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Comparative Evaluation of Different Plant Residues on the Soil and Leaf Chemical Composition, Growth, and Seed Yield of Castor Bean (*Ricinus communis*)

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ABSTRAK

Penyelidikan kesan sisa sabut koko, sekam padi dan habuk kayu ke atas pertumbuhan, hasil benih, daun dan komposisi kimia tanah kacang kastor yang dijalankan pada tahun 1999 dan 2000 di zon hutan hujan Akure, Nigeria. Rawatan diguna pada 6t/ha, direplikakan sebanyak empat kali dan disusun secara rawak blok lengkap (RCB) dengan 300kg/ha baja NPK 15-15-15 juga rawatan kawalan (tanpa baja; tanpa sisa). Tanah dan kesan organik dianalisis secara kimia. Parameter yang direkodkan bagi pokok kacang kastor adalah ketinggian, kelebaran daun, ukur lilit batang, tanah dan N, P, K, Ca, Mg daun, nilai pH tanah, O.M dan hasil benih. Keputusan menunjukkan ada peningkatan signifikan ($p<0.5$) pada ketinggian, indeks kelebaran daun, ukur lilit batang, tanah dan daun N, P, K, Ca, Mg, nilai pH tanah, O.M dan hasil benih pokok kastor melalui rawatan kesan organik dan dibandingkan dengan rawatan kawalan. Rawatan menggunakan sabut koko meningkatkan berat benih sebanyak 55% dan 80% dalam dua tanaman kacang kastor berbanding rawatan sekam padi. Berbanding dengan sisa tumbuhan, rawatan NPK paling banyak menyumbang kepada peningkatan ketinggian, kelebaran daun, dan ukur lilit batang tetapi mengurangkan kesan benih.

ABSTRACT

This work investigated the effect of plant residues such as cocoahusk, ricebran and saw dust on the growth, seed yield, leaf and soil chemical composition of castor bean in 1999 and 2000 at Akure in the rainforest zone of Nigeria. The treatments were applied at 6t/ha, replicated four times and arranged in a randomized complete block (RCB) with NPK 15 -15 -15 fertilizer applied at 300 kg/ha and a control (no fertilizer; no residue). The soil and organic amendments were chemically analyzed. The parameters recorded for castor oil bean were plant height, leaf area, stem girth, soil and leaf N, P, K, Ca, Mg, Soil pH, O.M and seed yield. Results showed that there were significant increases ($p<0.05$) in plant height, leaf area index, stem girth, soil and leaf N, P, K, Ca, Mg, soil pH, O.M and seed yield of castor oil plant under different organic amendment treatments compared to the control. The cocoahusk treatments increased seed weight by 55% and 80% in the two crops of castor oil bean to the ricebran treatment. Compared to the plant residues, the NPK treatment resulted in the greatest increases in the plant height, leaf area and stem girth but reduced seed yield.

INTRODUCTION

Castor oil bean, which is considered to be an ordinary plant by farmers in tropical countries, has now become an important crop in the world market. Traditionally, they are used as fencing materials by farmers around homes and farms, however, the essential oil component of its seeds has not been exploited fully.

Essential oils have been used for thousands of years, not only in aromatherapy, but also in perfumes, pharmaceuticals and food flavoring, and as a more recent innovation in bio-pesticides. Spore CTA (2000) reported that the market for essential oils is well established, at an estimated \$1.2 billion per year and with the growing interest in "healthy" lifestyles in Europe, for example, demand is rising steadily.

Between 1992 and 1997, millions of dollars were invested by local banks and companies: the World Bank, the United Nations Industrial

Development Organization (UNIDO) and the (ACP-EU) center for the development of essential oil industry. However, the investment failed because of lack of attention to consistent supply of plant materials, quality control and plant diseases.

Consequently, the production of castor oil beans in Nigeria and other tropical countries is still inadequate to support an essential industry. Some of the reasons that contribute to this situation are continued decline in soil fertility and lack of information on its production hamper increased production and yield. Efforts aimed at improving soil fertility using chemically prepared inorganic fertilizers may not be viable because of high cost of purchase, scarcity at the farmers' level and their negative effect on soil quality with continuous use.

Therefore, there is justification for alternative sources of fertilizers which are inexpensive, sustainable and environmentally sound.

Based on an extensive literature review, it is concluded that the research information on the use of plant residues such as sawdust, rice bran and cocoahusk for optimal castor oil bean is limited and conclusive. The objectives of this study are to compare the effects of these residues on soil fertility, growth, seed weight and leaf chemical composition of castor oil bean.

MATERIAL AND METHODS

Field Experiment

The experiments were conducted at Akure in the rainforest zone of Nigeria on a sandy loam soil, skeletal, kaolinitic, isohyperthemic oxic paleustalf (Alfisol) or Ferric Luvisol (FAO) with pH (H_20) of 5.2, organic matter 0.51%, 0.02%N, 4.6mg/kg Bray P1 extractable P, 0.05mmolkg^{-1} exchangeable K, 0.12mmolkg^{-1} exchangeable Ca and 1.12mmolkg^{-1} exchangeable Mg. The soil was under arable crops for 10 years and the field experiments were conducted in 1999 and 2000.

Three plant residue treatments (ricebran, sawdust, and cocoa pod husk) were individually applied at 6tha^{-1} to each crop castor oil bean. Additional treatments included inorganic fertilizer treatment (300 kgha^{-1} of NPK 15-15-15) and a complete control which did not receive fertilizer nor organic amendment. The 5 treatments were arranged in a randomized complete block design and replicated four times on each castor oil crop. The plots were 4m x 4m (16m^2) and the soils were ploughed and harrowed to maintain adequate tilth while the residue treatments were incorporated into the soil two weeks before planting to allow adequate decomposition.

Two dried seeds of castor oil bean were planted per hole of 2 cm deep hole on May 12, 1999 and April 30, 2000. The plant and row spacing were 100 cm and 100 cm respectively. The plots were manually weeded in the second, fifth and eighth weeks after planting respectively while the insects were controlled by spraying Karate at the rate of 1.8mL a_i. i L^{-1} of water at 2,4 and 6 weeks after planting.

Leaves were taken from the middle part of the stem at 18 weeks after planting and oven-dried for two days at 70°C. After grinding the sub-samples, 2 g each was dry-ashed using a muffle furnace at 450°C for 6 hours.

The nutrients in the ashed leaf of castor bean were extracted with water to measure the nutrient content of the leaf tissue. Percent N was determined by microjeldahl method (Jackson 1964) while the percent P was determined by using vanado-molybdate solution. Percent K and Ca were determined by flame photometer while Mg was determined on atomic absorption spectrophotometry for the plants of castor bean selected for each treatment plot.

In-addition, the six plants in each plot (24 plants per four replicates) were also selected for plant height, stem girth and leaf area measurements. These parameters were measured at 2 week intervals until 16 weeks after planting. The leaf area per plant was determined by measuring some representative leaves of the plant and this was used to calculate the total leaf area on castor bean plant. From the figures obtained, the leaf area index (m^2 of leaf area per m^2 of soil area) was calculated using the formulae LAI = LA/GA where LA = Leaf area and GA = Ground area or soil area.

Harvest or matured seeds capsule started at 22 weeks after planting and continued at four days interval until senescence using a total of 16 plants per plot (64 plants per four replicates)

Source and Preparation of Organic Materials

Cocoa pod husk and rice bran were obtained from the cocoa plantations and rice mill unit of the Federal College of Agriculture, Akure respectively while the sawdust was obtained from a local sawmill industry at Akure. The organic materials were air dried and processed to allow partial decomposition and quick release of nutrients for crop use. The dried cocoa pod husk was ground using hammer mill while the ricebran and sawdusts were each partially composited separately for six weeks to reduce the C/N ratio.

During compositing of cocoa husk pod, sawdust and ricebran, some quantity of soil was added at a ratio of 1:2 of the proportion of the organic materials.

Chemical Analysis of Organic Materials

The processed forms of the three organic materials were analyzed for P, K, Ca, Mg, Na, and micronutrients content using wet digestion method with 25mL nitric acid, ($HN0_3$), 5ml sulphuric acid (H_2S0_4) and 5 ml of hyperchloric acid ($HC10_4$).

For P analysis, colour absorbance was determined using a spectronic 20 at 442 Um and a flame photometer was used for other nutrients except Mg, Zn, Fe, Cu and Mn concentrations which were determined using an atomic absorption spectrophotometer. Nitrogen was determined by microkjeldahl method (A.O.A.C 1970).

Soil Sampling and Analysis Before Planting

30 core soil samples were collected, mixed, air dried, sieved using a 2mm sieve prior to routine analysis. The processed soil samples were analyzed as follows:

(i) Soil pH (1:1 soil/water) and 1:2 soil/0.01M CaC_2 solution was determined using glass calomel electrode (Crockford and Nowell 1956).
(ii) Percent nitrogent was determined by using mirokjeldahl method (Assoc of Anal. Chem. 1970).
(iii) Available phosphorus was extracted from the soil by using Bray Pi extractant and determined using a spectronic 20 at 882 Um (Murphy and Riley 1962).
(iv) Exchangeable cations (K, Ca, Mg and Na) were extracted using 1m $NH_4OAcpH7$ solution and the concentrations were determined with a flame photometer (Jackson 1958) while Mg content was measured using an atomic absorption spectrophotometer.
(v) The exchangeable acidity (H+ abd $^{Al3+}$) was measured from 0.01M HCL extracts by titrating with 0.1 NaOH (McLean 1965).
(vi) The micronutrients (Mn, Cu, Zn and Fe) were extracted with 0.1M MC1 (Ogunwale and Udo, 1978) and measured with Perkin Elmer atomic absorption spectrophotometer.

Soil Analysis After the Experiment

At the end of each experiment, soil samples were taken from each plot per treatment, air-dried and passed through 2mm sieve for routine chemical analysis. The procedure for the analysis of soil pH, O.M, N, P, K, Ca, Mg and Na were as described above.

Statistical Analysis

Data were subjected to ANOVA F-test and means separation by Duncan Multiple Range Test (DMRT) at the 5% possibility.

RESULTS

Table 1 shows the chemical analysis of the soil before the experiment. The soil is highly acidic and very low in O.M and nitrogen. The available N, P, K, Ca, Mg and Na in the soil were less than the critical levels 0.15% N, 10mg/kg^{-1}P, 0.2 mmol Ca and Mg, and 0.30 mmolkg^{-1} K recommended for crop production in South West Virginia (Agboola and Corey 1973; Adeoye 1986, 1983; Folorunso *et al.* 2000). The poor chemical composition of the spoil implied that the castor bean would respond favorably to the application of organic materials for optimum production. The high value of bulk density 1.62Mgm^3 would affect root development and nutrient uptake by the plant.

Organic Materials Analysis

Table 2 presents the chemical composition of the plant residues used for the cultivation of castor bean. Among the plant residues, the compost based cocoa husk had the highest nutrient content of C, N, K, Ca, Mg, Fe, Mn, Cu and Zn followed by compost based ricebran and the sawdust had the lowest nutrient contents. Ricebran and sawdust had the highest C/N ratio (1:23 and 1:19) respectively but these C/C ratio values were still relatively lower than their ordinary forms because they were composted.

Effect of Plant Residues on Castor Bean Leach Chemical Composition

Plant residues increased leaf tissue % N, P, K. Ca, and Mg of castor bean significantly ($p<0.05$)

TABLE 1
Soil chemical composition before planting castor oil plant

pH		Organic matter						Exchangable cations		
H_2O	$CaCl_2$	N	P	K	Ca	Mg	Na	Bulk	Density	Soil Type
%		mg/kg soil			mmol/kg soil				Mgm^{-3}	
5.20	4.80	0.51	0.02	4.60	0.05	0.12	0.12	0.43	1.62	Alfisol

+ Analysis based on dry sample basis

TABLE 2
Chemical analysis of the organic fertilizers

Organic Fertilizers	C	N	C/N	P	K	Ca	Mg	Na
	mg/kg			mg/L		%		
Sawdust-based Compost (SC)	8.00	0.42	18.96	10.00	5.12	0.10	1.30	4.39
Rice bran-based Composed (RC)	14.00	0.60	23.33	56.00	7.93	0.12	1.80	4.33
Cocoahusk-based Compost (CC)	16.00	1.44	11.11	100.00	20.59	9.34	7.10	4.41

+ The organic fertilizers were composted for six weeks and soil added before application, hence, low C/N values to the original forms.

TABLE 3

Treatments	Crop 1 (1999)					Crop 2 (1999)				
	N	P	K %	Ca	Mg	N	P	K %	Ca	Mg
Control (no fertilizers)	0.60d	0.15d	0.20c	0.16d	0.15d	0.50c	0.12d	0.15c	0.13c	0.12d
Sawdust-based Compost (Sc)	1.40c	0.34c	0.38b	0.30c	0.28c	1.80d	0.53c	0.45d	0.47b	0.35c
Ricebran-based Compost	1.80c	0.39c	0.40b	0.43	0.31b	2.10c	0.58c	0.52c	0.50b	0.40b
Cocoahusk-based Compost	2.40b	0.50b	0.64a	0.70a	0.42a	2.80b	0.73b	0.68b	1.10a	0.65a
NPK Fertilizer	3.20a	0.78b	0.64a	0.13d	0.12d	3.80a	0.92a	0.72a	0.10d	0.10e

Treatment means within each column followed by the same letter are not significantly different from each other using Duncan Multiple Range test at 5% level.

compared to the control (Table 3). Cocoa husk gave the highest values that leaf N, P, K, Ca and Mg followed by ricebran and sawdust respectively. The residues had higher values of Ca and Mg than NPK 15-15-15 treatment; however, the use of NPK fertilizer resulted in higher leaf N, P and K contents of castor bean compared to the use of plant residues.

Effect of Plant Residues on Growth and Seed Yield of Castor Bean

The plant residues and NPK fertilizer increased the seed yield (Table 4), plant height (Table 5), leaf area index (Table 6) and stem girth (Table 7) significantly ($p<0.05$) relative to the control treatment.

Plant height, leaf area index, stem girth and seed weight of castor bean were greatest in the cocoa husk plots followed by the rice bran and sawdust treated plots respectively.

Cocohusk ricebran and sawdust treatments increased mean plant height by 80%, 71% and 65% respectively compared to the control treatments. NPK increased plant height, leaf area and stem girth of castor bean more than the three residues cocohusk, ricebran and sawdust.

Cocohusk increased the seed weight of castor bean better than NPK and control treatments. For instance, cocoa husk increased the seed weight of castor oil plant by 55 and 80% in crops 1 and 2 compared to that of ricebran treatment.

Effect of Plant Residues on the Soil Chemical Composition After Harvest

Table 8 represents the soil chemical composition after the experiment on castor bean. The cocoa husk, rice bran and sawdust increased the soil N, P, K, Ca, Mg, Soil pH, O.M significantly ($p<0.05$) compared to the control treatment. The cocoa husk produced the highest values of soil N, P, K. Ca and Mg followed by rice bran and sawdust treatments respectively; however, soil N, P, K contents in NPK fertilizer treatment were higher than the organic residue treatment. The use of NPK also reduced the soil of pH and O.M compared to residue treatments.

DISCUSSION

The soils used for planting castor bean were generally low in pH. O.M, N.P, K, Ca and Mg and this could be responsible for the poor growth of castor oil plants as shown in the control treatment.

This observation is supported by Agoola and Corey (1973), Adeoye (1986) and Ayodele (1983) who had reported that poor growth of crops occurred in soils with less than 0.15%N, $10mg/kg^{-1}$-P and $0.2mmol\ kg^{-1}$ Ca and Mg critical levels considered for crop production in South-west Nigeria, therefore, it is expected that the application of cocoa husk, rice bran and sawdust would increase the growth responses and seed yield of castor bean.

The increase in plant height, leaf area and stem girth of castor bean grown with cocoa husk, rice bran and sawdust could be linked to their chemical composition. Among the residues, cocoa husk had the lowest C:N ratio which implies that it decomposes faster and makes its nutrients more easily available compared to rice bran and sawdust.

Cocoa husk had the highest available N, O, K, Ca, Mg, Fe, Mn, Cu and Zn content and this could be responsible for the best values of seed weight, plant height, leaf area index, stem girth, soil and leaf N, P, K, Ca, Mg, Soil pH and O.M. Rice bran and sawdust were the least efficient of the plant residue treatments in providing nutrients for castor bean. Accordingly, this might be responsible for the lowest values of leaf and soil N, P, K, Ca, Mg, soil pH and O.M, and measured growth parameters of castor bean in treated plots with sawdust and rice bran.

The fact that cocoa husk increased soil pH more than the other nutrients is consistent with previous findings that its ash contains high levels of K, Ca and Mg (Ojeniyi 1995) and the cocoa husk is an excellent source of K (Adu – Daaph *et al.* 1994).

The increase in soil pH as a result of cocoa residues application and superior seed yields provide evidence that this material is an excellent source of fertilizer for castor bean.

The finding that use of NPK fertilizer resulted in the greatest plant height, leaf area index and stem girth of castor bean compared to plant residues is also consistent with its relative higher N, P and K nutrient content than the residue. The N, P and K in the fertilizer are more readily available than those supplied by organic sources. However, it was observed that the NPK fertilizer encouraged the vegetation of castor bean but delayed the seed formation when compared to the residues.

TABLE 4

The effect of experimental treatments on seed weight of two crops of castor bean during the 1999 and 2000 growing seasons

Treatments	1999				2000				
	See + Capsule weight ($Kg/16m^2$)	Seed Weight							
		$Kg/16m^2$	Kg/ha	Metric Tonne	Seed + Capsule $Kg/16m^2$	$Kg/16m^2$	Kg/ha	Metric tonnes (MT)	Mean Seed Weight (MT)
(1) Control (no fertilizer)	46.80e	1.17e	731.30e	0.73e	46.70e	1.16e	729.70e	0.73e	0.73d
Sawdust Based Compost	162.20d	42.0d	2628.13d	2.63c	265.70c	6.64c	4151.60c	41.5c	0.73d
Rice bran Based Compost	187.10c	4.67c	2918.80c	2.92b	214.30d	5.36d	3350.0d	3.35d	3.13c
Cocoa husk Based Compost	290.90ab	7.27ab	4545.3b	4.55a	389.20a	9.73a	6081.3a	6.08a	5.32a
NPK 15-15-15	292.10a	7.30a	4562.50a	4.56a	381.00b	9.53b	5953b	5.95b	5.25a

+ Mean seed weight of castor bean contains values of 1999 and 2000 growing seasons.

TABLE 5
Effects of experimental treatments on plant height (cm) of castor bean during the 1999 and 2000 growing season

Treatments	1999	2000	Mean
Control (no fertilizer)	8.00e	7.80e	7.90e
Sawdust based compost	18.00d	21.30d	19.70d
Rice bran-based compost	27.60c	30.20c	28.90c
Cocoa husk based compost	40.40b	46.30b	43.40b
NPK 15 - 15 - 15	45.40a	50.00a	47.80a

Treatment means within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range Test at 5% level.

TABLE 6
Effects on experimental treatments on leaf area index (m^2 of leaf area per m^2 of soil area) of castor bean during 1999 and 2000 growing seasons

Treatments	1999	2000	Mean
Control (no fertilizer)	2.5d	2.80e	2.70d
Sawdust based compost	3.6c	4.5d	4.10c
Rice bran-based compost	3.8c	4.8c	4.30c
Cocoa husk based compost	4.0b	5.00b	4.50b
NPK 15 - 15 - 15	4.5a	5.5a	5.00a

Treatment means within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range test at 5% level.

TABLE 7
Effects on experimental treatments on stem girth of castor bean during 1999 and 2000 growing seasons

Treatments	1999	2000	Mean
Control (no fertilizer)	0.31d	0.30e	0.30d
Sawdust based compost	0.80c	1.10d	0.95c
Rice bran-based compost	0.90c	1.30c	1.10c
Cocoa husk based compost	1.30b	1.60b	1.45b
NPK 15 - 15 - 15	1.50a	2.30a	1.90a

Treatment means within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range test at 5% level.

CONCLUSION AND RECOMMENDATION

Cocoa husk, rice bran and sawdust can be effective sources of nutrients because their additions to the soil enhanced the leaf and soil N, P, K, Ca, Mg content, soil pH, O.M, seed weight, plant height, leaf area index and stem weight, plant height, leaf area index and stem girth of castor bean.

Based on experimental findings, it is recommended that cocoa husk applied at 6t/ha can be used as a fertilizer material for improving the nutrient availability and increasing production of castor bean on low fertility soils in the humid tropics. This recommendation stems from the fact that inorganic fertilizers are scarce and expensive for the growers of castor bean in most tropical countries.

TABLE 8
Effort of experimental treatments on soil chemical composition after harvesting castrol oil bean during 1999 and 2000 growing season

Treatments	Crop 1								Crop 2						
	O.M	N		P	K	Ca	Mg	pH	O.M	N	P	K	Ca	Mg	pH
	%			mg/kg soil			mmol/kg		%		mg/kg soil			mmol/kg	
Control (No fertilizer)	0.41c	0.05d	-	4.20d	0.09c	0.11d	0.13d	5.20cd	0.28d	0.03d	3.80e	0.05d	0.09d	0.10d	5.00cd
Sawdust-based Compost	1.52b	0.12c	-	10.20c	2.18b	0.35b	0.25c	6.60b	1.60b	1.16c	11.30d	2.23c	0.40c	0.32c	6.80b
Rice bran-based Composed	1.62b	0.13c	-	9.35c	2.24b	0.30c	0.28b	6.70b	1.68bc	0.18c	12.40c	2.52b	0.45b	0.48b	6.85b
Cocoahusk-based Compost	2.24a	0.23b	-	15.26b	3.42a	0.80a	0.78a	7.10a	3.10a	0.52b	23.82b	3.63a	1.20a	1.40a	7.20a
NPK 15 - 15 -15	0.32c	0.45a	-	21.45a	3.46a	0.08de	0.07de	5.60c	0.26d	0.58a	27.52a	3.92a	0.03e	0.04e	5.30c

Treatments means within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range Test at 5% level.

REFERENCES

ADEOYE, G.O. 1986. Comparative studies of ammonium bi-fluride chelate extractants and some conventional extractants for sedimentary soils of South Western Nigeria. Ph.D. Thesis, University of Ibadan, Ibadan, Nigeria.

ADU-DAAPH, H.K., J. COBBINA and E.O. ASARE. 1994. Effect of cocoa pod ash on the growth of maize. *Journal of Agric. Science Cambridge* **132:** 31-33.

AGBOOLA, A.A. and R.B. COREY. 1973. Soil testing N, P, K for maize in the soils derived from metamorphic and igneous rocks of Western State of Nigeria. Journal of Western State of Nigeria. *Journal of West African Science Association* **17(2):** 93-100.

Association of Analytical Chemist. 1970. Official method of analysis. Washington D.C.

AYODELE, O.J. 1983. Use of sorption studies for the determination of phosphorus requirement of selected crops. *Trop. Agric. Journal Trinidad* **1:** 27-33.

CROCKFORD, L. and R. NOWELL. 1956. *Laboratory Manual of Physical Chemistry.* Experiments 31 and 32, p. 58-59. New York: John Wiley and Sons.

FOLORUNSO, O.O., A.A AGBOOLA and G.O. AYODELE. 2000. Evaluation of three fertilizer models for P and K requirements for maize in South-western Nigeria. *Journal for Technical Education* NBTE **1 & 2:** 212-220.

JACKSON, M.L. 1958. *Soil Chemical Analysis.* Englewood Ciffs N.J: Prentice Hall.

MCLEAN, E.O. 1965. Aluminium. In *Method of Soil,* ed. M.C.A. Black, pp. 927-9323. Method of Soil Analyses Part 2, Agronomy 9, Amer. Soc. Agron. Madison, Wisconsin, U.S.A.

MURPHY, J. and J.P. RILEY. 1962. A modified single solution for determination of phosphate in natural water. *Analytics Glumni-Acta* **27:** 32-36.

OGUNWALE, J.A. and E.J. UDO. 1979. A laboratory manual for soil and plant analysis agronomy Dept. University of Ibadan. Nigeria. p. 201-206.

OJENIYI, S.O. 1995. That our soil may not die. In *10th Inaugural Lecture* of Federal University of Technology, pp. 3-5, March 23, Akure.

SPORE, C.T.A. 2000 New emerging trend in essential oil industry. A bi-monthly publication of centre for technical agriculture co-operation, Netherlands, p. 3.

WALKLEY, A. and I.A. BLACK. 1934. An examination of Degtajaroff method for determining soil organic acid filtration method. *Soil Science* **37:** 29-38.

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