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Effects of Nitrogen and Potassium Fertilisers on Growth, Chemical Components, and Seed Yields of a Forage Sorghum (*Sorghum bicolor* L. Moench) Grown on Oxic Paleustults Soil, Northeast Thailand

S. Pholsen, D.E.B. Higgs and A. Suksri[1]
Department of Environmental Sciences, University of Hertfordshire, Hatfield, Herts, AL10 9AB, U.K
[1]Department of Agronomy, Khon Kaen University, Khon Kaen 40002, Thailand

Abstract: This experiment was carried out at Khon Kaen University, Thailand to investigate the effects of nitrogen and potassium chemical fertilisers upon growth, chemical components and seed yield. Urea and potassium chloride were used for nitrogen and potassium sources, respectively. Nitrogen application rates were 0, 62.5, 125 and 187.5 kg N/ha and potassium rates were 0, 50, 100 and 150 kg K_2O/ha. The experiment was laid in a 4 x 4 factorial arranged in a Randomized Complete Block Design (RCBD) with four replications. The plant samples were taken at 52 and 82 days after emergence for dry weights of stem, leaves, flower heads, and leaf areas, and 93 days after emergence for seed head dry weights, seed yields and 1000-seed weights.
The results showed that leaf dry weights and leaf areas of the sorghum plants at 52 days after emergence increased with an increase in nitrogen levels whilst potassium levels had no significant effect. At 82 days after emergence, total dry weights, stem dry weights, leaf dry weights, flower head dry weights and leaf areas were unaffected by both nitrogen and potassium levels. This was also true for Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Dry Matter Degradability (DMD). Crude Protein (CP) values increased with an increase in nitrogen levels while a reverse was found with the brix values for both nitrogen and potassium levels. At 93 days after emergence, seed head dry weights, seed yields and 1000-seed weights were unaffected by both nitrogen and potassium levels.

Key words: Forage sorghum, dry matter yield, chemical components, dry matter degradability, leaf areas

Introduction

Growing forage sorghum for livestock production has been considered to be one of the urgent needs for livestock production in Thailand particularly in the northeastern region where feedstuffs are inadequately available in the hot and dry summer. The long dry period in summer means that there is a requirement for a large amount of fodder and silage as feedstuffs for both dairy and beef cattle. More data on growth parameters and seed yield of fodder sorghum cultivars is essential if livestock production in Thailand is to be expanded. Some pasture research experiments have been carried out, e.g. Australian Development Assistance Bureau's project, which was carried out at Khon Kaen University (Shelton and Humphreys, 1978 and Wilaipon and Pongsakul, 1983) and also Forage Legume Seed Production and Pasture Project of the Department of Livestock Development, Ministry of Agriculture and Cooperatives of Thailand (Manidool and Chantkam, 1986; Hare and Phaikaew, 1999). Nevertheless, feedstuffs for livestock remain inadequate for the expansion of livestock production. Data on forage sorghum cultivars especially those well adapted to the environmental conditions are very limited; Pholsen *et al.* (1998) carried out experiments on forage sorghum and reported that IS 23585 sorghum cultivar was considered to be one of the best cultivars adapted well to the Oxic Paleustults soil in Northeast Thailand. Therefore, this cultivar was chosen for further investigations, since it exhibited outstanding characteristics of both chemical components and yield. Other cultivars have been shown to be well adapted to other soil types, e.g. Rio, U-Thong and others (Suchato *et al.*, 1991; Agnal *et al.*, 1992; Powell and Hons, 1992; Phaikaew *et al.*, 1992).

To attain maximum output of forage sorghum in the very poor soil fertility of the Oxic Paleustults soil (Yasothon soil series), more experiments are needed on plant nutrition, especially with chemical fertilisers, particularly nitrogen and potassium. These two elements play a crucial role in growth of the crop plants, nitrogen has a significant role in the construction of amino acid compounds and proteins (Miller and Donahue, 1990; Salisbury and Ross, 1992), whilst potassium has its role in electron (e^-) transport in the photosynthetic e^- transport chain in supplying assimilates to sinks and other parts of the crop plants as stated by Overnell (1975) and Suksri (1998) in addition, the improvement of soil fertility with the use of soil amendments such as organic matter, crop residues and other sources, e.g. cattle manure, poultry manure is urgently needed.

The investigation reported here aims to provide more data on growth with respect to chemical components, dry matter degradability, brix value, and yield of this forage sorghum cultivar. Techniques of classical growth analysis were used to measure the changes in growth of the aerial plant parts of the crop plants (Sestak *et al.*, 1971; Bullock *et al.*, 1993) under a range of fertiliser treatments.

Materials and Methods

This experiment was carried out at the Experimental Farm, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Northeast Thailand during the rainy season of 1997 to investigate the effect of varying nitrogen and potassium levels on growth, chemical components, ruminal dry matter degradability, brix value, and seed yield of sorghum (*Sorghum bicolor* L. Moench), IS 23585 cultivar. The sorghum plants were grown on Oxic Paleustults soil and the final values of soil pH (1:2.5 soil:water by volume), organic matter, total nitrogen, available phosphorous and exchangeable potassium ranged from 5.9 to 6.4, 0.68 to 0.79%, 0.032 to 0.046%, 61 to 75 ppm and 44 to 90 ppm, respectively. The experiment was laid out in a 4 x 4 factorial arranged in a randomized complete block design (RCBD) with four replications. The chemical fertilisers being used were urea for nitrogen (N) and potassium chloride for potassium (K) and the application rates were 0 (N_0), 62.5 (N_1), 125 (N_2), and 187.5 (N_3) kgN/ha for nitrogen and 0 (K_0), 50 (K_1), 100 (K_2), and 150 (K_3) kgK_2O/ha for potassium. Therefore, there were 16 treatment combinations i.e. N_0K_0, N_0K_1, N_0K_2, N_0K_3, N_1K_0, N_1K_1, N_1K_2, N_1K_3, N_2K_0, N_2K_1, N_2K_2, N_2K_3, N_3K_0, N_3K_1, N_3K_2, N_3K_3. Two weeks before sowing an application of dolomite at the rate of 3,750 kg/ha was carried out in order to increase the initial mean value of soil pH of 5.3 to approximately 6.3. The ploughing of the experimental field was done twice and harrowing once. The plot size used was a 4 x 6 meters with a walking path of one meter in between the plots. Each plot was divided into 4 subplots and each subplot had an area of 3 x 2 meters. Each plot received phosphorus at the rate of 125 kg P_2O_5/ha before sowing. The distances between rows and within the rows were 50 x 10 cm, respectively. Approximately 3-5 seeds/hill of sorghum were sown by hand into their respective plots and accompanied by the application of Carbofuran 3 %G insecticide at the rate of 37 kg/ha. After sowing, a spraying of Atrazine herbicide at the rate of 2.2 kg/ha was carried out as a pre-emergence weed treatment. Three weeks after emergence, chemical fertilisers both N and K were applied to the crop plants and the crop plants were thinned leaving one plant per hill as well as ridging the hills along the row.

Weeding was carried out twice by hand at three weeks and six weeks after emergence. Weeding was no longer needed once the crop plants achieved high amount of leaf area per plant to cover the ground. The technique of growth analysis was used to measure the changes in growth with time of the aerial plant parts of the crop plants (Sestak *et al.*, 1971; Bullock *et al.*, 1993). The plant samples were taken at 52 days after emergence for leaf areas, leaf dry weights, and stem dry weights determinations. Ten plants were cut at random from each subplot at approximately 15 cm above ground level of each replication. The plants were separated into leaves, and stems for the determinations of leaf areas and dry weights. The second harvest of plant samples was carried out at 82 days after emergence for measurements as at the first sampling period plus flower head dry weights. Seed head, seed yields and 1000-seed weights were taken at 93 days after emergence. Juice squeezes from stems was measured individually for brix values (82 days after emergence) by Atago N1 brix 0-32 % brix meter, Japan. The plant samples were oven dried at 80°C for 72 hours for dry weight determinations. Fresh leaves were used for leaf area measurements determined by the use of a leaf area meter (model no. AAC-400, Hayashi Denko Co., Ltd., Japan).

For the second harvest at 82 days after emergence (seed milky stage), the plants samples were oven dried at 60 °C for 72 hours for the analysis of chemical components of crude protein (CP) by Kjeldal method. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method of Georing and Van Soest (1970) and ruminal dry matter degradability (DMD) by the method of Nylon bag technique of Orskov *et al.*, (1980). The data obtained were statistically analysed by the method of Analysis of Variance (ANOVA) and the differences due to treatment means were determined using Dancan's Multiple Range Test (DMRT) by MSTAT programme (Nissen, 1984).

Results and Discussion

Stem dry weights, leaf dry weights and leaf areas: At days after emergence (1^{st} harvest), the results show that increase in nitrogen levels did not increase stem weights, but leaf dry weights and leaf areas of the sorghu plants were increased with an increase in nitrogen leve However, an increase in potassium levels did not increa stem dry weights, leaf dry weights or leaf areas of the cr plants and no interaction between N and K levels (Tables and 2). These results indicate that at least some of t nitrogen levels used improved the leaf growth of t sorghum plants whilst potassium did not improve any of t growth parameters tested. This may be partly attributed a high leaching rate due to the high amount of rainfa during the months of August and September 1997 with t values of 175 and 110 mm, respectively. The leaching ra of nitrogen under heavy rainfall conditions could be rangi from 50 to 80 kg N/ha annually (Miller and Donahue, 199 whilst other nutrients may also be leached out of soils at high rate (Vomel, 1965/66; Muller *et al.*, 1985). Howeve this would not fully explain the differences between the and K treatments, unless unit residual N has a greater eff on growth than unit residual K. This could, in fact be t explanation since the positive effect of N is only on le growth parameters and it is well known e.g. Russ (Nissen, 1988), that N is the key macronutrient for le growth.

Table 1: Means of stem dry weights, leaf dry weights and le areas per plant of the sorghum plants at 52 days aft emergence (1st harvest) as influenced by nitrogen a potassium levels grown on Oxic Paleustults soil, Kh Kaen University, Northeast Thailand

Treatments	Stem Dry Weights (gm/plant)	Leaf Dry Weights (gm/plant)	Leaf Areas (cm^2/plant)
N_0K_0	16.56	8.34	1472
N_0K_1	17.07	8.56	1370
N_0K_2	18.84	9.63	1567
N_0K_3	15.01	8.05	1220
N_1K_0	16.81	9.20	1504
N_1K_1	15.11	9.38	1496
N_1K_2	16.75	9.30	1480
N_1K_3	20.43	10.10	1598
N_2K_0	19.46	9.59	1638
N_2K_1	18.65	10.74	1669
N_2K_2	17.88	9.87	1583
N_2K_3	20.69	10.58	1693
N_3K_0	16.72	9.59	1535
N_3K_1	17.94	10.64	1685
N_3K_2	24.93	11.14	2000
N_3K_3	19.59	10.16	1598
N	NS	*	*
K	NS	NS	NS
N x K	NS	NS	NS
CV (%)	23.45	16.20*	17.72

NS = Non significant. * = Significant at $P< 0.05$, CV = Coefficient of variation.

Total dry weights, stem dry weights, leaf dry weights flower head dry weights and leaf areas: At 82 days afte emergence (2nd harvest), total dry weights, stem dr weights, leaf dry weights, flower head dry weights and lea areas per plant were unaffected by both nitrogen an potassium levels (Table 3). These results suggest that th additional amounts of both nitrogen and potassium had n significant effect on the growth parameters measured b the time of this second harvest. At the first harvest (5 days) the sorghum plants did show some significant growt responses to increased nitrogen levels. This difference i responsing to fertiliser treatments between harvest

Table 2: Duncan's Multiple Range Test of means of leaf dry weights and leaf areas per plant of sorghum at 52 days after emergence (1st harvest) as influenced by nitrogen and potassium levels grown on Oxic Paleustults soil at Khon Kaen University, Northeast Thailand

Nitrogen levels	Leaf Dry Weights (gm/plant)	Leaf Areas (cm^2/plant)
N_0	8.64^b	1407^b
N_1	9.50^{ab}	1520^{ab}
N_2	10.19^a	1646^a
N_3	10.39^a	1705^a
K_0	9.59	1537
K_1	10.64	1555
K_2	11.14	1658
K_3	10.16	1527

Remarks: letters indicate significant differences of DMRT at probability of 0.05

and harvest 2 could be partly attributable to the low exchangeable value of potassium as found at the final sampling period and perhaps also the depletion of soil nitrogen and potassium with time and also the high leaching rate of soil nutrients as reported by Geleta *et al.* (1994). There had been some high amounts of rainfall in September and up to the second week of October (337 mm) but later a drought period occurred during the last two weeks of October, so the crop plants were affected by water stress for a long period of time. Furthermore, the rates of both nitrogen and potassium given to the crop plants could be rather low. This could possibly be the case where the growth of the crop plants became stunted particularly at the later part of the growth stage. However, total dry weights per land area were similar to those of Roa *et al.* (1999) for irrigated plants but much lower than the present work for plants relying on rainfall only. Furthermore, the final mean values of both soil nitrogen and exchangeable potassium were relatively lower than critical values (Shelton *et al.*, 1979), so these low values for soil nitrogen and exchangeable potassium may be considered as inadequate. The decline in leaf growth at the later growth stage could possibly be due to the imbalance of nitrogen and potassium ratio. Both soil nitrogen and exchangeable potassium levels were lower than critical values particularly potassium (44-90 ppm for soil K and 0.032 to 0.064% for soil N). Faungfupong *et al.* (1980) grown sorghum KU 257 variety at Nakonratchasima, Saraburi and Lopburi provinces, Thailand found that an addition amount of nitrogen and potassium up to 62.5 kgN-K/ha had no effect due to both nitrogen and potassium levels. Similarly Jaisil *et al.* (1980) also grown different varieties of sorghum at Khon Kaen Province, Thailand, they reported that seed yields of sorghum varieties tested did not respond to the application of nitrogen up to 132.3 kgN/ha and their seed yields were ranging from 1923 to 4618 kg/ha which were in many cases lower than the present work. Whilst the lowest sorghum seed yields of four varieties grown in nine provinces of Northeast Thailand were reported by Thiraporn (1980) with the average seed yields ranging from 1151 to 1860 kg/ha. The poor response to nitrogen and potassium of sorghum plants of the present experiment could possibly be due to the low amounts of soil nitrogen and potassium being available to the crop plants particularly in the later part of the growing season. These results are in agreement with work reported by Meyers and Asher (1982), and Seetharama *et al.* (1984) for sorghum and pearl millet.

In particular, the additional amounts of both nitrogen and potassium fertilisers had no significant effect on the key agronomic parameter, Seed Yield. This may be due to the rates of both nitrogen and potassium applied to the soil being too low and/or the depletion of soil nutrients by leaching, since there were low levels of both nitrogen and exchangeable potassium at the final harvest (as previously discussed). Seed yields attained in this work ranged from 3735 to 4491 kg/ha which were similar to those reported by Bordovsky *et al.* (1998) obtained under conventional tillage and also to the results of Roa *et al.* (1999) for irrigated sorghum.

Table 3: Means of total dry weights, stem dry weights, leaf dry weights, flower head dry weights and leaf areas of sorghum at 82 days after emergence (2nd harvest) as influenced by nitrogen and potassium levels, grown on Oxic Paleustults soil at Khon Kaen University, Northeast Thailand

Treatments	Total Dry Weights (gm/plant)	Stem Dry Weights (gm/plant)	Leaf Dry Weights (gm/plant)	Flower Head Dry Weights (gm/plant)	Leaf Areas (cm^2/plant)
N_0K_0	53.36	33.64	5.95	13.78	1278
N_0K_1	63.07	39.96	8.02	15.12	1721
N_0K_2	57.39	35.88	5.86	15.65	1259
N_0K_3	55.43	36.33	6.36	12.75	1365
N_1K_0	52.52	33.46	6.23	12.83	1339
N_1K_1	63.85	41.01	7.72	15.12	1658
N_1K_2	58.94	35.51	7.01	16.42	1505
N_1K_3	51.06	32.27	6.27	15.52	1347
N_2K_0	55.14	34.82	5.94	14.39	1275
N_2K_1	52.35	32.94	6.45	12.96	1386
N_2K_2	54.46	34.87	6.91	12.68	1484
N_2K_3	56.67	36.36	7.34	12.92	1576
N_3K_0	59.99	38.32	7.86	13.82	1687
N_3K_1	64.97	40.68	8.22	16.07	1766
N_3K_2	51.04	32.42	7.36	11.27	1582
N_3K_3	55.46	33.57	7.63	14.26	1640
N	NS	NS	NS	NS	NS
K	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS
CV (%)	19.99	20.06	24.00	25.62	24.00

Seed head dry weights, seed yields and 1000-seed weights: At the final (3rd harvest) at 93 days after emergence, the results showed that seed head dry weights, seed yields and 1000-seed weights of the sorghum plants were unaffected by either nitrogen or potassium levels (Table 4).

Table 4: Means of seed head dry weights, seed yields and 1000-seed weights of sorghum at 93 days after emergence (3rd harvest) as influenced by nitrogen and potassium levels grown on Oxic Paleustults soil, Khon Kaen University, Northeast Thailand

Treatments	Seed head Dry Weights (gm/plant)	Seed Yields (kg/ha)	1000-Seed Weights (gm/plant)
N_0K_0	27.75	4194	31.44
N_0K_1	27.39	4205	31.17
N_0K_2	24.68	3781	31.50
N_0K_3	24.50	3735	31.39
N_1K_0	24.63	3787	31.25
N_1K_1	27.50	3890	31.57
N_1K_2	28.38	4298	31.78
N_1K_3	28.38	4297	30.96
N_2K_0	29.23	4402	32.33
N_2K_1	28.00	4384	31.92
N_2K_2	28.88	4211	31.31
N_2K_3	29.38	4491	30.05
N_3K_0	25.73	3880	32.19
N_3K_1	26.78	4070	31.05
N_3K_2	29.25	4481	32.22
N_3K_3	29.25	4312	31.53
N	NS	NS	NS
K	NS	NS	NS
N x K	NS	NS	NS
CV (%)	13.12	13.34	4.27

Table 5: Means of brix values, crude protein (%CP), neutral detergent fibre (%NDF), acid detergent fibre (%ADF), and dry matt degradability (%DMD) at 24 and 48 hours of sorghum plants at 82 days after emergence (2nd harvest) grown on Oxic Paleustu soil at Khon Kaen University, Northeast Thailand (% on dry matter basis).

Treatment	Brix values	CP	NDF	ADF	24 hr DMD	48 hr DMD
N_0K_0	11.97	4.39	50.00	29.52	55.51	67.88
N_0K_1	11.48	4.57	50.62	28.95	54.92	68.79
N_0K_2	10.13	4.17	49.04	29.32	56.84	66.34
N_0K_3	10.08	4.26	50.50	28.70	53.81	66.29
N_1K_0	11.19	4.33	49.25	28.83	56.26	69.65
N_1K_1	10.37	4.83	49.37	29.49	57.12	67.44
N_1K_2	8.99	5.19	54.17	30.94	55.16	66.58
N_1K_3	9.65	4.98	51.50	29.45	57.54	70.83
N_2K_0	10.49	4.86	50.68	29.90	58.46	71.97
N_2K_1	11.47	4.44	51.20	30.23	56.24	66.76
N_2K_2	7.76	4.56	51.04	30.53	56.57	65.27
N_2K_3	10.81	4.73	48.99	28.28	54.42	67.95
N_3K_0	9.30	6.11	53.34	30.94	53.22	66.37
N_3K_1	8.90	5.26	52.35	30.54	54.69	68.19
N_3K_2	9.28	5.76	53.61	30.64	53.24	68.22
N_3K_3	7.44	5.64	54.11	31.59	52.98	66.76
N	*	*	NS	NS	NS	NS
K	*	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS
CV%*	16.64	12.86	7.43	7.89	8.16	5.48

Table 6: Duncan's Multiple Range Test of means of brix and crude protein values of sorghum plants at 82 days after emergence (2nd harvest) as influenced by nitrogen and potassium levels grown on Oxic Paleustults soil, Khon Kaen University, Northeast Thailand

Nitrogen and potassium Levels	Brix values	% CP
N_0	10.91[a]	4.35[b]
N1	10.05[a]	4.83[ab]
N_2	10.14[a]	4.65[ab]
N_3	8.73[b]	5.69[a]
K_0	10.74[a]	4.92
K_1	10.56[ab]	4.77
K_2	9.04[c]	4.92
K_3	9.49[bc]	4.90

Remarks: Letters indicate significant differences of DMRT at probability of 0.05

Brix values, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and dry matter degradability (DMD): Chemical component analysis, brix values and DMD at 82 days after emergence (2nd harvest) showed that nitrogen and potassium had some effects on brix values, i.e. higher levels of nitrogen and potassium decreased brix values of the sorghum plants whilst nitrogen levels increased crude protein (Tables 5 and 6). Therefore, nitrogen promotes crude protein content in the plant tissues of the sorghum plants at the second harvest. These results confirm the work reported by Buxton *et al.* (1999). However, potassium levels failed to promote brix values. This may be attributed to an imbalance between nitrogen and potassium resulting in low values of brix. Buxton *et al.* (1999) pointed out that high level of nitrogen depressed the uptake of potassium in plant tissues while the values of NDF, ADF, and DMD were not affected by nitrogen or potassium levels. This could possibly be due to the depletion of soil nutrients and perhaps also partly due to the drought period as previously discussed. Nevertheless, NDF and ADF values found by this work were relatively lower than that of Panichpol and Jeamjadecharoon (1999). DMD values were not influenced by both nitrogen and potassium levels. The similar values of DMD could possibly be due to an inadequate amount of soil available nitrogen, hence the sorghum plant tissues became tough. These results agree with the work reported by Devahuti *et al.* (1992) and Pholsen *et al.* (1998).

Summary: At 52 days after emergence (1st harvest), le dry weights and leaf areas of the sorghum plants increase significantly with an increase in nitrogen levels whil potassium levels had no significant effect. By the 2n harvest (82 days) no significant effects of nitrogen o potassium levels on total dry weights, stem dry weight leaf dry weights, flower head dry weights or leaf area were found. This may be due to the depletion of so nutrients by leaching and/or a drought period. Brix value decreased with an increase in potassium and nitrogen level whilst %CP increased with an increase in nitrogen levels Nitrogen and potassium levels had no effects on NDF, AD and DMD percentages of the sorghum plants. By the fin harvest (93 days after emergence), seed head dry weight seed yields and 1000-seed weights were also shown to b unaffected by the increase in levels of both N and K.

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