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Interaction Between Potassium and Organic Manure Application on Growth of Cowpea (*Vigna unguiculata* L.) And Soil Properties in Newly Reclaimed Sandy Soil

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Abstract: A field experiment (randomized complete block, factorial) was conducted during 2009 and 2010 in newly reclaimed sandy soil, New Valley of the western desert, Egypt to assess the interaction effects of potassium and farmyard manure (FYM) application on growth and soil properties of forage cowpea (*Vigna unguiculata* L. local variety). Factors and treatments are: K-application rate: 0, 48, 96 and 144 kg K/ha (K0, K1, K2 and K3, respectively); K-application timing: pre-seeding during seedbed preparation and post-seeding 20 days after seeding (T1 and T2, respectively); FYM rates: 0, 25, 50 and 75 m^3/ha (M0, M1, M2 and M3, respectively). Plant growth and soil property parameters were beneficially affected by K and FYM application singly or combined. The addition ratio of 1:2:3 for either K or M application rates gave yields of nearly the same ratios. The lowest yield and NPK uptake were obtained by T1 K0 M0 while, the highest increases of 130 to 210% were obtained with T1 K3 M3 or T1 K2 M3. Increasing K application from K0 to K1 or K2 decreased the bulk density (BD) (values being 1.549, 1.539, 1.510 and 1.519 mg/m^3 due to K0, K1, K2 and K3 respectively). Increasing FYM increased BD (values being 1.615, 1.520, 1.495 and 1.490 mg/m^3 due to M0, M1, M2 and M3, respectively). Field capacity (FC) and available water (AW) increased with increasing both K and FYM. FC = 10.81, 11.90, 13.47 and 15.91% due to K0, K1, K2 and K3, respectively; 9.72, 13.05, 14.75 and 15.73 % due to M0, M1, M2 and M3, respectively. AW = 9.37, 12.43, 12.07 and 13.61 % for K0, K1, K2 and K3, respectively.

Key words: Potassium fertilizer % Farmyard manure % Cow pea (*Vigna unguiculata* L.) % Soil properties % Sandy soil

INTRODUCTION

Cowpea is one of the most widely adapted, versatile and nutritious grain legume crops. It has high rates of fixation of atmospheric nitrogen among legume plants when grown in low fertility soils, such as sandy soils [1] and has a high demand for K for its growth [2]. Dry grains of cowpea are used for human consumption, while stems, leaves and pods, fresh and dry are used as feed-staff for animals [3]. Sandy soils are mainly infertile with poor physical properties and require addition of organic manure [4, 5] to improve their fertility. In such soils potassium does not interact strongly with the soil matrix, unlike in other soils of fine texture where K is retained more strongly on their colloidal complex. Therefore, in sandy soils K is easily lost by leaching by water percolating through the soil column [6, 7]. Organic manure increases structural stability and water retention of sandy soils [8]. Fertilization of cowpea with combinations of organic manure and mineral fertilizers, including K fertilizers, increased its growth, yield and especially nutrient uptake [9-12]. Although excess application of organic manures may particularly increase growth of shoots of young plants [13] it may induce an early senescence (signs of old age) on adult plants and increases its protein content [14].

The objective of the current study was to determine the interaction effects between potassium and organic manure application on growth of cowpea (*Vigna unguiculata* L.) and some soil properties in newly reclaimed sandy soil in the western desert of Egypt.

MATERIALS AND METHODS

A field experiment was conducted during two successive winter seasons 2009 and 2010 in the New Valley Agricultural Research Station, New Valley Governorate, Egypt in order to investigate the interaction

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Table 1: Properties of the soil of the experimental site.

Properties	Value
pH (1:2.5 soil: water suspension.)	7.31
EC (dS/m) in paste extract	1.35
Soluble ions ($mmol_c$/L)*	
Ca^{++}	3.91
Mg^{++}	1.81
Na^+	6.01
K^+	0.65
$HCO3^-$	2.17
Cl^-	7.23
SO_4^{--}	2.98
Organic matter (g/kg)	0.09
Calcium carbonate (g/kg)	81.5
Moisture constants, bulk density and hydraulic conductivity:	
Field capacity (w/w)	7.05
Wilting point (w/w)	1.89
Bulk density (mg/m^3)	1.67
Hydraulic conductivity (cm/h)	9.41
Total porosity (TP) and pore size-distribution (%):	
TP	34.44
Quickly-drainable pores (QDP > 28.84 µm)	26.59
Slowly-drainable pores(SDP 28.8 - 8.62 µm)	2.70
Water-holding pores (WDP 8.62 – 0.19 µm)	3.83
Fine-capillary pores(FCP < 0.19 µm)	1.32
Particle size-distribution (%):	
Coarse sand	37.25
Fine sand	54.66
Silt	4.19
Clay	3.90
Texture class	Sand
Available macro-nutrients (mg/kg):	
N:12.6; P: 4.4; K: 53.8	

* no soluble carbonate was detected.

Table 2: Properties of farmyard manure (FYM) used in the experiment.

EC dS/m	pH	Total nutrients (g /kg)				OM	OC	
---------(1:5 w:v extract)--------		N	P	K	C/N ratio	----------(g /kg)---------		BD (mg/m^3)
3.42	7.66	11.7	3.7	12.2	19.4	392	227	0.640

Note: OM=organic matter; OC= organic carbon; BD = Bulk density

effect between potassium and organic manure application on growth and some soil properties of forage cowpea (*Vigna unguiculata* L., local variety) in newly reclaimed sandy soils. The physical and chemical properties of the soil are presented in Table 1. Seeds of cowpea were pre-inoculated with inoculums of nodule bacteria then sown on April 1st in the first and second seasons on ridges 30cm apart at a seeding rate of 70 kg/ha. The experimental design was factorial in randomized complete block with three replicates. Factors and their treatments were as follows: (1) K rate (K): four rates of 0, 48, 96 and 144 kg K/ha as potassium sulphate (410 g K/kg), i.e. K0, K1, K2 and K3, respectively; (2) K timing (T): two timings of pre-sowing during land preparation and post-sowing 20 days after sowing i.e. T1 and T2 respectively; (3) Organic manuring (M): four farmyard manure (FYM) rates of 0, 25, 50 and 75 m^3/ha,i.e. M0, M1, M2 and M3, respectively. Table 2 shows FYM analysis. Plot size was 10.5 m^2 (3x3.5 m). All plots received a starter dose of 25 kg N/ha added broadcast 15 days after sowing as ammonium sulphate (206 g N/kg) as well as 15 kg P/ha (as ordinary calcium super phosphate 66 g P/kg). Addition of P and FYM was applied during land preparation. The crop was managed using the proper husbandry operations done in the area.

Soil and Plant Analyses: Soil samples were collected from the 0-15cm surface layer. One composite representative sample was taken before conducting the experiment. After termination of the experiment, soil samples were taken from each plot to assess changes in soil due to treatments. Three cuts were taken from the crop plant samples, oven-dried at 70ºC then ground and kept for analysis. Soil analyses included particle size distribution by the pipette method [15]. Other analyses included bulk density and hydraulic conductivity on undisturbed soil cores, soil pH (in a 1:2.5 w: v soil: water suspension), salinity of paste extract, organic matter and calcium carbonate (by a calcimeter) all of which are described by Richards [16] and Page *et al.* [17]. Soil moisture equilibrium at moisture tensions of 10, 33, 66 and 100 kPa (using a pressure cookers); and 1500 kPa (using a pressure membrane) were carried out according to the methods described by Richards and Weaver [18] and soil porosity and pore size distribution of quickly drainable pores (QDP) [>28.84µm], slowly drainable pores (SDP) [28.8-8.62µm], water holding pores (WHP) [8.62-0.19µm] and fine capillary pores (FCP) [<0.19µm] were all done according to Deleenher and De Boodt [19]. Plant samples were analyzed for N, P and K [20]. Data were statistically analyzed through analysis of variance [21].

RESULTS AND DISCUSSION

Fresh Yield: Yield increased upon K as well as of FYM application separately or in combination. Increasing the rate of K or FYM increased the yield of cowpea (Table 3). The pre-seeding application timing of K (T1) was superior to the post-seeding application (T2). Treatment which gave the lowest yield of 40.0 Mg/ha was that which received neither K nor manure (T1 K0 M0), while treatment which received the highest rates of both K and manure (T1 K3 M3) gave the highest yield; a considerable increase of 166%. This reflects the very low fertility status of the soil. The progressive yield increase due to K1, K2 and K3 averaged 18.0, 30.6 and 46.4%, respectively thus exhibiting a yield-response increment ratio of 1.0:1.7: 2.6 due to application of the three respective successive K-rates. Such response ratio is nearly identical to the K-rates ratio of 1:2:3. The implication of such a marked response of this scale and magnitude indicates a severe poverty of K in the soil for plant growth, hence a considerable response to K application.

The progressive response was particularly evident where manure was not applied with K being given pre-seeding. Where K was given post-seeding with no manure being given, there was no progressive increase associated with the increase in K application. The pre-seeding K-application, in general (main effect), was superior to the post-seeding one by 35.5% on average indicating a benefit of applying K in the seedbed of the plant in order to give the plant a starting push in its growth [22]. The response to manuring was also progressive and yield increased due to M1, M2 and M3 with averages of 13.0, 27.1 and 45.7% with a ratio of 1.0:2.1:3.5 due to the 3 respective successive K-rates. This response ratio is very much similar to that of the FYM-rates ratio of 1:2:3 reflecting the profound need for

Table 3: Interaction effects between K-fertilization, K-application time and FYM (farmyard manure) on fresh yield (Mg/ha) of forage cowpea (total of 3 cuts, means of two seasons).

		FYM-rates (m^3/ha) (M)				
K-timing* (T)	K-rates (kg/ ha)	0 (M0)	24 (M1)	48 (M2)	72 (M3)	Mean
T1 (Pre-seeding)	0 (K0)	40.0	52.5	57.5	63.8	53.5
	48 (K1)	60.0	65.0	72.5	83.8	70.3
	96 (K2)	67.5	71.3	85.0	88.8	78.2
	144 (K3)	71.3	78.8	90.0	106.3	86.6
Mean		59.7	66.9	76.3	85.7	72.2
T2 (Post-seeding)	0 (K0)	42.5	45.0	50.0	55.0	48.1
	48 (K1)	42.9	47.4	52.5	62.5	49.1
	96 (K2)	45.0	51.3	56.3	63.8	54.1
	144 (K3)	48.8	58.8	61.3	77.3	61.6
Mean		43.5	49.7	55.0	64.7	53.2
Means of K rate	0 (K0)	41.3	48.8	53.8	58.3	50.6
	48 (K1)	48.8	54.3	62.5	73.1	59.7
	96 (K2)	56.3	61.3	70.6	76.3	66.1
	144 (K3)	60.0	68.8	75.6	91.8	74.1
G. Mean		51.6	58.3	65.6	75.2	62.7

LSD at 0.05 T=2.0 R=3.2 M=3.2 TR=4.4 TM=4.4 RM=6.0 TRM=8.4

*K-application timings (T1) immediately before seeding; (T2) 20 days after seeding (source K-sulphate)

Table 4: Interaction effects between K-fertilization, K-application time and FYM (farmyard manure) on dry yield (Mg/ha) of forage cowpea (total of 3 cuts, means of two seasons).

		FYM-rates (m^3/ha) (M)				
K-timing* (T)	K-rates (kg /ha) (K)	0 (M0)	24 (M1)	48 (M2)	72 (M3)	Mean
T1 (Pre-seeding)	0 (K0)	10.5	13.6	13.9	16.2	13.5
	48 (K1)	15.5	16.3	17.7	20.6	17.5
	96 (K2)	17.3	18.1	20.9	22.0	19.6
	144 (K3)	18.3	19.7	21.6	24.8	21.1
Mean		15.4	16.9	18.5	20.9	17.9
T2 (Post-seeding)	0 (K0)	10.6	11.3	12.8	13.8	12.1
	48 (K1)	9.6	11.2	13.2	14.9	12.2
	96 (K2)	11.4	12.4	13.4	14.9	13.0
	144 (K3)	12.5	14.3	14.9	17.8	14.9
Mean		11.0	12.3	13.6	15.4	13.1
Means of K rate	0 (K0)	10.5	12.4	13.4	15.0	12.8
	48 (K1)	12.6	13.7	15.5	17.7	14.9
	96 (K2)	14.4	15.2	17.1	18.5	16.3
	144 (K3)	15.4	17.0	18.2	21.3	18.0
G. Mean		13.2	14.6	16.0	18.1	15.5

LSD at 0.05 T=0.5 R=0.8 M=0.8 TR=1.1 TM=ns RM= ns TRM=ns

Table 5: Interaction effects of K-fertilization, K-fertilizer application time and FYM (farmyard manure) on N-uptake (kg/ha) by cow pea forage (total of 3 cuts, means of two seasons).

		FYM-rates (m^3/ha) (M)				
K-timing* (T)	K-rates (kg K/ ha)	0 (M0)	24 (M1)	48 (M2)	72 (M3)	Mean
T1 (Pre-seeding)	0 (K0)	457	631	401	624	528
	48 (K1)	559	781	759	787	721
	96 (K2)	611	915	881	1023	858
	144 (K3)	718	452	931	843	736
Mean		586	695	743	819	711
T2 (Post-seeding)	0 (K0)	249	294	648	596	447
	48 (K1)	443	670	429	489	508
	96 (K2)	359	376	538	701	493
	144 (K3)	387	702	659	585	583
Mean		359	511	568	593	508
Means of K rate	0 (K0)	353	462	524	610	488
	48 (K1)	501	726	594	638	615
	96 (K2)	485	646	709	862	675
	144 (K3)	552	577	795	714	659
G. Mean		473	603	655	706	609

LSD at 0.05 T=30 R=43 M=43 TR=61 TM=61 RM=87 TRM=123

organic manure to increase the fertility of the sandy soil. The response in such a pattern was particularly marked under conditions of presence of K at its highest rate. Therefore, presences of ample amount of K in the sandy soil augmented the positive effect of organic manure in increasing soil fertility.

Dry Yield: The pattern of response to K and manure treatments was in many respects rather in line with that of the fresh yield. Dry yield progressively increased due to K as well as M separately or combined (Table 4). The T_1 was superior to the T_2 timing by an average of 36.6%. The lowest yield of 10.5 Mg ha^{-1} was obtained by T_1 K_0 M_0, while the highest was obtained by T_1 K_3 M_3 (24.8 Mg /ha) with a 136% increase. Mean increases due to K_1, K_2 and K_3 were 16.4, 27.3 and 40.6%, respectively, bearing a ratio of 1.0:1.7:2.5. The progressive response was particularly evident in absence of manure. Where K was applied at pre-seeding with no manure, a progressive increase due to increasing K application was considerable as compared with the same conditions with post-seeding application. In general (main effect) pre-seeding

K-application surpassed post-seeding application by 59.5% on average. The progressive yield increase due to M_1, M_2 and M_3 averaged 10.6, 21.2 and 37.1%, *i.e.* a yield- increment ratio of 1.0:2.0:3.5 for the 3 successive M-rates. Such a pattern of response occurred particularly in presence of K. In absence of K the increase due to M was less progressive since differences between M rates were less pronounced.

Overall Response of Yield: The considerable response of cowpea yield to K fertilization is implied by the near similarity of the response ratio and the ratio of K-application rates i.e.1:2:3 for both fresh and dry yields of cowpea. Such response of growth due to K application rates up to the highest level of K was evident although contents of available K in the soil (Table 1) greatly exceeded the 40 mg/kg considered by Abdel-Salam and Abdel-Haleem [23] as a level of K-deficiency in some Egyptian soils. It also reflects the low fertility of sandy soils [5], particularly and cowpea has a high demand for K [2]. Applying K during seedbed preparation (pre-seeding) proved much superior to applying it later on (post-seeding) and indicates a definite necessity for securing enough available nutrients for plant seedlings to acquire a starter growth advantage to enable its root network expansion [9,10]. Also such superiority is manifested by the progressive response to increasing K rate, when applied pre-seeding rather than post-seeding. The response of yield to organic manure was more pronounced than that relating K since the response ratio was very nearly identical to the ratio of M-application rates of 1:2:3. The manure is high in its nutrients (available and total) (Table 1). Positive response of cowpea to organic manure is reported by Sharma *et al*. [9], Singh *et al.* [10] and Menon *et al.* [12]. Organic manure rates applied in the current study was not excessive as that applied by Mukhtar *et al.* [14] who observed early sign of old age to cowpea upon applying excessive rates of farmyard manure. Applying a combination of potassium fertilizer and organic manure improves the fertility of the sandy soils and this was reflected by a considerable increase in plant growth [9]. Positive response to K and FYM is a function of increased water retention, field capacity, available water along with other properties of the sandy soil conducive to high fertility as shown in Table 8.

N-Uptake: Uptake of N increased with increasing potassium as well as manure application; and application of K before seeding gave higher uptake than when given after seeding. The lowest uptake of 96 kg/ha was obtained by the T2 K0 M0, while the highest was obtained by T1 K2 M3 with an increase of 123.9% (Table 5). The pre-seeding K-application surpassed the post-seeding one by 59.5% on average. Mean increases due to K1, K2 and K3 were 26.0, 38.3 and 35.0% respectively,

Table 6: Interaction effects between K-fertilization, K-application time and FYM (farmyard manure) on P-uptake (kg/ha) of forage cowpea (total of 3 cuts, means of two seasons).

		FYM-rates (m^3/ha) (M)				
K-timing* (T)	K-rates(kg K/ha)	0 (M0)	24 (M1)	48 (M2)	72 (M3)	Mean
T1 (Pre-seeding)	0 (K0)	51	85	61	88	71
	48 (K1)	109	103	107	126	111
	96 (K2)	109	115	133	160	129
	144 (K3)	84	107	114	148	113
Mean		88	103	104	130	106
T2 (Post-seeding)	0 (K0)	77	74	96	105	88
	48 (K1)	70	77	82	80	77
	96 (K2)	65	73	70	77	71
	144 (K3)	61	79	79	81	75
Mean		68	76	82	86	78
Means of K rate	0 (K0)	64	80	79	97	80
	48 (K1)	90	90	94	103	94
	96 (K2)	87	94	102	119	101
	144 (K3)	72	93	91	115	93
G. Mean		78	89	92	109	92

LSD at 0.05 T= 17 R=15 M=15 TR=19 TM=19 RM=12 TRM= 17

Table 7: Interaction effects between K-fertilization, K-application time and FYM (farmyard manure) on K-uptake (kg/ha) of forage cowpea (total of 3 cuts, means of two seasons).

		FYM-rates (m^3/ha) (M)				
K-timing* (T)	K-rates(kg K/ ha)	0 (M0)	24 (M1)	48 (M2)	72 (M3)	Mean
T1 (Pre-seeding)	0 (K0)	371	598	476	640	521
	48 (K1)	589	583	737	820	682
	96 (K2)	602	741	828	757	732
	144 (K3)	734	722	783	752	748
Mean		574	661	706	742	671
T2 (Post-seeding)	0 (K0)	356	354	522	496	432
	48 (K1)	351	401	451	527	433
	96 (K2)	364	432	479	522	449
	144 (K3)	391	624	534	668	554
Mean		365	453	496	553	467
Means of K rate	0 (K0)	363	476	499	568	476
	48 (K1)	470	492	594	673	557
	96 (K2)	483	587	654	639	591
	144 (K3)	562	673	659	710	651
G. Mean		470	557	601	648	569

LSD at 0.05 T= 22 R=29 M=29 TR= 35 TM=35 RM=62 TRM=88

Table 8: Implications of applying mineral K and organic FYM separately or combined on physical and soil-water properties after 3 cuts of cowpea forage crop (means of two seasons)

K-timing (T)	K-rate kg K/ ha	FYM m^3 /ha(M)	BD mg/ m^3	FC* %	WP* %	AW* %	QDP %	SDP %	WHP%	FCP%	TP %
T1 with seed preparation	0(K0)	0(M0)	1.70	5.98	1.23	4.75	27.43	1.76	2.99	1.23	33.41
		24(M1)	1.55	8.09	1.25	6.84	32.31	1.76	5.08	1.25	40.40
		48(M2)	1.52	6.41	1.43	4.98	28.06	0.55	4.43	1.43	34.46
		72(M3)	1.53	6.54	1.72	4.82	34.79	2.10	2.72	1.72	41.33
	48(K1)	0(M0)	1.69	6.07	1.30	4.77	30.54	1.19	3.58	1.30	36.61
		24(M1)	1.54	9.84	1.32	8.52	22.56	1.09	7.43	1.32	32.40
		48(M2)	1.49	12.40	1.66	10.74	24.28	2.06	8.68	1.66	36.68
		72(M3)	1.45	16.76	1.77	14.99	18.98	4.35	10.64	1.77	35.74
	96(K2)	0(M0)	1.57	7.14	1.30	5.84	25.16	1.08	4.76	1.30	32.30
		24(M1)	1.52	10.12	1.34	8.78	26.86	1.20	7.58	1.34	36.98
		48(M2)	1.55	17.05	1.39	15.66	21.54	4.50	11.16	1.39	38.58
		72(M3)	1.44	17.51	1.44	16.07	27.43	0.65	15.42	1.44	44.94
	144(K3)	0(M0)	1.57	8.57	1.34	7.23	29.58	1.91	5.32	1.34	38.15
		24(M1)	1.55	15.89	1.38	14.51	21.11	4.21	10.30	1.38	37.00
		48(M2)	1.48	15.80	1.46	14.34	19.36	3.59	10.75	1.46	35.16
		72(M3)	1.49	16.48	1.55	14.93	20.27	3.28	11.65	1.55	36.75
T2 20 days after seeding	0(K0)	0(M0)	1.65	11.49	1.28	10.21	18.79	2.58	7.63	1.28	30.28
		24(M1)	1.51	13.82	1.42	12.40	19.96	1.47	10.93	1.42	33.78
		48(M2)	1.47	16.60	1.49	15.11	16.85	2.08	13.03	1.49	33.45
		72(M3)	1.46	17.51	1.69	15.82	20.54	1.38	14.44	1.69	38.05
	48(K1)	0(M0)	1.63	16.00	1.15	14.85	20.78	0.91	13.94	1.15	36.78
		24(M1)	1.50	17.30	1.39	15.91	13.92	4.92	10.99	1.39	31.22
		48(M2)	1.51	17.22	1.49	15.73	17.03	1.10	14.63	1.49	34.25
		72(M3)	1.54	15.56	1.69	13.87	29.66	1.38	12.49	1.69	45.22
	96 (K2)	0(M0)	1.56	7.08	1.26	5.82	34.68	1.99	3.83	1.26	41.76
		24(M1)	1.50	15.32	1.37	13.95	16.03	1.85	12.10	1.37	31.34
		48(M2)	1.44	15.97	1.69	14.28	20.52	4.94	9.34	1.69	36.49
		72(M3)	1.50	17.51	1.70	15.81	23.67	1.74	14.07	1.70	41.18
	144(K3)	0(M0)	1.57	15.44	1.40	14.04	19.78	1.67	12.37	1.40	35.21
		24(M1)	1.49	13.97	1.51	12.46	21.93	3.81	8.65	1.51	35.90
		48(M2)	1.50	16.27	1.72	14.55	23.63	2.04	12.51	1.72	39.90
		72(M3)	1.50	17.95	1.73	16.22	25.94	5.96	10.26	1.73	43.89

Note: Bulk density (BD), Field capacity (FC), wilting point (WP), available water (AW), QDP= quickly drainable pores [28.84µ], SDP= slowly drainable pores [28.8-8.62µ], WHP= water holding pores [8.62-0.19µ], FCP= fine capillary pores [< 0.19µ], TP=Total porosity; mineral K is sulphate (400 g K/kg) ;*On weight basis.

bearing a ratio of 1.0:1.5:1.3. The progressive increase accompanying increasing K occurred in particular in absence of manures with pre-seeding, rather than with post-seeding. At M2 in presence or of manure or in its absence, the increase progressed up to the highest rate of K3, unlike in presence of M1 or M3 when the increase due to K progressed up to K2 only. This indicates that the M2 rate is a suitable background manure rate for positive response to K up to its highest rate. Balanced combination of K and N is necessary for a positive high response to K application [13]. The progressive N-uptake increase due to M1, M2 and M3 averaged 27.5, 38.5 and 49.3, respectively i.e. uptake increment ratio of 1.0:1.4:1.8 for the 3 successive M-rates. The progressive increase in N uptake with manure application was particularly marked in presence of the K3 potassium rate.

P-Uptake: Uptake of phosphorus took a trend which was in many respects rather similar to that of N-uptake. The increase in P-uptake in response to K addition was progressive particularly in presence of manure. Also the increase in P-uptake in response to manure addition was progressive particularly where the K was given at its highest rate (Table 6). The pre-seeding application of K caused higher P-uptake than the post-seeding one, an average considerable increase of 35.9%. The lowest P-uptake of 51 kg/ha was obtained by T_1 K_0 M_0, while highest uptake of 160 kg P/ha was obtained by T_1 K_2 M_3 which caused about 214% increase. The P-uptake increases due to K_1, K_2 and K_3 averaged 17.5, 26.3 and 16.3 % respectively, bearing a ratio of 1.0:1.5:0.9. In absence of manure or in presence of M_2, the increase due to K progressed up to the highest rate of K_3, while in presence of M_1 or M_4 the increase du to K progressed up to K_2 only. The increase accompanying increasing K was evident only in treatments was applied at pre-seeding; and in the same time particularly where manure was applied. On the other hand, where K was applied at post-seeding, there was no progressive increase for P uptake. The P-uptake increases due to M_1, M_2 and M_3 averaged 14.1, 17.9 and 39.7%, respectively *i.e.* a yield-increment ratio of 1.0: 1.3: 2.8, for the 3 successive M-rates. The progressive increase in N uptake with manure application was particularly marked in presence of the K_2 rate.

K-Uptake: Uptake of K was in line with that of N. The increase in K-uptake as a result of K application progressed up to the highest K rate particularly where M_1 or M_3 were present (Table 7). Also the increase in K-uptake due to manure addition was progressive particularly in presence of K_1. Treatments where K was applied before seeding gave on average, 43.7% more K uptake than given by the post-seeding treatments. The lowest K-uptake of 351 kg/ha was obtained by T_2 K_1 M_0, while the highest uptake of 828 kg K/ha was obtained by T_1 K_2 M_2,which surpassed the former treatment by 136%. Average K-uptake increases due to K_1, K_2 and K_3 were 17.0, 24.2 and 36.8%, respectively, bearing a ratio of 1.0:1.4:2.2. The progressive increase in uptake of K which accompanied the progressive increase in K application was particularly evident where no manure was present or where the lowest rate of manure was present. The K-uptake increases due to M_1, M_2 and M_3 averaged 18.5, 27.9 and 37.9%, respectively *i.e.* a yield-increment ratio of 1.0:1.5:2.0 for the 3 successive M-rates. The progressive increase in K-uptake which accompanied progressive manure rates was particularly marked in absence of potassium addition.

Physical and Soil-water Properties after Crop Harvest: Treatments caused marked effects on soil physical properties as well as soil-water properties. Bulk density (BD) decreased with increasing K addition (Table 8). Averaging BD values are 1.549, 1.539, 1.510 and 1.519 due to K_0, K_1, K_2 and K_3 respectively. Addition of manure decreased BD, from with average values of 1.615, 1.520, 1.495 and 1.490 due to M_0, M_1, M_2 and M_3 respectively. Average BD for the pre-seeding and the post-seeding treatments were 1.540 and 1.520 respectively. Field capacity (FC) increased with increasing rate of K; average FC values are 10.81, 11.90, 13.47 and 15.91% due to K_0, K_1, K_2 and K_3 respectively. Averages for pre-seeding and post-seeding treatments are 11.29 and 15.32% respectively. Manuring caused an increase in FC and average values were 9.72, 13.05, 14.75 and 15.73% due to M_0, M_1, M_2 and M_3 respectively. Average pre-seeding and post-seeding FC are 11.9 and 15.33 % respectively. Available water (AW) increased with increasing K addition; average AW values are 9.37, 12.43, 12.07 and 13.61% for K_0, K_1, K_2 and K_3, respectively. Averages for pre-seeding and post-seeding treatments were 9.86 and 13.85%, respectively. The effect of K application, addition of manure and K-timing could be attributed to increase yield and higher soil organic matter (from decaying crop residue) thus improving soil physical properties and consequently soil-water properties [24].

CONCLUSIONS

Sandy soils are of low fertility and need application of fertilizers as well as organic manures. Although growing legume crops, particularly when grown for forage purposes, is beneficial in increasing fertility of such soils, addition of organic manure and other mineral fertilizers is necessary. Rates of up to such high levels of 144 kg K/ha and 27 m^3/ha proved positive giving considerable cowpea forage increases, nearly proportional to the increases in the application rates of the K fertilizer or farmyard manure (FYM). Mineral K fertilization particularly if given during seedbed preparation- along with FYM improved soil fertility, increased plant growth, caused changes in properties including soil-water relationships, bulk density, porosity, soil water-holding capacity, all of which are beneficial to plant growth.

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