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A BASIC STUDY FOR DEVELOPMENT OF FARM ON "Murram" AREA IN KENYA*

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INTRODUCTION

The Jomo Kenyatta University College of Agriculture and Technology, abbreviated to JKUCAT, hereafter, was constructed on a poor and almost neglected farm for sisal (*Agave sisalana* Perrine), a drought resistant perennial fiber crop. The approximate location on a map is 0° 15′ S latitude, and 37° 10′ E longitude and about 1550 m above the sea (Kenya Soil Survey, 1978). Natural vegetation flora is a secondary level savanna of tall *Hyperrhenia-Combretum* wooded grassland (Seki and Ngumi 1986). Before the university construction, soil of the campus area was surveyed by the Kenyan Government (Kenya Soil Survey, Ministry of Agriculture), and the results were published (Kenya Soil Survey, 1978).

Even though this Kenyan report had pointed out that sisal crops had been cultured economically only on the slightly higher-lying places in the campus area, we did not understand why the crop plants, (maize and some leguminous ones) grew better on the top of hillocks (high places) than on neighboring slightly low grounds in the university farm, despite the hydrologic condition in central Kenya where rainfall was less than potential evaporation, 600 to 1,100 mm of annual rain fall and 1,550 to 2,200 mm of annual potential evaporation (Kenya Soil Survey, 1982), and it was naturally thought that soil water is more in relatively low places than in hillock area as a result of natural flow of gravitational soil water. However, it could be recognized that the pres-

*This study had been programmed and performed from 1983 to 1984 by Japanese Staffs of the Jomo Kenyatta University College of Agriculture and Technology to contribute reference data for big improving reconstruction works of the farm of this university (JKUCAT).

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ence of a hard rocky layer so called "murram" near the soil surface of the university farm resulted in such difficult phenomenon.

The murram, a popular name in Kenya, is called in scientific publications "petroplinthite (murram)" (Kenya Soil Survey, 1978) or "massive ironstone layer (petroferric horizon)" (Kenya Soil Survey, 1982). However, it seems to be a kind of laterite according to many investigators (Kyuma, 1970; Russell, 1973; Wrigley, 1981), and the word "murram" is also used to indicate a type of laterite (Wrigley, 1981). Therefore, it is called "murram" in this paper.

The regular layman people excluding soil scientists might assume that the upper soil on the murram was developed through its weathering, because there was a popular soil name "murram soil", or so called "ironstone soil" (Kenya Soil Survey, 1982). However this Kenyan publication has described "the soils themselves may have genetically different" origin from the ironstone.

Before the reconstruction works in 1984-1985, the presence of murram was thought to be a main cause of the low production of the university farm, because it brought about shallow surface soil. It restricted the effective rooting zone and the capacities of available water and mineral nutrients.

The reconstruction works were composed mainly by the completion of an irrigation system, the construction of the farm management building, and farm re-construction, *i.e.,* the preparation of a sufficient amount of topsoil by soil dressing and crushing murram.

MATERIALS AND METHODS

Four soil groups were collected from tops of hillocks and respective neighboring slightly low sides. After passing the soil through a 5-mm sieve, the same amount of the soil in a/5,000-sized pots was used for a preliminary culture experiment. The soil samples were divided into two groups, non fertilized ones and fertilized ones with each 0.5 g of N by ammonium sulfate, 0.5 g of P_2O_5 by calcium superphosphate and 0.5 g of K_2O by potassium sulfate per pot. Seven maize (*Zea mays* L. cv. Katumani) seeds were sown in each pot on 12, September 1983. Thinning was carried out when the seedlings grew to the three leaf-stage leaving two big and uniform ones. The growth of plants was compared between each soil group after 31 days of careful culture in a screen house at the university college.

To evaluate the productivity of crushed murram, another culture experiment was carried out using maize (the same with the above one) and lowland rice (*Oryza sativa* L. subsp. *indica* cv. Sindano). Soil materials used were the crushed murram and rich nursery soil in the university farm as a control. Each soil material, passed through a 5-mm sieve, was divided into the following three groups, 1) non fertilized one, 2) applied with inorganic fertilizers, *i.e.*, each 0.5 g of N, P_2O_5 and K_2O, and 3) applied 30 g/pot of dried and crushed cattle faeces in addition to inorganic fertilizers (0.5 g each). Throughout the thinning process, two maize plants per pot and three rice plants (including tiller shoots) per pot were selected and grown. Plant culture was continued during 29 days for maize plants and 85 days for rice plants from 13 and 14, February, 1984, respectively. All of the above culture experiments were designed and performed by four replications.

Soil survey was carried out using mainly soil boring sticks. The pit method was also undertaken in this survey, but not so many observation pits could be dug, because the murram layer was too hard to dig by man power.

For the chemical analysis, the murram granules from topsoil of four different places were collected on a 2-mm sieve. And then, they were separated from impurities, washed thoroughly with tap water, and rinsed twice with deionized water. After drying, they were crushed by a ceramic mortar and pestle to pass through a 0.2-mm sieve. A fine soil material (called clay-like material hereafter) and slightly weathered trachytic tuff samples under the murram were also collected at a pit surveyed middle place, and they were crushed and screened like the murram.

The fine particles less than 0.2 mm were digested with concentrated hydrochloric acid. The residue in the digestion was filtered, ignited and weighed as the amount of crude silica. Sesquioxides were determined by the gravimetric method using the filterate of hydrochloric acid digested solution. Iron was determined by the atomic absorption spectrophotometry. The amount of alumina was calculated by the subtraction of iron oxide from sesquioxides. Potassium, magnesium, calcium and sodium in the filtrate were determined by the atomic absorption spectrophotometry. Potassium were determined using the second class analytical line (404.4 nm) because of the lack of sensitivity of attached photomultiplier in the atomic absorption spectrophotometer at the range of the first class analytical line of potassium (766.5 nm).

Mechanical strength of the murram was measured using a universal testing machine at the concrete laboratory of the department of technology in the university college. Using about 12 cm cubes of the murram, the horizontal pressure required to crush the cube was measured. The test cubes were finished to have a couple of flat and paralleled vertical faces using a small amount of cement to give uniform pressure on the whole area of both pressing faces.

RESULTS AND DISCUSSION

1) *Comparison of plant growth between soil at the top of the hillock and at neighboring slightly low side*

A preliminary culture experiment was undertaken to clarify the reason for the difference between better plant growth on the top of the hillock and stunted growth on neighboring slightly low sides using four groups of soil. Although maize plants on a hillock grow better than on the neighboring slightly low side under field conditions, the pot cultured plants grow similarly on three groups of soil within the same soil texture, *i.e.*, ironstone soil, abbreviated murram soil, hereafter. The remainder is a group of the murram soil (low side) and the black cotton soil (vertisol) (classified according to an explanation of Kenya Soil Survey, 1982; even on a hillock) as shown in Table 1. The surface

TABLE 1. Comparison of maize growth on soils from top hillock and soils from each neighboring low side (g fresh weight/plant)

Treatment	1		2		3		4	
	L(MS)	H(MS)	L(MS)	H(MS)	L(MS)	H(V)	L(MS)	H(MS)
-F	5.7	5.2	4.8	6.4	4.4	11.8	4.5	8.3
+F	23.3	24.8	26.0	24.1	24.4	36.4	20.1	19.7

Sample of No. 1～3 were collected near 6H to northern direction. No. 4 was near eastern corner in the farm fence.
L : Low side soil. H : Top hillock soil. (MS) : Murram soil. (V) : Vertisol.
-F : No fertilizer (control treatment).
+F : With fertilizer (0.5 g each of N, P_2O_5 and K_2O/pot).

soil is mixed with murram granules because a massive ironstone layer, *i.e.*, murram layer, starts within 50 cm of the surface (Kenya Soil Survey, 1982). A kind of vertisol is distributed even on a well drained hillock top, and it is deep, very friable and smeary (Kenya Soil Survey, 1982). The black soil on a northern hillock in the university farm is considerably rich so as to sustain about a half of maize growth on the fertilized murram soil. Therefore, the different growth of plants between high and neighboring low sides under natural condition is not generally related to the difference of soil chemical property.

2) *Distribution of murram at the university farm*

Fig. 1 shows the points of soil survey in the farm area. Table 2 shows the soil depth and the condition of substrata at surveyed points.

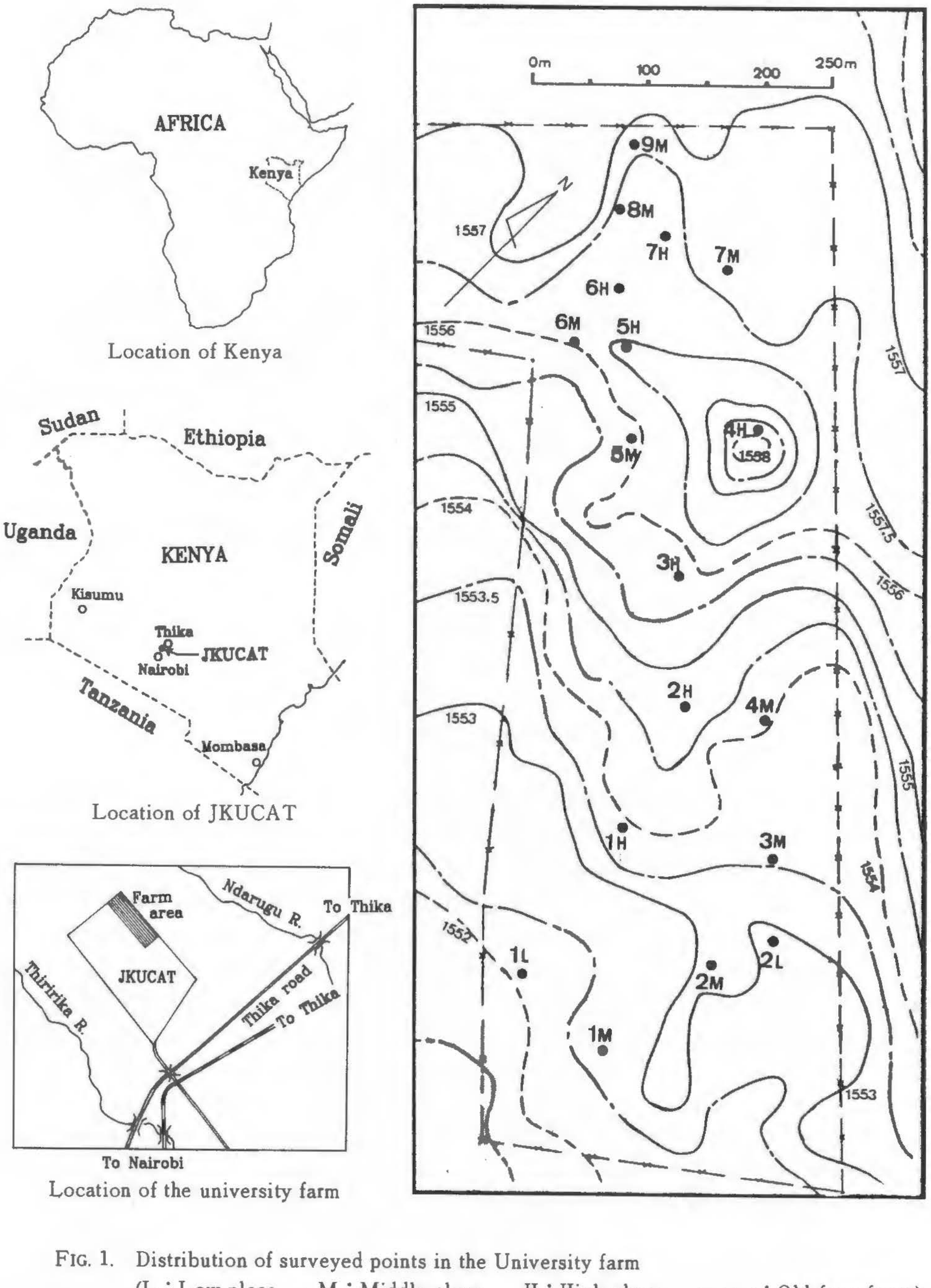

FIG. 1. Distribution of surveyed points in the University farm
(L : Low place M : Middle place H : High place —×— : Old farm fence)

TABLE 2. Relation between soil depth (cm), condition of surface soil and substratum

Low place	1L	2L
Surface soil	V	V
Effective soil depth (cm)	105	70
Botom condition	105	70

Middle place	1M	2M	3M	*4M	5M	*6M	7M	8M	9M
SS	MS	MS	MS	MS	MS	MS	MS	MS	MS
ESD	—	—	25	8	—	—	—	—	—
BC	85	50	45	95	25	240	20	12	38

High place	1H	*2H	3H	4H	5H	6H	7H
SS	MS	FS	MS	FS	FS	FS	FS
ESD	—	25	—	—	100	100	43
BC	60	150	55	120	110	110	50

*Points surveyed by pit method.
Surface soil (SS): group of the surface soil.
V : Vertisol. MS : Murram soil. FS : Ferralsols (not abundant murram granules).
Effective soil depth (ESD): effective rooting zone.
— : Very shallow and hard surface soil, not cultivated.
Bottom condition (BC): additionally total soil depth (with loose murram) and final reaching point of boring.
___ : Depth up to parent rock (trachytic tuff, cm).
═══ : Depth up to hard murram layer (cm).
No mark indicates no hard layer within the reach of the soil boring stick.

We classified firstly the field area on the bases of the relative height levels, not on the bases of the absolute height levels; because the effective soil depth on the murram seemed to correlate with the relative height in the neighboring land. According to this classification, the condition of soil and murram was surveyed and considered as follows.

a) High place: This place is a half to a few meters higher than the middle place (see the next item), and thought to be never waterlogged even after a heavy rain. As shown in Table 2 and Fig. 2-A, there is no or only slight murram within 50 cm of topsoil. The depth of the soil down to the murram seemed to be proportional to the height of the land. It is clear in Fig. 2A illustrated a rough soil profile between No. 6M and No. 5H points. In the surveyed points, the hard murram appeared from a depth of 50 cm or more in the high place (Table 2). On a northern hillock in the university farm, even though a black cotton soil was distributed, the area was narrow and out of this profile observation. Except for this one, the soil in the northern and eastern area seems to be classified into the murram soil (Ferralsols in the

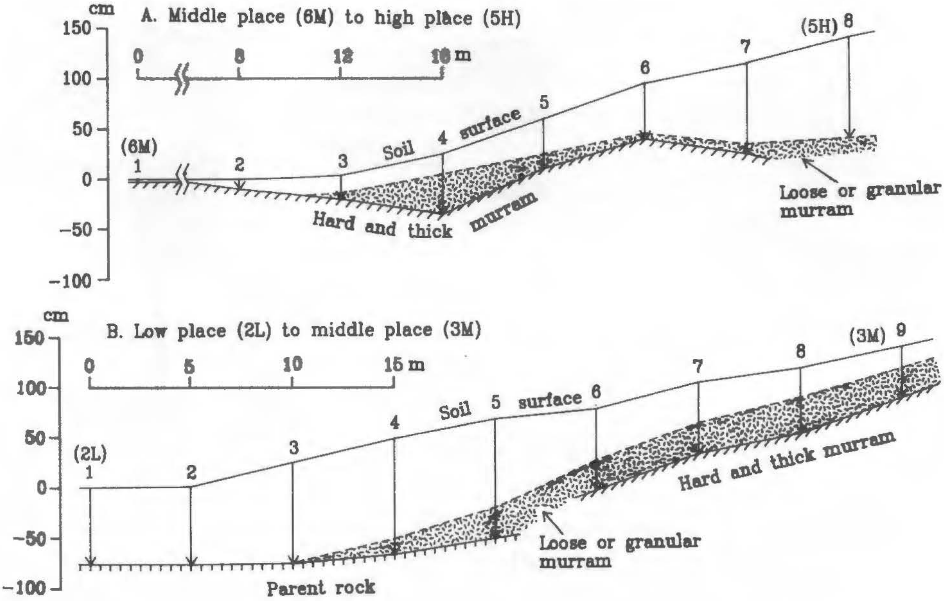

FIG. 2. Interrelation between ground level, effective soil depth and murram

FAO/UNESCO soil classification system), which are distributed in a well drained area. The murram found in depths in this area was loose, or was found in the soil profile only as scattering murram granules of a few mm in diameter. These granules seem to be the same material as so called "pisoferric material" (Kenya Soil Survey, 1978), "pisoferric phase" (Kenya Soil Survey, 1982), "nodule" (Kyuma, 1970), or "pisolithic", "nodular" and "pea-iron gravel" (Russell, 1973).

The high place No. 2H point, pit surveyed, seemed to be intermediate of the high and middle places, because the neighborhood of this point was too flat and had relatively wide upper land, accordingly the soil will be easily saturated with water after a heavy rain; although the level of ground was about one meter higher than that in the neighboring middle place (*e.g.* No. 4M). As shown in Fig. 3(A), the plinthite layers in the murram increased with depth; about 30 cm of a clay like layer was found at the bottom part, though the effective surface soil containing few murram was somewhat shallow here.

b) Middle place: In this place, the soil is occasionally waterlogged and sometimes dried up for the arid atmosphere and the strong tropical solar radiation. Hard and thick murram was easily found at this place. They were called "indurated murram" (Kenya Soil Survey, 1978), or "massive ironstone layer, petroferric horizon or petroferric phase" (Kenya Soil Survey 1982).

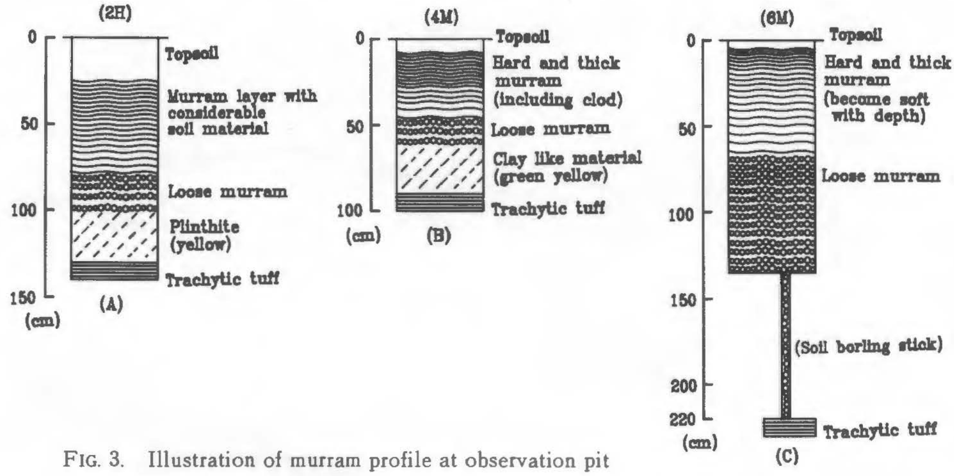

FIG. 3. Illustration of murram profile at observation pit

As shown in Table 2 and Fig. 2-A, the effective soil depth up to the murram layer, was very shallow; less than 20 cm of the depth could be seen at the surveyed points. The soil in this is classified into the murram soil, *i.e.*, ironstone soil, because the murram, massive ironstone, appears less than 50 cm deep (Kenya Soil Survey, 1982). The shallow surface soil contained usually a lot of murram granules as a result of past plowing. The thicknes of the murram layer is 50 to 240 cm, but measurement of the accurate murram thickness is difficult, because the murram layer is too hard to reach to the parent rock by the soil boring stick or by the observation pit dug with a man power pick. Under the murram, pyroclastic rocks, trachytic tuff (Kenya Soil Survey, 1978), were found, independent of the thickness of the murram (Table 2).

At the No. 4M pit point, the thickness of surface soil was negligibly shallow, and the murram was very hard. The thickness of the murram layer was about 50 cm as illustreted in Fig. 3(B),. Under the murram, the layer of about 35 cm of green yellow, ferrous colored, clay-like material was found, and this color changed to red (ferric one) within a few days after exposed to the air. The top of the trachytic tuff was present at the depth of 90 cm from the surface. Because the murram was hard and dense here, very few roots were found in this layer. They might penetrate through a thin clay layer or a small number of cracks in the murram.

At the No. 6M pit point, the murram appeared almost directly on the ground surface as illustreted in Fig. 3(C). Except about 30 cm of the surface murram, the deeper one was not so hard. As the murram was very thick here, the top of the parent rock could be checked only by the soil boring stick from the bottom of the observation pit. On the walls of this observation pit, few plant roots could be found even near the bottom (about 130 cm in depths) like the other places.

c) Low place: The ground is about one meter lower than the middle places. The soil might be waterlogged or water-saturated throughout the rainy season. In this place, the murram layer could not be found in the soil profile as can be seen in Table 2 and Fig. 2-B. The depth of the soil at this survey points was 70 cm or more. This soil may be classified into a Vertisol. This soil appears in an imperfectly drained area, and that is deep, dark gray to black, very firm, cracking clay (Kenya Soil Survey, 1982). It is the same with commonly called "black cotton soil" in Kenya. The substratum (parent material) of this soil is a pyroclastic rock, trachytic tuff (Kenya Soil Survey, 1978).

As illustrated in Fig. 2-B, at the marginal zone of the black cotton soil area, red murram granules (ferric nature) appear on the top of the trachytic tuff, underlying the black cotton soil. The murram granules became dense with increasing ground level, and the murram containing layer became thick and hard. That is, the murram granules appear firstly in the oxidative horizon, where the imperfectly weathered parent rock, *i.e.,* newly weathered mineral soil, is predominant, and soil humus is very poor. This could be found when the additional soil boring was made toward a slightly high point, *i.e.,* from No. 2L point to No. 3M point as shown in Fig. 2B.

As described above, the hard and thick murram was distributed near the soil surface at a moderate height where the soil was shallow. On the other hand, soil is somewhat deep at the top of a hillock. Therefore, the different growth of plants between the top of hillock and neighboring low side under natural condition was mostly induced by the big difference of soil water capacity depending on the extent of effective soil depth.

3) *Chemical composition of murram*

To confirm the origin of the murram by chemical analysis, the main constituents of the murram were determined. As shown in Table 3, the murram granules, free from clay particles, contain a lot of iron and a little silica as compared with the soil or the parent rock under the murram. The values in Table 3 showed the net content excluding the component of water or loss on ignition. Total of a few percent of analytical error in this table could not be prevented, because the re-examination was quite difficult for the imperfect facilities of the university laboratory.

The average composition of the murram is 51% of iron oxide, 31% of silica and 13% of aluminum oxide. The composition of clay-like

TABLE 3. Chemical composition of murram granules (%)

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	CaO	K_2O
1(4M)	36.12	16.49	47.36	0.06	0.00	0.02	0.10
2(2H)	27.01	12.56	54.57	0.06	0.01	0.02	0.09
3(6M)	27.80	10.08	57.06	0.05	0.01	0.01	0.08
4(8M)	34.09	13.45	46.55	0.07	0.01	0.06	0.13
*5	73.92	16.40	9.18	0.22	0.02	0.05	0.28
**6	80.54	12.03	7.09	0.23	0.09	0.03	0.15

Sampling points of murram granules as shown in Fig. 1 and Table 2 are given within parentheses.
*Clay-like materials under the murram at 4M.
**Trachytic tuff under the murram at 4M.

material and the parent rock, trachytic tuff, is clearly different from those of the murram, in which the iron oxide is 9 and 7%, silica was 74 and 81% and aluminum oxide was 16 and 12%, respectively. From the above data, the murram is thought to be a kind of iron concretion (Kenya Soil Survey, 1978; Kenya Soil Survey, 1982). Therefore, it differs from the hardpan constituted of iron and aluminum (Cone and Lipscomb, 1972).

Dressing of potassium or lime may be necessary in addition to nitrogen and phosphorus application, because the contents of those nutrients are low in the murram, compared with clay-like material, as can be seen in Table 3. However, potassium dressing would be unnecessary in the university farm, because the irrigation water from Ndarugu river contains, 5.8 ppm K (Moritsugu, 1985). Of course, it seemed to be quite reasonable that the rate of fertilizer application or liming should be determined through adequate field experiments.

4) *Mechanical strength of murram*

Judging from our observation, the murram should be crushed to improve the university farm, because it was composed by soil material, abundant iron oxide and some of clay-like material. To check the possibility to crush the murram, the mechanical strength was previously measured. The murram shows an accumulation of laminating layers in the profile of soil surveyed, which looks like alternating piles of iron rich skeletal layers and clay layers. Therefore, the breaking pressure seemed to be different by the direction of force, *i.e.*, vertical or horizontal. In this study, horizontal pressing was selected, because it was natural when the mechanical breaking was carried out by the practical way, *e.g.*, use of a bulldozer and a ripper attachment.

The murram mass to make the test cubes were collected at the middle place, 4M point, and high place, 2H point (Fig. 1). The one from the middle place is hard and thick, the other is somewhat soft because it includes numerous layers of plinthite consisting a sizable thickness. As can be seen in Table 4, the size of murram cubes is not uniform, be

TABLE 4. Minimum pressure required to break murram cubes

Sample	Size of cross section		Breaking pressure	
*4M-1	12.5×12.4cm	155cm^2	3,955kg	25.5kg/cm^2
4M-2	12.4×12.9	160	9,080	56.8
2H-1	13.0×12.4	161	5,795	36.0
2H-2	12.7×12.3	156	5,305	34.0
2H-3	10.9×11.6	126	3,520	27.9
**Concrete	10.0×10.0	100	35,000	350.0

*A big clayey clod was contained in the cube.
**Approximate reference value of a concrete testing cube.

cause the preparation of the test cube is difficult for the fragility of the murram, especially when the murram is rich in soil.

The minimum pressure required to crush the murram is distributed between 25.5 and 56.8 kg/cm^2 (Table 4). The breaking pressure of the hard murram is about 55 kg/cm^2, while that of regular concrete is about 350 kg/cm^2. This means that the strength of murram is less than 1/6 of the regular concrete. When the murram contains a considerable amount of soil material, the minimum pressure is less than 40 kg/cm^2. This tendency is also found when the clayey clod is included in the cube as can be seen in Table 4. On the strength of the murram, it has been said that the murram is weak as a base of a building when it is directly constructed on the murram, because it includes clay (JICA, 1978; Kenya Soil Survey, 1978).

In any event, it was said that the murram could be crushed somewhat easily because it contained soil materials. It was also supposed from the road improving works at the Juja crossing (in front of the university college in 1984), where many bulldozers were used with their ripper attachment to crush a few meters depth of upper part of trachytic tuff.

5) *Culture experiment using crushed murram*

The following three methods can be considered as the methods for the development of a farm on the murram: a) to remove the murram from the surface of the land, if sufficient amounts of soil materials are present under the murram; b) to put a lot of good soil on the murram; c) to crush the murram to prepare the soil materials.

The first method is difficult, unless the profitable use of large amounts of murram, *e.g.*, the material for roadbed, is established. In addition, it is possible if a considerable amount of soil materials is present under the murram. The second method seems to be expensive because much good soil must be transported. The last one may be somewhat convenient.

Although the second method was planned to improve part of the university farm, it might be too expensive to expand it into whole area of the farm. Accordingly, culture experiments using crushed murram were designed and performed with maize and rice plants. As a reference, climatic conditions (averages of monthly temperatures, relative humidity, and rainfall) during 1984 are shown in Table 5. Annual rainfall accumulated in 1984, about 500 mm, is less than the average value of about 850 mm, for four neighboring weather stations (Kenya Soil Survey, 1978). The arid conditions, *i.e.*, low humidity and little rainfall, are severe to plants, while the temperature seems to be good.

TABLE 5. Monthly climatic data of the farm of Jomo Kenyatta University College of Agriculture and Technology in 1984

Month	Temperature (℃)			Rainfall (mm)	**Relative humidity (%)
	Average	*Maximum	*Minimum		
Jan.	19.4	— (27.4)	— (11.4)	9.0	—
Feb.	20.2	— (29.7)	— (10.4)	1.6	—
Mar.	20.8	31.0 (28.3)	8.0 (13.2)	13.9	33
Apr.	21.5	30.0 (27.4)	12.0 (15.5)	58.6	40
May	20.6	29.0 (26.7)	9.5 (14.4)	0.5	38
Jun.	18.3	26.5 (24.6)	8.0 (11.6)	9.3	41
Jul.	17.6	25.5 (22.1)	8.0 (13.0)	49.1	51
Aug.	16.7	26.0 (21.7)	7.0 (11.7)	9.8	51
Sep.	19.2	29.0 (26.1)	7.0 (12.3)	20.5	36
Oct.	19.5	27.0 (24.2)	11.0 (14.7)	136.5	52
Nov.	19.0	25.5 (23.3)	12.5 (14.7)	130.5	57
Dec.	18.1	26.5 (23.2)	8.5 (13.0)	54.6	49

*Monthly maximum or minimum. Within parentheses the average of the daily maximum or daily minimum is given.

**Monthly average of relative humidity at 14.00h.

As control soil, the best soil was collected from the nursery bed in the university farm. The soil was rich so as to sustain vigorous maize growth even without fertilization, *i.e.*, the dressing was ineffective as shown in Table 6. The plants grew well on the crushed murram, when sufficient and adequate amounts of fertilizers were applied. In rice plants, the growth on the crushed murram is never inferior to those on the good nursery soil. This might be caused by a prolonged growth period to obtain considerable bulk as in maize plants. The data of Table 6 suggest that abundant dressing of fertilizers is recommendable

TABLE 6. Comparison between plant growth on crushed murram and that on rich soil of the university farm

Treatment	Maize			Rice	
	Height	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
*Soil	76.9cm	84.4g/pot	9.2g/pot	38.3g/pot	9.3g/pot
S+F	75.5	81.6	9.2	103.8	26.6
S+F+M	70.1	81.2	8.8	117.0	30.3
**Murram	31.4	11.6	1.2	3.4	0.7
M+F	59.1	40.4	4.8	112.8	27.2
M+F+M	66.4	50.2	5.6	118.0	30.6

*Soil (S): control soil, without fertilization.

**Murram (M): crushed murram, without fertilization.

+F : application of 0.5 g each of N, P_2O_5 and K_2O/pot.

+M : application of 30 g of dried and crushed cattle faeces/pot.

to the crushed murram, especially in initial time, because the soil substitute is poor as observed from the insufficient maize growth even when fertilizer is applied together with cattle manure.

In this stand point, the culture of paddy rice is recommendable, because the efficiency of applied fertilizen in the paddy soil is advantageous. This might result in vigorous growth of rice plants on the crushed murram when the fertilizers or the manure was applied (Table 6).

SUMMARY

The murram, a kind of laterite, a hard reddish rocky material found near soil surface, was widely distributed almost all over the farm area of the Jomo Kenyatta University College of Agriculture and Technology, Juja, Kenya. Before the reconstruction of the university farm in 1984, the presence of the murram was a big difficulty which decreased the production of the university farm caused by a very shallow surface soil. To seek an early solution of this difficulty, a study was undertaken on the distribution, physical or chemical property, and crop productivity of the murram in the farm area. As a result of several experiments, the following facts could be pointed out. 1) The thick and hard murram was present near the soil surface at a relatively moderate height, and the murram was inconspicuous at high and low places. 2) At the border between low and middle places, the murram appeared on the top of the parent rock, *i.e.*, under the black cotton soil. 3) The clay-like layers were found in the under- and inter-murram layers, even though the murram was hard and thick. 4) The murram granules con-

sisted mostly of iron oxide (ca. 51 %), this was clearly in contrast to the low content of iron oxide in clay-like material (ca. 9 %) and trachytic tuff (ca. 7 %) under the murram. 5) The mechanical strength of the murram is less than 1/6 of regular concrete. Considerable amounts of clay-like material in the murram weakens the strength. 6) The crushed murram is not poisonous to plants and has a sufficient capacity to sustain the vigorous growth of plants when an adequate amount of fertilizer is applied.

Thus, we concluded that the farm could be improved by crushing the murram with equivalent value to a newly developed one by the soil dressing on the murram directly.

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REFERENCES

Cone, L. W. and Lipscomb, J. F. 1972. The History of Kenya Agriculture. pp. 17-18. University Press of Africa, Nairobi.

JICA (Japan International Cooperation Agency). 1978. Survey Report on the Basic Master Plan for the Construction of Jomo Kenyatta College of Agriculture and Technology. p. 38. (in Japanese).

Kenya Soil Survey. 1978. Detailed Soil Survey of The Jomo Kenyatta College of Agriculture and Technology, Juja (Kiambu District). pp. 1-19. Ministry of Agriculture, Republic of Kenya, Nairobi.

Kenya Soil Survey. 1982. Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980 (Explanatory note). pp. 12-13. Ministry of Agriculture, Republic oc Kenya, Nairobi.

Kyuma, K. 1970. Secondary ferruginous formations in the tropical soils, especially concretions and nodules. Southeast Asia Research. 7 : 571-581. (in Japanese).

Moritsugu, M. 1985. A preliminary investigation on chemical quality of inland waters in Kenya. Ber. Ohara Inst. landw. Biol. Okayama Univ. 19 : 25-34.

Russell, E. W. 1973. Soil Condition and Plant Growth (10th Edition). pp. 729-735. E.L.B.S. and Longman, London.

Seki, T. and Ngumi, W. 1973. A flora of vascular plants at Jomo Kenyatta College of Agriculture and Technology, Central Province, Kenya. Hikobia 9 : 509-520.

Wrigley, G. 1981. Tropical Agriculture (4th Edition). pp. 12-14. Longman, London and New York.