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Effects of Nitrogen Stress on Panicle Structure of Sorghum *cv.* Texas 610 SR.

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ABSTRACT. Three solution culture experiments were conducted at the University of Queensland, Australia, from 1986/87 to study the effects of nitrogen stress during various growth stages on growth and panicle development of grain sorghum cv. Texas 610 SR. The first experiment was conducted to study the effects of nitrogen stress during various stages in Growth Stage I (GS I i.e. before panicle initiation) and the second experiment to study the effects of nitrogen stress during various stages in GS II (i.e. after panicle initiation). The third experiment was designed to cover both growth stages GS I and GS II.

The number of whorls and the total number of primary branches were not reduced with nitrogen stress. However, the total number of secondary branches was reduced only when nitrogen stress was imposed at or before panicle initiation. The earlier the stress was imposed, the greater the reduction in number of fertile secondary branches. Both total and fertile tertiary branches were more susceptible to the stress than the secondary branches. When nitrogen stress was imposed early, they caused primary branches in the lower whorls to abort, thereby reducing the number of secondary and tertiary branches. The loss in fertility of primary, secondary and tertiary branches resulted in a reduction in the number of fertile florets.

INTRODUCTION

Nitrogen is universally lacking in most soils and additions are needed for crops to grow properly (Clark, 1982). Sorghum is an annual crop to which nitrogen fertilizer is best applied in split dressings at planting and then as a side dressing at pre-boot stage (Evenson and

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Byth, 1970; Cowie and Asher, 1972). Nitrogen fertilizer is highly soluble in water; it can be lost from the rooting zone easily either by runoff or leaching. It can be volatilized as NH_3 in high temperatures or released as nitrogen gas by denitrification under anaerobic conditions. Therefore, a sorghum crop may experience a lack of nitrogen at any time of its growing period. It is important to know what happens to a crop of sorghum when nitrogen becomes deficient during certain growth stages and how nitrogen particularly affects the growing panicle and its structure. Therefore a series of glass – house solution culture experiments were conducted to study the effects of nitrogen deprivation during various growth stages on growth and panicle structure of sorghum. Results of two experiments are been discussed in this paper.

MATERIALS AND METHODS

Sorghum bicolor *cv.* Texas 610 SR was grown in an evaporatively cooled glass – house using solution culture technique in both experiments. Seeds were sterilized, aerated overnight and germinated in an incubator for 2 days at 28 C. Two seedlings were planted in each seedling container of culture vessels. On day 3, the seedlings were thinned to two per pot. All the treatments were replicated three times; the pots were completely randomized within four rows in the centre of the glass – house.

The plants were grown by the Programmed Nutrient Addition technique (Asher and Blamey, 1986) using the "NUTRADD" program to calculate the daily demand for each nutrient element for the duration of each experiment. The "NUTRADD" program was also used to select the most suitable amounts and combinations of salts to satisfy the demand for each element. From these data, nutrient addition schedules were prepared. The nitrate to ammonium ratio was maintained at 8:1 to help stabilize solution pH (Clark,
1982).

These experiments were conducted during the months of October to December 1987 and 1988. The daily maximum glass – house temperature ranged from 26 C to 35 C, and the minimum from 20 C to 23 C during the night.

There were six treatments in both experiments. In Experiment 1, nitrogen supply was discontinued at every 3 days, while in Experiment 2 at every 6 days, both starting from 6 (1–6) before panicle initiation. There were 10 harvests from non-stressed (control) plants. To assist in the timing of the nitrogen withdrawal treatments, plant development was monitored by destructively harvesting and examining stem apices of plants grown in 10 extra pots which were planted 10 days earlier than the main trial.

Nitrogen stress treatments were imposed by transferring the pot lids plus seedling containers to fresh pots containing nitrogen free nutrient solution.

At harvest the number of leaves, dry weights and the number of days taken for panicle initiation and anthesis were recorded and the panicles were dissected and panicles less than 1 cm in length were preserved in 100% amyl acetate for Scanning Electron Microscopy (SEM). The panicles larger than 1 cm in length were examined under a large magnifying lens for the number of whorls, primary branches, secondary branches, tertiary branches, and florets. Both the total number of branches and the number of fertile branches were counted wherever possible.

RESULTS

The number of leaves and the number of days for panicle initiation in different treatments are given in Table 1.

The dimensions of the young apices of control plants and plants grown in treatments 1–3 and 1 are presented in Table 2 and Plate 1. On day 22, control panicle of the control plants was initiated and was larger in size. At this time, the apices of the nitrogen stressed plants were still in the vegetative phase. For example, the panicle diameter of the control plant was about 0.03 mm at initiation while those of the treatments 1–3 and 1 were about 0.02 mm and 0.013 mm respectively. In the same manner, the growth of the respective panicles was slowed down accordingly as nitrogen stress continued. On day 25, primary branches of the control panicle were fully developed and secondary branches were only starting to develop from the base (Plate 1). However, in treatment 1–3, the apices were still in the vegetative

Table 1. Effects of nitrogen stress on the growth measurements of grain sorghum *cv.* Texas 610 SR.

Parameter	Days after nitrogen withdrawal					l.s.d.
	Control	20	32	44	57	5%
No. of leaves	16	10	12	16	16	2.4
No. of days for PI	28	39	28	28	28	5.3
No. of days for Anthesis	57	60	59	57	57	1.6

phase while the apices in treatment 1 were initiated. On day 28, the panicle of the control plant was about 8 and 5 times larger than those of treatments 1–3 and 1 respectively.

There was no effect of nitrogen withdrawal on the number of whorls (Table 3). The panicles of the control plants and the plants in the treatments from which nitrogen was withdrawn had 11 to 12 whorls.

Nitrogen stress had no effect on the total number of primary branches (Table 3). Panicles of the plants in all treatments, including the control had a mean of 58.5 primary branches per panicle.

When nitrogen stress was imposed before panicle initiation (treatments 1–6 and 1), there was a significant reduction in the total number of secondary branches (Table 3). The reduction was about 40 to 45% relative to the control treatment.

Withdrawal of the nitrogen supply reduced the number of fertile secondary branches, with the effect being more pronounced the earlier the nitrogen was withdrawn. The number of fertile secondary branches was reduced by 91% and 89% when nitrogen was withdrawn before panicle initiation on day 20 (treatment 1–6) and day 26 (treatment 1) respectively.

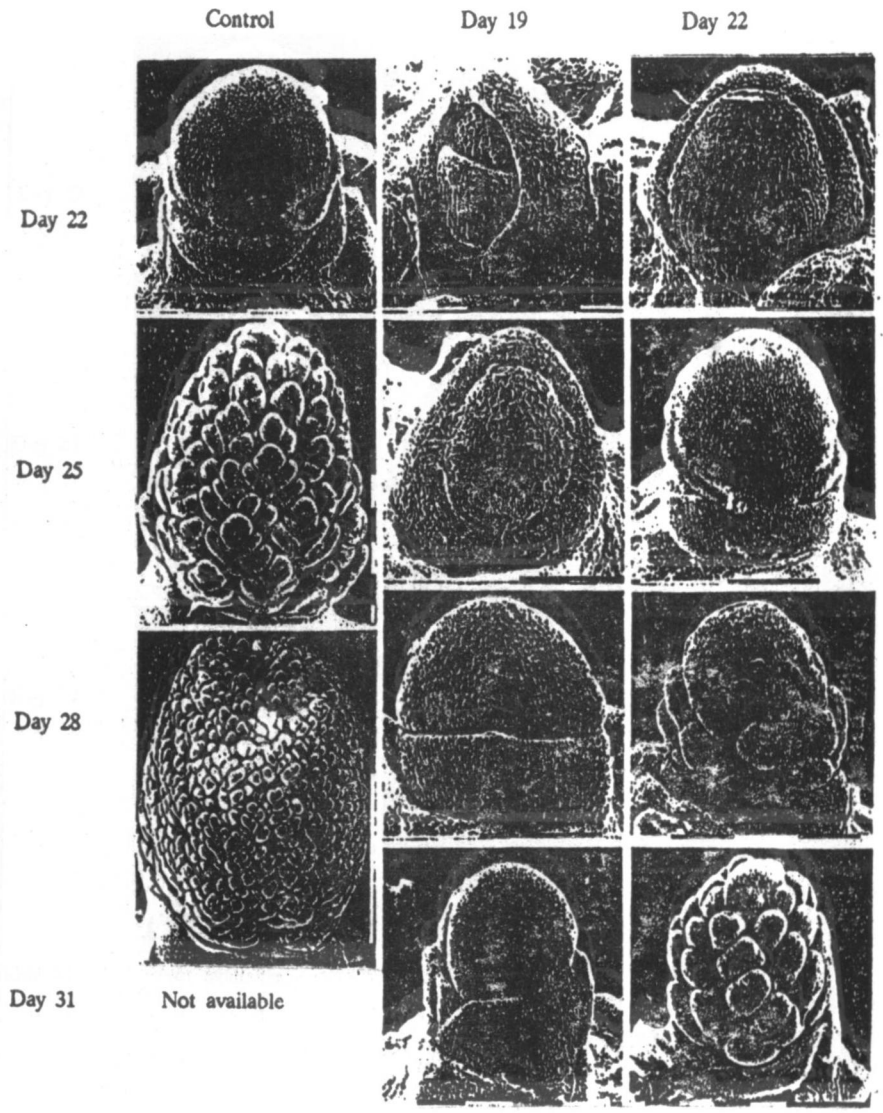

Plate 1. **Effects of nitrogen withdrawal on day 19, day 22, and the unstressed control on the apex development of grain sorghum cv. Texas 610 SR on 22, 25, 28 and 31 days after transplanting.** (Scale bars = 0.1 mm).

Table 2. Effects of nitrogen stress on the panicle dimensions (mm) of grain sorghum *cv.* Texas 610 SR harvested on days 25, 28 and 31.

Parameter	Control	I – 3	I	l.s.d. 5%
Day 22				
Apex length	0.030	n.a.	n.a.	– –
diameter	0.028	n.a.	n.a.	– –
Day 25				
Apex length	0.10	n.a.	0.020	0.031
diameter	0.09	n.a.	0.018	0.030
Day 28				
Apex length 0.14	0.017	0.030	0.011	
diameter	0.19	0.013	0.030	0.012
Day 31				
Apex length n.a.	0.026	0.040	0.012	
diameter	n.a.	0.028	0.050	0.014

n.a. not available

The number of fertile tertiary branches was reduced significantly by withdrawal of nitrogen supply (Table 3). The decrease was particularly marked in those treatments in which nitrogen was withdrawn before, at, or just after panicle initiation. In fact; no fertile tertiary branches were produced in treatment 1 – 6, and only 6 per two plants in treatment 1 (Table 3).

In general, the total number of tertiary branches in the panicle was less than the total number of secondary branches. However, the total number of tertiary branches was reduced by withdrawal of nitrogen supply; the earlier the nitrogen supply was withdrawn, the greater was the reduction in the total tertiary branches (Table 3). This reduction was particularly large when the nitrogen supply was withdrawn before

Table 3. Effects of nitrogen withdrawal on the development of panicle components and on fertility of secondary and tertiary branches at the final harvest (day 74, unless otherwise specified) in Experiment 2.

Parameter	Day from which nitrogen was withdrawn							
	Control	20 (I−6)	26 (I)	32C (I+6)	38D (I+2)	44E (I+18)	50 (I+24)	l.s.d 5%
No of Whorls A	12	11.2	11.6	11.3	11.2	11.2	11.6	0.8
Primary Branches A								
Total A	63	57	57	59	59	55	58	7.4
Fertile B	63	40	57	59	59	55	58	10.2
Secondary Branches								
Total A	441	220	260	415	418	396	398	35.3
Fertile B	438	48	62	266	300	343	361	41.7
Tertiary Branches								
Total A	417	68	100	334	369	363	383	29.8
Fertile B	401	0	6	60	120	334	341	12.2
Fertile								
Florets B	2617	187	219	1097	1306	1445	1541	45.7

A Mean of 5 harvests of 3 replicates;
B Mean of 3 replicates at the fourth harvest;
C Data for day 56;
D Data for day 62;
E Data for day 68.

panicle initiation, reaching 84% when nitrogen was withdrawn on day 20 (treatment 1-6) and 76% when nitrogen was withdrawn on day 26 (treatment 1).

The number of the florets in the panicle was reduced by withdrawal of the nitrogen supply at all stages of plant growth (Table 3). However, the reduction was greatest in those treatments (1-6, 1) in which the nitrogen supply was withdrawn before or at panicle initiation (Table 3). The number of fertile florets per panicle in these two treatments was 187 and 219, respectively, compared with 2617 florets per panicle of plants grown in the control treatment.

DISCUSSION

The results of these experiments emphasize the importance to sorghum plants of an adequate nitrogen supply during the growing period, especially early in the growing season. Withdrawal of nitrogen supply at any stage of plant growth from 6 days prior to panicle initiation to anthesis reduced both the growth rate and the total number of fertile florets; these reductions were greater the earlier the withdrawal of the nitrogen supply. Cowie (1972) reached a similar conclusion in earlier work on grain sorghum as did Chapman and Keay (1971) with wheat, and Chadhokar (1971) with *Paspalum plicatulum*.

Effects of Nitrogen stress on panicle structure

The number of whorls did not change significantly in all the experiments of the present study; however, Cowie (1972) observed a small but significant decrease in the number of whorls due to the nitrogen stress. He used sorghum *cv.* Texas 610 which is very similar to Texas 610 SR and observed about 10.4 and 11.5 whorls with and without nitrogen stress respectively. In the present study there was an average of about 11 whorls irrespective of treatment.

The scanning electron microscopy studies showed that there was no significant effect of nitrogen stress on the total number of primary branches produced on the reproductive apex. But there was a significant difference in the diameters of the reproductive apices due to the nitrogen stress treatments (Table 3). It appears that the nitrogen stress imposed

in early stages of the plant growth: (1) delays panicle initiation, (2) reduces the diameter of the apices, and (3) has a high probability of aborting primary branches. Quinby and Schertz (1970) have proposed that the diameter of the apical meristem increases with each leaf initiated and that the size of the panicle is related to the size of the meristem initiating it. Since the total number of the primary branches in the present study showed no difference due to the treatments, it indicates that the number of primary branches is not flexible. Brown (1978) suggested that there is little scope to alter the potential number of the primary branches in a panicle since it is strongly determined by genetic factors. Therefore, it appears that nitrogen stress during early stages is unlikely to contribute any changes in the basic structure of the panicle. However, when nitrogen stress was imposed before panicle initiation, the fertility of the primary branches was significantly reduced.

A different situation arose during the later stages of panicle development, especially during the initiation of the secondary and tertiary branches. This period was very susceptible to nitrogen stress. When nitrogen was withheld before panicle initiation, the total number of secondary branches was reduced significantly causing many of the secondary branches to be sterile. Cowie (1972) suggested that decrease in the number of secondary branches was due to nitrogen stress during floral initiation and flowering. This reduction may be due to the competition for nitrogen within the branches, which leads to abortion of florets as well.

The tertiary branches seem to be the most susceptible, compared with others, to nitrogen stress as it reduced both the total and fertile number of tertiary branches, when imposed at any stage of growth. Yet, the stress imposed in early stages had a greater effect on the fertile tertiary branches. The fertility of the tertiary branches is best discussed in relation to the fertility of the florets; as more and more florets became sterile, more and more tertiary branches will be classified as infertile. The number of fertile florets remaining in the panicle depend on the nitrogen reserve in the plant and how much of that can be retranslocated to the panicle. It is apparent that the panicles of the starved plants extract nitrogen from the other sources like leaves, stems and roots (Dias, 1990). Since there is competition between the panicle and the other growing tissues for the nutrients of the plant, the demand of the panicle will not be met fully (Evans, 1972; Brown, 1978, Dias, 1990). It was observed that the nitrogen concentration in the

inflorescence of the adequate nitrogen treatment as well as nitrogen stressed treatments were almost the same during the initial stages, but in the later stages, the nitrogen concentration of inflorescence on nitrogen deprived plants, started to drop below those of the control plants (Dias, 1990). Work done with wheat showed similar results on the spikelets. Single (1964) found that nitrogen deficiency prior to initiation caused a reduction in spikelet numbers. Lanager and Liew (1973) observed that florets of the most basal spikelets of wheat tend to develop slowly and with nitrogen stress they produced few or no grains. From the present study, it could be concluded that the number of branches or the florets in the panicle, could be suppressed during the early stages of floral or branch development due to (1) the competition for nitrogen between the panicle and other growing tissues such as leaves and tillers, or (2) intra whorl competition which aborted the florets and the higher order branches because of the limited availability of nitrogen to the lower whorls within the panicle.

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