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Yield and Nitrogen Accumulation By Andropogon gayanus And Schizachyrium sanguineum Grown under four Nitrogen and Water Application Regimes in gravel and sand pot culture

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Abstract

Andropogon gayanus and Schizachrium sanguineum grass plants were grown in sand and gravel media under two levels each of applied nitrogen and water to study the effect of growth medium texture on yield and nitrogen accumulation inthe two species. Nitrogen level was varied by applying the nutrient solution once every other day to one group of experimental plants and once in four days to another group. Water was applied at the same frequency but alternated in time with the nutrient solution. There were on the whole four treatments.

Both grasses had their highest yields when grown in sand. Applying nutrient solution every other day and water once in four days resulted in the highest grass yield. Higher nitrogen concentration in both grass tissues was obtained in gravel and S sanguineum accumulated more nitrogen when the two grasses are compared.

The results obtained in the experiment confirm results obtained from other studies on yield and nutrient accumulation by grasses in compact and coarse soils and the ways the result could be useful in active savanna management are discussed.

Introduction

Plants require nutrients and water from the soil to be productive. Absorption of these is through the root system in the soil for most plants but absorption may be hampered or completely inhibited by the physical conditions of the soil. It is generally accepted that compact, fine textured soils inhibit root development while friable soils tend to promote extensive root system (Diebold 1935, Prumel 1975). Veihmeyer, & Hendrickson (1948) found that lateral roots of grasses growing on sand were longer and more densely branched than in the same grasses found in loam soil.

If the soil is coarse and capillary action consequently low, too great lowering of the soil water table may result in a soil too dry to promote maximum yields. Coupland & Johnson (1965) found that some species developed more deeply in sand presumably because of the deeper penetration of root into the substratum and as a result have higher yield.

Roots respond in both amount and direction of growth to differences in water content and aeration. By varying these factors through the application of more or less water, not only the root system but also the above-gound parts of the plant and yield may be affected, since a close correlation exists between the growth of roots and tops. Where the soil is dry root development is greatly retarded or even ceases and the above-ground parts are consequently reduced. A moderate soil water content, enough to ensure good growth stimulates the root to greater development, resulting in greatly increased absorbing surface. On the other hand in extreme cases where water is limiting it may become expedient to concentrate production energies in the root system as is often the case with plants in dry habitats where most of the plants biomass is in the root system.

The rate of uptake of nutrients by plants is linearly related, up to a certain extent, to the rate of nutrient availability in the soil. The higher uptake rate with higher input is often reflected in higher relative biomass production and/or higher concentration of the nutrient in the plant's tissues (Van Keulen 1977). For example, plant nitrogen concentration has been shown to be a good indicator of the nutrient's status in the soil (de Wit <u>et al</u> 1963). Adegbola <u>et al</u> (1968) also observed that grass dry matter production and utilization by livestock increased with an increase in the rate of nitrogen fertilization in the wet savanna zone of Nigeria.

All parts of the plant do not respond to nutrient application equally. Rhyle (1970) applied two different levels of nitrogen to dense stands of <u>Dactylis glomerata</u> grown under controlled conditions and observed a three-to four- fold increase in total dry weight per unit area with the higher nitrogen application. This increase resulted from wider and much larger leaves giving rise to a 60% increase in shoot weight at the higher nitrogen level.

The effect of nutrient level increase is mediated through the root system.

Rogers (1935) showed that roots of plants grown in soil with alternate layers enriched with nutrients branched more profusely and had higher yield in the enriched layers. This observation is further strengthened by Weaver and Clement (1938) which showed that crops grown inrich soil have roots that are shorter, more branched and more compact than those grown in similar but poorer soil. In nature these factors of nutrient supply, soil moisture levels and soil texture act together to affect the performance of theplant. This present study is an attempt to evaluate the effect of these factors, soil texture, moisture availability and nutrient level on the performance of two widely distributed savanna grasses, Andropogongavanus and Schizachyrium sanguineum under laboratory conditions. To minimize complexity only one nutrient, nitrogen, is investigated. Nitrogen was chosen because it is often limiting in tropical ecosystems especially savannas. Grasses are the major utilisable resource of the savanna which occupies 70% of the land area of West Africa and the factors that affect their production need to be clearly understood for improved management.

Foster and Mundy (1961) described A. gayanus as the best suited for Northern Nigerian range conditions and Adegbola (1962) ranks it highest in palatability comparable to legumes such as Stylosanthes and Centrosema for grazing stock. Further, Tetteh (1974) showed that A. gayanus is heavily grazed by cattle, sheep and goats on the Achimota range in Ghana. Isichei (1983) observed that A. gayanus and other Andropogon species in the humid savanna zones of Nigeria were better accumulators of nitrogen than other grass species.

Unlike A.gayanus, Schizachyrium sanguineum is relatively unpalatable to livestock, probably because of its coarseness. Opakunle (1978) found it a more efficient accumulator of nitrogen than A. gayanus when supply is very low. It is of interest to find out how this contrast is affected by the nature of the growth medium and how these grasses apportion absorbed nitrogen to the various plant parts since the parts serve different purposes in the plant and not equally utilized.

Materials and Methods

Sandy material deposited along a run-off drainage channel was first soaked in HCl to solubilize mineral elements and destroy microorganisms and organic matter after which it was flushed continuously with distilled water until the pH was 6.5. The sandy material was then air dried and, after all stones had been removed, was sieved through a 2mm mesh to separate it into two textural groups. One group included all soil (mineral) particles less than 2mm to 4mm diameter and without stones and pebbles. For the purpose of this experiement we refer to the first group as sand and the second group as gravel (Plaisance and Cailleux 1981).

Twenty-four 5½ litre, 20cm deep buckets with three drainage holes drilled at the bottom of each were filled with sand and another 24 filled with gravel in readiness for the experiment.

Since it was difficult to germinate the seeds of the two grasses chosen for the experiment, sprouts from their rhizomes were used. Dormant rhizomes of Andropogon gayanus and Schizachyrium sanguineum were taken from the Old Oyo Forest Reserve, Igbeti where they grow naturally and planted in the University of Ife Botanical Garden in December 1983. The rhizomes started to sprout two weeks after planting and four weeks after emergence, the sprouts were transplanted into the sand-filled experimental buckets, one plant per bucket. Twelve A. gayanus and twelve S. sanguineum sprouts were planted one to a bucket in each of the sand-filled and gravel-filled buckets respectively. The buckets were set in a screen house and were wetted daily with distilled water 200ml), for an initial period of two weeks to allow them become established in the sand and gravel media. The wetting was contiued for a further three weeks with distilled water and in addition, ammonium nitrate solution ($0.029gl^{-1}$) which supplied an equivalent of five parts per million nitrogen to the plants was also applied. This was to further ascertain that the plants were firmly established before the commencement of the experiment.

On the 8th March 1984 the experiment began with the wetting of the plants with 200ml of a nutrient solution that contained 35 ppm nitrogen in form of potassium nitrate ($0.216gl^{-1}$, 30ppm N) and ammonium nitrate ($o.029gl^{-1}$, 5 ppm E). The nutrients that are known to be utilized by plants, all in the proportions formulated by Hewit (1952). The chosen level of nitrogen was considered adequate for grass growth. The single concentration of 35 ppm N was used for the experiment and various treatments listed below were achieved by varying the frequency of application. In a similar manner 200ml distilled water was used for wetting the plants and the frequency of application varied according to the desired treatment.

The twelve sand-filled and twelve gravel-filled buckets for each plant were divided into four groups of three buckets each of which was given the following treatment.

Group:	Nutrient solution application and watering regime
1.	200ml nutrient solution every other day, watering with 200ml distilled water once every four days ("full nutrient, low water treatment, FNLW")
2.	200ml nutrient solution and watering with 200ml distilled water once every four days ("low nutrient, low water treatment LNLW")
3.	200ml nutrient solution and 200ml watering with 200ml distilled water once every other day ("full nutrient, full water treatment, FNFW")
4.	200ml nutrient solution once every four days and watering with 200ml distilled water once every other day ("low nutrient, full water treatment, LNFW")

The nutrient solution application and watering schedule continued until the grasses matured. Maturity was assumed when the first inflorescences appeared. All senesced leaves were collected from the plants dried and weighted and these leaves were added to the final dry weight at maturity. The number of tillers produced by each plant in the two species was also counted before harvesting.

At harvest the plants were separated into leaves, stems and roots by cutting. The plants were dried to constant weight at 80°C, weighed and ground in an 800RPM 8" laboratory mill through a 1.5mm mesh ready for analysis sof percentage total nitrogen.

Analysis for total nitrogen was carried out by the Ejeldahl method as described by Tel and Rao (1982).

Analysis of variance was used to test significant differences in data and where necessary the student-Newman-Keuls a posteriori test (Sokal and Rohlf 1969) was used to rank data when significant differences existed.

Results

Grass Yield

The yields of the two grass species and their leaves, stems and roots are shown in Figure 1. The nutrient and watering regimes producing the highest and lowest yields under the two expeimental growth media texture are shown in Table 1. The two grass species are not being compared because naturally Andropogon gayanus is a bigger grass at maturity than Schizachyrium sanguineum and as Figure 1 shows, its yields was higher in the present experiment.

Both grasses had significantly higher mean yields (151.96g per pot and 74.55g per pot for A. gayanus and S. sanguineum respecively) in the sand medium than in the gravel medium (93.58g per pot and 61.74k per pot for A. gayanus and S sanguineum respectively) with the difference in yield being more pronounced in A gayanus ($P< 0.001$) than in S. sanguineum ($P< 0.05$).

As shown in Table 1, the full nutrient, low water treatment gave the highest yields in both A. gayanus and S. sanguineum while the low nutrient, low water and low nutrient, full water regimes were intermediate. The differences in grass yields under each of the four watering and nutrients application regimes were not statistically significant in A. gayanus either in sand or in the gravel medium. In S. sanguineum the differences in yield resulting from the various treatments were statistically significant both in the gravel medium ($P<0.01$) and in the sand medium ($P<0.05$). A slightly different pattern is observed when the leaves, stems and roots are considered in each of the two species.

When the shoot and root yields of A gayanus are considered separately, the full nutrients, low water regime still produced the highest yield of 97.15g per pot in the shoots. In the gravel and sand media the differences among shoot yields under the four different treatments were statistically significant ($P < 0.05$ and $P < 0.001$ respectively). In the roots the highest yields of 28.75g per pot were obtained under the full nutrient, full water treatment in gravel and 35.35g per pot under the full nutrient, low water in sand. Differences in Andropogon root yields under the various treatments and the two media were, however, not statistically significant.

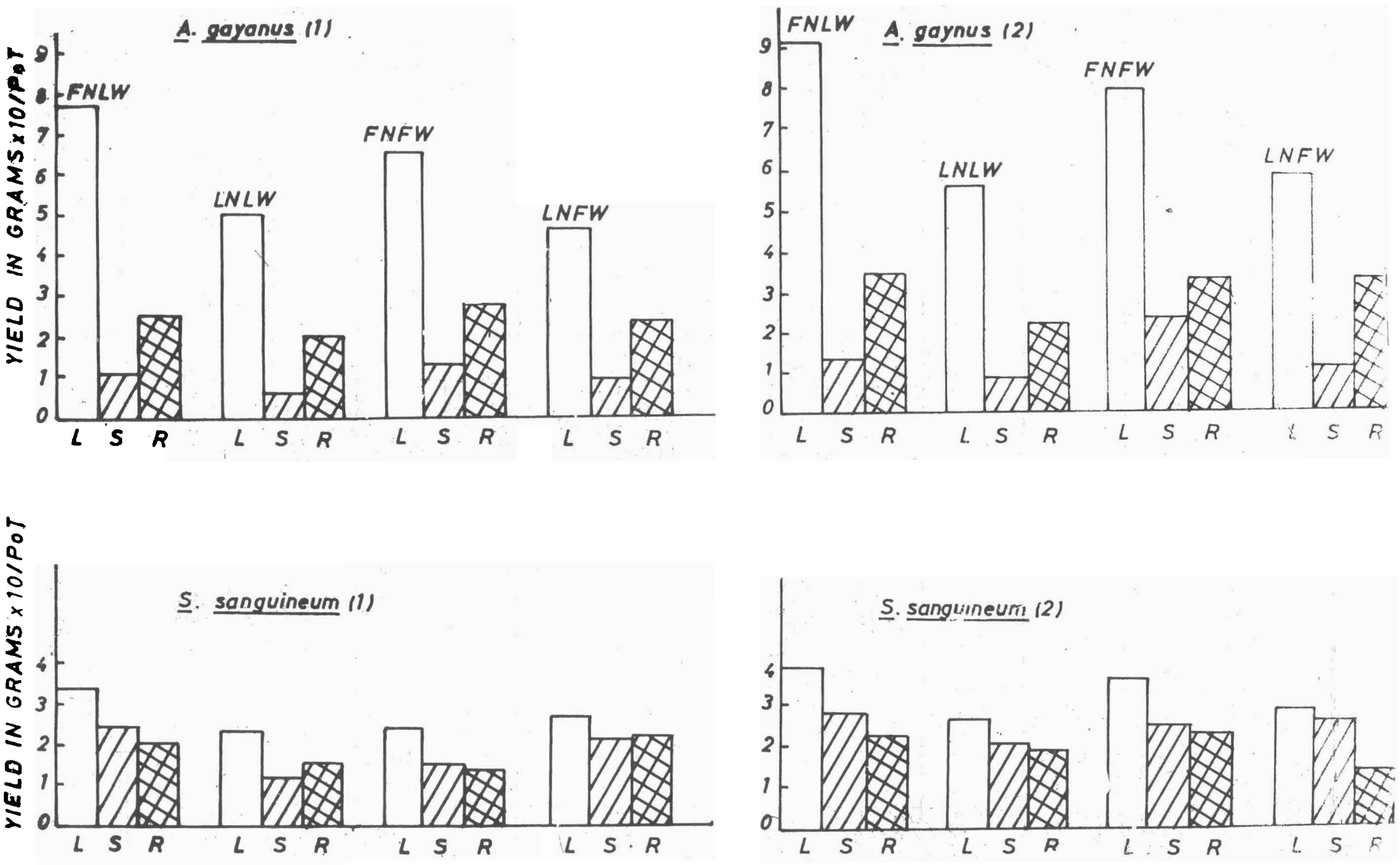

Fig. 1: Mean yield of leaves, stem and roots of *Andopogon gayanus* and *Schizachyrium sanguineum* grown in gravel (1) and sand (2) pot culture under four nutrient and water application regimes, L = Leaves, S = Stems, R = Roots.

Table 1: Rating of the effects of four different nutrient and water treatment regimes on yield in two grasses,

Schizachyrium_sanguineum and Andropogon_gayanus grown in gravel and sand pot cultures

	Gravel Rank of yield (g per pot) values			Sand Rank of yield (g per pot) values		
Andropogon gayanus	Highest	Inter-mediate	lowest	Highest	Inter-mediate	Lowest
Leaves	FNLW (79.13)	FNFW (65.35 LNLW (50.87)	LNFW (46.13)	FNLW 92.32)	FNFW 79.11) LNFW (58.52)	LNLW (56.57)
Stem	FNLW (12.21)	FNFW (9.08) LNLW (8.04)	LNFW (5.70)	FNLW (23.38)	FNFW 13.77) LNFW (11.61)	LNLW (8.28)
Root	FNFW (28.75)	FNFW (26.43) LNLW (24,85	LNFW (18.79)	FNLW (35.35)	FNFW (33.17) LNFW (33.26)	LNLW (22.40)
Whole Plant	FNFW (114.64)	FNFW (106.46) LNLW (77.86	LNFW (75.35)	FNLW (141.44)	FNFW (135.66) LNFW (103.38)	LNLW (87.25)
Schizachyrium sanguineum	Highest	Inter-mediate	Lowest	Highest	Inter-mediate	Lowest
Leaves	FNFW (34.21)	FNFW (24.37) LNLW (26.48	LNFW (23.43)	FNLW (39.11)	FNFW (35.32) LNFW (28.37)	LNLW (26.91)
Stems	FNFW (24.43)	FNFW (15.68) LNLW (19.52	LNFW (11.17)	FNLW (28.03)	FNFW (24.24) LNFW (25.07)	LNLW (20.17)
Roots	FNFW (20.75)	FNFW (15.28) LNLW (20.66	FNFW (13.20)	FNLW (22.90)	FNFW (22.04) LNFW (18.44)	LNLW (13.25)
Whole Plant	FNFW (78.44)	FNFW (66.67) LNLW (49.87	FNFW (48.02)	FNLW (89.48)	FNFW (81.59) LNFW (66.69)	LNLW (65.14)

In Schizachyrium, highest shoot yields of 57.69g per pot and 66.58g per pot were obtained under the full nutrient, low water treatment in both gravel and sand media respectively buy yield differences were also not significant. In the roots the highest yield of 20.75g per pot was obtained in the gravel medium under the full nutrient, low water treatment, treatment with the full nutrient, full water treatment giving the lowest yield of 13.20g per pot in the gravel medium. In sand it was the low nutrient full water treatment that gave the lowest yield of 13.25g per pot. Root yields in S. sanguineum were not statistically significant.

Leaves gave the highest yield of all plant parts in both species irrespective of treatment or growth medium (Fig. 1). In A. gayanus the roots were next in yield and stems the lowest. In S. sanguineum it was the stems and roots respectively except in the gravel medium where, under the low nutrient, low water and the low nutrient, full water treatments, root yield were marginally higher than stem yields. These differences in yields by plant parts were significant (P< 0.05) with the yields of the parts being more different in A. gayanus than in S. sanguineum (Fig. 1).

Further differences were shown by the two species in the mean number of tillers than S. sanguineum in the both the gravel and sand media and under all treatments. The order of production of tillers in A. gayanus in both sand and gravel was as follows: full nutrient, low water (7.67 tillers per pot, and 6.33 tillers per pot respectively); low nutrient, low water (5.67 tillers per pot and 5.33 per pot respectively); >full nutrient, full water; (4 tillers per pot and 3.67 tillers per pot respectively); >low nutrient, full water (4.33 tillers per pot and 3.000 tillers per pot respectively) (See Fig. 2). In S. sanguineum the highest number of tillers (7 tillers per pot) in the gravel was produced under the full nutrient, full water treatment while the full nutrient, low water and the low nutrient, low water treatment produced equal numbers (4 tillers per pot) which were intermediate and the low nutrient, full water treatment produced the lowest (2.67 tillers per pot). The same trend was more or less observed in the sand medium. These differences in tiller production under the treatment were found to be statistically significant (P < 0.05). In agreement with the observations above on the differences between the two

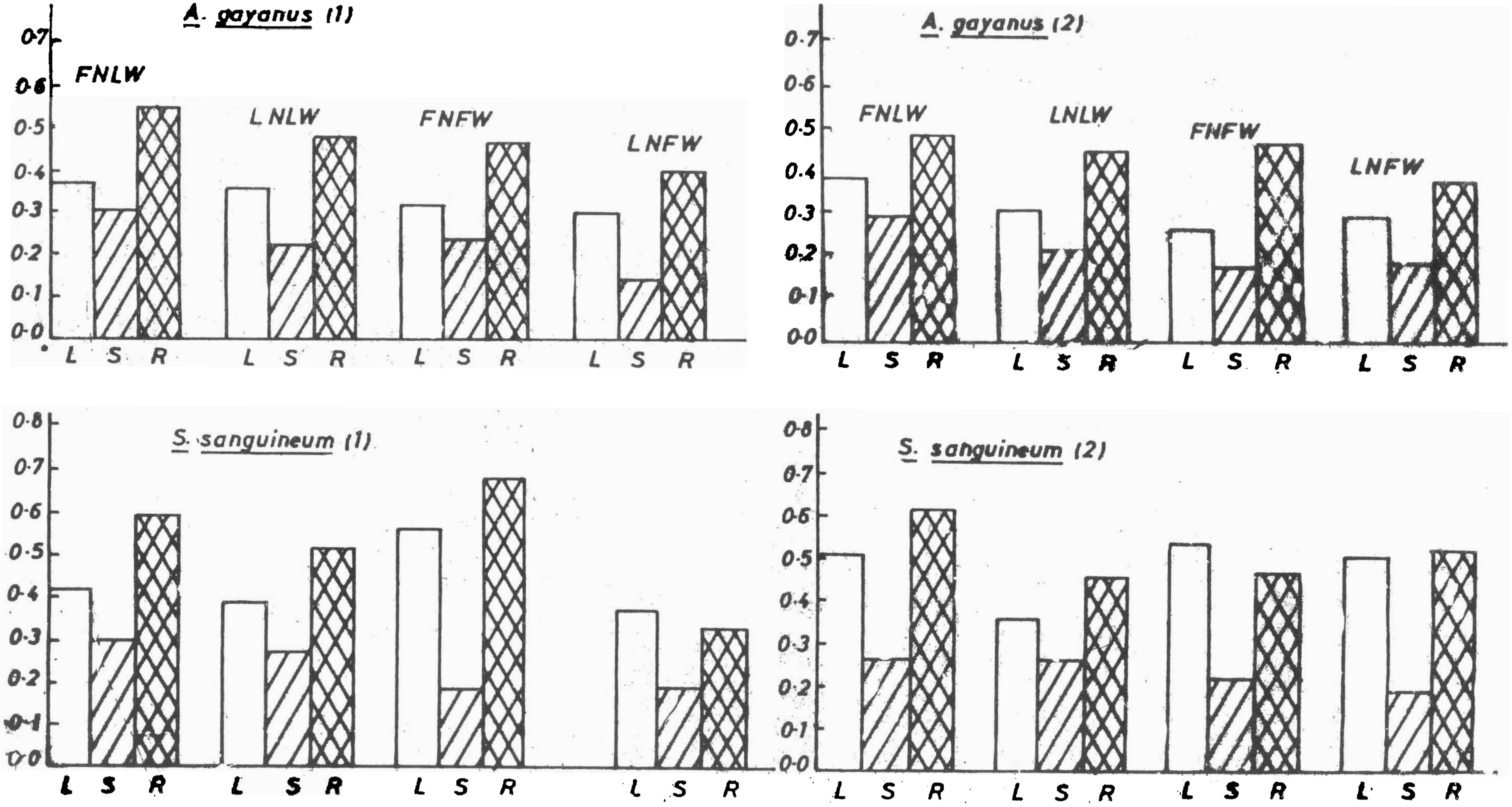

Fig. 3: **Mean percentage total nitrogen per oven dry weight of leaves, stem and roots of** ***Andopogon gayanus*** **and** ***Schizachyrium sanguineum*** **grown in gravel (1) and sand (2) pot cultures under four nutrient and water application regimes, L = Leaves, S = Stems, R = Roots.**

species, significant interactions were found between medium texture and species ($P < 0.05$) and treatment and species ($P < 0.05$). This means that the texture of the medium and the treatments applied affected the species tiller production differently.

One other difference observed between *A. gayanus* and *S. sanguineum* is the difference in the distribution of their roots within the growth medium. In *A. gayanus* 60% of the roots by dry weight were in the bottom 5cm of the bucket while 25% were in the top 5cm with the middle 5cm holding about 15% of the root dry weight. In *S. sanguineum* the proportions were 40%, 32% and 28% respectively, a more even distribution than in *A. gayanus*.

Nitrogen accumulation by the two grasses.

Percentage nitrogen concentration in the two grasses in the sand and gravel media under the four nutrient and water application regimes are shown in Fig. 3. The nutrient and water application regime resulting in the highest and lowest nitrogen accumulation values in whole plants, leaves, stems, and roots of the two grasses are shown in Table 2.

In both the sand and gravel growth media and under all treatments *S. sanguineum* showed higher nitrogen concentration than *A. gayanus* in all plant parts. This difference was however, found not to be statistically significant. There was also no significant difference in nitrogen concentration in plants grown in gravel and sand. Further, nitrogen concentration levels did not vary significantly with the nutrient and water application regime in *S. sanguineum* but it did in *A. gayanus* ($P < 0.001$). In both plants nitrogen accumulated in leaves, stems and roots differed significantly.

In the two grasses, under all the four treatments and in sand and gravel, roots showed the highest nitrogen accumulation (0.46g per pot and 0.51g per pot for *A. gayanus* and *S sanguineum* respectively) followed by the leaves (0.32g per pot and 0.44 per pot for *A. gayanus* and *S. sanguineum* respectively) and then the stem (0.21g per pot and 0.23g per pot for *A. gayanus* and *S. sanguineum* respectively). The difference in roots, leaves and stems was significant ($P < 0.001$).

The full nutrient, low water treatment gave the highest nitrogen concentration of (1.22g per pot and 1.43g per pot in *A.*

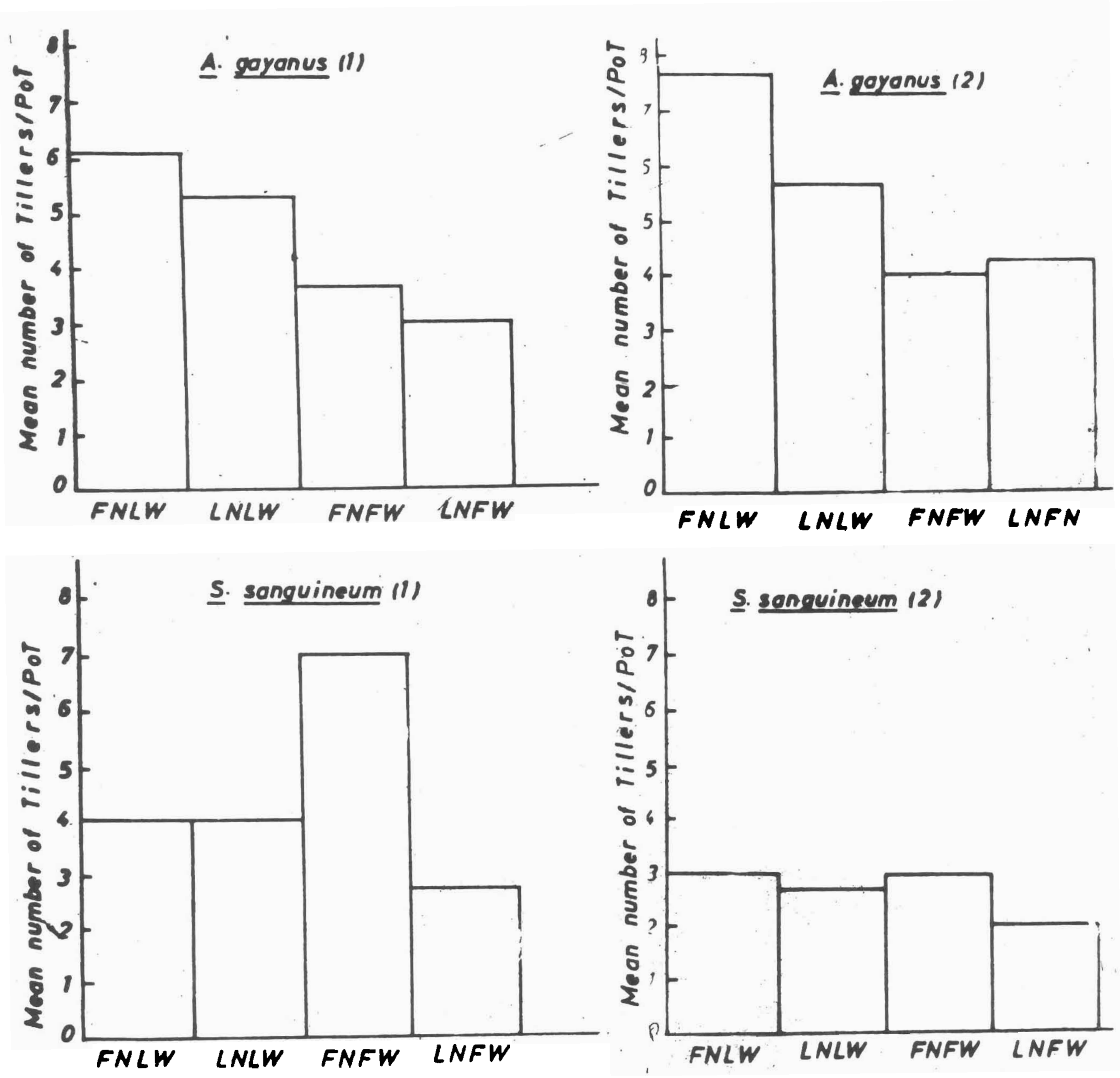

Fig. 2: Mean number of tillers of *Andopogon gayanus* and *Schizachyrium sanguineum* grown in gravel (1) and sand (2) pot culture under four nutrient and water application regimes.

gayanus and S. sanguineum respectively in the gravel medium (Table 2). The low nutrient, full water treatment gave the lowest (0.83g per pot and 0.89g per pot in A. gayanus and S. sanguineum respectively). Highest accumulation were also recorded under the full nutrient, low water treatment in sand except in S. sanguineum where the highest concentration in the leaves was under the full nutrient, full water treatment. An interesting difference between the two species is that A. gayanus, in the sand medium, treatment where full watering was administered gave the lowest nitrogen concentration in the plants parts while in S. sanguineum the low watering treatments (all under low nutrients) gave the lowest concentrations. Furthermore, in A. gayanus nitrogen concentration in the plant parts were significantly different under the four treatments in both sand ($P < 0.05$) and gravel ($P < 0.01$) while no difference was observed in S. sanguineum among the treatments. Again, in A. gayanus consistently more nitrogen was accumulated in gravel than in sand ($P < 0.01$) under all treatments but in S. sanguineum there was no pattern.

Discussion

The two grass species used for the study had their higher dry matter yields in the sand medium than in the gravel medium because water is retained for a longer time in the sand medium than in the gravel medium. Apart from retaining more water the finer medium also provides more surface area for root development and nutrient absorption. In both grasses root and whole yield were higher in the sand medium.

Water and nutrient application frequency was based on the expected fast drainage of the growth medium. The result suggest that watering was too frequent so the yields obtained were not exactly in the expected direction. Had the plants been under water stress, the full nutrients, full water treatment (alternate application of water and nutrients, each every other day) would have given the highest grass yield but it did not. The highest yields were obtained under the full nutrient, low water treatment. So what seems to have determined the yield at maturity of the grasses is the quantity of available nitrogen. Available in the sense that the more frequent the watering, the more the applied nutrient is leached from the medium. But that does not mean that the growth media were saturated with water and that water was not a limiting factor inproduction during the

Table 2: Ratings of the effect of four different nutrient and water treatment regimes on nitrogen concentration in two grasses; Schizachyrium sanguineum and Andropogon gayanus grown in sand and gravel pot cultures.

	Gravel Rank of yield (g per pot) values			Sand Rank of yield (g per pot) values		
Andropogon gayanus	Highest	Inter-mediate	lowest	Highest	Inter-mediate	Lowest
Leaves	FNLW (0.37)	FNFW (0.33 LNLW (0.36)	LNFW (0.30)	FNLW 0.38)	FNFW 0.29) LNFW (0.30)	LNLW (0.26)
Stem	FNLW (0.30)	FNFW (0.18) LNLW (0.22)	LNFW (0.13)	FNLW (0.29)	FNFW (0.18) LNFW (0.21)	LNLW (0.17)
Root	FNFW (0.55)	FNFW (0.48) LNLW (0.48)	LNFW (0.40)	FNLW (0.48)	FNFW (0.47) LNFW (0.48)	LNLW (0.37)
Whole Plant	FNFW (1.22)	FNFW (0.97) LNLW (1.07	LNFW (0.83)	FNLW (1.14)	FNFW (0.89) LNFW (0.86)	LNLW (0.84)
Schizachyrium sanguineum	Highest	Inter-mediate	Lowest	Highest	Inter-mediate	Lowest
Leaves	FNFW (0.56)	FNFW (0.41) LNLW (0.38)	LNFW (0.37)	FNLW (0.52)	FNFW (0.49) LNFW (0.50)	LNLW (0.35)
Stems	FNFW (0.29)	FNFW (0.19) LNLW (0.26	LNFW (0.19)	FNLW (0.25)	FNFW (0.21) LNFW (0.25)	LNLW (0.18)
Roots	FNFW (0.68)	FNFW (0.59) LNLW (0.51	FNFW (0.33)	FNLW (0.60)	FNFW (0.45) LNFW (0.50)	LNLW (0.49)
Whole Plant	FNFW (1.43)	FNFW (1.29) LNLW (1.15	FNFW (0.89)	FNLW (1.338)	FNFW (1.18) LNFW (1.18)	LNLW (1.04)

experiment. That water was important is shown by the fact that the low nutrient, low water treatment gave the lowest yields.

It could be concluded that both nutrients and water are important for production but it takes the plant some time to absorb all the supplied nutrients. Low-level of nutrient is very easily absorbed while high nutrient levels are not so rapidly absorbed such that frequent watering as was the case under the full water treatment (watering every other day) leaches out some of the nutrients.

The best indication of the level of nitrogen available to the plant is the level in the plant. The full nutrient, low water treatment gave the highest nitrogen concentration while the low nutrient, full water and low nutrient treatments gave the lowest. This is the order expected on the basis of the explanation given above.

The observed higher nitrogen concentration of nitrogen in S. sanguineum than in A. gayanus agrees with the observation of Opakunle (1978) that in growth medium low in nitrogen S. sanguineum is a better accumulator than A. gayanus. This situation is reversed Opakunle observed, at high levels of nitrogen in the growth medium and explains why S. sanguineum is found in nutrient-poor soils than A. gayanus. Opakunle had applied 630, 210, and 42ppm nitrogen levels compared with 35ppm used in the present experiment. Thus, in relation to Opakunle's situation S. sanguineum should be a better accumulator in the present experiment.

The distribution of the roots of the two grasses in the growth medium is of interest in relation to nutrient utilization by the two grasses. The near even distribution of roots of S sanguineum throughout the depth of the growth medium supports the hypothesis that its nutrient requirement is well met so the roots need not be concentrated at particular levels of the medium. A. gayanus, on the other hand had most of its root at the bottom of the bucket where the applied nutrients will collect before draining out of the bucket. The next area of concentration of the roots was in the top 5cm of the growth medium where the nutrients are absorbed immediately after application. In savannas roots of grasses are often found in the top 20cm of the soil profile (Menaut and Cesar 1979) and Frost et al. (185) have noted that this restriction of grass roots to the top soil is a strategy in competition for nutrients with trees which are usually deeper rooted.

While root zonation helps to explain nutrient utilization by the two grasses under the present experimental conditions it may be necessary to point out that an entirely different pattern will be found in natural situations in the presence of competition.

The higher concentration of nitrogen in those plants grown in gravel may have been as a result of high dry matter accumulation in the sand grown grasses. If absolute nitrogen amounts (nitrogen concentration multiplied by gross dry weight) are compared, the sand grown grass had more. This is akin to the situation where grasses in drier savannas have higher concentrations of nutrients in them than those found in wetter savannas (Isichei, 1983).

The higher concentration of nitrogen in the roots than in the leaves or stems of the grasses indicates translocation of nitrogen to the roots, a characteristic typical of perennial grasses at maturity (Isichei 1983). Translocation to the roots takes place at the end of the growing season such that stored nitrogen is saved from annual fires and used to support new growth in the next season.

This study was carried out under artificial condition but the results obtained have implications for savanna management. First, the differential in nitrogen accumulation between grass species when they are growing in the same environment (Isichei 1983) has been confirmed. The observation that plants grown in gravel where there was less water retention had higher nitrogen concentration than those grown in sand which retained more water is also of importance in the management of humid savannas. Usually soil water and nutrient levels influence plant nutritive quality by altering the relative production of structural (carbohydrate) and cytoplasmic (protein) components. The production of cytoplasmic components is enhanced if nutrient availability. On the other hand if water is increased relative to nutrients high carbohydrate production results (Frost et al. 1985). What is needed in African savanna is not more carbohydrate production but more nutritious grasses.

References Cited

Adegbola, A. A. (1962. Variations among the Guinea grass types occuring in parts of Northern Nigeria. Pasture Research Notes No. 1 Ministry of Agriculture and Natural Resources, Western Region, Nigeria.

Adegbola, A. A., Onayinka, B. O. & Eweje, J.K. (1968). The management and improvement of natural grassland in Nigeria. Nigerian Agriculture Journal 5(1): 4-6.

Coupland, R.T., & Johnson,R.T. (1965). Rooting characteristics of native grassland species in Saskatchewen. Journal of Ecology 53: 475-507.

De Wit, C.T., Dijkshoorn, W. & Noggle, J.C. (1963. Ionic balance and growth in plants. Verslagen van het Landbouwkundig Onderzoekingen in Nederland 69.

Diebold, C.H. (1935). Some relationship between soil type and forest site quality. Ecology, 16: 640 - 647.

Foster, W.H. & Mundy, E.J. 1961). Forage species in Northern Nigeria. Tropical Agriculture (Trinidad). Vol. 38: 311 - 318.

Frost, P., Menaut, J. C. Walker, B., Medina, E. Solbrig, O.T. & Swift, M.J. (1985). Responses of savannas to Stress and Disturbance. A proposal for a collaborative programme of Research Special issue, Biology International IUBS, Paris.

Hewit, E.J. (1952). Sand and water culture methods used in the study of plant nutrition. Commonwealth Bureau Horticulture Plantation Crops (Great Britain) Technical Commonwealth. 22.

Isichei, A.O. (1983). Nitrogen concentration in the major grasses of the Derived and Guinea Savanna Zones of Nigeria in relation to season and site. Tropical Agriculture (Trinidad) 60: 48 - 52.

Keulen, H. Van, (1977). Nitrogen requirement of rice with special reference to Java. Contribution for the Centre for Research Institute Agriculture Bogor: No. 30. 67.

Menaut, J.C., & Cesar, J. (1979). Structure and Primary productivity of Lamto savannas, Ivory Coast. Ecology, 60: 1197 - 1210.

Opakunle, J. S. (1978). Nitrogen partitioning in relation to season and nitrogen content of the growth medium in two Nigerian occurring grasses, Andropogon gayanus Kunth, and Schizachyrium sanguineum (Retz.) Alston. Unpublished M.Sc. Thesis, University of Ife, Nigeria. pp. 91.

Plaisance, g. & Cailleux, A. (1981). Dictionary of Soils. Amerind Publishing Co. PVT Ltd, New Delhi, Bombay, Calcutta and New York.

Prummel, J. (1975). The effect of soil structure on phosphate nutrition of crop plants. Netherland Journal of Agriculture Sciences 23(1): 62-68.

Rogers, W. S. (1935). Soil factors in relation to root growth. Transaction of International Congress of Soil Science. 1: 249 - 253.

Ryle, G.T.A. (1970). Effect of two levels of applied nitrogen on the growth of S. 37 Cocks foot in small simulated swards in a controlled environment. Journal of British Grassland Society 25 (1): 20-29.

Sokal, R.F. & Rohlf, F.J. (1969). Biometry: W.H. Freeman and Co, San Francisco.

Tel, A.D. & Rao, P.V. (1982). Automated and Semi-automated Methods for Soil and Plant Analysis. Manual series No. 7 International Institute for Tropical Agriculture, Ibadan.

Tetteh, A. (1974). Preliminary observations on preference of harbage species by cattle, sheep and goats grazing on range, on the Achimota Experimental Farm. Chana Journal of Agricultue Science. 65: 487 - 493.

Weaver, J.E. & Clement, F. C. (1938). Plant Ecology. Mc Graw-Hill Book Company Inc. New York and London.