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Research Article

Effect of Nitrogen Fertilizer Source, Soil Type and Season on Growth Performance of Two Sorghum Cultivars

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Abstract

Background and Objective: The growth performance of sorghum is influenced by soil structure of location and the source of nitrogen fertilizer applied during planting. Greenhouse experiment was conducted during spring and repeated in autumn of 2017 planting season, to investigate the influence of nitrogen fertilizer source, soil type and cultivar on the growth parameters of sorghum. **Materials and Methods:** The experiment was a 2×2×4 factorial experiment fitted into a complete randomised design. Two soil types used were loamy sandy and sandy soil. Two sorghum cultivars planted were PAN 8826 and PAN 8625 and 4 nitrogen fertilizer sources were ammonium sulphate, urea, LAN and control. The measured growth parameters were plant height, number of leaves per plant, leaf area, leaf chlorophyll content, stem diameter and root mass. **Results:** Nitrogen fertilizer source had significant effect ($p \leq 0.05$) on leaf chlorophyll content, leaf area, stem diameter and fresh root mass. Sorghum fertilized with nitrogen fertilizer source, ammonium sulphate had significantly higher leaf chlorophyll content of 14.28 than other sources of nitrogen fertilizer. Sorghum fertilized with nitrogen fertilizer sources, ammonium sulphate, LAN and urea had significantly larger stem diameter of 1.07 cm than control. Planting season also had significant effect ($p \leq 0.05$) on plant height and number of leaves/plant. Sorghum planted during spring had significantly taller plant height of 72.0 cm and higher number of leaves/plant of 6.5 than sorghum planted in autumn. **Conclusion:** In this study, nitrogen fertilizer irrespective of source responded positively in terms of stem diameter and leaf chlorophyll content. This study indicated that, sorghum should be planted in spring to obtain higher plant height and number of leaves/plant.

Key words: Leaf area, plant height, soil type, stem diameter, fertilizer, chlorophyll, greenhouse effect

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sorghum is a warm-weather crop, which requires high temperatures for good germination and growth. Sorghum has been reported to have high stress tolerance, including temperature, water and salt stresses[1]. Temperature is an important factor controlling the growth and development of the sorghum plant. Crops such as sorghum are likely to be grown under higher temperatures[2]. Sorghum is considered to be hardier under extreme heat and drought conditions compared with other major crops[3].

Sorghum seed germination requires warmer soil temperatures compared with crops such as soybean and maize[3]. Sorghum has a good prospect to be developed in marginal dry land that are not managed[4]. Grain sorghum can be grown with greater success than maize on less-fertile soils, shallow soils and heavy turf soils. High strength silty clay and clay horizons and a calcic horizon in the silty clay loam delay sorghum rooting and affect crop growth[5]. Slightly acidic loamy sand produces sorghum with higher plant height compared to sorghum grown on strongly acidic sandy clay loam[6]. It was further reported that slightly acidic loamy sand was able to support sorghum growth as much as strongly acidic sandy clay loam.

Application of nitrogen fertilizer enhances the growth and yield of sorghum[7]. They have reported that, the effect of nitrogen fertilizer on the height of sorghum become apparent from 6 weeks after sowing. Nitrogen fertilization increased number of leaves/plant and leaf area of cereal crop[8]. Amin[9] reported that all growth parameters were affected by nitrogen fertilization from different sources. It was further reported that the increase in plant height attained by ammonium sulphate nitrate explained by the efficiency of nitrogen sources which composed of ammonium and nitrate. Nitrogen source, ammonium nitrate fertilizer increased number of days to mid-tasseling, mid-silking and shelling percentage in corn study[10].

Earlier maturing sorghum cultivars are recommended under water stress conditions to promote timely physiological maturity[11]. Medium to late maturity can be cropped to increase percentage emergence under low soil water availability[12]. Medium maturity hybrids are better adapted to limited irrigation conditions than late maturing hybrids[13]. It was further reported that, late maturing sorghum types yield more than earlier maturing types, but with possibilities of not reaching maturity before occurrence of frost. The sorghum plant flowered and matured significantly earlier under drought condition[14]. Majority of sorghum farmers in South Africa are only suing one specific source of nitrogen fertilizer and have no information about the influence of other sources on production of sorghum. The selection of good performing cultivar and location with preferred soil type for sorghum production is still a challenge to most farmers. The objective of this study was to determine the effect of nitrogen fertilizer source, soil type and cultivar on growth performance of sorghum.

MATERIALS AND METHODS

Description of the experimental site: The experiment was carried out in a greenhouse of the North-West University Research Farm (25°48'S, 45°38'E, 1012 m.a.s.l) during Autumn and repeated in Spring of 2017 plating seasons. It is located 8 km from the city of Mafikeng in the North-West province of South Africa towards the Botswana Boarder. The mean maximum temperature is 37°C while the mean minimum temperature is 7-11°C. Area is semi-arid tropical and receives summer rainfall with an annual mean of 571 mm[15]. Approximately 68% of annual precipitations in this area fall between November and January in relatively few heavy downpours with a pronounced dry season from April to September. The soil at the site belongs to Hutton series according to South Africa soil classification, with sandy loam texture[15,16]. According to FAO-UNESCO[17] soil of North-West University Research Farm is classified as Ferric luvisol.

Experimental design: The experiment was a 2×2×4 factorial design fitted into a complete randomised design. Two soil types used were loamy sandy soil and sandy soil. Two sorghum cultivars used was PAN 8826 and PAN 8625 and the 3 nitrogen forms used are ammonium sulphate, urea and LAN and control pots. The two cultivars were planted in each soil type randomly. The experiment was replicated 3 times, in each replicate, there were 16 treatment combinations placed randomly. The total pots in the experiment were 48.

Soil sampling and chemical analysis: The soil was collected from separate locations of the North-West province. The loamy sandy soil was collected at Mafikeng and the sandy soil was collected at Taung. The soil was collected at a depth of 0-15 cm. The soil was sent to ARC-IIC for the analysis of chemical properties (N-NO_3, N-NH_4, Bray 1-P) and physical properties (sand, clay and silt percentage). Part of the soil collected was analysed for other chemical properties such as pH at NWU plant-soil laboratory. To determine pH according to Van Reeuwijk[18] a pH meter readings reproducible to 0.05 pH unit must be used. The laboratory analyses for soil texture, chemical and physical properties before planting are as indicated in Table 1.

Table 1: Soil chemical and physical properties of loamy sand and sandy soil used during planting

Soil properties	Loamy sand soil	Sandy soil	Method
Chemical properties			
Soil pH (water)	6.90	6.80	Saturated water paste
$N\text{-}NO_3$ (mg kg^{-1})	3.90	3.75	Extraction 0.1 N K_2SO_4
$N\text{-}NH_4$ (mg kg^{-1})	0.75	0.75	Extraction 0.1 N K_2SO_4
Phosphorus (mg kg^{-1})	4.00	1.00	Bray 1
Physical properties (%)			
Sand	76.00	89.00	Texture hydrometer
Silt	7.00	2.00	Texture hydrometer
Clay	17.00	9.00	Texture hydrometer

Planting and planting method: The 1st experiment was conducted during autumn, 2017. The 2nd experiment was conducted during spring, 2017. The 48 pots were filled with 5 kg of different soil types. The numbers of seeds sown per pot were 3 seeds. The planting depth of seeds in sandy and loamy sandy soil was 5 cm. The quantity of water to be applied was 500 mL, 3 times/week using a measuring cylinder.

Cultural practices: After emergence plants were thinned to maintain 1 plant/pot. In the case where germination did not occur, replanting was done. Due to similarities at early stages of the plants, thinning was delayed to properly identify the true plant. Weeding was done by hands to control weeds in each pot. The quantity of the irrigation water was measured each time when irrigating the pots.

Fertilizer application: Different forms of nitrogen fertilizer were applied based on the recommended application during planting. The rate of nitrogen forms that was applied in pots was 120 kg ha^{-1}. However, the amount of nitrogen forms applied in each pot was calculated and reduced to grams since well its pot trail. Calculations were done according to the soil type and the results analysed for each soil type at the ARC-IIC. Phosphorus fertilizer was applied in the soil where there was insufficient amount based on the laboratory soil analysis.

Data collection: The plant height was measured from the base of the stem to the tip of the highest leaf using a measuring tape. Stem diameter was measured by an aid of an instrument called Vernier calliper. Chlorophyll was measured using the chlorophyll meter. The measurement will be taken in the middle of a fully developed leave. Leaf area was measured from the length and width of the leaf[19] $(L\times W)\times 0.75$. Number of fully developed leaves was counted from sorghum plants until the appearance of panicle. The roots were separated from the shoots by cutting them, then washed thoroughly. Length was measured using a measuring tape and mass was measured using a scale. The roots were dried for 72 h in temperatures of 70°C.

Statistical analysis: The analysis of variance was performed using Genstat, 11th edition[20]. The least significant difference (LSD) was used to separate the means. The probability level of <0.05 was considered to be statistically significant.

RESULTS

Plant height: According to analysis of variance, nitrogen fertilizer source, soil type and cultivar had no significant effect ($p>0.05$) on sorghum plant height (Table 2). Season had significant effect ($p<0.001$) on sorghum plant height. Based on LSD sorghum planted during spring had significantly higher plant height of 72.0 cm than other season. The interactions of treatment factors had no significant effect ($p>0.05$) on sorghum plant height.

Stem diameter: Analysis of variance showed that, soil type, cultivar and season had no significant effect ($p>0.05$) on sorghum stem diameter (Table 2). Nitrogen fertilizer source had significant effect ($p<0.001$) on sorghum stem diameter. Stem diameter of sorghum fertilized with ammonium sulphate, LAN and urea had significantly larger stem diameter of 1.07 cm than control. The interaction of nitrogen fertilizer source×cultivar×soil type had significant effect ($p<0.001$) on sorghum stem diameter. The interaction of nitrogen fertilizer source×cultivar had significant effect ($p<0.001$) on sorghum stem diameter.

Fresh root mass: Based on analysis of variance, cultivar, soil type and season had no significant effect ($p>0.05$) on sorghum fresh root mass (Table 2). Nitrogen fertilizer source had significant effect ($p = 0.01$) on sorghum fresh root mass. Sorghum fertilized with ammonium sulphate, LAN and urea had significantly higher fresh root mass of 50.6, 52.5 and 52.8 g, respectively than control. The interaction of nitrogen fertilizer source×season had significant effect ($p = 0.004$) on sorghum fresh root mass.

Number of leaves/plant: Analysis of variance indicated that, nitrogen fertilizer source and soil type had no significant effect ($p>0.05$) on number of leaves/plant (Table 3). Cultivar had significant effect ($p = 0.002$) on sorghum number of leaves. Sorghum cultivar, PAN 8816 had significantly higher number of leaves of 5.92 than other cultivar. Analysis of variance also indicated that, season had significant effect ($p<0.001$) on sorghum number of leaves. Sorghum planted during spring had significantly higher number of leaves of 6.33 than other season. The interactions of treatment factors had no significant effect ($p>0.05$) on number of leaves/plant.

Table 2: Effect of nitrogen fertilizer source, cultivar, soil type and season on sorghum plant height (cm), stem diameter (cm) and fresh root mass (g/plant)

Treatments	Plant height	Stem diameter	Fresh root mass
Nitrogen sources			
Control	62.8^{a}	0.49^{b}	33.9b
Ammonium sulphate	63.4^{a}	1.07^{a}	50.6^{a}
LAN	62.1^{a}	1.07^{a}	52.5^{a}
Urea	62.9^{a}	1.07^{a}	52.8^{a}
$LSD_{(0.05)}$	5.69	0.12	10.58
Cultivar			
PAN 8625	61.3^{a}	0.91^{a}	45.2^{a}
PAN 8816	64.3^{a}	0.93^{a}	49.2^{a}
$LSD_{(0.05)}$	4.02	0.08	7.48
Soil type			
Loamy sandy	64.5^{a}	0.94^{a}	49.4^{a}
Sandy	61.2^{a}	0.92^{a}	45.4^{a}
$LSD_{(0.05)}$	4.02	0.08	7.48
Season			
Autumn	53.6^{b}	0.92^{a}	47.4^{a}
Spring	72.0^{a}	0.92^{a}	47.4^{a}
$LSD_{(0.05)}$	4.02	0.08	4.48

Means followed by the same letter in each column are not significantly different ($p \leq 0.05$)

Table 3: Effect of nitrogen fertilizer source, cultivar, soil type and season on sorghum number of leaves/plant, leaf area (cm^2) and leaf chlorophyll content

Treatments	Number of leaves	Leaf area	Chlorophyll content
Nitrogen sources			
Control	5.54^{a}	178.4^{bc}	6.83^{b}
Ammonium sulphate	5.63^{ab}	162.50^{c}	14.28^{a}
LAN	5.38^{ab}	217.90^{a}	14.25^{a}
Urea	5.92^{b}	233.80^{a}	12.70^{a}
$LSD_{(0.05)}$	0.53	38.09	3.28
Cultivar			
PAN 8625	5.31^{b}	203.60^{a}	11.69^{a}
PAN 8816	5.92^{a}	192.70^{a}	12.34^{a}
$LSD_{(0.05)}$	0.38	26.93	2.32
Soil type			
Loamy sandy	5.75^{a}	201.60^{a}	12.17^{a}
Sandy	5.48^{a}	194.70^{a}	11.85^{a}
$LSD_{(0.05)}$	0.38	26.93	2.32
Season			
Autumn	4.90^{b}	198.10^{a}	12.06^{a}
Spring	6.33^{a}	198.10^{a}	11.96^{a}
$LSD_{(0.05)}$	0.38	26.93	2.32

Means followed by the same letter in each column are not significantly different ($p \leq 0.05$)

Leaf area: Based on analysis of variance, cultivar, soil type and season had no significant effect ($p>0.05$) on sorghum leaf area (Table 3). Nitrogen fertilizer source had significant effect ($p = 0.001$) on sorghum leaf area. Leaf area of sorghum fertilized with LAN and urea had significantly larger leaf area of 217.9 and 233.8 cm^2, respectively that leaf area of sorghum fertilized with other nitrogen fertilizer sources. Interaction of nitrogen form×season had significant effect ($p<0.001$) on sorghum leaf area.

Leaf chlorophyll content: According to analysis of variance, cultivar, soil type and season had no significant effect ($p>0.05$) on leaf chlorophyll content (Table 3). Nitrogen fertilizer source had significant effect ($p = 0.001$) on sorghum leaf chlorophyll content. Sorghum fertilized with ammonium sulphate, LAN and urea had significantly higher leaf chlorophyll content of 14.28, 14.25 and 12.70 respectively than control. The interaction of nitrogen form×season had significant effect ($p = 0.010$) on the chlorophyll content of sorghum leaves.

DISCUSSION

Sorghum planted in spring produced higher plant height and number of leaves/plant in this study. This might be attributed to favourable temperatures for sorghum growth during spring season. This result agreed with similar findings by Hatfield and Prueger[21], who reported that vegetative development increases as temperatures rise to the species optimum level. It was further reported that vegetative development usually has a higher optimum temperature than for reproductive development.

Sorghum fertilized with nitrogen sources, ammonium sulphate, LAN and urea had large stem diameter, higher fresh root mass and leaf chlorophyll content. All three sources of nitrogen in this study showed positive influence on the selected measured parameters. The large stem diameter under nitrogen fertilizer sources corroborated with the findings by Carpici *et al.*[22], who reported that stem diameter of cereal crop increased under nitrogen fertilizer application. Sebetha and Modi[23] also reported that nitrogen fertilization had significant influence on the growth of cereal crop. According to studies conducted by Yoder and Pettigrew-Crosby[24] ammonium sulphate contributed more to chlorophyll content of corn compared to nitrogen form urea.

Cultivar had an influence on number of leaves per sorghum plant. The higher number of leaves/plant of cultivar PAN 8816 might be attributed to genetic makeup of the cultivar. This observation corroborates the findings by Meena and Mann[25], who reported that the differential behaviour of sorghum varieties in respect of growth parameters could have explained by the variation in the genetic constitution of the cultivar. This shows that PAN 8816 thrive best under higher temperatures of spring better than late maturing cultivars of PAN 8625. According to PANNAR[26], it was revealed that PAN 8816 has wide adaptability to environments whether planted early or late in the season. The soil type in this study did not influence on the sorghum growth parameters measured. The interaction of nitrogen fertilizer source×season contributed significantly to the growth of sorghum and affected leaf area, leaf chlorophyll content and fresh root mass.

CONCLUSION

In this study, nitrogen fertilizer irrespective of source responded positively in terms of stem diameter and leaf chlorophyll content. In terms of sorghum leaf area, two sources of nitrogen (LAN and urea) responded positively as compared to ammonium sulphate. Sorghum cultivar PAN 8816 performed well in terms of leaf production per plant. This study indicated that, sorghum should be planted in spring to obtain higher plant height and number of leaves/plant. Soil type in this study did not have any influence on the measured sorghum growth parameters.

SIGNIFICANCE STATEMENT

This study discovered that, sorghum cultivar PAN 8816 is well performing cultivar in terms of growth performance. Nitrogen fertilizer irrespective of source is important on growth performance of sorghum under different soil types. This study also indicated that, spring should be considered as a good season for sorghum planting.

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