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Effects of Nitrogen and Potassium Rates and Planting Distances on Growth, Yield and Fodder Quality of a Forage Sorghum (*Sorghum bicolor* L. Moench)

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Abstract: This forage sorghum experiment was carried out at the Experimental Farm, Faculty of Agriculture, Khon Kaen University, Northeast Thailand to investigate effects due to N-K_2O rates and different planting distances. The experiment was laid out in a 3x4 factorial arranged in a Randomised Complete Block Design with four replications and consisted of twelve treatment combinations (3 rates of N-K_2O and 4 planting distances). The results showed that an increase in N-K_2O rates significantly increased most growth parameters of the sorghum plants. Whilst an increase in planting distances significantly increased stem and leaf dry weight/plant but decreased Leaf Area Index (LAI). Dry weight/plant of lower dead leaves was not affected by either N-K_2O rates or planting distances. The highest LAI value only reached 5. An increase in N-K_2O rates did not affect crop growth rate (CGR), whilst an increase in planting distances significantly decreased CGR. Leaf area duration (D) significantly increased with an increase in N-K_2O rates. Brix value significantly increased, but only at the highest rate of N-K_2O. Seed head and seed yield significantly increased with an increase in N-K_2O rate, but the reverse was found with an increase in planting distances. The highest total dry weight and seed yield were found with the highest rate of N-K_2O (650-100 kg ha^{-1}) and the narrowest planting distance (50x10 cm). Total dry weight and seed yield were positively correlated to D. The highest Crude Protein (CP) was found with the highest rate of N-K_2O and the widest planting distance (50x25 cm). Neutral Detergent Fibre (NDF) was not affected by either N-K_2O rates or planting distance, but Acid Detergent Fibre (ADF) was significantly affected by planting distance. Dry Matter Degradability (DMD) was not significantly affected by N-K_2O rates, yet planting distance did have a significant effect on DMD.

Key words: N-K_2O rate, forage sorghum planting distance, total dry weight, seed yield and fodder quality

INTRODUCTION

In spite of the low fertility of Yasothon soil series (Oxic Paleustults) as stated by Chuasavathi and Trelo-ges[1], Pholsen and Suksri[2]. There have been some published data on sorghum, e.g. Pholsen *et al.*[3,4], Pholsen and Suksri[2] grown on this soil series. However, the available data is relatively limited, particularly the effects due to nitrogen and potassium rates in growth and yield with respect to different planting distances, since nitrogen and potassium play an important role on growth and yield of most cash crops[5]. Nevertheless, there has been some published data with respect to N and K ratio on cassava yields. Suksri and Wongwiwatchai[6] grew cassava (*Manihot esculenta* Crantz) on Yasothon soil series. They showed that a ratio between N and K of 1:2.5 gave the highest tuber yield. The significant increase in tuber yield could have been largely attributable to K, since K has a significant role in the translocation of assimilates to sinks by influencing electron ($^{-e}$) transport in the transport chain of crops[5,7,8]. In increasing quality of fodder in terms of Crude Protein (CP), N fertiliser is important for protein synthesis. Pholsen and Suksri[2] reported that CP significantly increased with an increase in the high rate of N application in chemical fertiliser plus organic amendments in sorghum cultivation.

Therefore, it is of considerable value to carry out an experiment on growth, yield and fodder quality of sorghum in relation to different rates of N and K fertilisers, with respect to different planting distances on Yasothon soil series.

MATERIALS AND METHODS

This experiment was carried out at the Experimental Farm, Faculty of Agriculture, Khon Kaen University, Northeast Thailand during April to September 2001, to investigate the effects due to different application rates of N and K fertilisers and different planting distances in relation to growth, yield and fodder quality of IS 23585

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forage sorghum (*Sorghum bicolor* L. Moench). The experiment consisted of twelve treatment combinations in a 3x4 factorial arranged in a Randomised Complete Block Design with four replications. Three rates of N and K were 450-50 (F_1), 550-70 (F_2) and 650-100 (F_3) kg N-K_2O/ha. Four planting distances were 50x10 (D_1), 50x15 (D_2), 50x20 (D_3) and 50x25 (D_4) cm between and within rows, respectively (i.e. 200,000, 133,333, 100,000 and 80,000 plants ha^{-1}, respectively). Dolomite at a rate of 3,125 kg ha^{-1} was thoroughly applied two weeks before sowing. The land was ploughed twice followed by harrowing once. Triple super-phosphate [$Ca(H_2PO_4)_2$] was evenly applied to the soil as a basal dressing at a rate of 125 kg P_2O_5 ha^{-1} before harrowing. The plot size used was 3x4 m with a footpath of 1.5 m width in between the plots. Each plot was divided into five subplots for five sampling periods. Seeds of IS 23585 sorghum were sown directly into the soil to a depth of 3-5 cm in given distances followed by an application of Carbofuran 3% G insecticide at a rate of 37.5 kg ha^{-1}. After sowing, Atrazine herbicide at a rate of 2.20 kg ha^{-1} was sprayed into the soil to control pre-emergence of weed seed. Seven days after emergence, seedlings were thinned out leaving only one seedling per ditch. The plant samples were taken at five growing intervals, i.e. at 3, 5, 7, 9 and 11 weeks after emergence. Ten plant samples were taken at random from each subplot with a cutting height of 15 cm above ground level and they were used for the determinations of total dry weight/ha, stem dry weight/plant, leaf dry weight/plant, dead leaf dry weight/plant, leaf area/plant and also brix values of stem, including seed yields. An analysis for chemical components (fodder quality) was carried out at 11 weeks after emergence. The plant samples were oven dried at 75°C for 72 h for dry weight, whilst the plant samples for analysis of chemical components were oven dried at 65°C and were ground to pass through a 1 mm screen grinder. The technique of growth analysis was used to measure the changes in growth of the aerial plant parts[5,9,10]. Crude protein, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Dry Matter Degradability (DMD) in cattle rumen for 48 h and brix values were carried out according to Pholsen *et al.*[4]. Soil pH, organic matter, total soil N, available P and extractable K were measured and carried out according to Chuasavathi and Trelo-ges[1], Only the data taken at 3, 7 and 11 weeks after emergence are presented in this study. The data were statistically analysed using a SAS Computer Programme[11].

RESULTS

Soil analysis: Mean values of initial soil pH, organic matter (%), total soil N (%), available P (ppm) and extractable K (ppm) were 5.85, 0.67, 0.0358, 36.75 and 52.75, respectively. The ranges of mean values at the final sampling period were 5.68-5.74, 0.61-0.67, 0.031-0.033, 45-57 and 22-27, respectively.

Table 1: Total dry weight, stem dry weight, leaf dry weight, leaf area and leaf area index of the sorghum plants at 3 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

	Planting distances (cm)				
N-K_2O Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	Average F
Total dry weight (kg ha^{-1})					
F_1	682.00	491.00	457.00	409.00	510.00b
F_2	782.00	517.00	477.00	513.00	572.00a
F_3	846.00	522.00	450.00	512.00	582.00a
Average D	770.00a	510.00b	461.00c	478.00b	
Stem dry weight (g/plant)					
F_1	0.82	1.01	1.08	1.48	1.09b
F_2	0.98	1.05	1.17	1.71	1.23a
F_3	1.08	1.07	1.23	1.73	1.28a
Average D	0.96d	1.04c	1.16b	1.64a	
Leaf dry weight (g/plant)					
F_1	2.60	2.68	3.50	3.64	3.10b
F_2	2.94	2.82	3.61	4.71	3.52a
F_3	3.15	2.85	3.26	4.66	3.48a
Average D	2.89c	2.78c	3.45b	4.33a	
Leaf area (cm^2/plant)					
F_1	1059.00	1094.00	1426.00	1484.00	1266.00b
F_2	1199.00	1152.00	1472.00	1920.00	1436.00a
F_3	1286.00	1164.00	1333.00	1903.00	1421.00a
Average D	1181.00c	1137.00c	1410.00b	1769.00a	
Leaf area index					
F_1	2.12	1.46	1.43	1.19	1.55b
F_2	2.40	1.54	1.47	1.54	1.74a
F_3	2.57	1.55	1.33	1.52	1.74a
Average D	2.36a	1.52b	1.41b	1.42b	

Letter indicate significant differences of DMRT at probability of 0.05

Total dry weight, stem dry weight, leaf dry weight, leaf area, dead leaf dry weight, Leaf Area Index (LAI), Crop Growth Rate (CGR), leaf area Duration (D), brix values and seed yields: At 3 weeks after emergence, mean total dry weight significantly increased with an increase in N-K_2O rates, but only up to F_2, where F_2 was similar to F_3 with values ranged from 510 to 582 kg ha^{-1}. Whilst effect due to planting distances on total dry weight/ha significantly decreased, but only up to D_3 where D_2 was similar to D_4 with values ranged from 461 to 770 kg ha^{-1} for D_3 and D_1, respectively (Table 1). Stem dry weight significantly increased with an increase in N-K_2O rates up to F_2 where F_2 was similar to F_3 with values ranged from 1.09 to 1.28 g/plant for F_1 and F_3, respectively. An increase in planting distances significantly increased stem dry weight with values ranged from 0.96 to 1.64 g/plant for D_1 and D_4, respectively. An increase in N-K_2O rates significantly increased leaf dry weight but an increase was observed only up to F_2, whilst wider planting distances significantly increased leaf dry weight with values ranged from 2.89 to 4.33 g/plant for D_1 and D_4, respectively.

Table 2: Total dry weight, stem dry weight, leaf dry weight and dead leaf dry weight at 7 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

	Planting distances (cm)				
N-K_2O					Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Total dry weight (kg ha^{-1})					
F_1	5294.00	5200.00	4530.00	4552.00	4894.00c
F_2	6289.00	5447.00	5049.00	4875.00	5415.00b
F_3	6741.00	6131.00	5688.00	5048.00	5902.00a
Average D	6108.00a	5593.00b	5089.00c	4825.00d	
Stem dry weight (g/plant)					
F_1	13.78	22.45	27.81	35.60	24.91c
F_2	17.53	24.22	32.67	37.72	28.03b
F_3	19.34	27.07	37.03	39.70	30.79a
Average D	16.88d	24.59c	32.50b	37.67a	
Leaf dry weight (g/plant)					
F_1	8.59	11.90	12.27	15.79	12.14c
F_2	9.96	12.09	12.71	17.83	13.15b
F_3	10.35	14.47	14.87	18.05	14.43a
Average D	9.63c	12.82b	13.28b	17.22a	
Dead leaf dry weight (g/plant)					
F_1	4.10	4.65	5.22	5.51	4.87
F_2	3.97	4.54	5.11	5.40	4.76
F_3	4.02	4.44	4.98	5.35	4.70
Average D	4.03d	4.54c	5.10b	5.42a	

Table 3: Leaf area, leaf area index and crop growth rate of the sorghum plants at 7 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

	Planting distances (cm)				
N-K_2O					Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Leaf area (cm^2/plant)					
F_1	2017.00	2794.00	2882.00	3708.00	2850.00c
F_2	2337.00	2840.00	2985.00	4186.00	3087.00b
F_3	2429.00	3399.00	3492.00	4238.00	3390.00a
Average D	2261.00c	3011.00b	3119.00b	4044.00a	
Leaf area index					
F_1	4.04	3.73	2.88	2.97	3.40c
F_2	4.67	3.79	2.98	3.35	3.70b
F_3	4.86	4.53	3.49	3.39	4.07a
Average D	4.52a	4.02b	3.12c	3.24c	
Crop growth rate (g/m^2/week)					
F_1	138.32	133.05	134.53	126.01	132.98c
F_2	157.86	137.21	151.20	123.47	142.43b
F_3	173.43	161.82	160.82	130.92	156.75a
Average D	156.53a	144.03b	148.85ab	126.80c	

Letter indicate significant differences of DMRT at probability of 0.05

A similar trend to that of leaf dry weight was found with leaf area with values ranged from 1,181 to 1,769 cm^2/plant for D_1 and D_4 and from 1,266 to 1,421 cm^2/plant for F_1 and F_3, respectively. An increase in planting distances significantly decreased Leaf Area Index (LAI), but the decrease was found only at D_2, whilst a further increase in planting distances had no effect on LAI with mean values ranged from 1.52 to 2.36 for D_2 and D_1, respectively. A similar trend to that of leaf area on fertiliser treatments was found with LAI with mean values of 1.55 and 1.74 for F_1 and F_2, respectively.

At 7 weeks after emergence, total dry weight significantly increased with an increase in N-K_2O rates with mean values ranged from 4,894 to 5,902 kg ha^{-1} for F_1 and F_3, respectively (Table 2). An increase in planting distances significantly decreased total dry weight with mean values ranged from 4,825 to 6,108 kg ha^{-1} for D_4 and D_1, respectively. Stem dry weight significantly increased with an increase in fertiliser rates and also did with an increase in planting distances. Stem dry weights due to fertiliser rates ranged from 24.91 to 30.79 g/plant for F_1 and F_3 and due to planting distances ranged from 16.88 to 37.67 g/plant for D_1 and D_4, respectively.

N-K_2O rates significantly increased leaf dry weight with mean values ranged from 12.14 to 14.43 g/plant for F_1 and F_3, respectively. Whilst an increase in planting distances, in most cases, significantly increased leaf dry weight with mean values ranged from 9.63 to 17.22 g/plant for D_1 and D_4, respectively.

N-K_2O rates had no effect on dead leaf dry weights, whilst an increase in planting distances significantly increased dead leaf dry weight with mean values ranged from 4.03 to 5.42 g/plant for D_1 and D_4, respectively.

An increase in N-K_2O rates and planting distances significantly increased leaf area with mean values ranged from 2,850 to 3,390 cm^2/plant for F_1 and F_3 and from 2,261 to 4,044 cm^2/plant for D_1 and D_4, respectively. An increase in N-K_2O rates significantly increased LAI with mean values ranged from 3.40 to 4.07 for F_1 and F_3, respectively. However, an increase in planting distances, in most cases, significantly decreased LAI with mean values ranged from 4.52 to 3.12 for D_1 and D_3, respectively. An increase in N-K_2O rates significantly increased crop growth rate (CGR) with mean values ranged from 132.98 to 156.75 g/m^2/week for F_1 and F_3, respectively. Nevertheless, an increase in planting distances, in most cases, significantly decreased CGR although D_3 was similar to D_1 and D_2 with mean values ranged from 126.80 to 156.53 g/m^2/week for D_4 and D_1, respectively (Table 3).

At 11 weeks after emergence, total dry weights significantly increased with an increase in N-K_2O rates with mean values ranged from 12,470 to 14,110 kg ha^{-1} for F_1 and F_3, respectively (Table 4). An increase in planting distances significantly decreased total dry weight with mean values of 9,848 to 18,223 kg ha^{-1} for D_4 and D_1, respectively. An increase in N-K_2O rates significantly increased stem dry weight with mean values ranged from 60.20 to 68.39 g/plant for F_1 and F_3, respectively. Similarly, an increase in planting distances significantly increased stem dry weight with mean values ranged from 54.70 to 73.31 g/plant for D_1 and D_4, respectively.

An increase in N-K_2O rates and planting distances significantly increased leaf dry weight with mean values

Table 4: Total dry weight, stem dry weight, leaf dry weight and dead leaf dry weight of the sorghum plants at 11 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

N-K_2O	Planting distances (cm)				Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Total dry weight (kg ha^{-1})					
F_1	17229.00	12973.00	10719.00	8958.00	12470.00c
F_2	18152.00	13914.00	11011.00	10094.00	13292.00b
F_3	19289.00	14979.00	11681.00	10493.00	14110.00a
Average D	18223.00a	13955.00b	11137.00c	9848.00d	
Stem dry weight (g/plant)					
F_1	51.90	57.72	65.22	65.96	60.20c
F_2	54.15	63.80	67.82	75.24	65.25b
F_3	58.07	66.59	70.17	78.74	68.39a
Average D	54.70d	62.70c	67.74b	73.31a	
Leaf dry weight (g/plants)					
F_1	14.06	18.62	19.71	23.57	18.99c
F_2	16.30	19.15	19.80	28.12	20.84b
F_3	17.43	23.67	23.95	29.24	23.57a
Average D	15.93c	20.48b	21.15b	26.97a	
Dead leaf dry weight (g/plants)					
F_1	9.36	9.25	9.03	9.10	9.19
F_2	9.10	8.99	8.90	8.92	8.98
F_3	8.68	8.94	8.66	8.61	8.72
Average D	9.04	9.06	8.86	8.88	

Table 5: Head dry weight, leaf area and leaf area index of the sorghum plants at 11 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

N-K_2O	Planting distances (cm)				Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Head dry weight (g/plants)					
F_1	10.82	11.71	13.24	13.36	12.28c
F_2	11.22	12.42	13.60	13.89	12.78b
F_3	12.26	13.15	14.04	14.57	13.51a
Average D	11.43c	12.43b	13.63a	13.94a	
Leaf area (cm^2/plant)					
F_1	2346.00	3108.00	3289.00	3933.00	3169.00c
F_2	2721.00	3196.00	3304.00	4693.00	3478.00b
F_3	2909.00	3950.00	3996.00	4880.00	3934.00a
Average D	2659.00c	3418.00b	3530.00b	4502.00a	
Leaf area index					
F_1	4.69	4.15	3.29	3.15	3.82c
F_2	5.44	4.26	3.31	3.76	4.19b
F_3	5.82	5.27	4.00	3.90	4.75a
Average D	5.32a	4.56b	3.60c	3.53c	

Letter indicate significant differences of DMRT at probability of 0.05

of 18.99, 20.84 and 23.57 g/plant for F_1, F_2 and F_3 and ranged from 15.93 to 26.97 g/plant for D_1 and D_4, respectively. An increase in N-K_2O rates and planting distances had no significant effect on dead leaf dry weight.

An increase in N-K_2O rates significantly increased head dry weight with mean values of 12.28, 12.78 and 13.51 g/plant for F_1, F_2 and F_3, respectively (Table 5). An increase in planting distances, in most cases, significantly increased head dry weight although D_3 was similar to D_4 with mean values ranged from 11.43 to 13.94 g/plant for D_1 and D_4, respectively. An increase in N-K_2O rates

Table 6: Crop growth rate, leaf area duration and brix value of the sorghum plants at 11 weeks after emergence as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

N-K_2O	Planting distances (cm)				Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Crop growth rate (g/m^2/week)					
F_1	201.38	150.08	93.63	63.57	127.17
F_2	199.53	128.36	85.94	94.41	127.06
F_3	205.03	131.74	97.56	99.70	133.51
Average D	201.98a	136.73b	92.38c	85.89c	
Leaf area duration (m2.week)					
F_1	1.63	2.17	2.30	2.90	2.25c
F_2	1.87	2.25	2.36	3.32	2.45b
F_3	1.98	2.61	2.77	3.80	2.68a
Average D	1.83c	2.34b	2.48b	3.20a	
Brix value (%)					
F_1	10.51	10.94	10.91	10.92	10.81b
F_2	10.58	11.06	11.07	11.15	10.97b
F_3	11.29	11.47	11.71	11.82	11.57a
Average D	10.79	11.16	11.23	11.29	

Letter indicate significant differences of DMRT at probability of 0.05

significantly increased leaf area with mean values ranged from 3,169 to 3,934 cm^2/plant for F_1 and F_3, respectively. An increase in planting distances, in most cases, significantly increased leaf area although D_2 was similar to D_3 with mean values ranged from 2,659 to 4,502 cm^2/plant for D_1 and D_4, respectively. A similar trend to that of leaf area/plant was found with LAI with mean values ranged from 3.82 to 4.75 for F_1 and F_3, respectively. In contrast, an increase in planting distances, in most cases, significantly decreased LAI although D_3 was similar to D_4 with mean values decreasing from 5.32 to 3.53 for D_1 and D_4, respectively.

An increase in N-K_2O rates had no significant effect on CGR with mean values ranged from 127.06 to 133.51 g/m^2/week for F_2 and F_3 respectively (Table 6). An increase in planting distances, in most cases, significantly decreased CGR with mean values decreasing from 201.98 to 85.89 g/m^2/week for D_1 and D_4, respectively. Nevertheless, an increase in N-K_2O rates significantly increased leaf area duration (D) with mean values ranged from 2.25 to 2.68 (m^2. week) for F_1 and F_3 and an increase in planting distances, in most cases, significantly increased D from 1.83 to 3.20 (m^2. week) for D_1 and D_4, respectively.

An increase in N-K_2O rates, in most cases, significantly increased brix value although F_1 was similar to F_2 with mean values ranged from 10.81 to 11.57 % for F_1 and F_3, respectively, whilst an increase in planting distances had no significant effect on brix value with mean values ranged from 10.79 to 11.29 % for D_1 and D_4, respectively.

An increase in N-K_2O rates significantly increased dry seed head yield with mean values ranged from 5,405

Table 7: Dry seed head yield, seed yield and 1000-seed weight of the sorghum plants as influenced by planting distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

N-K_2O	Planting distances (cm)				Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Dry seed head yield (kg ha^{-1})					
F_1	7840.00	5567.00	4544.00	3668.00	5405.00c
F_2	8189.00	5847.00	4635.00	3783.00	5614.00b
F_3	8630.00	6074.00	4778.00	4040.00	5880.00a
Average D	8220.00a	5829.00b	4652.00c	3830.00d	
Seed yield (kg ha^{-1})					
F_1	6254.00	4440.00	3625.00	2926.00	4311.00c
F_2	6533.00	4664.00	3698.00	3018.00	4478.00b
F_3	6884.00	4845.00	3811.00	3223.00	4691.00a
Average D	6557.00a	4650.00b	3711.00c	3056.00d	
1000-seed weight (g)					
F_1	32.85	32.31	31.49	32.49	32.28
F_2	32.79	32.70	32.56	32.03	32.52
F_3	32.13	31.75	32.30	31.60	31.95
Average D	32.59	32.25	32.11	32.04	

Table 8: Crude protein, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Dry Matter Degradability (DMD) of the sorghum plants at 11 weeks after emergence as influenced by plant distances and N-K_2O rates, grown on Yasothon soil series (Oxic Paleustults)

N-K_2O	Planting distances (cm)				Average
Rates (kg ha^{-1})	D_1	D_2	D_3	D_4	F
Crude protein (% on DM basis)					
F_1	7.58	7.60	7.41	8.54	7.78b
F_2	7.58	7.90	7.24	8.54	7.81b
F_3	8.65	7.93	8.45	8.16	8.30a
Average D	7.94b	7.81b	7.70b	8.41a	
NDF (% on DM basis)					
F_1	62.57	59.84	61.27	62.34	61.50
F_2	59.93	60.42	62.61	60.72	60.92
F_3	60.69	60.40	64.87	60.99	61.74
Average D	61.06	60.22	62.91	61.35	
ADF (% on DM basis)					
F_1	32.86	36.94	37.43	33.86	35.27
F_2	33.08	36.40	38.09	34.80	35.59
F_3	35.07	35.99	36.27	35.84	35.79
Average D	33.67b	36.44a	37.26a	34.83b	
DMD (% on DM basis)					
F_1	59.60	61.09	60.46	61.21	60.59
F_2	60.74	60.08	58.20	59.66	59.67
F_3	59.55	61.55	56.67	59.88	59.41
Average D	59.96ab	60.90a	58.44b	60.25a	

Letter indicate significant differences of DMRT at probability of 0.05

to 5,880 kg ha^{-1} for F_1 and F_3, respectively (Table 7). In contrast, an increase in planting distances significantly decreased dry seed head yield with mean values decreasing from 8,220 to 3,830 kg ha^{-1} for D_1 and D_4, respectively. An increase in N-K_2O rates significantly increased seed yield with mean values ranged from 4,311 to 4,691 kg ha^{-1} for F_1 and F_3 and a reverse was found with an increase in planting distances, i.e. a decrease from 6,557 to 3,056 kg ha^{-1} for D_1 and D_4, respectively. An increase in N-K_2O rates and planting distances had no significant effect on 1000-seed weight.

Relationship between total dry weight and leaf area duration (D) and between seed yield and D: There was a positive and significant relationship between total dry weight and D ($Y = 20.996X+55.206$, $R^2 = 0.93^{**}$) and also between seed yield and D ($Y = 3.7105X+26.478$, $R^2 = 0.83^{**}$).

Fodder quality: An increase in N-K_2O rates significantly increased Crude Protein (CP) only at the highest rates of N-K_2O (F_3) where F_1 and F_2 were not significantly different from each other with values ranged from 7.78 to 8.30 for F_1 and F_3, respectively (Table 8). Similarly, an increase in planting distances significantly increased CP only at the widest distance (D_4) with mean values ranged from 7.70 to 8.41 for D_3 and D_4, respectively. An increase in N-K_2O rates and planting distances had no significant effect on Neutral Detergent Fibres (NDF) with mean values ranged from 60.92 to 61.74 for F_2 and F_3 and from 60.22 to 62.91 for D_2 and D_3, respectively.

An increase in N-K_2O rates had no significant effect on Acid Detergent Fibres (ADF) with mean values ranged from 35.27 and 35.79 % for F_1 and F_3, respectively. An increase in planting distances, in most cases, significantly increased ADF but only up to D_2, whilst D_2 was similar to D_3 and D_4 was similar to D_1 with mean values ranged from 33.67 to 37.26 for D_1 and D_3, respectively. An increase in N-K_2O rates had no significant effect on Dry Matter Degradability (DMD) with mean values ranged from 59.41 to 60.59% for F_3 and F_1, respectively. An increase in planting distances, in most cases, significantly increased DMD but D_3 was slightly lower than D_1 with mean values ranged from 58.44 to 60.90 for D_3 and D_2, respectively.

DISCUSSION

Mean values of soil pH at initial and final sampling period were similar although dolomite was applied. This could be attributable to some leaching amount of Ca and Mg occurring during rainy season and partly due a certain amount of both nutrients was used by the sorghum plants[7]. At initial soil sampling, it was found that available soil P was adequate, whilst extractable soil K was relatively low[12]. The high amount of available soil P could have been attributable to the previous history of crop cultivation, whilst the low value of extractable K may have been partly attributable to the previous cultivation of cassava and sorghum when cassava demanded high amounts of K for tuber development[6]. The results at final soil analysis indicated that organic matter and total soil N, in most cases, were slightly lower than that of the initial soil analysis data except available soil P, i.e. mean available soil P value was slightly higher than that of the

initial value, whilst soil K value was relatively lower. This may be attributable partly to high leaching rates of soil K and the sorghum plants could have taken up a large amount of nutrients for growth. The previous crop history and high leaching rate of soil nutrients have been reported by a number of workers[5,7,13-16]. Yasothon soil can be classified as a poor soil series for high crop yield, particularly for most cash crops in the region, even though available soil P in this work was relatively high[1,2,4].

At initial sampling period, 3 weeks after emergence, an increase in N-K_2O rates significantly increased total dry weight/ha, stem dry weight, leaf dry weight and leaf area/plant but only up to F_2 where F_2 was similar to F_3 The results indicated that a clear effect due to chemical fertilisers rates was not found. This must be attributable to the plant age, since the sorghum plants had attained only a small amount of growth during this short growing period. An increase in the planting distances significantly increased most growth parameters per plant of the sorghum. The results indicated that an increase in the planting distances could have favoured the growth of the sorghum plants. LAI decreased due to an increase in land area per plant. LAI values, in all cases, were relatively low suggesting small levels of light interception among leaf canopies. Nevertheless, it may be too early to evaluate the growth of the sorghum plants at this stage of growth since the accumulation of dry matter was relatively small.

At 7 weeks after emergence, an increase in N-K_2O rates significantly increased total dry weight/ha. On the contrary, an increase in planting distances significantly decreased it. This could have been attributable to the number of plant populations per unit land area where the closer the distance the higher the plant populations and the greater the amount of total dry weight/ha. Stem dry weight/plant significantly increased with both an increase in N-K_2O rates and planting distances. The results indicated that stem growth was better with those wider spaced than the narrower planting distances, since the competition for soil moisture, nutrients and light interception among leaf canopies may not yet be a severe problem for the plants. A similar trend to that of stem dry weight/plant was also found with leaf dry weight and leaf area/plant, whilst dead leaf dry weight/plant was significantly affected most by an increase in planting distances, but not with N-K_2O rates. An increase in N-K_2O rates also significantly increased LAI, whereas LAI values due to planting distances were significantly decreased with an increase in planting distances. The results indicated that D_1 (50x10 cm) was a more efficient density for nutrients and radiant energy interception among leaf canopies than the rest, although LAI did not reach maximum (8-10)[5]. The results indicated an inadequate amount of soil moisture level. Therefore, it is possible that more than 90 % of radiant energy was intercepted by leaf canopies[17]. Crop Growth Rate (CGR) significantly increased with an increase in N-K_2O rates added to the soil but significantly decreased with a wider planting distance. CGRs were much higher than that of Pholsen and Suksri[2]

At 11 weeks after emergence, an increase in N-K_2O rates significantly increased total dry weight/ha of the sorghum plants, whilst an increase in planting distances significantly decreased it. The results indicated that further increases in total dry weight/ha could have been possible with some higher rates of N-K_2O. This trend was also found with stem dry weight/plant. However, an increase in planting distances significantly increased both stem dry weight and leaf dry weight/plant. Dead leaf dry weight/plant was not affected by either N-K_2O rates or planting distances. The high amount of lower dead leaves could be due to high environmental temperatures, the advance in plant age along with the low soil moisture regime and partly attributable to the re-translocation of assimilate to upper leaves or grains[17-22]. Some similar trends to that of stem dry weight and leaf dry weight/plant were found with head dry weight and leaf area/plant. LAI values significantly decreased with an increase in planting distances. The results partly indicated the poor fertility of Yasothon soil hence the spacing between and within the rows must be readjusted for increasing optimum LAI. That is a narrower planting distance than 50x10 cm between and within rows must be used for further experiments.

An increase in N-K_2O rates had no effect on CGR, whilst an increase in planting distances significantly decreased it. This must be attributable to the number of plant populations per unit land area as previously discussed. CGRs, in most cases, were lower than that of Pholsen and Suksri[2]. For leaf area duration (D), D values significantly increased with an increase in N-K_2O rates since high rates of chemical fertiliser assist in prolonging life of green leaves[2]. Brix values significantly increased with an increase in N-K_2O rates but only with the highest rates. This may be attributable to the effect of potassium, since it has an important role in increasing sugar content in plant tissues of many crop plants such as sugar cane, orchard fruit and others[5].

For dry seed head yield and seed yield/ha, the results showed that an increase in N-K_2O rates significantly increased dry seed head yield and seed yield/ha, whilst an increase in planting distances significantly decreased both of them. The best treatment for dry seed head yield and seed yield was found with D_1F_3 (N-K_2O rates of 650-100 kg ha^{-1} and the distance between and within the

rows of 50x10 cm). Seed yield/ha was much higher than those reported by Pholsen *et al*[3,4] and in most cases, seed yields and total dry weight with the same plant distance at 11 weeks after emergence were much higher than that of Pholsen and Suksri[2]. Hegari sorghum cultivar treated with 50, 100 and 150 kg N ha^{-1} and population of 125,000 to 250,000 plants ha^{-1} had no significant effect on grain yields (1,974 to 2,116 kg ha^{-1}) under soil moisture stress conditions[23]. Faungfupong *et al*.[24] found that KU257 sorghum cultivar with population of 156,863 plants ha^{-1} gave the highest grain yield of 4,036 kg ha^{-1} compare with lower plant population. Faungfupong *et al*.[25] reported that with a population of 133,333 and 200,000 plants ha^{-1} of two sorghum cultivars gave mean grain yields of 2,782 and 2,706 kg ha^{-1}, respectively.

With fodder quality (chemical components), Crude Protein (CP) significantly increased in both the highest rate of N-K_2O and the widest planting distance (F_3D_4). The results indicated that the highest N-K_2O rates gave the best result on CP, since a large amount of N is required for the constituent of protein as stated by Pholsen and Suksri[2].

The results for Neutral Detergent Fibre (NDF) revealed that NDF values were not affected by either N-K_2O rates or planting distances, whilst Acid Detergent Fibre (ADF) was significantly affected by planting distances. N-K_2O rates had no effect on ADF nor Dry Matter Degradability (DMD). This can be attributable to perhaps inadequate amounts of soil moisture content as a result of an erratic rainfall pattern and also effects due to high environmental temperatures. Therefore, it may be an advantage if soil moisture content is kept at an adequate level throughout the experimental period, which would possibly help to explain more clearly the effect due to N-K_2O rates and different planting distances. With this work, CP, NDF and ADF were higher, while DMD was lower than that of Pholsen *et al*.[4].

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