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THE EFFECTS OF MALASSES WASTEWATER ON COMMON BEAN YIELDS IN ACID SOILS OF KENYA

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Abstract

Muhoroni Agro-Chemicals and Food Company produces approximately 1.2 million litres of wastewater per day that empties into River Nyando. The wastewater discharged is not environmentally friendly and calls for proper treatment and disposal modalities. The study explored disposal of the wastewater by formulation of organic fertilizer and using it to reverse soil acidity. The fertilizer was used to grow common bean crop. Both field and greenhouse experiments were conducted for two seasons at Chepkoilel Campus, Moi University, Eldoret. Soil samples taken during cropping seasons were used to determine changes in soil chemical properties. After harvesting, the grain yields and economic analysis of treatments were done. Important results of the study were that combination of wastewater, biogas effluent, lime produced the highest increase in soil pH of over 1.2 units in both seasons. It also registered the highest increase in overall grain yields by over 250% in both seasons over the control and posted highest net profit of over US$ 416. The soil organic carbon and calcium increased by over 0.3 Cmol/kg while Olsen phosphorus increased by over 10 ppm in treatments with lime. Therefore, the organic fertilizer formulated is suitable in acidic soils.

Key words: soil acidity, wastewater, lime, biogas effluent, common bean crop

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Introduction

Improved cropping systems, involving major crops that rely on the use of high rates of inorganic fertilizers, continuously for several years often lead to unsustainability in production and also pose threat to the environment (Patra *et al.,* 2000). It is well known that where cows have been kept for a long time, soil fertility is good and productivity is excellent. This is confirmed by Ofori and Santana (1990) and Schleich (1985) who noted that cow dung improved productivity of soils more than inorganic fertilizers, due to slow nutrient release. Organic manures provide a means of recycling nutrients for plant growth and to counteract the decreasing organic moisture content of most modern agricultural soils (Wong *et al*., 1998).

Continuous use of ammonium fertilizers in Uasin Gishu district for the production of cereals especially maize and wheat has lead to soil acidification. Materechera and Mkabela (2002) also observed that about 13,000 hectares of land in South Africa that have been under black wattle plantation for long time was more acidic than contiguous land without the tree. Therefore, the wattle trees that grow in the vast area of the region have also contributed to soil acidity. Such soils as is the case with Uasin Gishu soils, are characterized by high Aluminium (Al) and Manganese (Mn) ions solubility and inadequacy of key elements, particularly Phosphorus (P), calcium (Ca), nitrogen (N) and Molybdenum (Birech, 2000). This problem of soil acidity can be alleviated by using wastewater from Muhoroni Agro- Chemical and Food Company, which is alkaline. The effluent has levels of Biological oxygen demand (BOD), chemical oxygen Demand (COD), sodium phosphates, nitrates, sulphate and gallic acid. The final effluent discharged to River Nyando has the following characteristics, pH 9.12, Brown colour, BOD level of less than 500mgL^{-1} and quantity of 1.2 million litres a day. Since the company produces large quantities of this wastewater and are highly polluting, land treatment was considered favourable approach to disposing of the increasing volume of wastewater.

Information on fertilizing value of the wastewater from Muhoroni Agro-chemicals and Food Company on tropical soils was lacking yet Ndalut (2006) observed that the vegetation on riverbanks of River Nyando to which wastewater flows into was healthy. This agitated establishments of fertilizing value of the wastewater. In this study common bean (*Phaseolus vulgaris*) was used to evaluate the fertilizing (nutritive) value of the wastewater. The national annual demand for common bean has been estimated at 450,000 metric tones, but the actual annual production is only about 150,000 – 200,000 metric tones (African Agriculture, 2008). The total area under bean cultivation in Kenya is estimated to be 800,000 hectares (African Agriculture, 2008) leading to actual bean yields of up to 250 Kg/ha, partly under mixed cropping. In pure stands, yields of 700 Kg/ha have been reported (Songa *et al*., 1995). This yield is low compared to a potential yield of up to 5000 Kg/ha achieved in other countries such as Mexico under field conditions (Rodriquez and McDonald Jr. 1989). Bean production in humid and sub-humid tropics is limited by low soil fertility, particularly soil acidity related nutrients deficiencies and toxicities such as; low soil available phosphorus (Aggarwal, 1994). The main objectives of the present study were to explore disposal of molasses wastewater by turning into organic fertilizer and reversing soil acidity.

Materials and Methods

Study area

Field experiment was conducted at

Chepkoilel Campus farm, Moi University at Eldoret in Uasin Gishu district of Kenya. The season 1 crop was planted in September and harvested in December 2006 while season 2 was planted in April and harvested in July 2007. The site is about 2140 M above the sea level and receives annual rainfall of 900-1300 mm and records a mean annual temperature of 25°C (Jaetzold and Schmidt, 1983). The soils are of igneous origin and acidic (pH 4.5-5.0) with low fertility and moisture storage. They are well drained, non-humic and shallow, underlain with murram over petrifferic phase. They are classified as Rhodic ferralsol according to the FAO/UNESCO (FAO/UNESCO, 1974) classification and oxisols according to the USDA classification (Soil survey staff, 1975).

Field and green house experiments

There were a total of eleven treatments laid out in randomised complete block design (RCBD) with three replications. The wastewater was obtained from Muhoroni Agro-chemicals and Food Company and was analysed using AAS, calorimetry and flame photometer for anions such as phosphates, nitrates and cations such as Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Fe^{3+}, Zn^{2+}, Cu^{2+} including heavy metals such as Cd^{2+}, Pb^{2+}, and Cr^{3+} prior application to the field. The lime was obtained from Koru, Kisumu which has a composition of 49% CaO. Diammonium phosphate (DAP-46% P_2O_5) was also used as a source of P at rates of 40KgPha^{-1} while the biogas effluent was obtained from Chepkoilel Campus farm of Moi University and analysed for phosphate, nitrates and organic carbon prior application to the field. Finally Minjingu rock phosphate (13%P) was obtained from department soil science Moi University. The factor levels were; Factor A- lime (rates 10tha^{-1}), Factor B- phosphorus (40 KgPha^{-1}) and Factor C- bean genotype (GLP X 92-Mwitemania).

The treatments were; Diammonium phosphate (DAP), Wastewater (WW), Wastewater + lime (WL), Biogas effluent (BE), Wastewater + biogas effluent (WBE), Wastewater + biogas effluent + lime (WBL), Rock phosphate (PR), Wastewater + Diammonium phosphate (DAPWW), Wastewater + rock phosphate (PRWW) and Nil (control)

Land preparation started with land clearing and plot demarcation. The land was ploughed using a hand Jembe making sure the weeds were buried in the soil and allowed for 20 days for the weeds to decay then thereafter it was ploughed the second time making sure the soil is fine in readiness for panting. The plot size was 8m by 6m. The spacing between rows was 50 cm and within rows was 15 cm. Two seeds were sown per hill and thinning was done 30 days after sowing, leaving only one plant per hill. The treatments were applied along planting furrows. To prevent or control different diseases and pests; spraying was done at different times as it was necessary. Seedling that germinated 21 days after sowing and those that survived was expressed as a percentage. Pods were counted on 6 random plants 90 days after sowing. After harvesting, a random sample of 15 pods were taken, shelled and seeds counted. After shelling, the seeds were dried in the sun for 5 days to obtain moisture content of 13%. The weights of dried seeds were measured to determine yields in Kgha^{-1}. These yields were used for all evaluations and comparisons.

Greenhouse experiment was conducted for comparison purposed with the field. The same treatments in the field were done under greenhouse condition. To examine the effect of treatment on the seedlings under controlled conditions, untreated soil from the same site was used. Two Kg of air dry soil was mixed treatments and placed in 15 cm diameter pots. The pots were arranged in complete block design with two replications. Seeds were planted to 20 mm depth in each pot and thereafter the seedlings were watered twice a week with a tap water.

Seed and soil analysis

A random sample of 100 seeds were obtained from the dried seeds and weighed for each plot. The electrical conductivity (EC) of the harvested seed samples were measured according to the procedure described by Hampton (1995). Total P in the seeds was determined using the ascorbic acid procedure-No pH adjustment. Dry seeds from each treatments was sampled and ground to pass a 60mesh (<0.3mm) and analyzed for total N. Seed protein content was determined by multiplying the %N content by a factor of 6.25(Novosamsky *et al*., 1974). The seeds were then analyzed for Ca, Cu, Fe, Zn, Pb, Cr and Cd using the AAS.

Soil samples were taken from each plot (systematic quadrate method) to a depth of 20cm using soil auger just before the start of the experiment. Another soil sampling from each plot was done to the same depth during the cropping season at intervals of three weeks and pH in water (1:2.5) taken immediately. The soils were air dried in a well ventilated room for duration of 7 days, after which they were gently crushed to break soil lamps and then sieved through a 2mm mesh. The soils needed for the total N and organic carbon were further ground in a mortar in order to pass through a 60 mesh screen and to obtain ≤0.3 mm soil particles. The soils obtained were analysed for total N (%), organic carbon (%), available P, exchangeable bases and exchangeable acidity to determine how it changed with time according to procedures described by Okalebo *et al*., (2002).

Finally economic analysis was done by comparing the net revenue from each treatment. Net revenue is the difference between the total revenue received from sale of beans seeds and total expenditure incurred from planting to harvesting. All data were analysed statistically using SSPS software package. Statistical analysis consisted of analysis of variance (ANOVA), least significance difference (LSD) and Pearson correlation coefficient (r).

RESULTS AND DISCUSSION

Composition of wastewater and biogas effluent

The wastewater was found to contain 0.009% P, 0.077% N, 2.783% OC and 0.48 ppm Ca while biogas effluent was found to contain 0.607% P, 1.750% N and 35.920% OC among other essential elements as shown in table 1 below.

Table 1: Concentration of various elements in wastewater and biogas effluent

Property	wastewater	Biogas effluent
P (%)	0.009	0.607
N (%)	0.077	1.750
OC (%)	2.783	35.920
K (ppm)	30.677	2.197
Pb (ppm)	0.017	-
Cd (ppm)	0.000	-
Cr (ppm)	0.000	-
Fe (ppm)	0.070	-
Zn (ppm)	0.134	-
Cu (ppm)	0.363	-
Na (ppm)	21.823	-
Ca (ppm)	0.480	-
Mg (ppm)	0.713	-

Field Experiments

Soil chemical analysis

The soil chemical properties of the experimental site analysed for the two seasons under various treatments are presented in Table 2 below.

Table 2: Soil chemical properties of the field experiments for the first and second season

Treatments	ST	SS	pH	N	OC	Ex. Acidity	K	Na	Ca	Mg	Al	H	P
				(%)		------------	------------	C mol/Kg	------------	------------	------------	------------	ppm
NIL		s1	4.4	0.1	1.8	0.8	0.8	2.3	2.0	1.1	0.2	0.6	5.1
	1	s2	4.9	0.1	2.0	0.9	0.8	2.2	2.0	1.2	0.2	0.7	7.7
		s1	4.5	0.2	1.8	0.9	0.9	2.3	2.1	1.0	0.2	0.7	4.9
	2	s2	4.9	0.1	2.0	0.9	0.8	2.2	2.0	1.2	0.2	0.7	7.7
	3	s1	4.2	0.1	1.9	0.8	0.9	2.3	2.1	1.0	0.2	0.7	3.6

		s2	4.9	0.1	2.0	0.9	0.8	2.3	2.0	1.3	0.2	0.7	9.9
DAP		s1	4.3	0.1	1.8	0.8	0.8	2.3	2.0	1.0	0.2	0.6	4.8
	1	s2	4.8	0.1	2.0	0.9	0.8	2.3	2.0	1.6	0.2	0.7	9.0
		s1	4.2	0.6	1.8	0.9	0.8	2.4	1.8	1.1	0.2	0.7	4.7
	2	s2	4.7	0.2	2.0	0.8	0.8	2.3	2.1	1.4	0.2	0.6	7.0
		s1	4.1	0.4	1.9	0.9	0.8	2.4	1.7	1.0	0.2	0.7	4.5
	3	s2	4.6	0.8	1.9	1.1	0.8	2.3	1.6	1.4	0.2	0.9	5.5
WW		s1	4.5	0.1	1.8	0.8	0.8	2.2	2.0	1.1	0.2	0.6	4.9
	1	s2	4.9	0.5	1.9	0.9	0.7	2.2	1.9	1.4	0.2	0.8	5.0
		s1	4.9	0.2	1.9	0.8	0.8	2.3	2.1	1.2	0.1	0.7	8.6
	2	s2	5.1	0.2	2.0	0.8	0.8	2.3	2.0	1.2	0.2	0.6	7.2
		s1	5.3	0.1	2.0	0.7	0.8	2.2	2.1	1.1	0.1	0.6	6.2
	3	s2	5.4	0.2	2.1	0.8	0.8	2.3	2.0	1.2	0.1	0.6	10.0
BE		s1	4.5	0.1	1.8	0.8	0.8	2.2	2.0	1.1	0.2	0.7	5.0
	1	s2	4.8	0.2	2.0	0.8	0.8	2.2	2.0	1.2	0.2	0.7	7.1
		s1	4.8	0.5	2.0	0.7	0.8	2.3	2.0	1.1	0.1	0.6	9.8
	2	s2	5.1	0.5	2.4	0.8	0.8	2.3	2.2	1.2	0.1	0.6	10.1
		s1	5.1	0.4	2.1	0.8	0.8	2.4	2.0	1.2	0.1	0.7	6.4
	3	s2	5.3	0.3	2.3	0.8	0.8	2.2	2.2	1.3	0.1	0.5	10.0
WL		s1	4.5	0.1	1.8	0.8	0.8	2.3	2.0	1.1	0.2	0.6	4.6
	1	s2	4.9	0.2	2.0	0.8	0.8	2.3	2.0	1.1	0.1	0.7	6.8
		s1	5.0	0.2	1.9	0.5	0.9	2.4	2.3	1.2	0.1	0.4	16.9
	2	s2	5.2	0.3	2.1	0.8	0.8	2.3	2.3	1.2	0.1	0.6	15.4
		s1	5.4	0.1	2.0	0.4	0.8	2.4	2.4	1.1	0.1	0.3	13.3
	3	s2	5.6	0.2	2.1	0.8	0.8	2.3	2.3	1.2	0.1	0.5	13.4
PR		s1	4.6	0.1	1.8	0.9	0.8	2.3	2.0	1.0	0.2	0.7	4.7
	1	s2	4.8	0.2	2.0	0.8	0.8	2.2	2.0	1.2	0.2	0.6	7.0
		s1	5.0	0.4	1.9	0.6	0.9	2.3	2.2	1.2	0.1	0.5	21.1
	2	s2	5.2	0.3	2.2	0.9	0.9	2.4	2.3	1.5	0.1	0.6	12.5

		s1	5.5	0.2	2.0	0.6	0.9	2.3	2.3	1.2	0.1	0.5	15.2
	3	s2	5.6	0.2	2.1	0.8	0.8	2.3	2.2	1.5	0.1	0.5	10.6
WBE		s1	4.5	0.1	1.8	0.8	0.8	2.3	2.0	1.1	0.2	0.6	4.7
	1	s2	4.8	0.2	2.1	0.8	0.8	2.3	2.0	1.2	0.2	0.7	7.3
		s1	4.7	0.2	1.9	0.7	0.8	2.4	2.1	1.2	0.1	0.6	10.7
	2	s2	5.1	0.3	2.4	0.8	0.8	2.3	2.1	1.3	0.2	0.6	10.0
		s1	5.0	0.1	2.1	0.8	2.3	2.2	2.2	1.1	0.1	0.6	8.7
	3	s2	5.2	0.2	2.3	0.8	0.8	2.3	2.2	1.2	0.2	0.6	9.9
DAPWW		s1	4.6	0.1	1.8	0.8	0.8	2.3	2.1	1.1	0.2	0.6	5.8
	1	s2	4.9	0.2	2.0	0.8	0.8	2.3	2.0	1.2	0.2	0.6	7.8
		s1	4.9	0.6	1.9	0.8	0.9	2.3	2.1	1.2	0.1	0.6	9.7
	2	s2	5.2	0.6	2.1	0.8	0.8	2.3	2.0	1.3	0.2	0.6	13.2
		s1	5.2	0.4	2.0	0.7	0.9	2.3	2.1	1.2	0.1	0.6	8.2
	3	s2	5.4	0.5	2.0	0.8	0.8	2.3	2.0	1.2	0.2	0.6	11.5
PRWW		s1	4.5	0.1	1.8	0.8	0.8	2.3	2.0	1.1	0.2	0.6	4.9
	1	s2	4.9	0.2	2.0	0.8	0.8	2.2	2.0	1.3	0.2	0.7	7.7
		s1	5.0	0.2	2.0	0.8	0.8	2.4		1.2	0.1	0.6	16.2
	2	s2	5.2	0.5	2.0	0.8	0.8	2.3	2.2	1.2	0.2	0.6	11.5
		s1	5.4	0.1	2.0	0.7	0.8	2.3		1.2	0.1	0.6	11.9
	3	s2	5.7	0.2	2.1	0.7	0.7	2.3	2.3	1.4	0.1	0.6	10.1
WBL		s1	4.4	0.1	1.8	0.9	0.8	2.3		1.0	0.2	0.7	6.0
	1	s2	4.8	0.2	2.0	0.8	0.7	2.2	2.0	1.3	0.2	0.6	7.5
		s1	5.1	0.7	2.0	0.6	0.8	2.4		1.2	0.1	0.5	24.9
	2	s2	5.3	0.8	2.5	0.5	0.7	2.3	2.4	1.3	0.1	0.5	17.3
		s1	5.9	0.5	2.1	0.4	0.8	2.3		1.2	0.0	0.4	18.8
	3	s2	6.0	0.7	2.4	0.3	0.7	2.3	2.6	1.3	0.1	0.3	14.7

KEY: ST- Sampling Time, 1= before the start of the experiment, 2= six weeks after planting,

3= three weeks after harvesting, C mol/Kg= Centimole/Kilogram, ppm= parts per million, SS= Seasons, s1= first season and s2= second season.

Soil pH (H_2O) before treatment ranged from 4.3 to 4.6 in the first season and 4.8 to 4.9 in the second season. Compared to the control, there was significant rise in soil pH in all treatments for both seasons with the highest being WBL which increased from 4.4 to 5.9 (Figure 1) in the first season and 4.8 to 6.0 (Figure 2) in second season. This may be increased exchangeable Ca in the soil and decreasing Al level by forming insoluble aluminium hydroxide. However, there was slight drop from 4.3 to 4.1 in the first season and 4.8 to 4.6 in the second season in soil receiving DAP. This was shown by Fenn *et al.*,(1987) to be partly due to absorption of ammonium by plant roots releasing H^+.

Figure 1: Changes in soil pH related to treatments over three sampling periods for the first season of the field experiments.

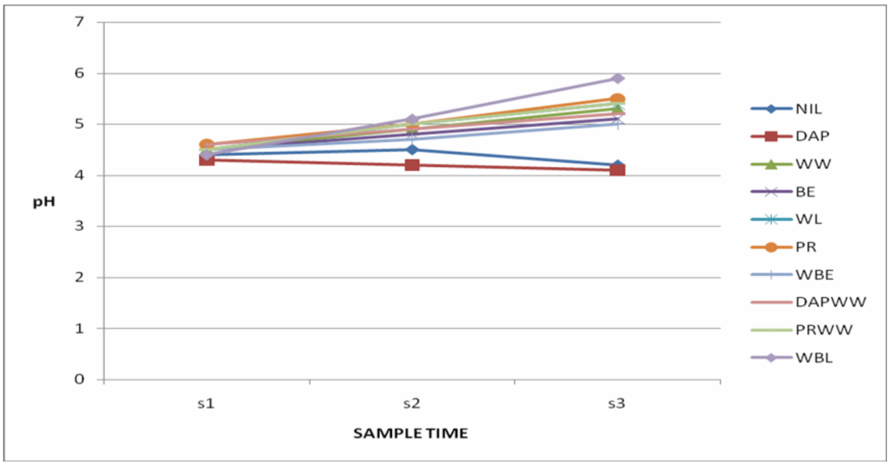
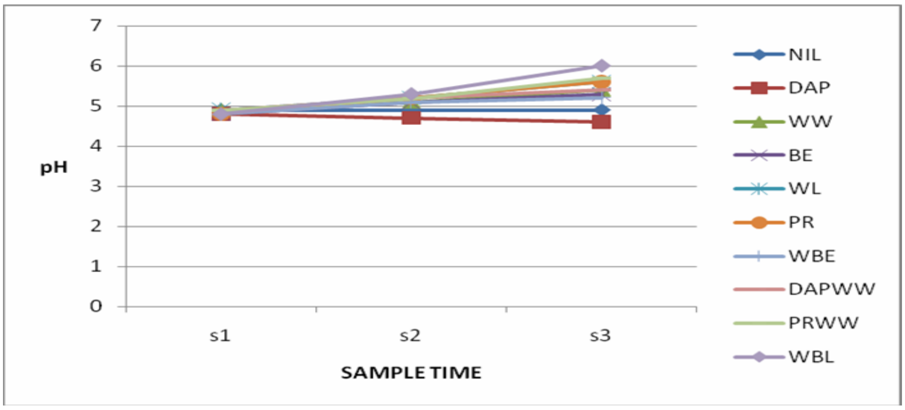


Figure 2: Changes in soil pH related to treatments over three sampling periods for the second season of the field experiments.



s1= before planting, s2 = six weeks after planting, s3 = three weeks after harvesting

Concentration of K, Na and Mg remained fairly constant throughout the cropping seasons except in soil receiving PR in the second season where the concentration of Mg increased from 1.2 C mol/Kg to 1.5 C mol/kg. Concentration of Ca increased in all treatments in which lime was incorporated such as WBL and WL which ranged from 2.0 to 2.6 C mol/Kg in the firs season and 1.9 to 2.4 C mol/kg in the second season. This is attributed to direct application of lime. However, there was a drop in soil receiving DAP from 2.0 to 1.7 C mol/kg in the first season and 2.0 to 1.6 C mol/kg in the second season. The exchangeable acidity (Al+H) decreased substantially in all treatments except in soil receiving DAP and the control (NIL) where there was a marked increase for both seasons. For OC, P and N, there were positive changes from input of all the treatments to increase levels of these three parameters compared to control. Marked increase in Olsen P was found in treatments in which lime was incorporated such as WBL and WL. The highest was WBL which increased from 6.0 to 24.9 ppm in the first season and 7.5 to 17.3 ppm in the second season. This was due to release of phosphates to the soil which had been sorbed by Al and Fe as explained by Sanchez (1977). The trend was increase between planting and 6th week after planting and slight drop after harvesting. However, there was a slight drop in soil receiving DAP from 4.8 to 4.5 ppm in the first season and 9.0 to 5.5 ppm in the second season. OC increased in treatments with wastewater and biogas effluent. The highest was WBL which increased from 1.8 to 2.1 C mol/Kg in the first season and 2.0 to 2.5 C mol/Kg in the second season. The two treatments contain high levels of OC which translated directly to high increase in the soil. OC in DAP and the control remained fairly constant. N increased in all treatments with highest being the soil that received WBL and DAP. WBL in increased from 0.1 to 0.7 % in the first season and 0.2 to 0.8 % in the second season while DAP increased from 0.1 to 0.6 % in the first season and 0.2 to 0.8 % in the second season. This is due to high concentration of nitrogen in DAP.

The effect of treatment on seed germination, plant survival, yield and yield components

The effect of treatment on seed germination, plant survival, yield and yield components for both seasons are presented on table 3.

Table 3: Germination, survival, yield and yield components of the field experiments for the two seasons under various treatments

Season 1						
Treatment	Germination %	Survival %	Pods/Plant	100 Seed Weight	Seeds/Pod	Grain Yields (kg/ha)

NIL	60.08	85.57	5.11	20.40	4.72	280.66
DAP	35.10	89.67	9.39	23.77	3.91	356.51
WW	66.04	99.21	12.04	21.25	3.90	549.49
BE	72.92	88.15	12.42	21.70	3.76	579.69
WL	70.10	99.48	17.03	26.11	4.02	600.53
PR	76.80	94.24	23.14	25.31	4.10	946.19
WBE	65.02	98.68	19.44	20.55	3.82	609.41
DAPWW	21.49	98.48	26.51	24.76	4.07	325.95
PRWW	0.00	0.00	0.00	0.00	0.00	0.00
WBL	96.82	99.67	33.23	27.69	5.19	1609.33
Season 2						
NIL	82.54	99.00	5.39	20.10	3.83	480.75
DAP	57.93	98.20	11.22	24.12	3.86	781.7
WW	94.04	99.99	13.06	21.99	3.93	902.24
BE	75.07	96.93	13.40	21.95	3.82	725.16
WL	86.09	99.12	17.50	26.69	4.09	765.15
PR	94.04	98.02	23.88	25.85	4.12	1277.31
WBE	87.49	99.39	21.52	20.43	4.01	941.01
DAPWW	48.88	98.91	30.81	24.38	4.21	575.1
PRWW	61.93	99.13	25.46	25.79	4.21	911.18
WBL	98.21	99.81	36.27	26.85	5.24	1809.96

The germination of sown seeds was higher in the soil receiving treatment in which lime was incorporated and PR. The soil receiving WBL had the highest germination of 96.8% in the first season and 98.2% in the second season. The available P could have had positive effect on seed germination. The effect of P on germination could be a result of its supply of energy in form of ATP (adenosine- triphosphate) (Mayor and Ijakoff, 1989). Poor germination of 0.0%, 21.5% and 35.1% in the first season and 61.9%, 48.9% and 57.9% in the second season were observed in soil receiving PRWW, DAPWW and DAP respectively. In cowpea Al toxicity was reported to specifically inhibit embryo development during imbibition which resulted in severe reduction in hypocotyl growth (Horst, 1985). Therefore, the soil pH could have had indirect effect in influencing seed germination. This phenomenon can be used to explain why there was poor germination of seeds in soil receiving DAP. Plant survival was above 99% in the soil receiving the treatment that contained wastewater for both seasons. On the other hand, the soil that received treatment without wastewater was slightly low with control having the least of 85.6% in the first season. This was due to high infestation of bean fly and aphids in seedlings growing in soil receiving treatments without wastewater. This suggests insecticidal effect in treatments in which wastewater was incorporated. There was no germination in soil which PRWW was used as a treatment in the first season but there was an impressive germination of 61.9%in the second season. This was attributed to rainfall which was well distributed in second season unlike first season. All the treatments increased pod numbers significantly with WBL being the highest with an average of 500% over the control (NIL) in both seasons. DAP was the lowest with an average of 80% over the control in both seasons. In general, treatment in which lime was incorporated, the pod numbers were above 20 per plant including PR. Pod numbers were directly correlated to pH (r = 0.686*). Similarly, pod numbers were also directly correlated to grain yield (r = 0.73*).

WBL was the only treatment that had significant increase in seeds per pod by an average of 10% over the control in the first season. However, all the treatments increased seed numbers over the control in the second season with WBL being the highest with 37% over the control. An increase in soil pH in this treatment is accompanied by increase in N, P, S availability and a decrease in toxic Al (Fagaria *et al.*, 1991).

Treatments in which lime was incorporated such as WL and WBL had significant increase in seed weight of over 29% over the control in both seasons. This conforms to work done by Rahman *et al*, (1996) where the seed weight and seed size of tomatoes and Soya beans were increased due to lime.

Table 4: ANOVA for yields in the field experiments.

Tests of Between-Subjects Effects Dependent Variable: grain yields (Kg/ha)					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected	10919832	11	992712.008	54.451	0.000

Model					
Intercept	40770182	1	40770181.676	2236.261	0.000
TREATMEN	9264644	10	926464.387	50.817	0.000
SEASON	1655188	1	1655188.222	90.788	0.000
Error	984495.9	54	18231.405		
Total	52674510	66			
Corrected Total	11904328	65			

a R^2 = .917 (Adjusted R^2 = .900)

The ANOVA analysis of grain yields differed significantly ($p<0.05$) in terms of treatments used and seasons. WBL produced highest grain yields of 1609 kg/ha in the first season which was an increase of 473% over the control and 1810 Kg/ha in the second season which was an increase of 276% over the control (Table 4.3 and 4.4). Other treatment that had significant increase in yield were BEL which produced 1045 kg/ha in the first season and 1218 kg/ha in the second season.

PR produced 946 Kg/ha in the first season but increased significantly to 1277 kg/ha in the second season. Season two yields were greater than season one in all the treatments. This is attributed to high and better rainfall distribution in the second season compared to the first season. Responses of grain yields to treatments in the field are illustrated on figure 3 and 4.

Figure 4: Overall effect of treatments on grain yields in field experiements for the first season.

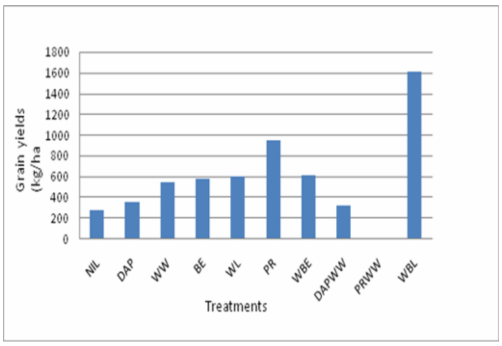
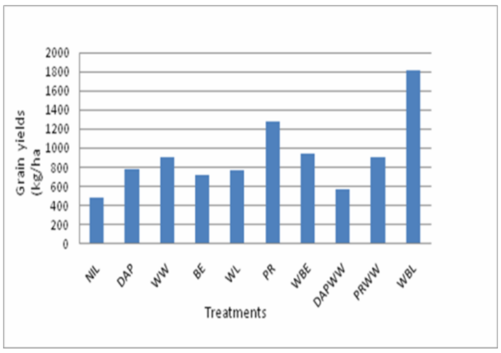


Figure 4: Overall effect of treatment on grain yields in field experiments for the second season.



Greenhouse pot experiments

The effect of treatments on germination, yield and yield components

The effects of treatments on germination are presented on table 5.

Table 5: Germination, yield and yield components of the greenhouse experiments for the two seasons under various treatments

Season 1				
Treatment	Germination %	Pods/Plant	Seeds/Pod	Grain Yields (Kg/ha)
NILL	33.30	2.04	2.74	37.47
DAP	25.00	3.04	2.15	38.58
WW	66.65	4.58	2.70	174.71
BE	91.65	4.80	2.91	276.12
WL	83.30	4.92	2.90	309.46
PR	75.00	4.90	3.00	278.92
WBE	83.3	3.95	2.93	192.84
DAPWW	0.00	0.00	0.00	0.00
PRWW	0.00	0.00	0.00	0.00
WBL	100.00	5.14	3.03	432.50
Season 2				
NILL	50.00	3.09	2.77	85.83
DAP	50.00	4.14	2.50	129.35
WW	66.65	4.83	2.82	198.53
BE	91.65	4.89	2.92	287.50
WL	83.30	5.00	2.85	318.63
PR	83.30	4.81	3.24	330.29
WBE	75.00	4.37	3.17	209.17
DAPWW	25.00	4.00	3.07	75.16
PRWW	25.00	4.14	3.07	83.66
WBL	100.00	5.67	3.30	525.00

Germination was higher in treatments in which lime was incorporated such as WBL and BEL which had germination percentage of 100% and 92% respectively in the first season and 100% in the second season. Poor germination was observed in soil receiving DAP, DAPWW and PRWW which had germination percentage of 25%, 0% and 0% respectively in the first season. In the second season there was an improvement in which DAP, PRWW and DAPWW had germination of 50%, 25% and 25% respectively. This was comparable to the results obtained in the field experiments. This was reflection to the observation in the field.

Apart from DAPWW and PRWW all treatments increased pods per plant in the first season with BEL and WBL producing 150% and 151% respectively over the control. This was highest compared to all the other treatments. In the second season the two treatments also produced the highest pod numbers of 72% and 82% respectively over the control. PR, WBL and BEL also produced the highest seed numbers in the first season. These were 9%, 11% and 12% respectively over the control. The same treatments also increased seed numbers by 17%, 19% and 17% respectively over the control in the second season.

Table 6: ANOVA for yields in the green house experiments.

Tests of Between-Subjects Effects **Dependent Variable: Grain yield (Kg/ha)**					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	957886.1	11	87080.556	58.346	0.000
Intercept	2093123	1	2093123.151	1402.441	0.000
Season	30249.49	1	30249.490	20.268	0.000
Treatment	927636.6	10	92763.663	62.154	0.000
Error	47759.54	32	1492.486		
Total	3098769	44			
Corrected Total	1005646	43			

a R^2= .953 (Adjusted R^2= .936)

The ANOVA analysis on grain yields also differed significantly ($p<0.05$) in terms of the seasons and treatments. WBL produced the highest yield of 432 Kg/ha in the first season and 525 Kg/ha in the second season. The other treatment that showed significant increase in grain yield is BEL which produced 370 Kg/ha in the first season 445 Kg/ha in the second season. Generally, greenhouse yield and yield components were lower than field experiments. However, the relationship between the effect of treatments on yield and yield components were almost similar in both field and greenhouse experiments. Figure 5 and 6 illustrates the response of grain yields to various treatments in the greenhouse.

Figure 5: Overall effect of treatments on grain yields in Greenhouse experiments for the first season.

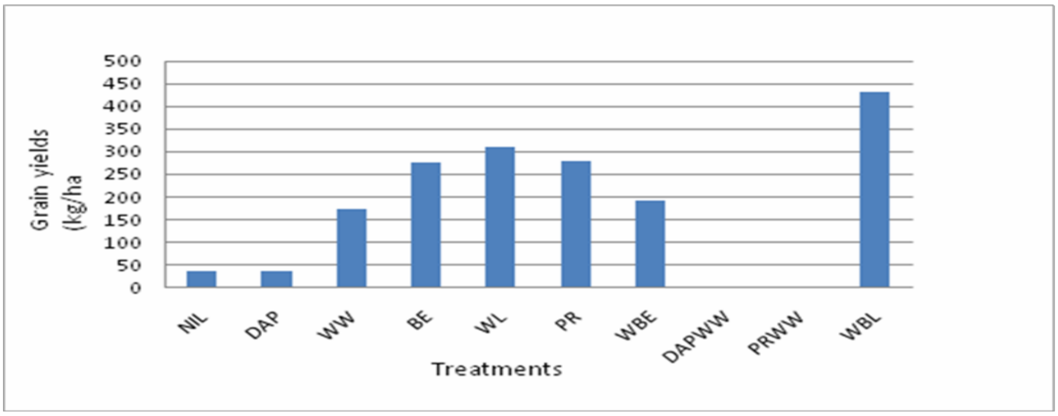
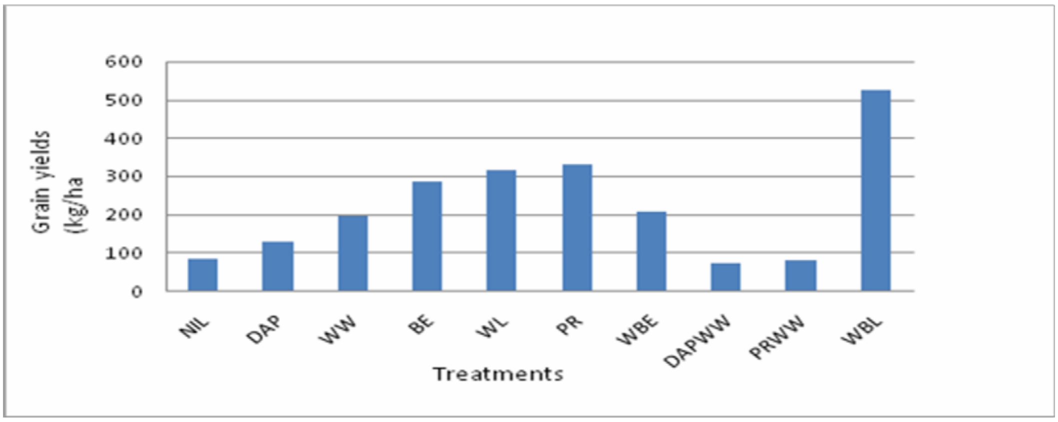


Figure 6: Overall effect of treatments on grain yields of Greenhouse experiments the first season.



The effect of treatment on seed quality

The properties of seed under different treatments of are presented in table 7.

Table 7: The mean effect of treatments on seed quality attributes and nutrient content.

Treatments	N	P	Protein	Ca	Pb	Cd	Cr	Fe	Zn	Cu	EC
	(%)				ppm						MuS
NIL	3.53	0.31	22.08	0.17	0.00	0.00	0.00	1.89	0.95	0.24	17.01
DAP	3.87	0.30	24.17	0.17	0.00	0.00	0.00	1.94	0.91	0.02	16.75
WW	3.54	0.30	22.10	0.16	0.02	0.00	0.00	1.54	1.04	0.51	16.80
BEL	3.94	0.30	24.44	0.16	0.09	0.01	0.02	1.83	0.77	0.45	15.21
BE	3.48	0.30	21.73	0.18	0.00	0.00	0.00	1.44	0.90	0.44	16.66
WL	4.00	0.30	24.85	0.18	0.01	0.00	0.01	1.88	1.21	0.37	15.27
PR	3.89	0.31	24.33	0.15	0.00	0.00	0.00	1.64	1.54	0.44	15.75
WBE	3.47	0.31	21.69	0.16	0.00	0.00	0.00	2.06	0.92	0.28	16.96
DAPWW	3.64	0.32	22.73	0.18	0.01	0.00	0.00	1.97	0.91	0.40	17.21
PRWW	3.88	0.32	24.25	0.17	0.00	0.00	0.00	1.74	1.01	0.25	15.93
WBL	3.93	0.30	24.56	0.16	0.00	0.00	0.01	1.55	1.49	0.65	15.15

Treatments containing lime such as BEL, WL and WBL increased both %N and protein content by 11%, 12% and 11%, respectively. Lime is known to increase seed N, P, Ca, Mg, S and seed protein concentration of cowpea (Parvatheppa *et al.,* 1995). Other treatments that showed significant increase in seed N and protein content were DAP and PR which had an increase of 9% and 10%. The correlation between Olsen P and seed protein was significant (r = 0.611*) shows that P uptake by plants is also important in improving seed protein. Both seed Ca and P remained fairly constant in all the treatments.

Treatments containing lime significantly reduced the EC of the seed leachate by over 10%. EC was inversely correlated to seed P(r = - 0.478**) and seed protein content (r = -0.823*). The treatments that contained lime such as WBL showed low EC indicating that it is of high quality. Concentration of Pb in seeds was above 0.01 ppm in treatments such WW, BEL, WL and DAPWW. These concentrations were above WHO and FAO but below KEBS recommended concentration limits. Other heavy metals such as Cd, Cr, Fe, Zn and Cu were below the WHO, FAO and KEBS recommended concentration limits. The correlation between soil conditions and seed quality factors are presented in Table 8.

Table 8: Correlation between soil conditions and seed quality factors.

	soil pH	Olsen p	P (%)	Protein	Ca	EC
soil pH	1.000	.886**	NS	NS	NS	-.628*
Olsen p	.886**	1.000	NS	.611*	NS	-.853**
P (%)	NS	NS	1.000	NS	NS	NS
Protein	NS	.611*	NS	1.000	NS	-.823**
Ca	NS	NS	NS	NS	1.000	NS
EC	-.628*	-.853**	NS	-.823*	NS	1.000

Economic analysis

Table 6 below shows the net profit attributed to each treatment. WBL, PR and BEL registered profits in both seasons. The other treatments recorded losses because yields obtained were too low. In the first season WBL, PR and BEL gave profits of US$ 416.38, 78.38 and 70.50 while in the second season they registered profits of US$ 624.50, 450.75 and 331.50 respectively. Availability of resources for making the fertilizer at low cost also and better crop establishment contributes to high net profit. The estimates of the inputs per hectare are given in Table 9.

Table 9: Gross margin analysis for bean grain production using various treatments for the two seasons

Season 1				
Treatments	Input cost/ha (US$)	Total revenue/ha (US$)	Net profit/ha	% profit
NIL	956.25	315.00	-641.25	-67
DAP	1056.25	400.50	-655.75	-62
WW	1040.00	617.63	-422.38	-41

BE	968.75	652.50	-316.25	-33
WL	1381.25	676.13	-705.13	-51
PR	958.88	1064.25	+78.38	+8
WBE	1056.25	685.13	-371.13	-35
DAPWW	1093.75	366.75	-727.00	-66
PRWW	1058.56	0.00	-1060.81	-100
WBL	1393.75	1810.13	+416.38	+30
Season 2				
NIL	956.25	541.13	-415.13	-43
DAP	1056.25	879.75	-176.50	-17
WW	1040.00	1014.75	-25.25	-2
BE	968.75	778.13	-153.13	-16
WL	1381.25	860.63	-520.63	-38
PR	958.88	1436.63	+450.75	+46
WBE	1056.25	1058.63	+2.38	0
DAPWW	1093.75	646.88	-446.88	-41
PRWW	1058.56	1024.88	-33.69	-3
WBL	1393.75	2036.25	+642.50	+46

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Conclusion

Land treatment is an alternative way of disposing wastewater from Muhoroni Agrochemicals and Food Company. Development and improving nutritive value of organic fertilizer helps to solve the problem of soil acidity apart from improving the soil structure and water retention capacity of the soil. Fertilizer developed from organic matter is cost efficient to most smallhold farmers who cannot afford inorganic fertilizers. In acidic soils organic fertilizers offers a better option for good yields. Low soil pH and low available soil nitrogen, phosphorus and calcium are limiting factors for bean production in Uasin Gishu soils. From gross margin analysis, combination of lime, wastewater and biogas effluent is a cost efficient fertilizer to smallhod farmers than inorganic fertilizer (DAP)

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