Materials and Methods

3. MATERIALS AND METHODS

3.1. EXPERIMENTAL DESIGN

The experimental design was that of a split plot experiment with five replications (blocks) in two locations (e.g. FEDERER 1955); the two locations were the undrained and the drained basin of the impoundment and were considered in the statistical analysis as the only ones of interest. Each block, 9x20 m in size, was divided into two main plots, 4x20 m each, separated from each other by a 1 m wide walkway. The two burning treatments viz. (i) unburned and (ii) burned were assigned randomly to the two main plots. Each main plot, in turn, was then split into five split plots, 4x4 m each, to which the five following fertilizer treatments were allocated at random: (i) no fertilizer added, control (C); (ii) addition of 200 kg/ha actual nitrogen in the form of ammonium-nitrate (N); (iii) addition of 200 kg/ha actual phosphorus in the form of triple superphosphate (P); (iv) addition of 625 kg/ha agricultural grade lime (L); and (v) combined addition of nitrogen phosphorus and lime at above rates (NPL) (Fig. 6). Within every split plot a 0.5x0.5 m quadrat was systematically chosen and permanently marked.

3.2. DRAINING TREATMENTS

The impoundment was drained in mid-November 1980 and a central dyke was constructed during December of the same year, dividing the impoundment into two roughly equal basins. The water control structure on the west basin was closed in February 1981 and due to snowmelt and spring rains the water table reached its original level in that basin by May 1981. In the east basin, on the other hand, the water control structure remained open and drainage continued through 1981 to 1983 (Fig. 2).
Between August 1 and October 12, 1982, the mean water level of eight measuring stations in the drained basin was on the average of 17 measur-

ing days at 28.4 ±0.6 (1 S.E., n = 17) cm below the soil surface with a range from 23.0 ±2.5 (1 S.E., n = 8) cm to 31.6 ±2.5 cm (Fig. 2). By contrast, in the undrained basin the water table remained constantly at the surface of the floating mat (Fig. 5).

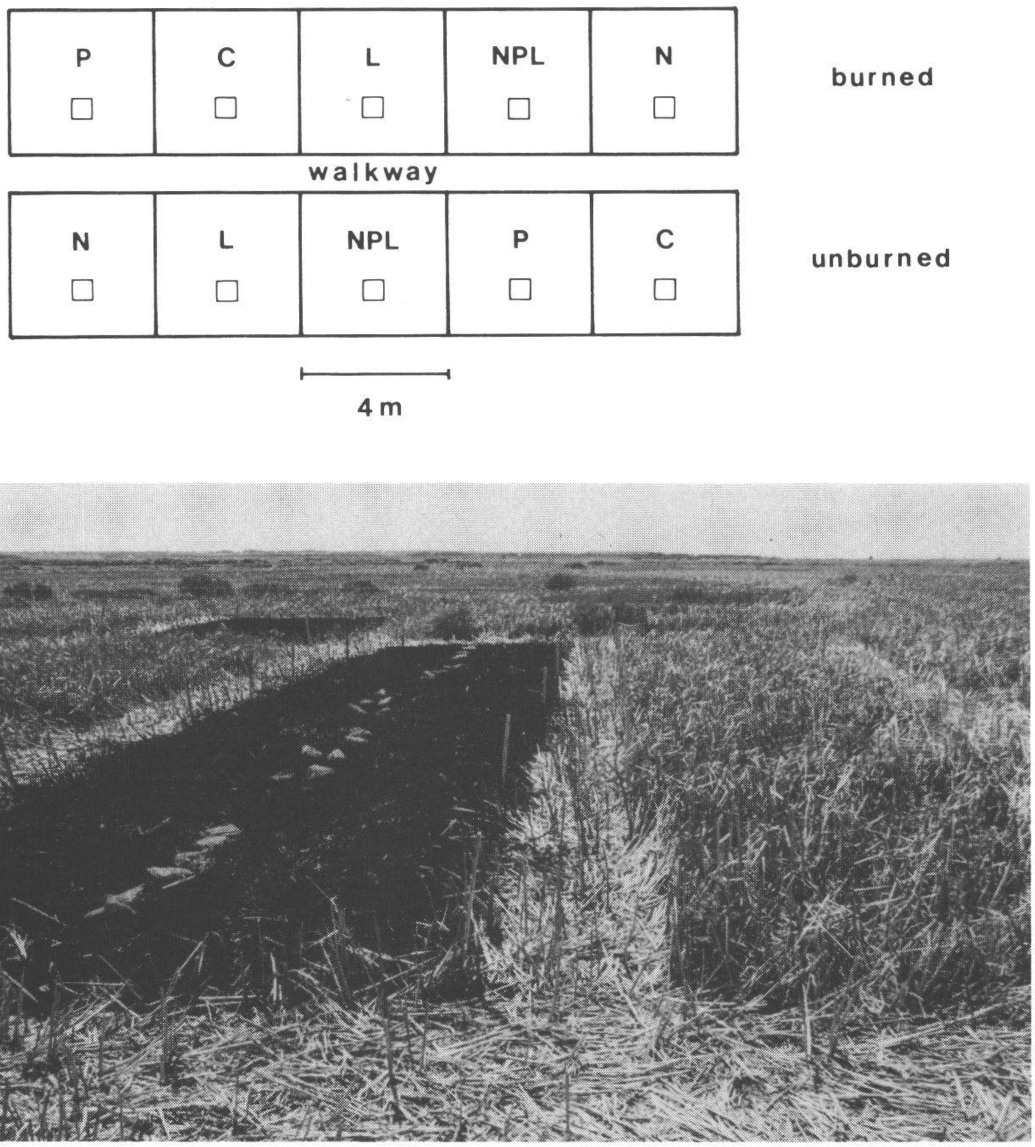

Fig. 6. Experimental design.
Top: Layout of one of the ten blocks. Burning treatments were the main plot treatments and fertilizer treatments the split plot treatments. The small quadrats within the split plots represent the permanently marked 0.5 x 0.5 m plots. C: no fertilizer added; N: 200 kg/ha nitrogen added; P: 200 kg/ha phosphorus added; L: 625 kg/ha lime added; NPL: nitrogen, phosphorus and lime added at above rates. **Bottom:** One of the blocks immediately after burning. In the burned part the bags used for studying the decomposition of surface litter can be seen.

3.3. BURNING AND FERTILIZER TREATMENTS

Burning was carried out on June 3, 1982. The low intensity fires consumed most of the above-ground material but did not penetrate into the organic soil. The above-ground material consisted at the time of burning mainly of surface litter, only few new shoots had already emerged and they were still small. Due to a short residence time of the fire coupled with the high moisture content of the mat, the heat penetrated only into the uppermost centimeters of the mat. The rhizomes of Typha glauca located at a mean depth of 11.6 ±0.35 (1 S.E., n = 118) cm were, thus, well protected from the heating effects.
Burning was carried out in spring for three reasons. First, at that time of year fire does not inflict any severe direct damage to Typha as does, for instance, burning in summer (KRüSI and WEIN 1988). Second, nutrients released by burning are most likely not lost through leaching or surface run-off since at that time Typha starts to grow and can immediately use the available nutrients for biomass production. Finally, marsh fires are most frequent in springtime.
Fertilizer treatments were carried out on June 13, 1982. Fertilizer was applied by hand. The split plots subjected to the different fertilizer treatments were not isolated from each other by any devices, since horizontal water movements within the mat were expected to be negligible. The sharp boundaries of the nitrogen fertilized split plots, which were easily recognizable later in the year due to the dark green colour of the Typha plants growing there, substantiated the assumption.

3.4. MEASUREMENTS

3.4.1. Analytical phenological diagram

Phenological observations for Typha glauca were carried out weekly from late May through November 1982. On the whole, six different developmental stages were distinguished viz. (i) shoots present, (2) staminate spike visible, (3) shedding of pollen, (4) fruit set, (5) yellowing of leaves and (6) seed dispersal. Since the vast majority of the plants did not produce seed heads, the generative development was not studied in greater detail. Every week, the percentage of individuals at a particular phenological phase was estimated using a six-degree scale (+: 0-5%, 1: 5-20%, 2: 20-40%, 3: 40-60%, 4: 60-80%, 5: 80-100%).

3.4.2. Shoot emergence

Since shoot emergence started between two and four weeks before recording of growth parameters was initiated on June 12, the dates on which the first shoots emerged in the different 0.5x0.5 m permanent quadrats had to be assessed indirectly. The respective dates were determined for each unburned 0.5x0.5 m quadrat by extrapolating visually the shoot height vs. date curve backwards (Fig. 7). Estimation of the start of shoot emergence was not possible for the burned treatment plots since burning was carried out before recording of shoot height was initiated.

3.4.3. Shoot density, shoot height, basal shoot circumference and number of leaves per shoot

Number of shoots, total height and height of the green portion, later on referred to as "green height", of all the Typha shoots within the permanently marked 0.5x0.5 m quadrats (Fig. 6) were recorded weekly until mid-August and then biweekly. Recording was initiated on June 12 and terminated by October 18. Based on these data it was possible to describe the development of mean shoot density and mean plant height throughout the vegetation period. The final shoot density was defined as the mean number of shoots per square meter recorded during the period from August 6 to October 3, 1982. Preliminary sampling showed that the 0.5x0.5 m shoot density data had to be multiplied by 4 and divided by 1.162 in order to eliminate a systematic error (edge effect) and to make them comparable to values obtained using 1x1 m quadrats. As regards final mean shoot height, October 3 data were used. Basal shoot circumference and number of leaves per shoot were recorded between September 5 and 9, 1982.

3.4.4. Assimilation period

Length of assimilation period was expressed in two ways viz. (i) as "Assimilation period 0%" and (ii) as "Assimilation period 50%" (Fig. 7). Assimilation period 0% was defined as the time in days between the date when in spring the green shoot height was for the last time zero (0% of final shoot height) and the date in autumn when it became for the first time zero again. The respective dates were defined as the intersection of the green shoot height vs. date curve with the abscissa, and were determined for each 0.5x0.5 m permanent quadrat by visual extrapolation of the curve (Fig. 7). In the burned treatment plots, assimilation period

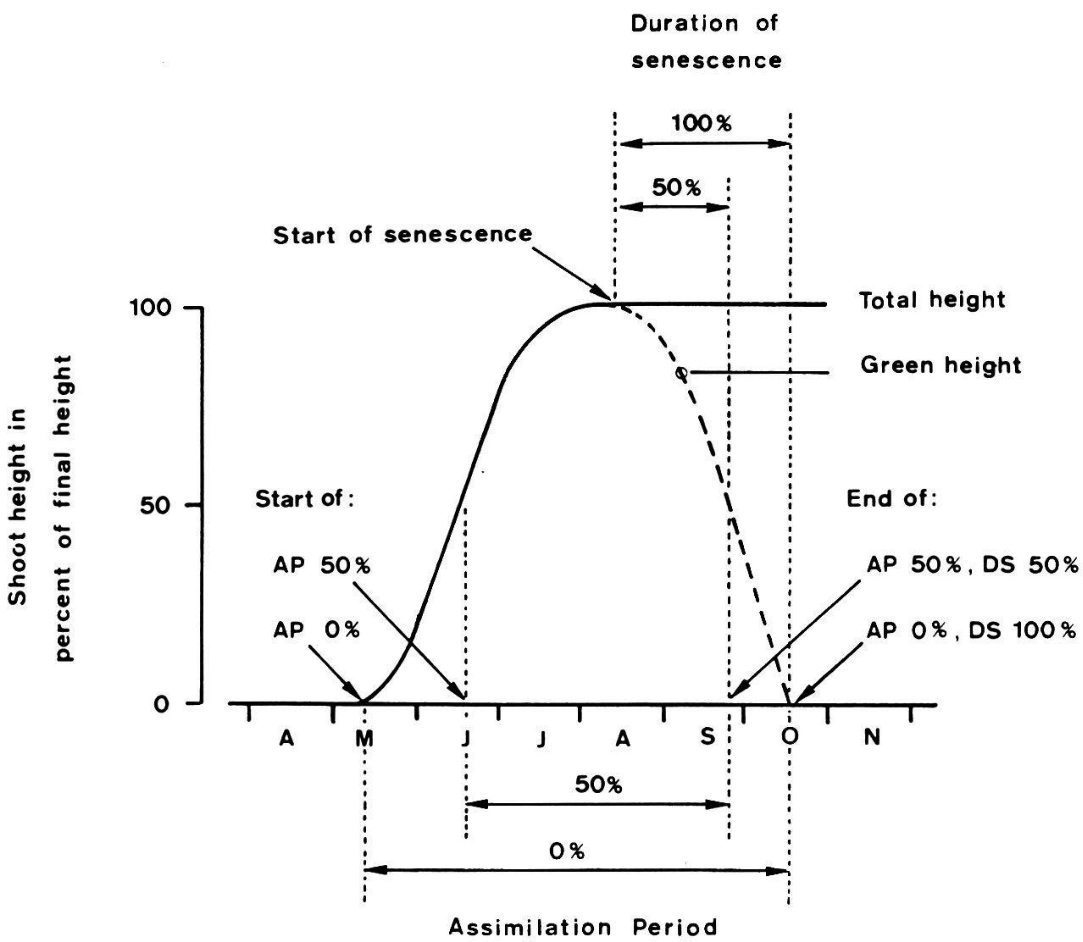

Fig. 7. Definitions of assimilation period and duration of senescence: Schematic diagram illustrating the definitions of start, duration and end of the "Assimilation period 0%" (AP 0%) and the "Assimilation period 50%" (AP 50%) as well as of the start of senescence and the "Duration of senescence 50%" (DS 50%) and the "Duration of senescence 100%" (DS 100%).

0% was considered to have started on or after the day of burning, growth before that date not being taken into account since fire destroyed practically all the shoots that had already emerged at the time.
Assimilation period 50% was defined as the time in days between the date when the height of the green shoot portion rose above and fell below 50% of the final shoot height. The respective dates were determined for each 0.5x0.5 m permanent quadrat by linear interpolation. It is argued that the assimilation period 50% represents the period of time during which the main bulk of photosynthesis is accomplished and reserves are built up in the rhizomes; in early spring, when shoots have not yet reached 50% of their final height, growth depends largely on rhizome reserves and in autumn, when the height of the green shoot portion has fallen below the 50% mark, the assimilating surface is too limited to increase substantially the amount of reserves built up during the vegetation period.

3.4.5. Senescence

The start of senescence was defined as the date on which the process of progressive yellowing of leaves commenced. The onset of progressive yellowing did not differ among the treatments: in all the plots, senescence started on the same day, i.e. August 14. Duration of senescence was defined as the period of time in days between the start of progressive yellowing, i.e. August 14, and the day on which the senescence process was complete to 50% (duration of senescence 50%) and to 100% (duration of senescence 100%), respectively. The senescence process was considered to be halfway through on the day on which the mean height of the green shoot portion fell below 50% of the total shoot height and considered to be 100% complete on the day on which all the shoots had become entirely brown (Fig. 7). For each 0.5x0.5 m permanent quadrat, the respective dates were determined visually on the shoot height vs. date graph (Fig. 7). The two measures, duration of senescence 50% and duration of senescence 100%, allow to estimate the rate of the senescence process in the different draining, burning and fertilizer treatments.

3.4.6. Susceptibility to drought and insect damage

Susceptibility to drought was quantified by measuring the length on which the leaves died back during periods of low rainfall; leaf die-back was expressed in percent of total shoot height at the time of recording. The percentage of shoots attacked by stem boring insect larvae was recorded on August 6 and September 3; the mean of the two sampling dates was used for analysis.

3.4.7. Standing crop

Above-ground standing crop was sampled in C- and NPL-plots only. In late October and early November, within each of these plots one 0.5x0.5 m quadrat was chosen at random, the above-ground biomass was cut at ground level, separated into (i) current year's (1982) Typha growth, (ii) current year's growth of plants other than Typha and (iii) litter. Samples were dried at 100 ^{o}C to constant weight. For the fertilizer treatments, where above-ground standing crop was not measured, current year's Typha shoot standing crop (S) was estimated for every treatment plot with help of multiple regression, using the means of final shoot height (H), final shoot density (D), basal shoot circumference (C) and number of leaves per shoot (L) as predictor variables; the regression equation was $\ln(S) = -7.5417 + 1.2549*\ln(H) + 0.9624*\ln(D) + 1.4997*\ln(C) - 0.8836*\ln(L)$ (r-square = 0.952). Typha shoot standing crop on June 19 (SJ) was estimated using the means of shoot height (HJ) and shoot density (DJ) at that date as predictor variables; the regression equation was $\ln(SJ) = -9.2629 + 2.4953*\ln(HJ) + 0.9368*\ln(DJ)$ (r-square = 0.949).

3.5. STATISTICAL PROCEDURES

Multiple regression was calculated in the logarithmic scale (natural logarithms), using PROC STEPWISE and PROC REG of the Statistical Analysis System (S.A.S. Institute 1982), and differences between draining, burning and fertilizer treatments were determined by analysis of variance

Table 2. Transformations used to make data appropriate for analysis of variance.

Variable	Transformation
- Start of shoot emergence	-
- Shoot density on June 12	logarithmic
- Shoot density on June 19	square root
- Shoot density on June 19 in percent of final shoot density	angular (arcsin $\sqrt{x}$)
- Final shoot density	square root
- Shoot height on June 19	-
- Final shoot height	x**1.57
- Basal shoot circumference	logarithmic
- Number of leaves per shoot	-
- Length of the assimilation period 0%	-
- Length of the assimilation period 50%	x**1.57
- Start of the assimilation period 0%	-
- Start of the assimilation period 50%	-
- Day after May 15 on which shoot height reached 71.1 cm	square root
- Duration of senescence 50%	-
- Duration of senescence 100%	-
- Green height in percent of total height on October 3	angular (arcsin $\sqrt{x}$)
- Susceptibility to drought (percent leaf die-back on June 19	angular (arcsin $\sqrt{x}$)
- Insect damage (percent infested shoots)	angular (arcsin $\sqrt{x}$)
- *Typha* shoot standing crop on June 19	logarithmic (ln(x+1))
- *Typha* shoot standing crop in Oct./Nov.	logarithmic
- Standing crop of plants other than *Typha* in Oct./Nov.	logarithmic
- Litter load in Oct./Nov.	logarithmic

with help of PROC GLM. The transformations used to make the data meet the assumptions of the analysis of variance are summarized in Table 2. Tests of significance were performed on the transformed data but means are reported in the untransformed scale; the means reported in the untransformed scale were also calculated in this scale and not back-transformed. When for a parameter more than one value per permanent 0.5x0.5 m quadrat was recorded, as was the case for final shoot density, shoot height, basal shoot circumference, number of leaves per shoot and percent leaf die-back, the means were used for analysis of variance. Analysis of variance was calculated for the entire data set (all four draining x burning regimes combined) as well as separately for the two draining (burning treatments combined) and the two burning (draining treatments combined) regimes. The fertilizer treatment sums of squares were decomposed into the four following planned orthogonal comparisions: C vs. NPL, C vs. N, C vs. P and C vs. L. Unplanned multiple comparisons between pairs of fertilizer treatment means were tested according to the T-method, and unplanned contrasts among fertilizer means according to SCHEFFE's method (SOKAL and ROHLF 1981). Tests of significance within a single draining x burning regime were made using the pooled error mean square of the two burning treatments in the respective draining regime.