.6	1,840.1 a	180.6 a	57.5 a	31.4 a	99.9 a	140 b	9.1 a	4.0 b	8.2 c
Triticale	368A	1.2	913.5 b	45.3 b	59.6 a	26.6 a	143.2 b	150 a	6.7 a	5.3 a	7.9 a
		2.4	1,356.6 a	60.5 a	57.9 a	27.7 a	151.8 a	150 a	7.3 a	5.6 a	7.7 a
		3.6	1,308.9 a	59.0 a	56.9 a	27.5 a	154.2 a	151 a	7.3 a	5.6 a	7.4 b

Means within column for each cultivar having the same letter are not significantly different at $P_{.05}$ level (New Duncan's Multiple Range Test).

TABLE A9. Mean squares and probability (P) values for F test for yield components, Minneola, 1979.

Source of Variation	Degrees of Freedom	Grain Yield kg/ha	Headed Tillers m. row	Test Weight kg/hl	Kernel Weight gm.	Plant Height cm.	Lodging	Weed Density	Winter Survival
Block	3	331,833.1	2,352.5	4.3	7.2	531.9	11.9	14.5	5.7
P		0.0287	0.0029	0.0331	0.1519	0.5932	0.0001	0.0003	0.0020
Variety	3	26,905,740.6*	11,827.9*	3,666.5*	151.1*	19,328.0*	331.1*	6.2*	15.1*
P		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0287	0.0001
Block X Variety	9	552,557.0	1,615.8	2.8	5.1	949.5	19.5	11.21	3.9
Nitrogen	2	137,848.5	1,072.2*	22.8*	30.8*	2,440.5*	1.5	0.4	---
P		0.2733	0.0030	0.0001	0.0010	0.0336	0.1781	0.8330	
Variety X Nitrogen	6	49,762.6	1,075.2*	0.2	11.0**	2,940.8	1.4	1.1	---
P		0.8234	0.0394	0.9924	0.0173	0.1872	0.7565	0.7424	
Block X Variety X Nitrogen	24	357,765.4	512.0	0.6	3.6	1,378.0	0.7	4.1	
Seeding Rate	2	6,385,090	1,008.4*	71.3*	0.5	124.6	0.5	0.1	0.78
P		0.0001	0.0375	0.0001	0.8880	0.8113	0.5277	0.9690	0.4832
Variety X Seeding Rage	6	828,072.6**	466.2	0.1	4.2	1,154.6	0.7	1.8	0.62
P		0.0001	0.4193	0.9986	0.3876	0.2277	0.5407	0.4962	0.7492
Nitrogen X Seeding Rate	4	157,656.5	131.9	2.6	3.3	1,00518	1.0	1.9	---
P		0.2081	0.8846	0.1312	0.5147	0.3112	0.3053	0.4215	
Variety X Nitrogen X Seeding Rate	12	78,848.9	540.7	0.6	2.0	1,064.6	1.2	1.0	---
P		0.6928	0.2116	0.9587	0.8982	0.2445	0.1625	0.9260	
Block X Variety X Nitrogen X Seeding Rate	48	196,374.3	614.2	2.9	4.8	2,175.1	2.3	7.3	

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE A10. Mean grain yield, yield components and lodging, weed and plant survival scores of wheat, barley and triticale at Manhattan and Minneola, 1979.

Specie	Cultivar	Grain Yield Kg/Ha	Headed Tillers no./m row	Test Weight Kg/HL	Kernel Weight g/1000	Plant Height cm	Heading Date Julien	Lodging Score 1-9	Weed Score 1-9	Survival Score 1-9
					Manhattan					
Wheat	Sage	2,568 a+	111.9 a	72.2 a	29.2 b	111.4 b	22 b	6.6 b	3.6 b	6.1 d
Wheat	Newton	2,532 a	93.9 b	70.9 a	27.7 b	93.8 c	21 c	6.6 b	3.5 b	6.7 c
Barley	Kanby	1,602 b	77.9 c	58.1 b	31.4 a	97.9 c	19 d	9.0 a	4.6 a	8.7 a
Triticale	368A	1,191 c	54.9 d	58.2 b	27.1 c	149.8 a	26 a	7.1 b	5.5 a	7.7 b
					Minneola					
Wheat	Sage	3,058 a	119.5 a	78.3 a	28.8 a	84.6 b	---	0.9 b	4.5 a	6.9 b
Wheat	Newton	3,108 a	113.6 ab	78.1 a	26.3 b	79.6 b	---	0.1 b	4.7 a	6.6 b
Barley	Kanby	1,811 b	94.9 bc	61.7 b	27.3 b	78.4 b	---	6.8 a	4.6 a	8.1 a
Triticale	368A	1,413 c	79.8 c	59.8 c	23.9 c	150.4 a	---	1.5 b	5.4.a	7.3 ab

+Means witin the same column for each cultivar having the same letter are not significantly different at $P_{.05}$ level (New Duncan's Multiple Range Test).

TABLE A11. Correlation coefficients of nitrogen with grain yield and yield components for wheat, barley and triticale cultivars at Manhattan and Minneola, Kansas, 1979.

Specie	Cultivar	Grain Yield	Headed Tillers	Test Weight	Kernel Weight	Plant Height	Lodging Score	Weed Score	Heading Date
		r							
					Manhattan				
Wheat	Sage	0.4370**	0.49806**	-0.00664	-0.47617**	0.45122**	0.37761*	0.24679	0.14143
Wheat	Newton	0.36416*	0.32808*	-0.07755	-0.60304**	0.24975	0.34866*	0.21376	0.25759
Barley	Kanby	0.16829	0.08238	0.02982	-0.39297*	0.31696	0.18235	0.00057	0.37802*
Triticale	368A	-0.04624	0.13757	-0.02982	-0.26016	0.27067	0.06319	0.14065	0.40959**
					Minneola				
Wheat	Sage	0.12605	0.09920	-0.15693	-0.52971**	0.47064**	0.19241	0.10071	-------
Wheat	Newton	0.02485	0.00513	-0.37117*	-0.35162*	0.25694	0.27588	0.26560	-------
Barley	Kanby	0.06494	0.27009	-0.22815	c0.19128	0.28839	0.00006	0.00015	-------
Triticale	368A	0.10569	0.03757	-0.68981**	c(.74850**	0.31447	0.07442	0.03784	-------

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE A12. Correlation coefficients of planting rate with grain yield and yield components for wheat, barley and *triticale* at Manhattan and Minneola, 1979.

Species	Cultivar	Grain Yield	Headed Tillers	Test Weight	Kernel Weight	Plant Height	Lodging Score	Weed Score	Survival Score	Heading Date
		r								
					Manhattan					
Wheat	Sage	0.36404*	0.20640	-0.19747	0.06569	-0.05319	0.29173	-0.24801	-0.80995**	-0.14213
Wheat	Newton	0.52204**	0.12135	-0.07528	0.10243	-0.00548	0.24469	-0.21258	-0.61076**	-0.34212**
Barley	Kanby	0.31365*	0.04233	-0.20634	0.12611	0.20412	0.02833	-0.23671	-0.69283**	-0.25279
Triticale	368A	0.310508	0.37032	-0.18475	0.11958	0.50171**	0.21887	0.15159	-0.61223**	-0.27211
					Minneola					
Wheat	Sage	0.36682*	0.02274	-0.59330**	0.21402	-0.08517	0.10935	0.04111	-0.16784	-------
Wheat	Newton	0.58066**	0.11179	0.76701**	-0.01202	0.03440	0.06473	-0.26632	0.07313	-------
Barley	Kanby	0.077914**	0.30641	0.58170**	0.30664	-0.01076	0.02377	0.02685	0.16284	-------
Triticale	368A	0.17411	0.02277	0.40692*	-0.11179	0.33933	-0.13223	0.03459	0.09998	-------

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE A13. Mean squares and respective F probabilities, P for grain yield and yield components at *Manhattan*, Kansas, 1980.

Source of Variation	DF	Grain Yield kg/Ha	Headed Tillers no./m	Headed Tillers %	Kernel Weight gm/1000	Test Weight kg/Hl	Kernels no./m	Kernels no./spike	Protein %	Harvest Index	Maximum Total Dry Matter gm/plot	Plant Height cm	Heading Date Julien	Lodging Score 1-9	Survival Score 1-9
		---------	-------	-Mean Squares	and F	Probabilities	for	-------							
Block	2	2,254,998.0	3,091.0	363.2	29.5*	2.2	0.4	68.4	0.4	0.2	1,356.6	153.9	5.6	0.3	1.6
P		0.0001	0.0133	0.0134	0.0123	0.5759	0.8131	0.0146	0.4508	0.5135	0.3035	0.0023	0.001	0.6976	0.0011
Variety	3	1,470,628.8	19,639.9*	852.9*	21.6	1008.5	0.6	67.6	11.4	0.4	27,439.5	19,919.7	59.7	77.2	107.8
P		0.0001	0.0001	0.0001	0.0128	0.0001	0.7902	0.0001	0.0001	0.3729	0.0001	0.0001	0.0001	0.0001	0.0001
Block X Variety	6	282,188.1	1,520.7	178.9	25.3	9.2	1.7	17.5	0.7	0.4	1,036.7	150.4	1.6	1.8	0.6
Nitrogen	2	217,553.1	932.5	712.9*	0.5	3.5	8.4	31.7	6.5	0.3	7,261.8	38.2	14.7	1.2	---
P		0.0001	0.0215	0.0162	0.9076	0.4162	0.0136	0.1282	0.0001	0.4032	0.0031	0.1922	0.0001	0.2420	
Variety X Nitrogen	6	150,550.0	355.7	242.5*	11.13	4.9	4.8	68.9	0.5	0.3	1,457.7	20.0	1.5	0.6	---
P		0.0003	0.1341	0.0348	0.1153	0.2918	0.0256	0.0008	0.4332	0.4426	0.2694	0.5058	0.0010	0.6622	
Block X Variety X Nitrogen	16	155,740.8	417.4	138.3	4.3	6.9	1.9	19.1	0.9	0.3	1,770.3	18.3	0.9	1.0	---
Seed Rate	2	2,584,805.3	382.6	89.9	6.2	12.1	3.1	13.9	0.6	0.3	3,685.9	32.3	2.3	0.3	2.8
P		0.0001	0.3714	0.542	0.3725	0.0537	0.1842	0.3968	0.3478	0.3811	0.0446	0.2456	0.0023	0.6946	0.0001
Variety X Seed Rate	6	30,347.5	989.5*	50.5	8.2	5.6	0.9	23.3	0.4	0.3	1,630.6	13.7	0.1	1.4	0.12
P		0.3930	0.0211	0.7642	0.2613	0.2236	0.7943	0.1758	0.6276	0.4399	0.2088	0.7196	0.8863	0.1491	
Nitrogen X Seed Rate	4	53,826.2	703.6	154.9	4.3	3.1	2.3	15.8	0.4	0.3	1,978.7	72.4	0.2	2.2	---
P		0.1258	0.0537	0.4321	0.5984	0.5279	0.2848	0.3836	0.5132	0.4174	0.1477	0.0196	0.6825	0.0379	
Variety X Nitrogen X Seed Rate	12	48,263.3	248.3	116.0	9.2	2.7	1.0	28.1	0.6	0.3	1,379.3	46.1	0.1	1.4	---
P		0.0958	0.4621	0.6472	0.1563	0.7420	0.8534	0.0588	0.4136	0.4675	0.2832	0.0381	0.9683	0.0813	
Block X Variety X Nitrogen X Seed Rate	48	28,336.9	470.8	220.6	6.1	3.9	1.78	14.8	0.5	0.3	1,109.7	22.3	0.3	0.8	---

*, ** - Significant; highly significant at $P_{.05}$ and $P_{.01}$ level, respectively.

TABLE A14. The effect of nitrogen on grain yield, yield components, lodging and survival for wheat, barley and triticale at Manhattan, Kansas, 1980.

Specie	Cultivar	Nitrogen	Grain Yield Kg/Ha	Headed Tillers no./m	Headed Tillers %	Kernel Weight gm/1000	Test Weight Kg/Hl	Kernels no./spike	Kernels X 10^3 no./m row	Protein %	Harvest Index	Maximum Tot. Dry Matter gm/plot	Plant Height cm	Heading Julien Days	Lodging Score 1-9
Wheat	Sage	0	1375a +	132a	63b	29.0a	78.2a	20a	4.6a	11.9a	0.44a	166a	94a	140b	3.4a
		50	1786a	142a	65a	29.3a	78.3a	21a	4.2a	12.1a	0.47a	179a	93a	141b	3.0a
		100	1812b	150a	65a	28.9a	78.1a	22a	4.8a	13.0a	0.43a	181a	94a	142a	4.0a
Wheat	Newton	0	1693c	148a	64a	31.7a	79.8a	18a	3.5a	12.4a	0.47a	159b	89a	140b	3.0a
		50	1804b	144a	70a	30.0a	78.9a	21a	5.3a	12.7ab	0.48a	212a	90a	141a	3.0a
		100	2298a	154a	71a	30.0a	79.4a	24b	5.9b	13.3b	0.50a	193a	93a	141a	3.1a
Barley	Kanby	0	1386b	109a	47a	30.3a	68.5a	27b	4.2a	11.6a	0.50a	153b	90b	137b	6.4a
		50	1393b	123a	57b	30.4a	68.8a	29ab	4.2a	12.1a	0.50a	173ab	93ab	138a	6.8a
		100	1691a	121a	63b	30.9a	67.6a	33a	5.9a	12.1a	0.50a	191a	95a	138a	6.8a
Triticale	368A	0	1065b	81a	60a	29.9a	67.0b	28b	4.4a	13.4b	0.39a	234a	148a	143b	3.4a
		50	1456a	92a	70a	31.8a	69.5a	31ab	4.9a	13.5b	0.39a	255a	148a	145a	3.6a
		100	1682a	95a	72a	31.9a	67.9ab	33b	4.5a	14.0a	0.41a	235a	149a	146a	3.7a

+Means within the same column for each cultivar with same letter are not statistically significant at $P_{.05}$ level (New Duncan's Multiple Range Test).

TABLE A15. The effect of seeding rate on grain yield, yield components, lodging and survival for wheat, barley and triticale at Manhattan, Kansas, 1980.

Specie	Cultivar	Seeding Rate 10^6 seeds/Ha	Grain Yield Kg/Ha	Headed Tillers no./m row	Headed Tillers %	Kernel Weight gm/1000	Test Weight Kg/Hl	Kernels no./spike	Kernels X 10^3 no./m row	Protein %	Harvest Index	Maximum Tot. Dry Matter gm/plot	Plant Height cm	Heading Julien Days	Lodging Score 1-9	Survival Score 1-9
Wheat	Sage	1.2	1302b+	138a	64a	29.5a	78.3a	21a	4.6a	13.2a	0.45a	167a	102.3a	142a	3.8a	3.5b
		2.4	1707a	143a	58a	29.0a	78.4a	23a	4.6a	13.2a	0.45a	180a	105.4a	142a	3.4a	3.7ab
		3.6	1965c	143a	63a	28.0a	78.0a	20a	4.4a	14.0a	0.44a	182a	104.9a	140b	3.0a	4.1a
Wheat	Newton	1.2	1614b	133a	70a	29.8a	79.7a	22a	5.0a	12.4a	0.49a	183a	89.7a	142a	3.0a	5.3b
		2.4	2018a	151ab	66a	30.5a	79.4a	21a	4.8a	12.7a	0.49a	198a	90.6a	140b	2.7a	5.6b
		3.6	2164a	162b	69a	30.8a	78.9a	21a	4.8a	13.2a	0.47a	183a	91.7a	140b	3.1a	6.0a
Barley	Kanby	1.2	1232b	113a	58a	30.0a	70.0a	28a	3.9b	11.6a	0.50a	153a	91.2a	138a	6.3a	7.7a
		2.4	1558a	122a	58a	30.8a	68.4a	32a	5.1a	12.1a	0.49a	173a	92.5a	137a	6.6a	7.8a
		3.6	1680a	128a	53a	30.4a	66.6a	29a	5.1a	12.1a	0.48a	191a	93.5a	137a	6.9a	8.0a
Triticale	368A	1.2	1146b	81a	69a	33.7a	68.1a	31a	4.2a	13.1a	0.41a	218b	146.9a	145a	3.1b	7.7b
		2.4	1493ab	85a	67a	30.7ab	68.3a	32a	4.7a	13.0a	0.40a	237ab	148.6a	144a	3.6ab	7.7b
		3.6	1565a	101a	66a	30.0b	68.1a	29a	4.8a	13.5a	0.37a	269a	150.7a	144a	4.0a	8.4a

+Means within each column for each cultivar with the same letter are not significantly different at $P_{.05}$ (New Duncan's Multiple Range Test).

TABLE A16. Mean square and their probability for F test for yield and yield components of wheat, barley and triticale at Manhattan and Minneola, Kansas during 1979 and 1980.

Source of Variation	Degree of Variation	Grain Yield kg/ha	Kernel Weight gm/1000 kernels	Test Weight kg/hl	Headed Tillers m/row	Plant Height cm	Lodging Score 1-9	Weed Score 1-9	Survival Score 1-9
		- - - - - - - -	- - - - - - - -	- - - - - -	- Mean Square and	P for F Test - -	- - - - - -	- - - - - -	- - - - - -
Location	1	31607420.4**	842.6**	1036.7**	31081.1**	1324.2**	194.8**	124.9**	0.89
P		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.3471
Variety	3	21081957.2**	44.6	4372.8*	29320.1*	43203.7**	377.5*	8.7*	50.1*
P		0.0001	0.7911	0.0207	0.0208	0.0001	0.0323	0.04313	0.0001
Location x varieties	3	6910176.7**	125.5**	247.3**	1667.7	82.9	29.53**	0.81	8.3*
P		0.0001	0.0001	0.0001	0.0654	0.1412	0.0001	0.7969	0.0001
Nitrogen	2	1373948.5**	18.3	22.2	1423.3*	357.1**	2.7	3.26*	------
P		0.0006	0.0638	0.0638	0.0225	0.0005	0.0755	0.0480	
Varieties x nitrogen	6	137067.9	9.4	0.9	1131.2	0.8	0.2	1.1	------
P		0.5995	0.1319	0.9891	0.1359	0.9999	0.9956	0.8292	
Location x varieties x nitrogen	8	271648.8	12.6*	5.6	225.0	96.8	0.8	0.7	------
P		0.1545	0.0272	0.1317	0.9547	0.0338	0.9222	0.9649	
Seed rate	2	9035653.5**	3.1	20.1**	936.4	84.0	0.9	0.9	7.2*
P		0.0001	0.5765	0.0040	0.2581	0.1595	0.5978	0.6853	0.013
Varieties x seed rate	6	404863.8*	3.0	0.5	978.5	30.0	0.9	1.6	0.7
P		0.0396	0.7795	0.9919	0.2066	0.6804	0.8023	0.6800	0.4835
Nitrogen x seed rate	4	102415.5	5.6	0.9	448.9	78.5	0.9	1.6	-----
P		0.6844	0.4098	0.9132	0.6250	0.1446	0.5484	0.6182	
Variety x nitrogen x seed rate	12	42206.4	6.8	1.2	378.0	67.2	1.5	0.9	-----
P		0.9964	0.2785	0.9795	0.8792	0.1336	0.9239	0.9568	
Location x variety x nitrogen x seed rate	201	17559.1**	5.6	3.5**	686.7**	45.3**	0.9**	2.4**	-----
P		0.0001		0.0001	0.0001	0.0001	0.0001	0.0029	

Error mean square, location x varieties x seed rate = 1.3, df = 88, and P = 0.0011** for grain yield.

*, ** - Significant, highly significant at $P_{.05}$ and $P_{.01}$, respectively.

ANALYSIS OF GROWTH AND YIELD OF WHEAT, BARLEY AND TRITICALE IN A SEMI-ARID ENVIRONMENT

by

EMMANUEL R. MORRIS

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ABSTRACT

Production practices for new wheat plant types and, to a large degree, for barley and triticale, are modifications of practices used for old, "standard" wheat cultivars. We compared agronomic potential and requirements of tall and semi-dwarf wheat cultivars, barley and triticale under different nitrogen fertilizer levels and seeding rates. Separate analyses of plant and kernel growth and yield components suggested ways to improve cultivars of the three species. Field studies were conducted on summer-fallowed sites on a tully silt clay loam soil at Manhattan in Northeast Kansas and on a harney silt loam soil at Minneola in Southeast Kansas during the 1979 and 1980 crop years. A split-plot factorial design with four cultivars as main plots, three nitrogen fertilizer rates as subplots, and three seeding rates as sub-subplots in four replications was used. Four cultivars -- 'Newton' and 'Sage' wheats, 'Kanby' barley and '368A' triticale -- were seeded at rates of 1.2, 2.4 and 3.6 million seeds per ha for each cultivar. Nitrogen rates of 0, 50, and 100 Kg N per ha as ammonium nitrate were top-dressed during early spring. Samples for yield and yield component determinations were taken at harvest. A growth analysis study was conducted on a separate but similar adjacent experiment at Manhattan during 1980. Samples for plant growth analysis and kernel filling rate determinations were collected at 11-day intervals from the onset of flowering during May until harvest in late June.

Nitrogen fertilization and seeding rate increased total accumulated dry matter per m^2 in wheat, barley and triticale cultivars. Early

nitrogen fertilization and seeding rate, respectively, increased the number of headed tillers per m row and hence the spike density for wheat, barley and triticale cultivars. Leaf area index, LAI, and kernels per m row were increased by nitrogen fertilization and seeding rates above 2.4 million seeds per ha in all cultivars. Nitrogen fertilization above 50 kg N per ha prolonged duration of green leaf area, LAD, and reduced specific leaf weight, SLW, and the relative rate of leaf area loss, $\overline{RILA}$, in wheat, barley and triticale. Seeding rate above 2.4 million seeds per ha gave thin but relatively smaller leaves and reduced the specific leaf weight, SLW, particularly in the two wheats and barley. Seeding rates above 2.4 million seeds per ha accelerated leaf area loss (i.e., more negative $\overline{RILA}$) in the two wheats and barley. Heavy seeding rates significantly increased survival of barley and triticale. Tillering was less important as yield determinant in triticale than in the other species. The percent of shoots that produced spikes was highest when no nitrogen fertilizer was applied or when seeding rate was low, but those did not compensate for low accumulated dry matter per m^2 and grain yield per ha. Barley and triticale had lower grain/leaf ratios and thus were less efficient in accumulating dry matter than the two wheats. Increases in nitrogen fertilizer or seeding rates depressed the grain/leaf ratios by significantly increasing green leaf area duration after anthesis or LAI at anthesis in the two wheats, barley and triticale. Differences among species in earliness of head emergence partly caused variation in effective kernel filling period duration. Nitrogen fertilization increased days to heading but decreased the effective filling duration period of the two wheats, barley and triticale. Higher spike filling rates induced by high nitrogen fertilization were associated with restricted effective filling period duration and slightly reduced kernel weights in barley and triticale. Triticale exhibited kernel shriveling, taller plant height and, consequently, lower harvest index than the two wheats and barley. The two wheats had relatively higher kernel weights and longer effective filling period duration than barley and triticale. Higher mean kernel filling rate of the late maturing triticale was compensated by depressed effective duration of kernel growth. Number of kernels per spike dominated the grain yield of barley and triticale. Shorter straw and large but compact spikes caused high harvest indices of barley and Newton wheat. Severe lodging probably contributed to low grain yield per ha of barley. High percent protein of triticale grain indicated its potential as a feed grain. Barley had the lowest protein percent. Differential grain yield per ha responses among species to nitrogen and seeding rate depended on number of headed tillers per m row and ability to withstand competitive stresses that limited the spike size and late yield components (mainly 1000-kernel weight) later in the season. High kernel filling rates and early emergence of spikes may extend the useful life of green leaf area and kernel filling period for higher yield in areas of short growing season. Marked improvements in winter survival and kernel weight and response to management practices will be essential for triticale to compete successfully with wheat. Increased seed size, plumbness of kernels, and lodging resistance will improve the grain yielding ability of barley.