CARBOHYDRATE AND NITROGEN RESERVES IN THE HARD RED WINTER WHEAT (*TRITICUM AESTIVUM* L.) VARIETY 'NEWTON'

by

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REVIEW OF LITERATURE

Graber et al. (1927) defined reserves as " carbohydrates and nitrogen compounds, elaborated, stored, and utilized by the plant itself as food.. " . The presence and function of carbohydrate reserves in grasses are well documented (Aldous, 1930; Graber et al., 1927; Weinmann, 1948). Monitoring seasonal trends of accumulation and depletion of carbohydrates has given some insight into their role as reserve substances and aided in range and crop management. Only a limited amount of effort has been directed towards investigating the presence and role of nitrogen reserves, however, and most studies on nitrogen concerned woody species (Martin et al., 1969) and perennial grasses (McKendrick et al., 1975; Rogers and Box, 1967; Weinmann , 1948).

Nitrogen was translocated during autumn from shoots to roots where it was stored for later use in _Trachydogon plumous_ (Weinmann, 1942). Nitrogen in shoots, crowns, and roots of short, mixed, and tall praire grass communities exhibited significant seasonal variation (Bokahari et al., 1974). Big Bluestem (_Andropogon gerardi_ Vitman) and Indiangrass (_Sorghastrum nutans_ (L.) Nash) rhizomes and shoots seasonally fluctuated in nitrogen content (McKendrick et al., 1975). Burning nitrogen-fertilized big bluestem pastures markedly influenced plant reserve nitrogen content (Owensby et al., 1977; Rains et al., 1975). Highest nitrogen reserves were in unburned pastures (Rains et al., 1975). The nitrogen content of blue grama (Bouteloua gracilus) herbage grown under different nitrogen rates varied throughout the growing season and reached a peak in the middle of the season (Uresk and Sims, 1975). Numerous other investigators reported seasonal fluctuations in the nitrogen and crude protein content of selected forage grasses (Rogers, 1967; Pettit, 1974).

Patterns of nitrogen accumulation in whole plants of wheat (Triticum aestivum L.) and triticale (Triticale hexaploide Lar.) nearly followed sigmoid paths (Pyare et al., 1978). Seasonal trends in the nitrogen content of wheat varieties 'Kanred' and 'Harvest Queen' varied throughout the growing season. Percent nitrogen in shoots was highest in early October, declined slightly until March, and decreased during the regrowth period to a low level late in the season (Miller, 1939).

Reserve substances play crucial roles in the plants' ability to overcome stress, particularly regrowth processes following dormancy. Our objectives were to monitor seasonal trends in carbohydrate and nitrogen reserves in winter wheat grown under four nitrogen fertilizer levels and to determine the influence of these reserves on regrowth potential.

MATERIALS AND METHODS

Field Study

Carbohydrate and nitrogen reserves were monitored in the hard red winter wheat (Triticum aestivum L.) variety 'Newton' during the 1980-81 season. The experiment was planted October 2, 1980, at the Agronomy Research Center, Manhattan, Ks, on Ivan and Kennebec silt loam, classified as a fine-silty mixed mesic cumulic hapludoll; analysis of the soil is shown in Table I. Plots consisted of three 6-row subplots 10 m long and 1.2 m wide seeded at a rate of 84 kg/ha. Four nitrogen treatments, 0, 50, 100, and 200 kg/ha, were applied October 8, 1980. Plots were arranged in a randomized complete block with the four nitrogen treatments and four replications.

Plants from each subplot were sampled at 2-week intervals throughout autumn and spring and at 4-week intervals during winter. During fall and winter a one meter row of plants from each subplot were dug from the soil and bulked to comprise a sample. Following spring regrowth collection of samples was reduced to a half meter row of plants per subplot. All plant material was washed with distilled water, counted, and sectioned with razor blades into roots, crowns (i.e., all below ground plant parts other than roots) , and shoots. The grain was sampled as a separate plant part after anthesis. All samples were dried at 80 C for 72 hr, weighed, and ground to pass through a 20-mesh screen.

Total nitrogen content of samples was determined by the standard microkjeldahl technique. Soluble carbohydrates were extracted by shaking 0.1-g samples in 100 ml of 70 C distilled water for 30 min. Extracts were filtered through Whatman #42 paper and an aliquot was reacted with 1 ml 5% (w/v) phenol and 5 ml H_2SO_4 . The reactants were mixed, cooled to room temperature, and absorbance was measured at 490 nm (Dubois, 1956).

Hydroponics Study

To assess the influence of carbohydrates and nitrogen reserves on regrowth potential in winter wheat, plants were transferred from the field to environmental chambers and grown in light and darkness with and without nitrogen fertilization. Whole plants were collected from each plot in the field March 3, 1981, prior to spring regrowth. Six plants from each treatment were washed in distilled water and transplanted into opaque containers holding two liters of modified Haoglund solution containing 5 mM K_2SO_4, 10 mM $CaCl_2*2H_2O$, 4 mM $MgSO_4*7H_2O$, and 1 mM KH_2PO_4 (pH = 5.0). Iron was supplied as 0.6 % $FeSO_4*7H_2O$ - 0.4 % tartaric acid and other micronutrients were added according to Haoglund and Arnon (1950). The solutions were adjusted to pH 5 with dilute sodium hydroxide. Nitrogen was supplied as 15 mM NH_4-NO_3 to the containers that received a nitrogen treatment; the other half of the containers received no nitrogen. Solutions were changed twice weekly and all containers were continuously aerated throughout the experiment.

Regrowth potential was determined by growing plants until growth ceased in a dark environmental chamber or to maturity in a lighted environmental chamber. The dark chamber was maintained at 40-50 % relative humidity and 15 C. The lighted chamber had a 16-hr photoperiod supplied by six 300-watt incandescent bulbs and 16 1500-ma fluorescence lamps, a relative humidity of 40-50 %, and temperature of 25 C during the light period and 15 C during the dark period. A randomized complete block design was used in each chamber. Plant containers within a block were rotated twice weekly to minimize variability. In the dark chamber all vegetation was clipped to a height of 3 cm above the container after transplanting and at weekly intervals until regrowth ceased. Regrowth potential was assesed by totaling dry matter production after each cutting. Samples transplanted into lighted chambers were harvested at maturity. Total dry weights were used to determine regrowth potential.

Field data were analysed with a split plot design when all dates were compared, using nitrogen rates as main plots and sampling dates as subplots. A two-way anova was used to analyse data on any date. Laboratory data were also analysed using two-way anova . Duncan's Multiple Range Test was utilized for all mean separation procedures (alpha = .05).

Fall temperatures were near the 30-yr mean, whereas winter, spring and summer temperatures were significantly higher than normal. Minimum daily temperatures were 4-10 C higher and maximum daily temperatures were 5-14 C higher than normal during late winter prior to the regrowth period. Precipitation was low throughout fall, near normal during winter, low during spring and higher than normal during summer (Fig. I).

RESULTS

Field Study

Dry matter of all plant parts increased throughout the growing season until late May, and then decreased during senesence and maturation (Table II). Nitrogen fertilization stimulated growth of all plant parts at each sampling date,

Table 1. Grain yield and nitrogen content of 'Newton' winter wheat grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Grain yield	Grain nitrogen content	
Kg/ha	Mg / plant	%	Mg / plant
0	915.2 A	3.16 B	28.0 A
50	927.5 A	3.27 B	28.8 A
100	840.7 A	3.84 AB	29.8 A
200	830.5 A	4.76 A	39.4 A

1/ Within columns means not followed by common letters are significantly different at the 5 % level according to Duncan's Multiple Range Test.

particularly dry weights of shoots during late fall, spring regrowth, and early spring. Differences primarilarly occurred between the control and nitrogen-treated plots, not among the 50, 100, and 200-kg/ha N rates. The 100 and 200 kg/ha nitrogen treatments yielded significantly higher shoot dry weights than the 50 kg/ha and control treatments following spring regrowth. No significant differences among N treatments occurred for shoot, crown, or root dry weights at maturity and nitrogen fertilization did not significantly influence grain yields (Table 1).

Percent water soluble carbohydrates in wheat crowns increased from October to January, decreased slightly during winter, and reached a low level during spring regrowth. Soluble carbohydrates were slightly replenished in late March and early April, but decreased during the remainder of the season (Fig. 1). Nitrogen fertilization did not influence concentrations of carbohydrates during the fall and winter, however, a significant depressing effect of nitrogen on carbohydrate percentages was apparent during spring regrowth in April and May. Concentrations of carbohydrates in crown tissue were approximately double those in shoots and roots during most dates. Shoot and root carbohydrate percentages were similar in the fall, winter, and early spring. Following spring regrowth, shoot carbohydrates dramatically increased after development of photosynthetically active tissue, whereas carbohydrate percentages in roots gradually decreased. Percent

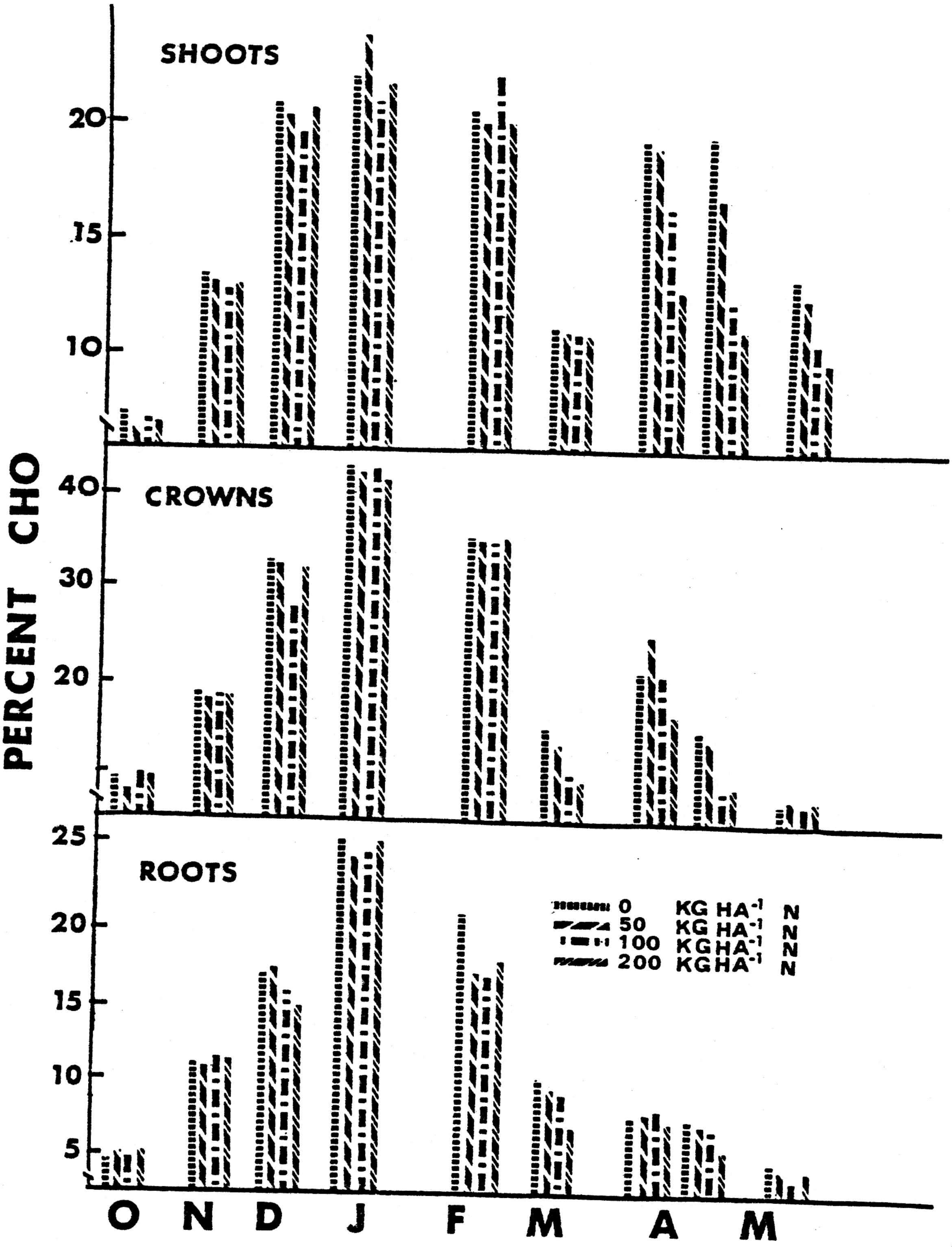

Fig 1. Seasonal trends of water-soluble carbohydrates in shoots, crowns, and roots of 'Newton' winter wheat grown with four nitrogen fertilizer levels in the field.

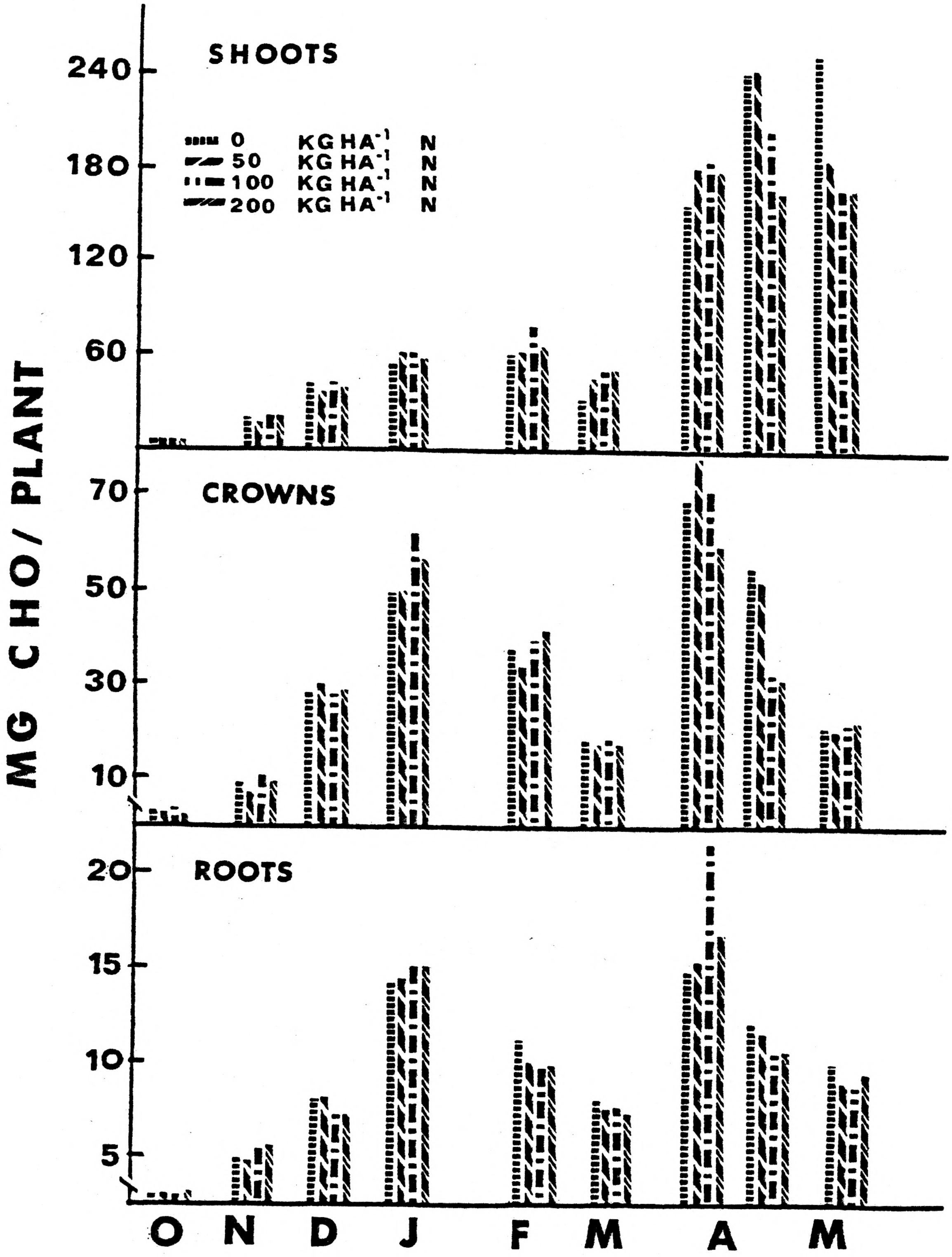

Fig 2. Seasonal trends of total water-soluble carbohydrates in shoots, crowns, and roots of 'Newton' winter wheat grown with four nitrogen fertilizer levels in the field.

carbohydrates in shoots, crowns, and roots reached a seasonal low level during senesence and maturation.

Total water-soluble carbohydrates in shoots, crowns, and roots increased throughout the fall and decreased during winter to a low level during spring regrowth. Total carbohydrates increased markedly in all plant parts after regrowth to a seasonal high level in April. Carbohydrates continued to increase in shoots through April, but decreased in crowns and roots. Total carbohydrates in all plant parts reached a seasonal low level at maturity (Fig. 2). Nitrogen fertilization did not influence total water-soluble carbohydrates in all plant parts during fall and winter, but it significantly decreased total carbohydrates in shoots and decreased them in crowns and roots during spring regrowth. A negative linear relationship was observed between carbohydrate content and nitrogen application rates in shoots, crowns, and roots at that time; a trend which continued until maturity (Fig.2).

Percent nitrogen was highest in October, decreased slightly during the fall, leveled off during winter and dropped marketly in spring to a seasonal low level in all plant parts at maturity (Fig. 3). Percent nitrogen was higher in shoots than in crowns and was lowest in roots at all dates. Nitrogen fertilization increased percent nitrogen in all plant parts at each date. Treatment differences in the field were significant only in the roots during fall,

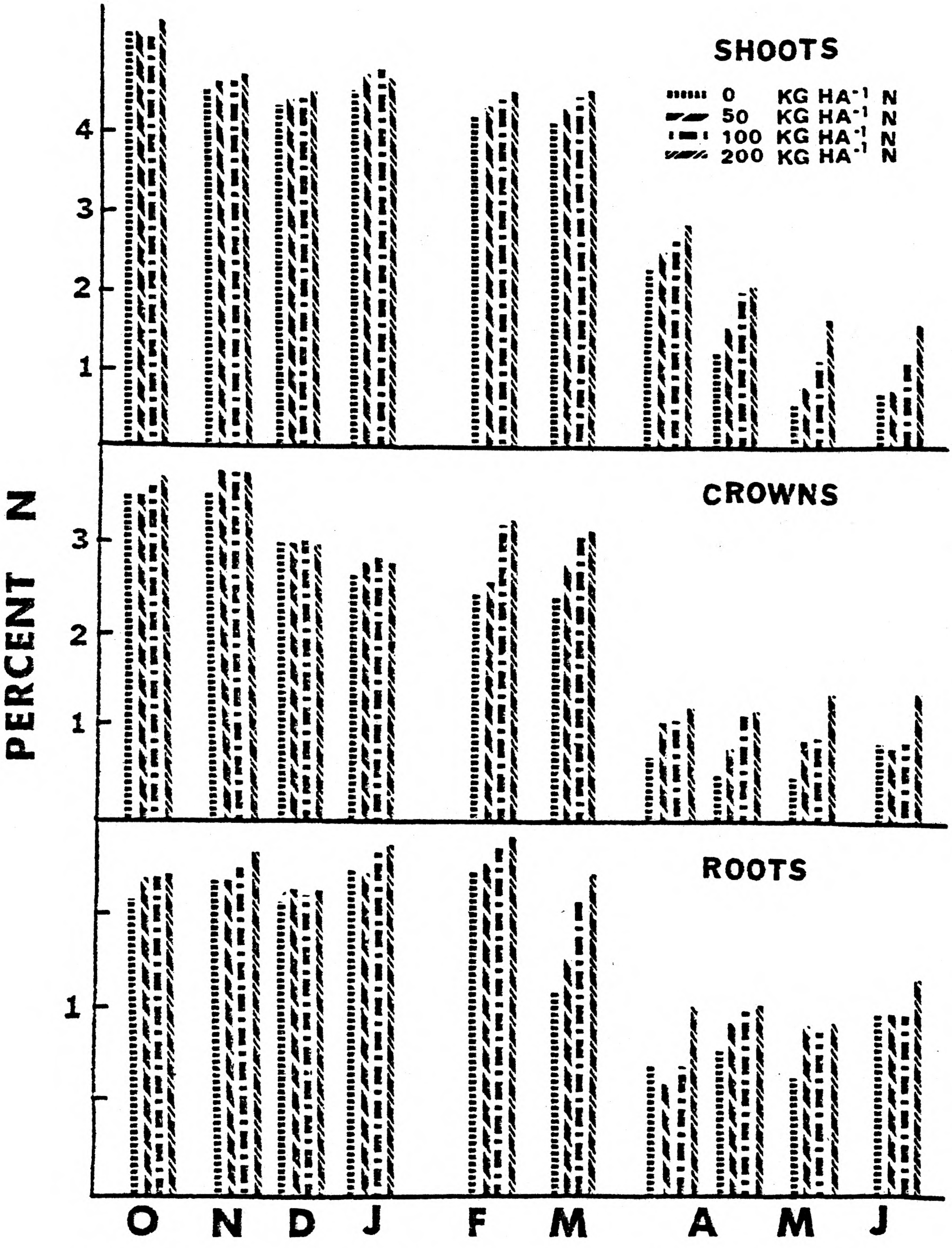

Fig 3. Seasonal trends of nitrogen content in shoots, crowns, and roots of 'Newton winter wheat grown with four nitrogen fertilizer levels in the field.

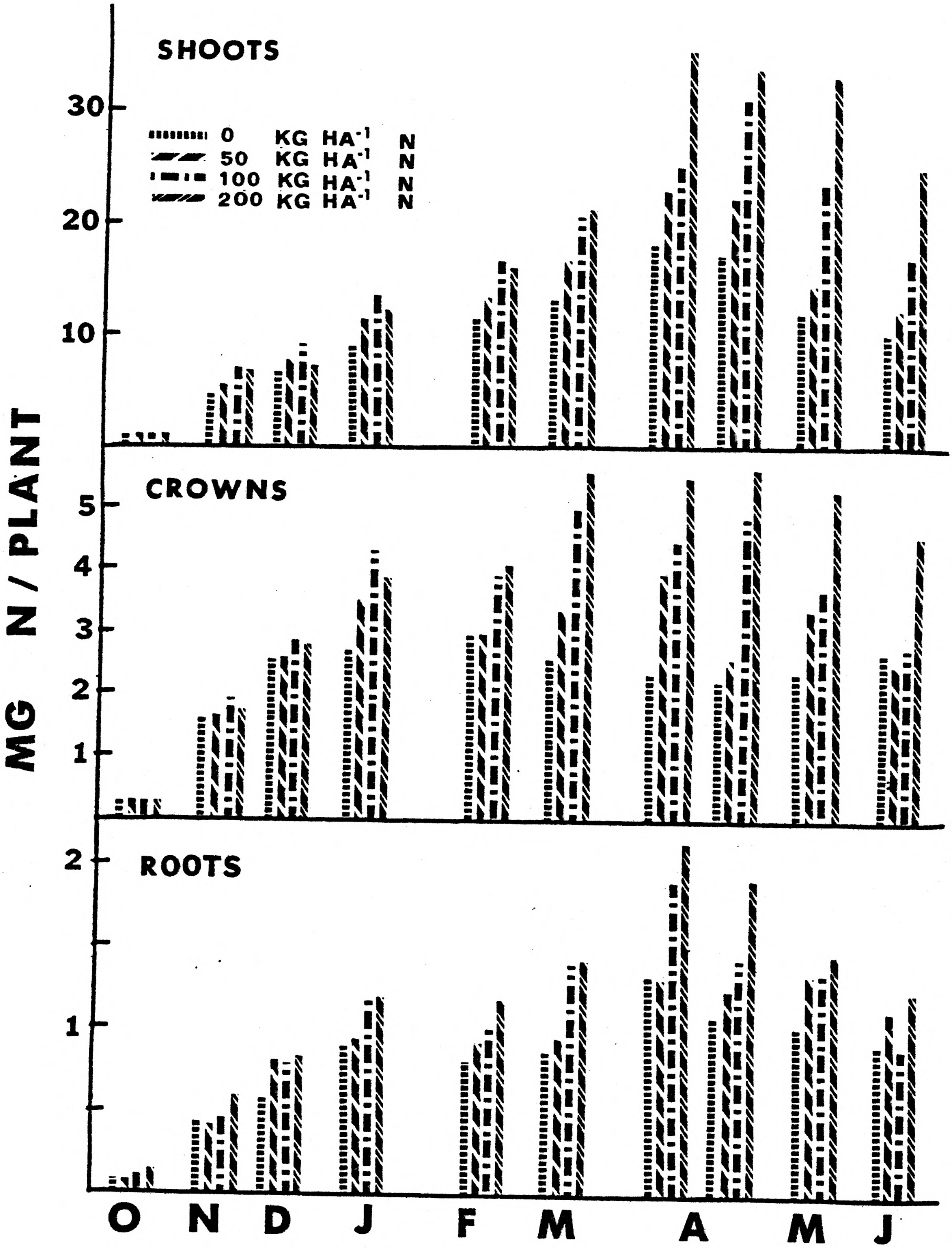

Fig 4. Seasonal trends of total nitrogen content in shoots, crowns, and roots of 'Newton' winter wheat grown with four nitrogen fertilizer levels in the field.

whereas differences were significant in all plant parts during late winter, spring, and early summer. Response to nitrogen fertilization increased significantly in the spring and summer months and highest nitrogen percentages occurred in plants grown under highest nitrogen levels (Fig. 3).

Accumulation of total nitrogen in shoots, crowns, and roots increased steadily from seedling emergence until March, reached a peak in April, and decreased throughout May and June (Fig. 4). Significantly greater accumulations occurred under the higher nitrogen treatments. The effect of nitrogen fertilization on tissue N contents was small during initial stages of development in the fall, increased slightly during the winter, and marketly increased in spring. A 2-fold difference in accumulation of nitrogen occurred between the lowest and highest nitrogen levels after spring regrowth; a trend that continued until maturity (Fig. 4). Total nitrogen decreased in shoots, crowns, and roots during May and June when it accumulated in grain. Total nitrogen content was highest in grain of plants grown with the higher N application rates (Table 1).

Hydroponics Study

Regrowth of vegetation in darkness was monitored until plant senescence. Regrowth of plants grown in darkness

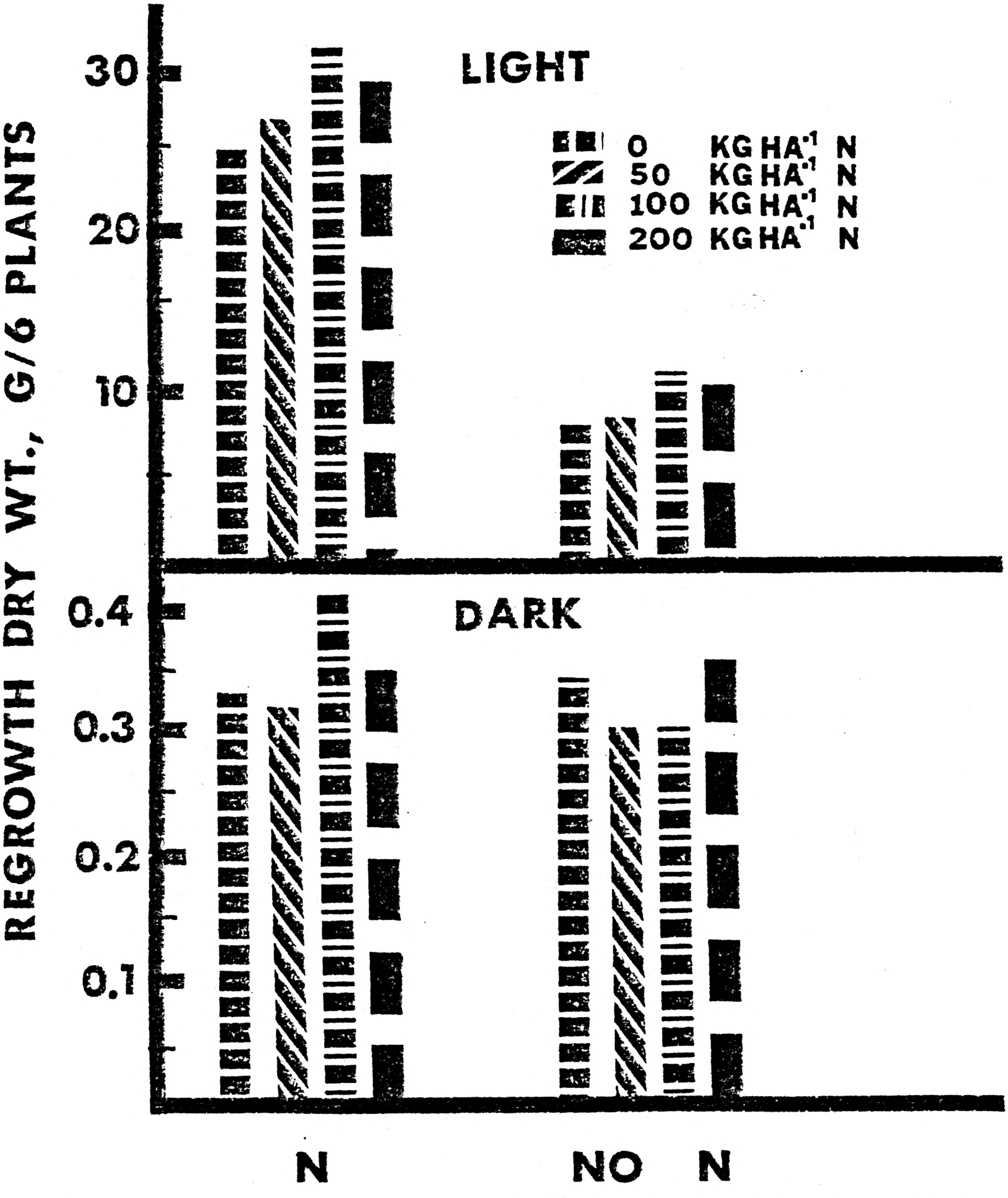

Fig 5. Regrowth of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field and transferred to hydroponic solutions with and without nitrogen in light (upper) and dark (lower) environmental chambers.

without nitrogen in the hydroponic solution was not affected by field nitrogen treatments. Plants grown in darkness with adequate nitrogen also differed little except that those grown under 100 kg/ha field nitrogen levels yielded significantly more regrowth than the others (Table 2).

Significant differences in total dry weights were noted between nitrogen-deprived and non-stressed plants in the lighted chamber at maturity. Dry weights of nitrogen-deprived plants in hydroponics increased linearly with field nitrogen application rates up to the 100 kg/ha rate. The non-stressed plants exhibited a similar trend, however, but only differed at the 10 % alpha level (Table 2). Grain yields from the hydroponically-grown non-stressed plants also were increased by nitrogen , being greatest at the 100 kg/ha level. Grain weights did not differ among the nitrogen-deprived plants. However, a strong trend between higher field nitrogen rate and greater grain production was apparent (Table 3). Differences in grain weights of plants grown with high nitrogen rates in the field and in hydroponic solutions containing nitrogen were associated with the number of spikes/plant (Table 4). Spikes/plant did not differ among nitrogen-deprived plants, although a positive trend was observed between number of spikes/plant and field nitrogen rates up to the 100 kg/ha N rate. Significantly fewer spikelets/spike were observed in nitrogen-deprived plants grown with low field nitrogen rates (Table 4).

Table 2. Regrowth of 'Newton' winter wheat grown with four nitrogen fertilizer levels in the field and transferred to hydroponic solutions with and without nitrogen in environmental chambers 1/.

N Trt	Dark		Light	
Kg/ha	Nitrogen	No Nitrogen	Nitrogen	No Nitrogen
	--------- g / 6 plants	-------------	-------- g / 6 plants	-------------
0	0.33 B	0.34 A	25.21 A b	8.17 B b
50	0.32 B	0.30 A	26.73 A ab	8.83 AB b
100	0.41 A	0.30 A	31.03 A a	11.10 A a
200	0.34 B	0.36 A	29.83 A ab	10.94 A a

1/ Within columns, means not followed by common upper case letters are significantly different at the 5 % level; Means not followed by common lower case letters are significantly different at the 10 % level according to Duncan's Multiple Range Test.

Table 3. Regrowth of 'Newton' winter wheat grown with four nitrogen levels in field and transferred to hydroponic solutions with and without nitrogen in lighted environmental chamber 1/.

N Trt	Shoots		Crowns		Roots		Seeds	
Kg/ha	---------------------		g dry wt. / 6 plants		-----------------------------			
			Nitrogen					
0	12.69	A	2.90	B	0.88	A	8.75	B
50	13.75	A	2.66	B	0.88	A	9.44	AB
100	14.67	A	2.86	B	1.12	A	12.38	A
200	14.04	A	4.20	A	1.01	A	10.59	AB
			No nitrogen					
0	3.52	B	1.83	C	1.25	B	1.58	A
50	3.87	AB	1.80	C	1.44	A	1.73	A
100	5.29	A	2.44	B	1.48	A	1.88	A
200	4.29	AB	3.00	A	1.54	A	2.11	A

1/ See footnote Table 1.

Table 4. Yield components and nitrogen content of 'Newton' winter wheat grown with four nitrogen fertilizer levels in field and transferred to hydroponic solutions with and without nitrogen in light environmental chamber 1/.

N Trt	Spikes/plant	Spikelets/spike	Seeds/spikelet	Seed wt.	Seed nitrogen	
Kg/ha				g / 100	%	Mg/plant
			Nitrogen			
0	2.83 B	14.47 A	1.74 A	2.12 A	3.38 A	294.33 A
50	3.75 A	14.08 A	1.51 A	1.98 A	3.30 AB	310.57 A
100	3.71 A	14.81 A	1.68 A	2.25 A	3.15 AB	388.58 A
200	3.75 A	14.64 A	1.68 A	1.94 A	3.10 B	327.65 A
			No nitrogen			
0	1.29 A	14.03 C	0.66 A	2.87 AB	1.61 A	24.93 A
50	1.46 A	13.94 C	0.75 A	2.79 AB	1.69 A	28.93 A
100	1.71 A	14.67 B	0.75 A	3.05 A	1.80 A	33.14 A
200	1.42 A	15.29 A	0.86 A	2.71 B	1.59 A	32.96 A

1/ See footnote Table 1.

DISCUSSION

Establishing reserve carbohydrates in grasses depends on a balance between the amount of photosynthate allocated for consumption (i.e., production and maintenance) and for reserves (Adegbola and McNeal, 1966). Accumulation of nitrogen in tissue of grasses was highest in plants grown with high nitrogen fertilization rates (Dee et al., 1967; Pettit and Fagan, 1974; Rains et al., 1975). In wheat, where rapidly metabolizing tissue creates a demand for nitrogenous compounds, accumulation occurred in greater quantities in shoots than in crowns or roots. Compared to shoots, however, percent nitrogen in crowns was relatively high, suggesting that nitrogen accumulated in wheat crowns as a reserve (Weinmann, 1948; Bokhari and Singh, 1974; Rains et al., 1975; Owensby et al., 1977).

Plants with higher tissue nitrogen content utilized more carbohydrate for metabolism of nitrogenous compounds, thus decreasing allocation of carbohydrates to reserves (Adegbola and McNeal, 1966; Green and Beard, 1966; Colby et al., 1965). Low carbohydrate reserve levels in winter wheat crowns that contained high tissue nitrogen resulted from accelerated metabolic processes. This explained the significantly greater shoot biomass in plants containing greater tissue N during and immediately following regrowth and lower levels of carbohydrates in crowns at that time (Adegbola and McNeal, 1966).

Our results showed that reserves were utilized to initiate regrowth in both nitrogen-deprived and non-deprived plants grown in hydroponic solutions and in darkness. Regrowth potential was limited by carbohydrates stored in crowns prior to sampling, not by nitrogen. Other research also suggested that carbohydrate reserve levels limited regrowth of grasses (Burton and Jackson, 1962; Adegbola and McNeal, 1966).

Unseasonably mild temperatures throughout the winter of 1980-81 advanced the phenological and physiological development of the wheat crop, influencing it to initiate regrowth processes earlier than expected. Quantities of carbohydrate reserves in crowns were similar among field N treatments, and were already approaching a seasonal low when sampled for the hydroponic study. The low quantity probably explained why regrowth halted after the first cutting and why regrowth was similar at the different nitrogen treatments in the dark chamber. Results might have been more informative if samples were collected when reserves were closer to their seasonal high level.

Plants grown without nitrogen in hydroponic solutions in lighted chambers were limited by nitrogen accumulated prior to sampling. Those plants with high levels of tissue N had greater overall growth and development in both nitrogen-deprived and non-deprived media. Results strongly support the role of nitrogen as a reserve substance and agreed with studies by Owensby et al., (1977), Rains et al., (1975), and Weinmann (1948).

Plants which were fertilized with 100 kg/ha field N treatment yielded best results in both field and lab studies. Levels of nitrogen in excess of the 100 kg/ha rate lowered carbohydrate reserves sufficiently enough to decrease regrowth potential. Nitrogen levels below 100 kg/ha N decreased accumulations of nitrogen in tissue sufficiently to lower regrowth potential.

In conclusion, adequate nitrogen fertility was essential for optimal growth and development of winter wheat. However, if levels become excessive, metabolic processes probably utilized greater quantities of carbohydrates which decreased carbohydrate reserve levels and lowered regrowth potential. Therefore, a crucial balance existed between levels of nitrogen accumulated in plant tissue which enhances regrowth and carbohydrates utilized to maintain metabolism of accumulated nitrogen.

REFERENCES

Adegbola, A.A. and C.M. McNeal. 1966. Effect of nitrogen fertilization on carbohydrate content of coastal Bermudagrass (*Cynodon dactylon*). Agron. J. 58: 60-64.

Aldous, A.E. 1930. Relation of organic reserves to the growth of some Kansas pasture plants. J. Amer. Soc. Agron. 22: 385-392.

Bokhari, U.G. and Singh. 1974. Standing state and cycling of nitrogen in soil-vegetation components of prairie ecosystem. Ann. Bot. 39: 273-285.

Burton, G.W. and J.E. Jackson. 1962. A method for measuring sod reserves. Agron. J. 54: 55-56.

Colby, W.G.,M. Drake, D.L. Field, and G. Kreowski. 1965. Seasonal patterns of frustosan in Orchardgrass stubble as influenced by nitrogen and harvest management. Agron. J. 57: 169-173

Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers, and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Ann. Chem. 28: 350-356.

Graber, L.F., N.T. Nelson, W.A. Luekel, and W.B. Albert. 1927. Organic food reserves in relation to the growth of Alfalfa and other perennial herbacious plants. Wisconsin. Agric. Exp. Stn. Res. Bull. 80. 128 p.

Green, D.G. and J.B. Beard. 1969. Seasonal relationships between nitrogen nutrition and soluble carbohydrates in the leaves of *Agrostis palustris* Huds., and *Poa pratensis* L. Agron. J. 61: 107-111.

Haoglund, D.R. and D.I. Arnon. 1950. The water culture method for growing plants without soil. Calif. Agr. Exp. Stn. Cir. 347 p.

Martin, M.M. Jr. and W.E. Splittstoesser. 1969. The utilization of carbohydrate and nitrogen reserve in the spring growth of Lilac. Physiol. Plant. 22: 870-879.

McKendrick, J.D., C.E.Owensby, and R.M. Hyde. 1975. Big Bluestem and Indiangrass vegetative reproduction and annual carbohydrate and nitrogen cycles. Agro-Ecosystems. 12: 75-93.

Miller, E.C. 1939. A physiological study of the winter wheat plant at different stages of its development. Kansas Agric. Exp. Stn. Tech. Bull. 47. 167 p.

Owensby, C.E., G.M. Paulsen, and J.D. McKendrick. 1970. Effects of burning and clipping on Big Bluestem reserve carbohydrates. J. Range Manage. 23: 356-362.

_____________., E.F. Smith, and J.R. Rains. 1977. Carbohydrate and nitrogen reserve cycles for continuous, season-long and intensive early stocked flint hills Bluestem range. J. Range Manage. 30: 258-260.

Pettit, R.D. and R.E. Fagan. 1974. Influence of nitrogen on irrigated Buffalograss yield and protein content. J. Range Manage. 27: 473-476.

Pyara, L., G.G. Reddy, and M.S. Modi. 1978. Accumulation and redistribution of dry matter and N in Triticale and Wheat varieties under water stress conditions. Agron. J. 70: 623-626.

Rains, J.R., C.E. Owensby, and K.E. Kemp. 1975. Effects of nitrogen fertilization, burning, and grazing on reserve constituents of Big Bluestem. J. Range Manage. 28: 358-362.

Rogers, J.D. and T.W. Box. 1967. Seasonal protein content of four sourthern mixed prairie grasses. J. Range Manage. 20: 177-178.

Uresk, D.W. and P.L. Sims. 1975. Influence of grazing on crude protein content of Blue Grama. J. Range Manage. 28: 370-371.

Weinmann, H. 1942. The autumnal remigration of nitrogen and phosporous in Trachypogon plusosus. J. South African Bot. 8: 179-196.

____________. 1948. Underground development and reserves of grasses: A review. J. Brit. Grassel. Soc. 3: 115-140.

APPENDIX

Table I. Fertility analysis of Ivan and Kennebec silt loam soil from field control plots at the Agronomy Research Center, Manhattan, Ks.

Rep	Depth	pH	Effect $CaCO_3$	Avail P	Exch K	NH_4^+	NO_3^-
	cm		Kg/ha			ppm	
1	0 - 15	7.5	0	112.0	324.8	10.9	10.6
	15 - 61	7.4	0	59.4	352.8	4.6	13.2
2	0 - 15	7.3	0	109.8	244.2	5.3	14.4
	15 - 61	7.5	0	100.9	263.2	4.2	18.2
3	0 - 15	7.0	0	123.2	266.6	5.2	8.8
	15 - 61	6.3	1500	62.7	197.1	5.6	18.6
4	0 - 15	7.1	0	112.0	272.2	5.0	12.9
	15 - 61	6.8	0	51.5	245.3	6.0	20.0

Table II. Seasonal trend in mean weights of shoots, crowns, and roots of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Oct 20	Nov 3	Nov 17	Dec 1	Jan 3	Feb 16	March 6	April 7	April 25	May 19	June 12
Kg/ha	--				Mg dry wt. / plant			--			
					Shoots						
0	18.3 A	48.9 B	120.3 B	186.8 A	208.0 B	267.2 C	300.7 B	812.8 C	1456.7 A	2191.2 A	1617.0 A
50	17.3 A	49.7 B	128.1 AB	179.6 A	252.3 AB	294.0 BC	393.2 A	916.8 CB	1645.1 A	2061.9 A	1812.5 A
100	20.1 A	52.3 AB	144.6 A	206.6 A	289.3 A	349.1 A	464.6 A	1068.3 AB	1768.6 A	1949.5 A	1668.0 A
200	19.9 A	55.1 A	141.4 AB	177.6 A	273.6 A	317.8 AB	473.3 A	1199.1 A	1642.6 A	2252.0 A	1617.0 A
					Crowns						
0	9.7 A	20.7 B	45.3 A	81.6 A	113.6 A	101.6 A	119.8 A	316.7 A	348.7 A	371.3 AB	283.0 A
50	9.1 A	21.9 AB	44.9 A	84.1 A	123.5 A	93.7 A	132.5 A	357.2 A	374.3 A	302.5 B	261.0 A
100	9.7 A	23.4 A	52.9 A	86.5 A	145.3 A	111.2 A	161.0 A	395.8 A	403.7 A	353.8 AB	312.8 A
200	9.7 A	23.6 A	50.6 A	85.8 A	140.9 A	115.8 A	168.6 A	365.2 A	396.1 A	380.0 A	313.7 A
					Roots						
0	8.0 A	15.2 A	26.9 A	38.8 A	50.5 A	47.1 A	77.6 A	164.7 A	150.2 A	170.9 A	86.2 A
50	7.8 A	15.2 A	26.9 A	38.9 A	53.9 A	52.4 A	74.7 A	176.8 A	150.9 A	143.1 A	120.2 A
100	8.1 A	15.8 A	26.8 A	38.2 A	60.5 A	54.5 A	83.1 A	238.8 A	147.3 A	154.8 A	84.0 A
200	9.4 A	16.0 A	30.0 A	40.4 A	60.1 A	52.6 A	79.1 A	209.4 A	167.0 A	159.8 A	99.5 A

1/ Within columns, means not followed by common letters are significantly different at the 5 % level according to Duncan's Multiple Range Test.

Table III. Seasonal trend in mean percent water-soluble carbohydrates of shoots, crowns, and roots of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Oct 20	Nov 3	Nov 17	Dec 1	Jan 3	Feb 16	March 6	April 7	April 25	May 19
Kg/ha						% Cho				
						Shoots				
0	7.65 A	12.93 A	13.60 A	21.01 A	21.50 A	20.13 A	11.33 A	18.86 A	18.90 A	14.96 A
50	6.43 B	12.84 A	12.65 AB	20.51 A	22.91 A	19.56 A	10.91 A	18.44 A	16.51 A	12.20 AB
100	7.39 A	12.18 A	12.22 B	19.60 A	20.72 A	21.68 A	10.72 A	16.07 AB	13.50 B	10.74 B
200	7.01 AB	12.50 A	12.70 AB	20.85 A	21.34 A	19.57 A	10.39 A	13.67 B	10.73 B	9.55 B
						Crowns				
0	9.98 A	20.99 A	18.52 A	32.85 A	43.67 A	35.32 A	15.42 A	22.75 A	15.32 A	5.54 A
50	8.50 A	21.61 A	17.02 A	32.66 A	40.47 A	33.80 A	13.54 B	24.06 A	13.87 A	6.57 A
100	10.25 A	20.69 A	17.98 A	28.75 B	42.04 A	34.19 A	11.86 C	19.53 B	8.41 B	6.23 A
200	9.74 A	22.06 A	17.73 A	31.33 AB	40.19 A	35.12 A	10.54 C	16.73 C	8.76 B	6.21 A
						Roots				
0	4.80 A	14.07 A	11.21 A	16.02 A	25.50 A	21.55 A	10.14 A	8.72 A	7.59 A	5.60 A
50	5.00 A	14.43 A	10.25 A	16.92 A	24.04 A	17.05 A	9.80 A	8.61 A	6.91 AB	5.35 A
100	4.80 A	14.93 A	11.68 A	15.24 A	24.72 A	16.72 A	8.97 AB	9.03 A	6.21 BC	4.76 A
200	5.27 A	14.02 A	11.51 A	14.48 A	25.10 A	17.23 A	7.69 B	8.30 A	5.73 C	5.34 A

1/ See footnote Table II.

Table IV . Seasonal trend in mean total water-soluble carbohydrates of shoots, crowns, and roots of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Oct 20	Nov 3	Nov 17	Dec 1	Jan 3	Feb 16	March 6	April 7	April 25	May 19
Kg/ha	----------	----------	----------	----------	Mg Cho / plant	----------	----------	----------	----------	----------
					Shoots					
0	1.39 A	6.37 A	16.36 A	39.20 A	45.08 A	53.85 B	34.31 B	152.08 A	223.93 A	236.20 A
50	1.12 B	6.37 A	16.24 A	36.94 A	59.23 A	58.11 B	43.41 AB	166.69 A	224.99 A	174.84 A
100	1.50 A	6.41 A	17.69 A	40.52 A	59.75 A	75.22 A	49.58 A	173.20 A	203.91 A	155.95 A
200	1.41 A	6.93 A	17.98 A	37.10 A	58.41 A	62.44 AB	49.29 A	160.86 A	154.65 A	157.65 A
					Crowns					
0	0.96 AB	4.33 B	8.44 A	26.92 A	49.52 A	35.80 A	18.92 A	71.69 A	54.28 A	20.18 A
50	0.78 B	4.73 AB	7.70 A	27.42 A	50.25 A	31.66 A	18.04 A	86.12 A	52.29 A	19.78 A
100	0.99 A	4.83 AB	9.45 A	24.83 A	60.88 A	38.28 A	19.02 A	78.28 A	33.81 B	22.18 A
200	0.94 AB	5.21 A	8.92 A	26.76 A	56.98 A	41.21 A	17.56 A	61.75 A	33.53 B	23.58 A
					Roots					
0	0.39 A	2.12 A	3.00 B	6.30 A	12.93 A	10.27 A	7.85 A	14.16 A	11.31 A	9.52 A
50	0.39 A	2.18 A	2.75 B	6.64 A	13.06 A	9.11 A	7.33 A	14.94 A	10.29 A	7.52 A
100	0.39 A	2.34 A	3.11 AB	5.84 A	14.93 A	9.06 A	7.42 A	21.72 A	9.35 A	7.38 A
200	0.49 A	2.20 A	3.46 A	5.83 A	15.05 A	9.09 A	6.03 B	17.06 A	9.61 A	8.72 A

1/ See footnote Table II.

Table V. Seasonal trend in mean percent nitrogen of shoots, crowns, and roots of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Oct 20	Nov 3	Nov 17	Dec 1	Jan 3	Feb 16	March 6	April 7	April 25	May 19	June 12
Kg/ha						% Nitrogen					
						Shoots					
0	5.14 B	4.68 A	4.49 A	4.33 A	4.36 B	4.00 B	3.84 C	2.23 B	1.19 D	0.70 C	0.80 B
50	5.15 B	4.71 A	4.51 A	4.43 A	4.58 AB	4.17 AB	4.17 B	3.34 B	1.40 C	0.81 BC	0.82 B
100	5.05 A	4.76 A	4.56 A	4.44 A	4.66 A	4.20 AB	4.49 A	2.53 B	1.73 B	1.07 B	1.04 AB
200	5.37 A	4.72 A	4.64 A	4.41 A	4.54 AB	4.45 A	4.62 A	3.00 A	2.08 A	1.51 A	1.37 A
						Crowns					
0	3.32 B	3.41 A	3.52 A	2.96 A	2.56 A	2.94 B	2.20 B	0.82 B	0.67 B	0.67 B	0.94 B
50	3.37 B	3.37 A	3.68 A	2.93 A	2.71 A	2.87 B	2.51 B	1.05 B	0.71 B	1.05 AB	0.90 B
100	3.56 AB	3.41 A	3.62 A	3.09 A	2.81 A	3.27 A	3.09 A	1.07 B	1.22 A	1.07 AB	0.94 B
200	3.67 A	3.46 A	3.67 A	2.96 A	2.76 A	3.26 A	3.12 A	1.45 A	1.36 A	1.34 A	1.36 A
						Roots					
0	1.54 A	1.70 B	1.67 C	1.55 A	1.64 B	1.64 C	1.12 B	0.72 B	0.75 C	0.59 B	0.91 B
50	1.61 A	1.77 AB	1.64 C	1.59 A	1.61 B	1.75 BC	1.24 AB	0.67 B	0.83 BC	0.89 A	0.90 B
100	1.62 A	1.91 A	1.74 B	1.56 A	1.80 A	1.86 B	1.54 AB	0.71 B	0.97 AB	0.83 A	0.91 B
200	1.65 A	1.88 AB	1.82 A	1.59 A	1.83 A	2.02 A	1.67 A	1.00 A	1.04 A	0.89 A	1.20 A

1/ See footnote Table II.

Table VI. Seasonal trends in mean total nitrogen of shoots, crowns, and roots of 'Newton' winter wheat plants grown with four nitrogen fertilizer levels in the field 1/.

N Trt	Oct 20	Nov 3	Nov 17	Dec 1	Jan 3	Feb 16	March 6	April 7	April 25	May 19	June 12
Kg/ha					Mg nitrogen / plant						
					Shoots						
0	0.9 A	2.3 B	5.4 A	8.1 A	9.1 B	10.7 B	11.6 C	18.1 C	17.1 B	14.8 B	12.3 B
50	0.9 A	2.3 B	5.8 A	7.9 A	11.5 AB	12.2 B	16.4 B	21.5 C	22.3 B	16.4 B	14.1 B
100	1.0 A	2.5 AB	6.6 A	9.2 A	13.5 A	14.7 A	20.9 A	26.3 B	30.4 A	20.0 B	16.5 B
200	1.1 A	2.6 A	6.6 A	7.8 A	12.4 A	14.1 A	21.9 A	36.7 A	34.4 A	33.4 A	24.0 A
					Crowns						
0	0.3 A	0.7 C	1.6 A	2.4 A	2.9 B	3.0 A	2.6 B	2.6 C	2.3 B	2.5 B	2.6 B
50	0.3 A	0.8 BC	1.6 A	2.5 A	3.3 AB	2.7 A	3.3 B	3.8 BC	2.6 B	3.2 B	2.2 B
100	0.4 A	0.8 AB	1.9 A	2.7 A	4.1 A	3.6 A	5.0 A	4.2 AB	4.9 A	3.7 AB	2.9 B
200	0.4 A	0.8 A	1.9 A	2.5 A	3.9 AB	3.8 A	5.3 A	5.2 A	5.3 A	5.1 A	4.3 A
					Roots						
0	0.1 B	0.3 A	0.5 B	0.6 A	0.8 B	0.8 B	0.9 A	1.2 B	1.1 A	1.0 A	0.8 A
50	0.1 AB	0.3 A	0.4 B	0.6 A	0.9 AB	0.9 AB	0.9 A	1.1 B	1.2 A	1.3 A	1.1 A
100	0.1 AB	0.3 A	0.5 B	0.6 A	1.1 A	1.0 A	1.3 A	1.6 AB	1.4 A	1.3 A	0.8 A
200	0.2 A	0.3 A	0.6 A	0.6 A	1.1 A	1.1 A	1.3 A	2.2 A	1.8 A	1.4 A	1.2 A

1/ See footnote Table II.

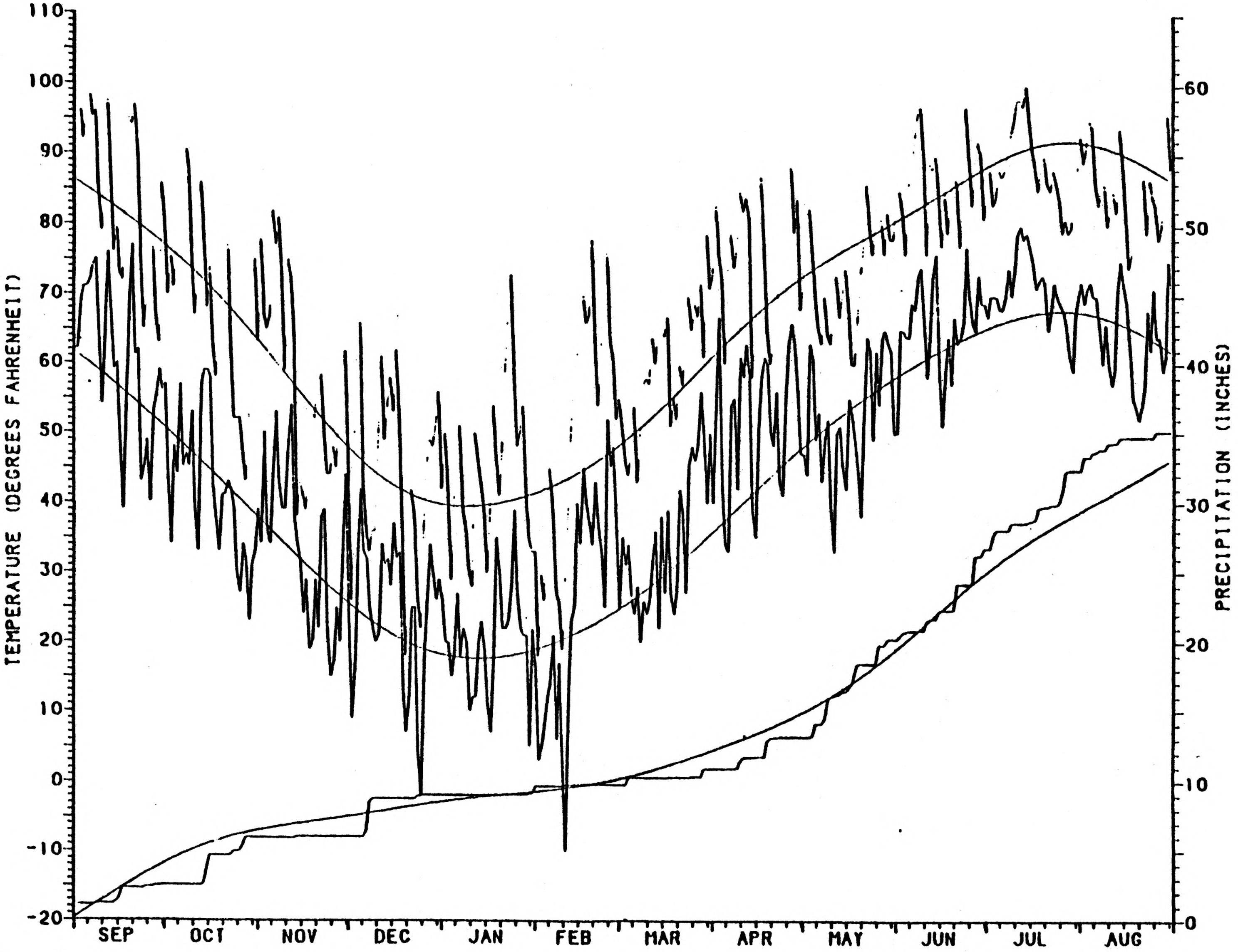

Fig I. Minimum and maximum daily temperatures and daily precipitation trends compared to 30 year average for Manhattan, Kansas, 1980-81.

CARBOHYDRATE AND NITROGEN RESERVES IN THE HARD RED WINTER WHEAT (*TRITICUM AESTIVUM* L.) VARIETY 'NEWTON'

by

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B.S.,S.U.N.Y. at Stony Brook, 1979

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Reserve substances play crucial roles in regrowth of plants following dormancy. Seasonal fluctuation in carbohydrate reserves of grasses have received much attention, but investigations concerning the presence and function of nitrogen reserves are limited. Seasonal trends of carbohydrate and nitrogen reserves were monitored and investigations were conducted to determine how these reserves influenced regrowth potential in hard red winter wheat (*Triticum aestivum* L.).

Field experiments consisted of four nitrogen treatments (0, 50, 100, 200 Kg/ha N) applied to 'Newton' wheat in four replications. Plants were collected periodically throughout the season and sectioned into shoots, crowns, and roots. Percent water-soluble carbohydrates increased during the fall, decreased slightly over winter, and reached a low during spring regrowth. Carbohydrates replenished in spring but decreased during the remainder of the season. Nitrogen fertilization significantly depressed percent carbohydrates during spring regrowth. Percentage N was highest in the fall, decreased throughout the season, and reached a low level in all plant parts upon maturity. Percent N was higher in shoots than in crowns, and lowest in roots. Significantly higher percent N occurred in plant tissue grown under higher N rates.

Plants were collected from field plots before spring regrowth and transplanted into hydroponic solutions with N or without N in lighted or dark environmental chambers. Regrowth potential was determined by growing plants until growth ceased in the dark chamber or to maturity in the lighted chamber. Nitrogen- and light-deprived plants exhibited no significant difference in regrowth. Light-deprived plants grown with adequate N gave similar results. In the lighted chamber, significant differences in total dry weights were observed between nitrogen-deprived and non-deprived plants at maturity. Field N fertilization significantly enhanced growth of both nitrogen-deprived and non-deprived plants.

We concluded that the regrowth potential of winter wheat depends on both carbohydrate and nitrogenous compounds stored in the plant prior to spring regrowth.