# Forage millet response to irrigation and nitrogen fertilization in the derived savanna zone of Nigeria

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SUMMARY

The effects of varying levels of irrigation (9 cm, 18 cm and 36 cm of water) and nitrogen fertilizer (0, 150 and 300 kgN/ha) on growth, yield and quality of forage millet grown on an oxisol in the dry season of the derived savanna environment at Nsukka in Nigeria were investigated. The experimental design was a randomized complete block in factorial. Crop height, growth rate and herbage dry matter yields increased with increasing rates of irrigation and nitrogen fertilization. The highest yield of whole plant crude protein produced with the 18 cm irrigation treatment was superior to the 9 and 46 cm irrigation treatments by 76.0 and 8.7 per cent respectively. The mean concentration of all assayed nutrients (N,P,K, Mg and Ca) in the forage were above the threshold for efficient ruminant livestock production. Increasing rates of irrigation increased N uptake and P concentration but decreased N concentration. Nitrogen fertilization increased N uptake, N and Ca concentrations but decreased P concentration at the highest rate of application. Interactions were significant. Maximum yields of forage dry matter (6425 kg/ha) occurred at 300 kgN× 36 cm of water, followed by 6125 kg/ha at 300 kgN×18 cm of water and 5739 kg/ha at 150 kgN/ha × 36 cm of water. Given the present very high cost of fertilizer, successful production of forage millet could be done with the lower fertilizer rate of 150 kgN/ha and 36 cm of water.

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RÉSUMÉ

OKPARA, D. A. & OMALIKO, C. P. E.: *Réaction de millet fourrager à l' irrigation et à l' engrais azoté dans la zone savane-dérivée du Nigéria.* Les effets des niveaux variables d'irrigation (9 cm, 18 cm et 36 cm d'eau) et d' engrais azoté (0, 150 et 300 kg N/kg) sur croissance, rendement et qualité de millet fourrager cultivé sur un oxisol pendant la saison séche de l'environment savane-dérivée à Nsukka du Nigéria étaient enquêtés. Le dessin experimental etait un bloc complet en factoriel. La taille culturelle, la proportion de croissance et les rendements de matiére séche d' herbage augmentaient avec l' augmentation proportionnelle d' irrigation et de fécondation azotée. Le plus haut rendement de protéine brute d' une plante entiére produite avec 18 cm de traitement d' irrigation était supérieur au 9 et 46 cm des traitements d' irrigation par 76.0 et 8.7 pour cent respectivement. La concentration moyenne de tous les nutritifs essayés (N, P, K, Mg et Ca) dans le fourrage étaient au-dessus du seuil de la production efficace du bétail ruminant. L'augmentation proportionelle d' irrigation augmentait la consommation de N et la concentration de P mais diminuait la concentration de N. La fécondation azotée augmentait la consommation de N, les concentration de N et Ca mais diminuait la concentration de P à la plus haute proportion d' application. Les intéractions étaient significatives. Les rendements maximum de matiére séche du fourrage (6425 kg/ha) se produisaient à 300 kg N × 36 cm d' eau, suivi par 6125 kg/ha à 300 kg N × 18 cm d' eau et 5739 kg/ha à 150 kg N /ha × 36 cm d'eau. Ètant donné le trés haut coût d' engrais à présent, une production réussie de millet fourrager pourrait être fait avec la proportion basse d' engrais de 150 kg N/ha et 36 cm d'eau.

## Introduction

A major problem confronting the livestock industry in most parts of the developing tropics during the annual dry season is inadequate supply of good quality herbage as crops wilt and dry up in response to severe moisture stress. This problem is further compounded by the apparent inability of most local farmers to conserve excess herbage produced during the wet season. Improvement in the supply system is possible and could be guaranteed by adopting dry season crop production in areas with available irrigation water.

In the derived savanna belt of Nigeria, farmers, between April and October (the wet season), concentrate on planting and harvesting of the arable crops and feed their stock with palatable volunteer weed species, crop residues and browse plants which are highly variable in supply and quality. In November to March (the dry season), there is no crop production because the soil is too dry. Irrigation has been successfully used in the region to produce arable crops during the dry season and has been shown in temperate regions to substantially increase herbage crop productivity during periods of moisture stress (Leafe, Jones & Stiles, 1977).

Apart from moisture stress, nitrogen deficiency has been identified as one of the most crucial factors that limit crop productivity in the humid tropics (Aken'Ova & Chheda, 1986). Substantial increases in both forage yields (Vicente-Chandler, 1966; Crowder & Chheda, 1974) and quality (Eck, Wilson & Tito, 1981) following nitrogen fertilization have been reported. The present studies aim at investigating the effects of varying levels of irrigation and nitrogen on forage millet grown in the dry season (from November to April) of the derived savanna zone of Nigeria.

## Materials and methods

The experiment was conducted on a fine sandy loam (Oxisol) at the University of Nigeria Farm, Nsukka, in the derived savanna agro-ecological zone during the dry season of November 1988 - March 1989. The soil had N content of 0.06 per cent, *p*H 4.8, cation exchange capacity, 6.4 cmol (+)/kg soil, and contained 79.4, 2.2 and 18.4 per cent sand, silt and clay, respectively (Source: Soils of the University of Nigeria, Nsukka Farm. Mimeograph, Department of Soil Science, University of Nigeria, Nsukka).

The treatments consisted of three irrigation regimes ($I_1$ = 9 cm, $I_2$ = 18 cm and $I_3$ = 36 cm of water) and three nitrogen fertilizer levels (0, 150 and 300 kgN/ha applied as ammonium sulphate) arranged in a randomized complete block factorial design with three replications. Each plot (8 m × 2 m) received 75 kg $P_2O_5$ and 40 kg $K_2O$/ha as single superphosphate and muriate of potash, respectively and lime at 2t/ha as limestone at seed bed preparation. A local variety of millet was sown by hand on 13 Dec 88 at a density of 111,000 plants/ha (30 cm × 30 cm spacing). The nitrogen fertilizer rates (0, 150 and 200 kg/ha) were broadcast on the appropriate plots (flats) a day after sowing (DAS). Irrigation at close to field capacity was uniformly applied (using watering can) to all plots up to 21 DAS to ensure proper seedling establishment. Beyond that date each plot received the appropriate amount of water ($I_1$, $I_2$ and $I_3$ corresponding to 25, 50 and 100 per cent field capacity, respectively). The irrigation levels were applied at 15 equal doses at a regular 4-day interval starting from 25 DAS.

Harvesting was made weekly from 35 DAS to 84 DAS. At each harvest, 3 plants per plot (plants per treatment) were randomly cut at soil level and the following attributes measured: crop height (cm), stem thickness (cm), numbers of green leaves and live tillers, proportion of plant fractions, leaf area index (LAI), crop growth rate (CGR) and herbage dry matter yield. Crop height was determined as height from the base of the plant to the tip of the panicle/leaves when raised vertically; stem thickness was determined by measuring the plant's circumference half-way along stem length. Leaf blade at least 50 per cent green was considered green.

Leaf area, LAI and growth rate were calculated using the formulae of Egharevba (1977), Hunt (1978) and Radford (1967) respectively. At each harvest, the samples were separated in the laboratory into the various morphological components, dried at 70 °C for 72 h and weighed immediately after drying to obtain dry matter yield. Nitrogen, phosphorus and potassium concentrations were determined by the automated simultaneous method of Faithful (1971) at the Analytical Laboratory Institute of Rural Science, University of College of Wales, Aberystwyth, UK. Crude protein was estimated as per cent N× 6.25 and crude protein yield as crude protein × dry matter yield. Magnesium and calcium were determined titrimetrically by the EDTA method. Analysis of variance was performed as outlined by Cochran & Cox (1975).

## Results and discussion

### *Crop morphology*

The influence of irrigation and nitrogen fertilization on the crop morphological attributes are shown in Table 1. Increasing the irrigation level up to $I_3$ resulted in healthier crops with significantly increased crop height and stem thickness. The millet plant attained a height of 174 cm and girth of 3.0 cm at $I_3$ irrigation treatment while a height of 114 cm and a girth of 2.7 cm were recorded at the $I_1$ irrigation treatment. Irrigation above the $I_2$ treatment did not significantly affect the number and proportion of green leaf in herbage. The application of nitrogen at the 150 and 300 kg N/ha rates produced taller tillers. The millet plant gave a height of 162 cm when fertilized at 300 kg N/ha and this was only significantly higher than the height (126 cm) obtained at O kg/ha.

The combined effect of irrigation and nitrogen fertilizer significantly affected crop morphological attributes. Tallest millet plants (190 or 189 cm) were produced by $I_3$ with N applied at either 150 or 300 kg/ha whereas $I_1$ without nitrogen fertilizer application gave shortest plants (108 cm). The greater vegetative growth obtained with $I_3 \times 150$ or $I_3 \times 300$ kg N/ha interaction was due to the more favourable

TABLE 1

*Main and Interaction Effects of Irrigation and Nitrogen on Forage Millet Crop Morphology, Growth and Yield*

| *Treatment* | *Crop height (cm)* | *Stem diameter (cm)* | *Mean number of green leaves* | *Mean number of live tillers* | *LAI* | *CGR (kg/ha week)* | *Herbage dry matter yield (kg/ha)* | *Crude protein yield (kg/ha)* |
|---|---|---|---|---|---|---|---|---|
| *Irrigation (cm of water)* | | | | | | | | |
| 9 ($I_1$) | 114 | 2.7 | 9.9 | 0.7 | 2.2 | 254.7 | 2,325.9 | 330.3 |
| 18 ($I_2$) | 160 | 2.9 | 10.7 | 10.2 | 2.8 | 489.9 | 4,567.6 | 580.9 |
| 36 ($I_3$) | 174 | 3.0 | 10.9 | 0.9 | 2.8 | 518.3 | 4,923.1 | 534.6 |
| LSD (0.05) | 7.6 | 0.1 | 0.9 | 0.2 | 0.4 | 13.7 | 130.0 | 23.6 |
| *Nitrogen rate (kg/ha)* | | | | | | | | |
| 0 | 126 | 2.8 | 8.2 | 0.3 | 1.9 | 234.1 | 2,288.0 | 221.1 |
| 150 | 159 | 2.8 | 1.0 | 253 | 2.3 | 468.7 | 4,346.3 | 521.6 |
| 300 | 162 | 3.1 | 12.5 | 1.5 | 3.5 | 560.1 | 5,182.4 | 703.0 |
| LSD (0.05) | 7.6 | 0.1 | 0.9 | 0.2 | 0.4 | 13.7 | 130.0 | 23.6 |
| *Cm of water × kg N/ha* | | | | | | | | |
| 9 × 0 | 108 | 2.6 | 8.3 | 0.3 | 1.8 | 180.6 | 1,644.4 | 183.4 |
| 9 × 150 | 115 | 2.6 | 9.4 | 0.4 | 2.0 | 256.8 | 2,336.1 | 341.7 |
| 9 × 300 | 119 | 3.0 | 11.9 | 1.3 | 2.9 | 326.7 | 2,997.2 | 465.8 |
| 18 × 0 | 128 | 2.9 | 7.9 | 0.3 | 2.0 | 255.5 | 2,613.9 | 245.7 |
| 18 × 150 | 174 | 2.8 | 10.5 | 1.4 | 2.3 | 551.0 | 4,963.9 | 616.3 |
| 18 × 300 | 178 | 3.1 | 13.8 | 1.8 | 4.1 | 663.2 | 6,125.0 | 880.6 |
| 36 × 0 | 143 | 2.8 | 8.4 | 0.3 | 2.0 | 266.1 | 2,605.6 | 234.2 |
| 36 × 150 | 190 | 2.9 | 12.5 | 1.2 | 2.7 | 598.4 | 5,738.9 | 606.8 |
| 36 × 300 | 189 | 3.3 | 11.7 | 1.3 | 3.6 | 690.4 | 6,425.0 | 762.6 |
| LSD (0.05) | 13.2 | 0.2 | 1.6 | 0.4 | 0.7 | 23.7 | 225.2 | 44.1 |

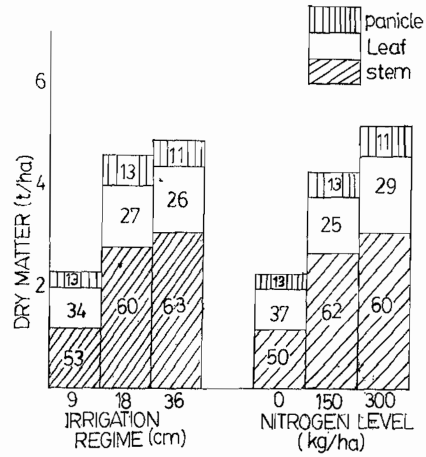


Fig. 1. Percentage of plant components of forage millet as influenced by irrigation and nitrogen fertilization

environment in the form of improved moisture level and adequate nutrient (nitrogen) supply. Irrigating at $I_3$ without any N application gave taller crop than $I_1 \times 300$ kg/ha probably because of the nitrogen toxicity experienced by plants in the latter (Fig. 1).

*Crop growth*

The $I_2$ and $I_3$ irrigation treatments as a mean of the three nitrogen rates produced similar LAI value (2.8) and this was significantly greater than the LAI (2.2) at $I_1$ (Table 1). LAI reached a plateau at $I_2$ while maximum CGR was obtained at $I_3$. The application of 300 kg N/ha gave the highest LAI and CGR. The crop LAI responded at both irrigation and nitrogen fertilization in a similar pattern with the peak being attained 42 DAS and declining thereafter, probably due to mutual shading of lower leaves but slight increases occurred at 70 DAS due primarily to the production of secondary tillers (Fig. 2 and 3).

Crop growth rate increased significantly with increasing rate of irrigation and nitrogen fertilizer. Highest and lowest rate of dry matter accumulation occurred at $I_3 \times 300$ kg N/ha and $I_1 \times 0$ kg N/ha, respectively such that growth rate in the former treatment nearly quadrupled the latter's. However, a significant depression in the CGR occurred in 63 DAS with both irrigation and nitrogen fertilization up to 70 DAS. Similar post anthesis decline in growth rate has been observed in maize (Haggar & Couper, 1972). The post heading reduction was probably due to weight losses of stem caused by increased respiration due to the accumulation of a large proportion of non-photosynthetic, but respiring, tissues (stem) at this period. With respiration increasing faster than the supply of assimilates, decrease in dry weight occurs. From 70 to 84 DAS, the CGR remained unchanged with nitrogen fertilization but the effect of the highest rate of irrigation increased significantly after 77 DAS are a result of secondary production of tillers.

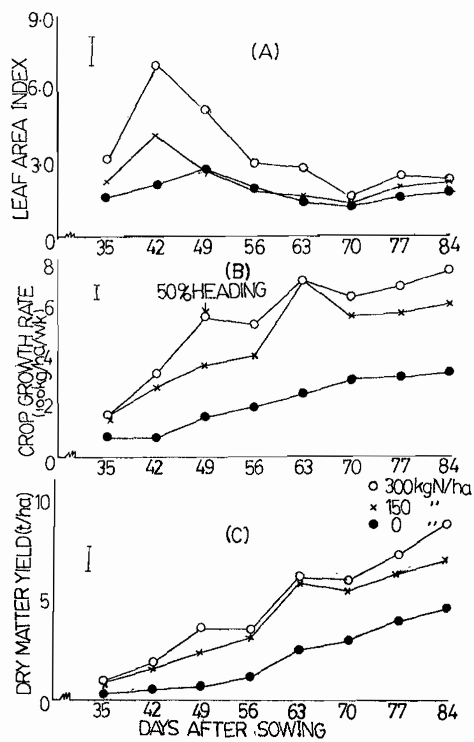


Fig. 2. Leaf area index (A), crop growth rate (B) and dry matter yield (C) of forage millet as influenced by irrigation and nitrogen fertilization. (Vertical bars represent least significant values at $P = 0.05$)

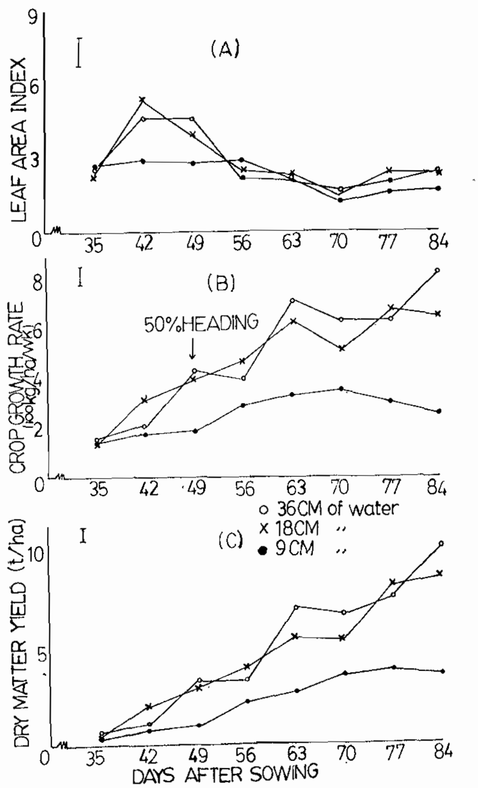


Fig. 3. Leaf area index (A), crop growth rate (B) and dry matter yield (C) of forage millet as influenced by irrigation and nitrogen fertilization. (Vertical bars represent least significant values at $P = 0.05$)

*Dry matter and crude protein yields*

Mean yields of dry matter and crude protein in response to the different levels of irrigation and nitrogen fertilizer are given in Table 1. The dry matter accumulation rates were a reflection of the crop growth rate pattern, that is, increasing with crop age (Fig. 2 and 3). Higher levels of irrigation and nitrogen gave herbage dry matter values that were significantly greater than lower rates. There were no dramatic responses as the irrigation level increased from $I_2$ to $I_3$ compared to increasing irrigation level from $I_1$ to $I_2$ or $I_1$ to $I_3$. Similarly, the nitrogen fertilizer effects as the rate increased from 150 to 300 kg N/ha was only 19 per cent compared to the 90 and 126 per cent increases obtained by increasing the rate from 0 to 150 and 0 to 300 kg N/ha respectively. The results obtained for nitrogen effects on yields of dry matter are similar to those reported by Aken'Ova & Chheda (1986), using *Pennisetum* hybrids.

There were significant interactions between irrigation and nitrogen in dry matter yield (Table 1) with the $I_3$ × 300 kg N/ha and $I_2$ × 300 kg N/ha treatment combinations giving remarkably high yields (6,125 kg/ha respectively). This indicates that the crop's responses to irrigation is augmented at increasing levels of nitrogen. Substantially high dry matter yield was obtained in $I_2$ ×300 kgN/ha because of the ability of the millet crop to withstand conditions of fairly low moisture availability, which is why it is an important crop in arid and semi-arid regions.

The total yield of crude protein of the millet significantly increased with increasing rate of nitrogen fertilizer. Similar results have been reported on both temperate and tropical forage graminaceous crops (Caros-Costas, Vicente-Chandler & Figarella, 1960; Reid, 1966; Aken'Ova & Chheda, 1986). The $I_2$ treatment significantly increased the crude protein yield by 76 per cent. The $I_3$ treatment, though, had significant effect on this parameter but was significantly inferior to the $I_2$ treatment.

The results suggest the possibility of manipulating the two farm inputs to attain similar results. For instance, $I_2$ × 300 kgN/ha would be as good as doubled that amount of water at the same fertilizer rate ($I_3$ × 300 kg N/ha - 6,125 and 6,425 kg/ha dry matter respectively).

For expensive fertilizer situations 150 kg N/ha × 36 cm of water will yield herbages only 400 kg/ha lower than 300 kg N × 18 cm of water (compare 6125 and 5939 kg/ha herbage yields). Feed conservation practices are at present non-existent in the agro-ecosystem (Nsukka) and, therefore, the prospects for direct consumption (grazing) are of great benefit. To obtain continuity in supply, sequential sowing could be adopted.

TABLE 2

*Main and Interaction Effects of Irrigation and Nitrogen on Uptake and Concentration of Nutrients in Forage Millet*

| *Treatment* | *N uptake kg/ha* | *Nitrogen* | *Per cent Phosphorus* | *Per cent Potassium* | *Magnesium* | *Calcium* |
|---|---|---|---|---|---|---|
| *Irrigation (cm of water)* | | | | | | |
| 9 ($I_1$) | 83.7 | 2.45 | 0.41 | 3.68 | 0.86 | 0.35 |
| 18 ($I_2$) | 164.2 | 2.21 | 0.51 | 2.82 | 1.04 | 0.22 |
| 36 ($I_3$) | 185.1 | 1.91 | 0.53 | 2.83 | 0.91 | 0.25 |
| LSD (0.05) | 29.6 | 0.13 | 0.06 | 0.32 | 0.02 | 0.02 |
| *Nitrogen rate (kg/ha)* | | | | | | |
| 0 | 95.2 | 1.78 | 0.53 | 3.32 | 0.77 | 0.23 |
| 150 | 139.9 | 2.28 | 0.49 | 3.01 | 1.04 | 0.29 |
| 300 | 197.8 | 2.51 | 0.42 | 3.01 | 1.01 | 0.30 |
| LSD (0.05) | 29.6 | 0.13 | 0.06 | N.S. | 0.02 | 0.02 |
| *Cm of water × kg N/ha* | | | | | | |
| 9 × 0 | 60.7 | 1.98 | 0.48 | 3.79 | 0.65 | 0.24 |
| 9 × 150 | 78.7 | 2.62 | 0.49 | 3.53 | 1.09 | 0.35 |
| 9 × 300 | 111.6 | 2.75 | 0.38 | 3.72 | 0.84 | 0.45 |
| 18 × 0 | 104.7 | 1.81 | 0.58 | 3.31 | 0.91 | 0.17 |
| 18 × 150 | 104.4 | 2.26 | 0.55 | 2.66 | 1.11 | 0.23 |
| 18 × 300 | 283.4 | 2.56 | 0.40 | 2.49 | 1.10 | 0.26 |
| 36 × 0 | 120.3 | 1.56 | 0.54 | 2.84 | 0.74 | 0.27 |
| 36 × 150 | 236.6 | 1.96 | 0.55 | 2.84 | 0.91 | 0.27 |
| 36 × 300 | 198.4 | 2.21 | 0.49 | 2.81 | 1.08 | 0.22 |
| LSD (0.05) | 51.2 | 0.22 | 0.10 | 0.56 | 0.04 | 0.04 |

*Nutrient concentration and nitrogen uptake*

The concentration of N, P, K Mg and Ca in herbage as a mean of eight harvests are presented in Table 2. Increasing rates of irrigation and nitrogen fertilizer were accompanied by decreases and increases in forage nitrogen, respectively. The high level of nitrogen in drought stricken plants has also been observed in several grain and forage crops (Gregory, 1979; Misra & Singh, 1982; Sui *et al.*, 1984; Eck & Musick, 1979) and is due to reduced nutrient dilution resulting from the lower rate of dry matter production. Also, increases in irrigation rate decreased K, increased P but had varied effects on Mg and Ca. Nitrogen fertilizer application increased Ca but decreased P. The concentrations of all assayed nutrients were remarkably very high in forage millet. Ferraris (1973) had remarked on the ability of millet to recover nutrients more efficiently from the sub-soil than other cereal crops. In this study, the concentrations of N and Ca fell within the required levels while P, K and Mg levels were far above the threshold required for efficient livestock production as given by ARC (1980).

Nitrogen uptake (dry matter yield × nitrogen concentration) significantly increased with increasing rates of irrigation and nitrogen fertilization (Table 2). Similar observations have been reported (Gregory 1979; Hatlitligil, Olson & Compton, 1984). The combined effect of irrigation and nitrogen significantly influenced uptake of nitrogen such that highest uptake occurred at $I_2 \times$ 300 kg N/ha while the lowest rate of uptake occurred at $I_1 \times$ 0 kg N/ha. The $I_2 \times$ 300 kg N/ha treatment combination maintained higher nitrogen uptake value than the $I_3 \times$ 300 kgN/ha treatment combination because of the fairly high rate of dry matter yield and a higher nitrogen concentration in the $I_2$ irrigation component (compare dry matter yield - 6,125 kg/ha for $I_2 \times$ 300 kg N/ha and 6,425 kg/ha for $I_3 \times$ 300 kg N/ha nitrogen concentration 2.56 per cent for $I_2 \times$300 kg N/ha and 2.21 per cent for $I_3 \times$ 300 kg N/ha).

## Conclusion

The results of these studies clearly demonstrate that improvement in supply of good quality forage millet during the dry season is feasible. For successful production, it is suggested that lower fertilizer rates of 150 kg N/ha and 36 cm of water be used in the ecological zone.

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