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Nutritional Aspect of Pureline Paddy *

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DURING the past twenty years much work has been done on the nutritional properties of cereals, notably wheat, maize and oats. With the development of rapid and convenient microchemical and microbiological methods, it was possible to study such problems as (*a*) verietal differences, (*b*) climatic differences, (*c*) effect of soil composition, and (*d*) effect of fertilizers on the vitamin, protein, mineral and fat contents. Since 1940, we have much useful information on some of these aspects but much of the work has been concentrated on wheat, maize and barley. In the School of Agriculture, University of Arkansas, Kik, Williams and others (1, 2) made a comprehensive study of rice grown in the United States and of the 16 varieties studied, 7 were investigated very thoroughly including the effect of milling, rinsing and cooking on their vitamin contents. They also studied the effects of storage and varietal influences on the vitamin content of rice.

Much of the work elsewhere has been chiefly concerned with the effects of processing of rice but the more fundamental problems have been studied more closely at the University of Arkansas. In Ceylon we are experimenting with nearly eighteen strains of pureline paddy and it would be useful to possess precise information on the biochemistry of the different strains in order to improve, among other things, the nutritional qualities of this cereal. We have studied the protein and vitamin contents of eighteen varieties of pureline paddy and all our experiments were conducted on 'brown rice', which is defined as rice obtained from 'rough rice' or paddy by careful removal of the hull without any injury to the germ and pericarp. This was achieved by the simple procedure of rubbing the grains between two pieces of boxwood, applying light pressure and collecting only the whole grains.

Moisture determinations were made according to the method recommended by the Association of Official Agricultural Chemists (3) and modified by Tate & Warren (4). Nitrogen estimations were done by the usual micro-Kjeldhal procedure using the catalyst mixture and digestion time recommended by Chibnall, Rees and Williams, (5). The vitamins thiamine, riboflavin and niacin were assayed by microbiological methods modified in our laboratory. Thiamine was determined by the use of *Lactobacillus fermenti*, riboflavin by *Lactobacillus Casei* and niacin by

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Lactobacillus arabinosus. These organisms are commonly employed for assaying these vitamins but we have modified existing methods to obtain better response and the details of such modifications will be published elsewhere.

We shall digress for a moment to comment on some observations made on other cereals such as wheat, maize and barley. With regard to wheat and barley rapid maturation was found to yield grains of higher protein contents than cereals grown in regions with mild humid climates resulting in a long growing season and slow maturation. Thus wheat and barley grown in the Steppes of Russia and in the Great Plains of North America consistently yielded grains with higher protein content (6, 7, 8). Genetic differences were also factors influencing the protein content although their contribution was not as great as environmental factors. For instance the protein content of hard red spring wheat harvested from 1925 to 1928 varied from 9 to 18 grams per cent. (9). Increasing the available nitrogen of the soil also resulted in an increased protein content of the grain. Thus wheat grown after legumes was generally of a higher protein content than when grown after cereal grains or grasses. Inorganic fertilizers also increased the protein content especially when application was delayed up to the time of blossoming. On the other hand studies on maize at the Illinois Experimental Station indicated pronounced variation in the protein content which was attributed to genetic differences (10). Thus in 39 inbred lines of maize studied the protein content ranged from 9.9 to 17.8 grams per cent. (11). Thus, age of maturation, location, fertilizers and genetic factors influenced the protein content of wheat, maize and barley. In the case of rice, however, there is hardly any information of this nature. According to our results, the protein content calculated on a moisture free basis varies from 7.69 to 11.88 or approximately 8 to 12 grams per cent. (Table II). The lowest values were obtained for the two strains of Suduheenati, being 7.69 for strain ICPY-15 and 8.06 for strain ICPY-19. The highest value of 11.8 was obtained for the 'white' variety Kurulutuduwi b-13. The other two white varieties Podiwi a-8 and Molagusamba g-18 have values of 10.75 and 10.25 respectively. The three 'white' varieties had an almost white pericarp unlike the rest whose colour varied from light to dark brownish red. With the information available we cannot ascribe these differences to genetic and/or environmental factors. Contrary to popular belief rice makes a substantial contribution to the protein in the Ceylonese diet. According to a Food Balance Sheet for 1948–49 prepared by the Director of Census and Statistics (21), of a total of 46g. protein per unit adult consumption per day, 24g. or a little over 50 per cent. come from cereals. One could see therefore, the nutritional significance of genetic or environmental studies to enhance the protein content of cereals in general and rice in particular.

In view of the relationship established between age and protein content of wheat and barley we have analysed our data for similar correlation. Table III gives the average nitrogen values of rice varieties arranged according to the age of maturation, namely 3, 3½–4, and 6 months. With the limited number of samples available our analysis has not revealed any significant relationship between age and protein content.

With regard to vitamin variations in cereals, some recent observations in America and Australia on wheat have established the influence of environment and variety on the thiamine content. For example, one variety of wheat grown in different districts in Australia varied in thiamine content from 360 to 690 μg/100g., clearly indicating the significance of environment (12). A comparison of the average values of different varieties of wheat grown in the United States and Canada showed variations, the thiamine content of soft winter varieties being less than the hard red spring variety (18). Twenty-eight varieties of maize in the United States showed a thiamine range of 230—760μg/100g. (13). M.C. Kik in Arkansas found that the thiamine content of rice was influenced by variety and to a lesser extent by location (2), and gave the thiamine range for 16 varieties of rice as 263–506μg./100g. Our experiments gave a thiamine range of 343–975 μg/100g. (Table II). Vellaiperunel 28724 gave the highest value of 975μg and Perillanel 26014 the lowest value of 343μg. The average thiamine value was 592 as compared with 335 for American varieties (2). The white varieties Podiwi a-8, Kurulutuduwi b-13 and Molagusamba g-18 gave values of 790, 760 and 501 respectively. These figures compare quite favourably with the average value of 592 for all varieties studied. Table III indicates that there is no significant relationship between age and thiamine content. On the other hand, from our results the coefficient of variation for thiamine has been calculated to be 25.7 (Table II) which seems to point to the possibility of genetic and/or environmental factors influencing the thiamine content. In passing it may be mentioned that although Kik (2) reported varietal variations other American workers (19, 20) have failed to observe significant varietal differences among the small number of samples studied.

Unlike thiamine, the riboflavin and niacin contents of wheat and rice do not appear to be significantly influenced by genetic and environmental factors (14, 15). On the other hand the niacin content of maize differs widely, different samples showing up to eightfold variation in the niacin content. A range of 790 to 6210 μg/100g for maize has been reported (16) and the differences are attributed to genetic factors. Richey and Dawson (17) from an extensive survey of the possibilities of breeding maize with a higher niacin content concluded that it was possible to develop strains with a higher niacin content. Our results with rice give (Table II) average values of 157 μg/100g for riboflavin and 6907 μg/100g for niacin, with ranges of 128–198 μg and 5573–7937 μg. respectively. The coefficients of variation are 12.74 for riboflavin and 10.03 for niacin which indicate that these two vitamins are not so appreciably affected by genetic or environmental influences, as thiamine with a coefficient of variation of 25.7. The 'white' varieties compare favourably with other varieties and in fact, one of them Kurulutuduwi b-13 has the highest riboflavin value. Here again no correlation between vitamin content and age could be established.

Accepting the data of the Director of Census and Statistics that 24g. of cereal proteins are consumed per day by an adult, about 270g. brown rice would be necessary to supply this quantity of protein. This is equivalent to a little less than 1½ 'chundus' of rice. This amount should, according to our results, supply the following amounts of vitamins :—

Thiamine 1.4 mg.	(70 per cent.	of recommended optimum requirement)	
Riboflavin, 0.38 mg	(13 per cent.	do.	)
Niacin, 16.7 mg.	(70 per cent.	do.	)

This would show that according to the present average rate of rice consumption, the outstanding vitamin deficiency would be riboflavin. We have not taken into account the appreciable vitamin losses resulting from milling, rinsing and cooking processes to which rice would be subjected before it is eaten. However the above calculation was intended to reveal the chief inherent vitamin deficiency of rice, which is shared by other cereals as well. (e.g. riboflavin values for whole wheat and maize are 100–120 μg and 130–150 μg. respectively).

SUMMARY

(1) Eighteen varieties of pureline paddy were studied including three varieties with a white pericarp.

(2) Marked differences exist in the protein and thiamine contents, probably due to genetic and/or environmental influences.

(3) There is no appreciable variation in the riboflavin or niacin values.

(4) The outstanding vitamin deficiency in rice is riboflavin, but this deficiency is common to cereals.

(5) The protein and vitamin contents of the three 'white' varieties compare very favourably with the average values for all samples.

(6) There is no correlation between age of maturation and the vitamin or protein content.

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REFERENCES

1. Kik, M. C. and Williams, R. R. (1945). Bulletin Nat. Res. Council, Washington, No. 112.
2. Kik, M. C. (1945). Univ. Arkansas College of Agriculture, Bull. 458.
3. Methods of Analysis of the Association of Official Agr. Chemists, 1940, 5th edition, 353.
4. Tate, F. G. H., and Warren, L. A. (1936). Analyst, 61, 367.
5. Chibnall, A. C., Rees, M. W. and Williams, E. F. (1943). Biochem. J. 37, 354.
6. Bailey, C. H. (1925). The Chemistry of Wheat Flour, New York.
7. Wheat Studies, Food Res. Institute, (1934), 10, 229.
8. Bayfield, E. G. (1936). Ohio Agr. Exp. Sta., Bull. p. 563.

9. Bailey, C. H. (1941). Minn. Agr. Exp. Sta., Tech. Bull. p. 147.
10. Frey, K. J. (1949). Agron. J., 41, 113.
11. Rodriguez, L. D. and others (1950). Cereal Chem. 27, 67.
12. Lundie, K., and Robertson, I. (1941). 12th rep. Nat. Heath & Med. Res. Council (Australia), Appendix II., 9.
13. Conner, R. T. and Straub, G. J. (1941). Cereal Chem. 18, 671.
14. Andrews, J. S. and others (1942). Cereal Chem. 19, 55.
15. Tepley, L. J. and others (1942). J. Nutr. 23, 417.
16. Burkholder, P. R. and others (1944). Yale J. Biol. Med. 16, 659.
17. Richey, F. D. and Dawson, R. F. (1948). Plant Physiol. 23, 238.
18. Nordgren, R. and Andrews, J. S. (1941). Cereal Chem. 18, 802.
19. Cailleau, R. and others (1945). Cereal Chem. 22, 50.
20. Williams, V. R. and others (1943). Cereal Chem. 20, 560.
21. Director of Census and Statistics (1949). F.A.O. April, No. p. 236.

TABLE I

Pureline Paddy (Brown Rice)

		Moisture g/100g	*N g/100g*	*Protein NX6.25*	B_1 *µg/100g*	B_2 *µg/100g*	*Niacin µg/100g*
1.	Dahanala 37 YM 2,014 (3)	11·0	1·30	8·13	514	170	5,100
2.	Dewaredderi 26,081 (6)	12·0	1·57	9·81	366	117	6,438
3.	Kaluheenati 39YM 3,254(3½)	12·0	1·44	9·00	590	143	6,548
4.	Kohumawi B—11(6)	10·0	1·45	9·06	555	130	6,064
5.	Kurulutuduwi* b-13 (6)	10·5	1·70	10·63	682	177	6,880
6.	Madael 39 MY 137 (3½-4)	12·0	1·30	8·13	635	119	5,971
7.	Molagusamba* g-18 (6)	10·5	1·47	9·19	448	150	6,944
8.	Murunga 38 YM 137 (3)	11·5	1·63	10·19	537	140	7,025
9.	Oddavalan 2,449/20 (4)	11·0	1·29	8·06	405	114	6,171
10.	Pachchaiperumal 2,462/11 (3)	11·0	1·25	7·81	388	161	5,611
11.	Perillanel 26,014 (4)	13·0	1·35	8·44	298	121	5,973
12.	Podiwi* a-8 (6)	9·5	1·56	9·75	715	155	6,944
13.	Pokkali (4)	10·0	1·34	8·38	572	140	6,053
14.	Suduheenati ICPY-15 (3½)	12·0	1·08	6·75	574	134	4,905
15.	Suduheenati ICPY-19 (3½-4)	10·5	1·15	7·19	469	129	5,365
16.	Sulai 27,614 (3½)	10·0	1·63	10·19	477	132	5,973
17.	Vellai Illankalayan 28,061 (4)	11·5	1·37	8·56	380	137	6,836
18.	Vellaiperunel 28,724 (3)	10·5	1·54	9·63	873	149	5,823
	Average Values	11·0	1·41	8·83	527	140	6,146
	Standard Deviation	0·88	0·185	1·156	137	16·5	580

* Indicates " white " varieties, *i.e.*, with a white pericarp. ( ) Age of maturation is given within brackets.

TABLE II

Pureline Paddy (Brown Rice)

(Values calculated on a moisture-free basis)

	N g/100g	Protein NX6.25	B_1 µg/100g	B_2 µg/100g	Niacin µg/100g
1. Dahanala 37 YM 2,014 (3)	1·46	9·13	578	191	5,730
2. Dewaredderi 26,081 (6)	1·78	11·13	416	133	7,315
3. Kaluheenati 39 YM 3,254 (3½)	1·64	10·25	671	162	7,440
4. Kohumawi B-11 (6)	1·61	10·06	617	144	6,739
5. Kurulutuduwi* b-13 (6)	1·90	11·88	762	198	7,689
6. Madael 39 MY 137 (3½-4)	1·48	9·25	722	135	6,786
7. Molagusamba* g-18 (6)	1·64	10·25	501	168	7,759
8. Murunga 38 YM 137 (3)	1·84	11·50	607	158	7,937
9. Oddavalan 2,449/20 (4)	1·45	9·06	455	128	6,935
10. Pachchaiperumal 2,462/11 (3)	1·40	8·75	436	181	6,306
11. Perillanel	1·55	9·69	343	139	6,866
12. Podiwi* a-8 (6)	1·72	10·75	790	171	7,671
13. Pokkali (4)	1·49	9·31	635	156	6,726
14. Suduheenati ICPY-15 (3½)	1·23	7·69	652	152	5,573
15. Suduheenati ICPY-19 (3½-4)	1·29	8·06	524	144	5,994
16. Sulai 27,614 (3½)	1·81	11·31	530	147	6,637
17. Vellai Illankalayan 28,061 (4)	1·55	9·69	441	155	7,725
18. Vellaiperunel 28,724 (3)	1·72	10·75	975	166	6,506
Average Values	1·59	9·94	592	157	6,907
Standard Deviation	0·151	0·944	152	20	693
Coefficient of Variation	9·47	9·47	25·7	12·74	10·03
Range	1·23—1·90	7·69—11·88	343—975	128—198	5,573—7,937

* Indicates "white" varieties, *i. e.*, with a white pericarp. ( ) Age of maturation is given within brackets.

TABLE III

(Values calculated on a moisture-free basis)

	N g/100g	B_1	B_2 µg/100g	Niacin
6 month-Varieties (5 varieties)				
Average value	1·73	619	163	7,434
3½-4 month-Varieties (9 varieties)				
Average value	1·50	553	146	6,742
3 month-Varieties (4 varieties)				
Average value	1·60	649	174	6,620

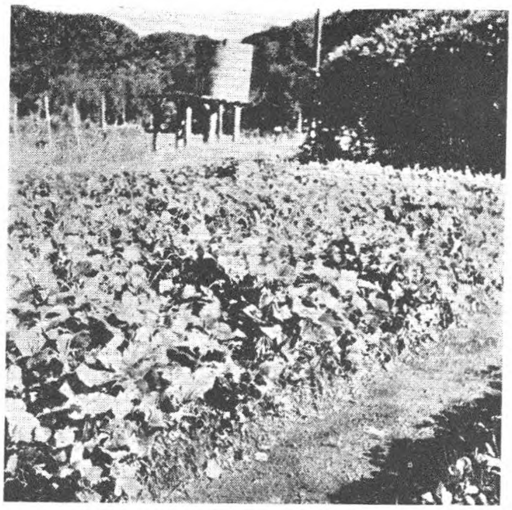

Photo 1.—Tropical kudzu

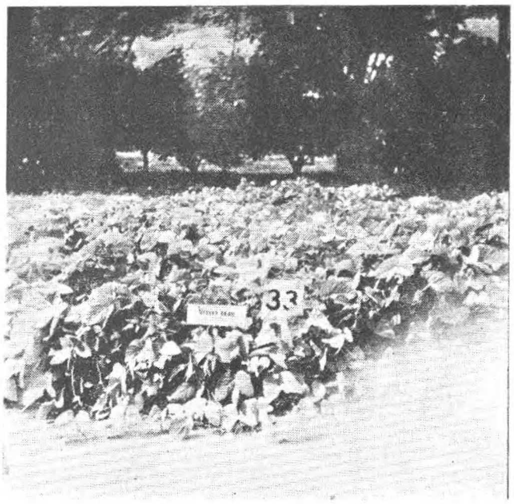

Photo 2.—Velvet bean

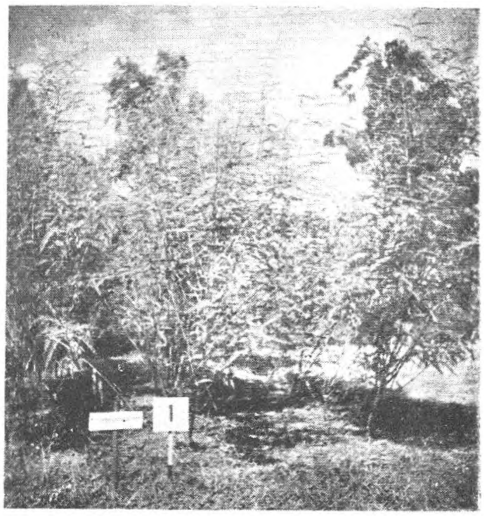

Photo 3.—*Sesbania cinerascens*

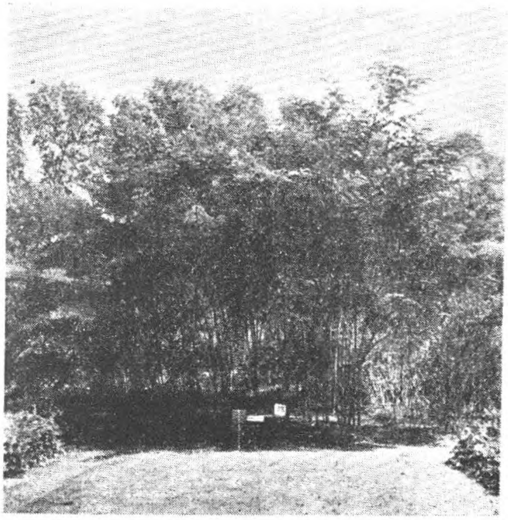

Photo 4.—*Indigofera teysmanii*

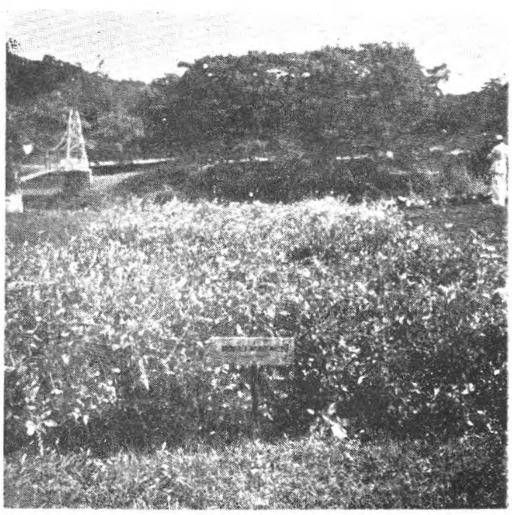

Photo 5.—*Desmodium limense*

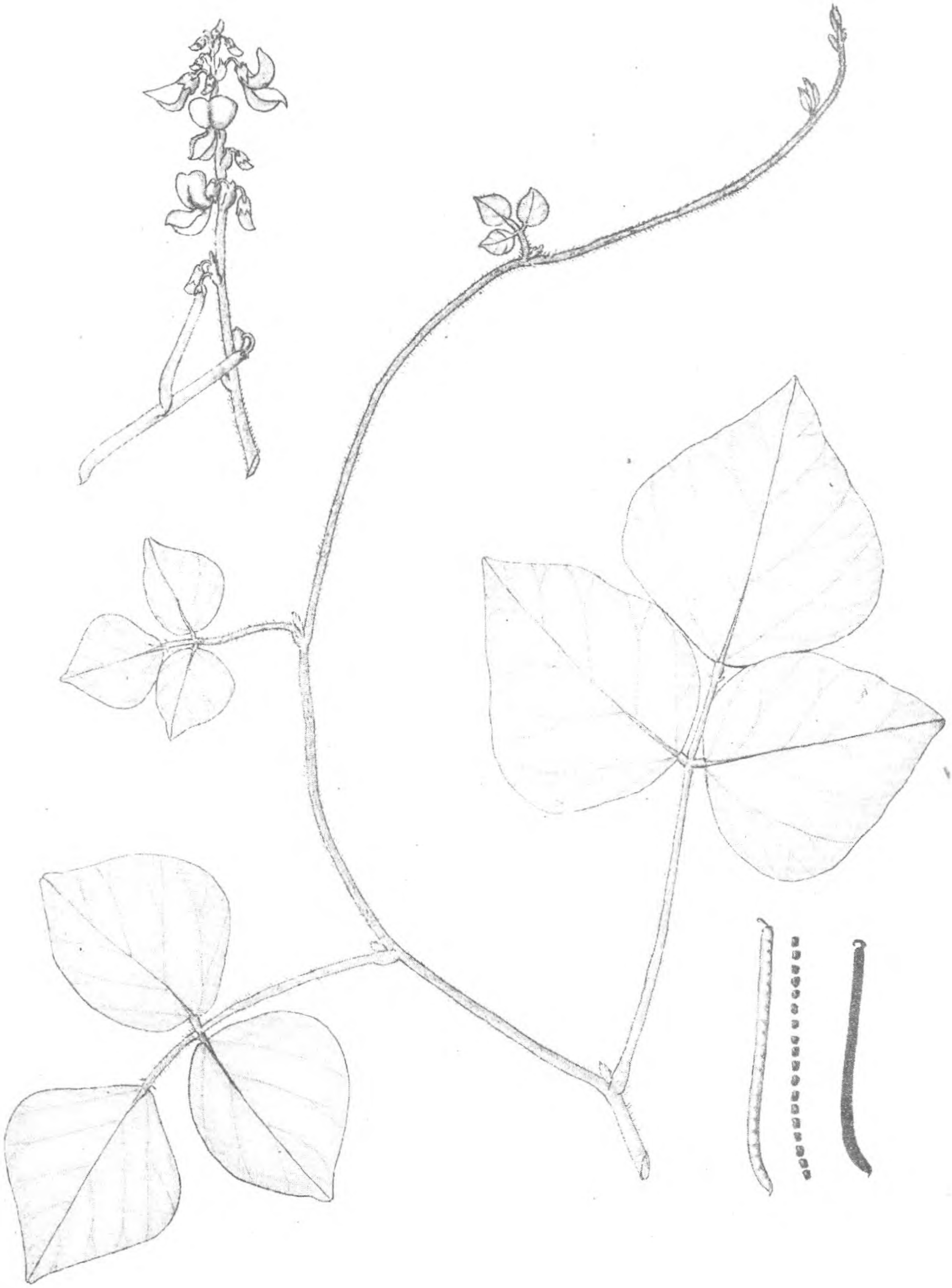

Fig. I—Tropical kudzu (*PUERARIA PHASEOLOIDES* (Roxb.) Benth.)—Showing a part of the raceme with flowers and pods, the twining stem with trifoliate leaves and mature pods and seeds.