INVESTIGATIONS INTO SOME ASPECTS OF THE PRODUCTION AND GENETIC IMPROVEMENT OF SOYABEAN, *GLYCINE MAX* (L.) MERRILL IN UGANDA

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"A thesis submitted in part fulfilment of
the requirements for the degree of
Master of Science in Agriculture
in the University of East Africa"

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April, 1969

I, Patrick Rutimbanzigu Rubaihayo, hereby declare that the work presented in this thesis has not been presented in any previous application to another University for a degree.

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TABLE OF CONTENTS

SUMMARY

The present investigations have revealed that Soyabeans were of considerable agricultural importance in the 1940's but the present acreage sown to Soyabean is quite insignificant. The crop can be satisfactorily grown in many parts of Uganda. With the present government's diversification policy and adapted high yielding cultivars and a good knowledge of agronomic aspects of cultivation, Soyabean production can be expected to increase again and be able to contribute to the agricultural economy of the country.

The experimental work described in the thesis was aimed at the evaluation of as many as possible of the available soyabean cultivars at Kabanyolo University Farm in order to screen out some potential commercial cultivars for the country and also to investigate problems of Soyabean cultivation.

A large number of cultivars has been collected at Kabanyolo for trial. They were grouped into three groups based on the period from sowing to maturity. The quick maturity types yielded poorly and the very longest termed cultivars did not crop well while the medium to the long term types yielded best. Some cultivars have yielded over 3000 lbs. per acre on experimental plot basis and have been recommended for commercial production.

The optimum time of planting has been investigated and, as with many other crops, yields can fall rapidly if planting is delayed once the rains have properly broken. The results have shown that Soyabeans should be planted with the first consistent rains, but if they come and then stop for more than three weeks, then the time regarded as early planting is when they start again. The problem of it being very difficult in practice to decide when it is safe to assume that the rains have really begun is considerable in East African agriculture. This is usually clear retrospectively but that is too late. Reduction in yields of over 40% have been recorded with 5 weeks of delayed planting after the rains have started.

The spacing has also been investigated and narrow inter-row and intra-row spacing arrangement has been found to give the highest yields. Yields were increased by over 40% by changing from the traditional spacing of 24" x 4" to 12" x 2". The major limitation for closer inter-row spacing is weed control and this remains a practical difficulty in the cultivation of the crop. Further research needs to be done with herbicides from the start that has been made and is reported in the thesis.

Soyabeans appear to show fairly inconsistent response to single fertiliser application but have showed constant and significant positive response to mixed fertilisers.

The interactions between cultivars (genotypes) and environments (seasons and locations) have been investigated. The genotype x season interactions were not significant at 5% level of probability but the genotype x location interactions were significant at the same level. This stressed the importance of using centres all over the country for testing and selecting cultivars to be recommended for commercial production.

1.1 Introduction

Although the Soyabeans have been grown in China for a long time, the U.S.A. is at present the major producer. Soyabean production as a real commercial crop in the U.S.A. began in 1930's. Acreage, average yields per acre and production have increased fairly steadily since that time. In 1965, the U.S.A. produced 71% of the world's output (Bentley, 1967).

Through efforts of research workers, important improvements have been made in climatic adaptability, yield of seed, protein and oil content, and resistance to lodging, shattering and disease. Due to the success of plant breeders there are now cultivars of Soyabean adapted to a wide range of climatic and soil conditions. The three main reasons for the increase in Soyabean yield per acre have been (a) improvements in genotype (b) general improvement in mechanisation and (c) improved planting and cultural practices including better weed control and increased use of fertilisers.

While direct consumption has produced the incentive for increased production in the Far East, the very rapid growth in production in the U.S.A. has largely been to supply meal to feed livestock. Soyabeans are grown for seed, hay, green manure and to a lesser extent for silage. Because of the valuable properties of the seed as a source of oil (up to about 20%) and protein (to about 40%), great importance is attached to its production as a raw material for oil extraction and there is an international demand for the seed used in the manufacture of high protein foods. The oil is used in foods, e.g. margarine, and cooking oils and also in industry for paints, varnishes, lubricants and printing ink. Because of their versatility and relative cheapness (35 Uganda cents per lb. in U.S.A. 25 cents per lb. in Uganda), soyabeans have become major oil seeds of the world trade, competing favourably with the more traditional oil sources such as olive, groundnuts and cotton seeds. Table 1 compares the prices of oil from these sources.

TABLE 1: Table of Vegetable oil prices (US cents/kg)
Source: FAO Production Yearbook, 1964

Year	Olive Oil (Italy)	Soyabean (U.S.A.)	Groundnuts Oil (European port)	Cotton Seed Oil (U.S.A.)
1955	84.3	25.6	28.8	28.0
1956	132.7	29.1	36.9	30.2
1957	88.8	26.9	36.0	29.8
1958	77.1	23.1	37.6	28.0
1959	99.1	19.8	30.0	24.7
1960	90.7	19.4	32.7	21.8
1961	83.0	25.5	33.0	28.7
1962	92.0	19.8	27.4	25.4
1963	112.6	19.6	26.8	22.9
1964	100.1	20.3	31.0	22.7

Soyabean protein is also relatively cheap as shown in Table 2.

Table 2: Table of Protein Prices in the U.S.A.
Source: Soyabean Digest, Sept., 1965.

Source	Dollars per lb.	% Protein	Dollars per lb. dry protein
Beef	0.70	15.2	4.60
Pork	0.50	11.6	4.30
Poultry	0.30	20.0	1.50
Non-fat dry milk solids	0.145	35.6	0.41
Dry beans	0.08	23.1	0.35
Soyabeans	0.05	34.9	0.14

On grounds of price the Soyabean compares well as a source of protein, oil, and livestock feeds with other vegetable and animal sources.

The problem of its acceptibility in the local diet seems to be diminishing as the new processed products come to market. Various attempts have been made in a number of countries to introduce Soyabean into the local diet. According to De et.al. (1967) on information from Asian countries, in most cases trials of Soyabeans as a food were restricted to institutions and the results were promising, but commercial production was never started. Extensive studies carried out by the Indian Research Fund Association, however also failed to show any superiority of soyabean over local pulse crops, e.g. green and black gram, chick peas and pigeon peas.

Eating habits, cultural patterns, and marketing facilities are all important considerations for the introduction of a new type of food. The food must possess organoleptic characteristics (taste, smell, colour, texture, etc.) that fit the expectation of the consumer and it should be presented in a form which would be easily incorporated in the local dishes or have resemblance to local foods and beverages. Attempts have been made in a few countries in Africa to introduce soyabean products without much success so far. In Uganda imported soyaflour has, however, been used successfully in the children's clinics and medical units. Popularisation of the soyabean has been rather difficult in countries which already have abundant supply of acceptable vegetable protein sources such as groundnuts, peas and beans and which soyabean is more or less unknown. One of the reasons for the decline (see later) of production after the world war II in Uganda was that soyabeans were unacceptable as a pulse because of the difficulty of cooking and flavour. Special processing methods therefore have to be introduced if the soyabean is to be successfully incorporated into the local diet.

Processing has already started in Uganda. A factory milling soyabeans has been put up to provide flour for the manufacture of protein-rich bread and buns. Already the Uganda Ministry of Education has a programme established in the Kampala area to provide soyabean buns at 10 cents each (each bun is equivalent in food value to an egg, each at 40 cents) to all children in government schools in the middle of the morning and hopes to expand this programme on a nationwide basis as sufficient supplied become available. In relatively short time most of the soya protein mixtures, e.g. soya sauce, soyamilk, soyaporridge, ect. will be on commercial production in Kampala. This will give proteins of an equivalent quality to the present animal proteins but at a greatly reduced price per unit of protein. Another factory in Jinja has started using soyabeans for the manufacture of animal feeds. One hopes that these feeds will be cheaper than imported feeds which in turn will make it cheaper to feed livestock, pigs and chicken thus producing cheaper eggs, milk, and meat. If this is realized, it should go a long way in answering protein malnutrition problem of Uganda.

There is no reason to suppose that it should not be possible to select soyabean cultivars suited to cultivation in

Uganda. The crop having so many advantages, it was considered in view of the policy of agricultural diversification that a new attempt should be made to re-introduce it into the agriculture of the country.

The work described in this thesis was aimed at evaluating many soyabean cultivars hoping to screen out some potential commercial cultivars for the country and to lay the foundations for a breeding programme to follow. Some variety trials and very little agronomic work had been carried out in Uganda before the work reported here was started. The effect on yield of agronomic factors like plant nutrient levels, weed control, spacing and time of planting was not evaluated simultaneously with the testing of the cultivars and thus the trials had rather limited value. The number of cultivars was also small. It is very important to understand fully the agronomic requirements of a crop before attempts on improvement are made. The environmental conditions should be such that the full potential of the genotype can be expressed but it is also valuable to be able to assess the relative merits of different genotypes in a range of environments. Many local and exotic cultivars have been collected at Kabanyolo and a study of the agronomic aspects of the cultivation of soyabean has been made in the present investigations.

1.2 Taxonomy

Ricker et. al. (1948) pointed out that the name of the soyabean according to the international rules of botanical nomenclature should be Glycine max (L.) Merill, and this name is now generally accepted. Glycine max belongs to the sub-family Papilionoideae of the Leguminosae. The genus includes between thirty and fifty species distributed generally throughout Asia but Glycine javanica is indigenous to Africa. The taxonomy of the soyabean as with many other crops species has been confused. Truly wild forms of Glycine max are not known and it is thus a cultigen but a closely allied form, Glycine ussuriensis (Morse, 1950), occurs commonly throughout Eastern Asia. It is believed that Glycine max originated from this wild species as there are intermediate forms grading from the wild into the domestic type. According to Veatch (1934) both Glycine max and Glycine ussuriensis with 2n = 40 are inter-fertile and their hybrids usually have normal fertility.

There is a great variation within the species Glycine max in many characters both of direct agricultural importance and others. Some variable characters and their mode of inheritance are shown in Table 3. The first mentioned character in each case is governed by a dominant allele.

Table 3: Table of some variable characters and their mode of inheritance

Source: Johnson et. al. (1962) Soyabean Genetics & Breeding

Character	Description	Inheritance	Reference
Plant habit	Tall, late plant	single gene	Woodworth 1923
	Short, early	single gene	
	Indeterminate stem	single gene	Woodworth 1933
	Determinate stem	single gene	
Leaves	Broad leaflets	single gene	Nagai 1926
	Narrow leaflets	single gene	
	Five leaflets per leaf	single gene	Takahashi et. al. 1919
	Three leaflets	single gene	
Pubescence	Brown	single gene	Woodworth 1921
	Gray	single gene	
Flowers	Purple	single gene	Takahashi et. al. 1919.
	White		
Pods	Dark	single gene	Woodworth 1923
	Light brown	single gene	
	Shattering	single gene	
	Nonshattering	single gene	Nagai 1926

Table 3 (continued)

Character	Description	Inheritance	Reference
Branches	Long, spreading	single gene	Nagai 1926
	Short, erect		
Seed coat	Yellow	single gene	Terao 1918
	Green	single gene	
	Brown	single gene	Nagai 1921
	Reddish-brown	single gene	Nagai 1921
	Black	single gene	Nagai 1921
	Brown	single gene	Nagai 1921
Cotyledons	Yellow	Cytoplasmic	Terao 1918
	Green		
Oil content	from about 15 - 25%	Partial dominance	Leffel et. al. 1958
Protein content	from 20 - 40%	slight partial dominance	Leffel et. al. 1958
Photoperiodic response	Day neutral, long-day, short-day	-	-

There is in general a negative correlation between oil percentage and protein percentage (Weiss et. al. 1952).

1.3 Origin and distribution

When the soyabean was first developed as a cultivated crop is not known. According to Morse and Cartter (1937) the plant was extensively cultivated in China long before written records were kept and the first records of the plant occurs in a "Materia Medica" written by Emperor Shen Nung in 2838 B.C.

Nageta (1960) has reviewed the literature on the subject and concluded that the origin of the soyabean culture still remains obscure. His results, however, indicated that the origin was in China, especially in the North and Central China. He based his conclusions in part on the distribution of *Glycine usseriensis* which he considers to be the progenitor of *Glycine max*. According to Morse (1950) there is little doubt that *Glycine max* was derived from *Glycine ussuriensis* since apparently no other wild plant found can possibly be its ancestor.

The early spread of the soyabean from China to other parts of the world is also speculative. Nageta, according to Johnson et. al. (1960) has postulated that soybean was introduced into Japan via Korea and presented information to suggest that it was introduced into Korea directly from North China sometime during the period 200 B.C. to 300 A.D.

According to them, Hamada in 1955 described preserved types from China stored in the Shosoin Treasury since about the seventh century that resembled the short-season types currently grown in Kyushu and Loochoo Provinces of Japan. Nageta (1960) interpreted this to indicate that the short-season types of Japan may have been introduced directly from Central China to South Japan.

According to Dies (1949) soyabean was introduced to Europe in 1712 by Engelbert Kaempfer, a German botanist who had spent the years of 1691 and 1692 in Japan and was introduced to America in 1804 by a Yankee Clipper ship coming from China. Dies states that Mease of Pennsylvania first mentioned in America literature shortly after this importation that the soybean was adaptable to Pennsylvania and should be cultivated.

The soybean is now cultivated throughout East and South-East Asia and extensively in North America. It is grown on a relatively small scale in India, Africa and South America. Although the soyabean was originally domesticated as a sub-tropical plant, cultivars adapted to the temperate, tropical and equatorial climates have since been developed. They are grown successfully as far South as Australia and as far North as Canada and can be grown successfully in the 12 hour days at the equator.

1.4 The natural breeding system

Soyabeans are completely self-fertile and normally they are self-pollinated. The flower opens early in the morning, although the time of opening may be delayed in cool, damp weather and in extreme cases the flower may not open at all. The pollen is normally shed cleistogamously. According to Garbar (1926) some natural cross-pollination occurs, but the amount is generally believed to be considerably less than one percent. Weber et. al. (1961) considers that the amount of outcrossing under natural conditions is about 0.5 per cent for plants in adjacent rows and up to 1 per cent for plants grown in close contact. According to Johnson et. al. (1960) Athow has observed as much as 16 per cent outcrossing of plants infected with tobacco ringspot virus (soybean bud blight disease). Casas (1961) obtained 5.2 per cent outcrossing of normal plants in cages containing honey bees compared to only 0.6 per cent for plants outside the cage. One must thus expect that the amount of cross-pollination will vary with density of plants per unit area and the population and activity of potential pollinators like bees.

A search by the geneticists for male-sterile, female-fertile types has so far been unsuccessful. Casas (1961) attempted the use of some selective gametocides but although pollen viability was reduced by the chemicals, the flowers failed to open properly and an actual decrease in outcrossing resulted compared with untreated checks.

Soyabean flowers are normally about 5 to 7 mm long and their smallness and fragileness impose a limitation on the ease with which controlled pollinations can be made. Artificial crossing is a tedious operation since the floral parts are so small and the time of emasculation and pollination varies greatly depending upon environment for best results. Flowers may be emasculated and pollinated the same day or on different days. Auckland (1965) working in Tanzania and Weiss (1949) working in the U.S.A. have suggested different times of the day to get the best results from emasculation and pollination. Auckland obtained the most satisfactory results between 8 and 11 a.m. while Weiss reported that the best results were obtained by emasculation and pollination from 4 p.m. to 7 p.m.

1.5 A case for soyabean production in Uganda

1.5.1 Nutritional justification

It is now generally recognised that protein malnutrition is a serious medical problem in Uganda despite generally adequate quantities of food. On a world basis too the supply of protein is inadequate. The protein deficiency expected in 1970 is estimated by Altschul (1967) to be 10 million tons of which 5.5 million is animal protein. The total protein deficit expected is 12% of the total supply two years ago and the deficit of good protein (well balanced in essential amino acids) is 22% of what was available then. In light of this grave situation, it is desirable to develop resources for cheap protein production so as to avoid increased cases of Kwashorkor and marasmus and also potentially to help other countries by producing an exportable surplus of high protein foodstuffs.

The high protein foods utilised in this country are mainly of animal origin such as eggs, milk, meat, fish, etc. but all of them are too expensive for regular dietary consumption and tend to be regarded as luxuries. Of the established crop plants, soyabeans offer the most economical and practical source of edible protein. A comparison of different foods for their food values is given in Table 4.

Table 4: Table of Protein contents and other food values of various foods used in tropical countries.

Source: B.S. Platt, M.R.C. Special Report No.302 (1962)

Food	Representative values for 100 gm of edible portion			
	Water (ml)	Protein (gm)	Fat (gm)	Carbohydrate (gm)
Maize meal (Zea mays)	12	9.5	4.0	72
Sorghum flour (Sorghum spp.)	12	10.0	2.5	73
Wheat flour	13	11.0	1.6	72
Bulrush millet meal	10	9.0	3.0	76
Finger millet meal	12	5.5	0.8	76
Rice polished	12	7.0	0.5	80
Fresh cassava	60	0.7	0.2	37
Banana	70	1.0	0.3	27
Irish potato	80	2.0	-	17
Sweet potato	70	1.5	0.3	26
Cowpea	10	22.0	1.5	60
Pea (Pisum sativum)	10	25.0	1.0	57
Kidney bean	10	24.0	1.0	46
Pigeon pea	10	20.0	2.0	58
Soyabean seed	8	35.0	18.0	20
Soyabean curd	85	7.0	4.0	3.0
Soyabean 'Milk'	93	3.4	1.5	1.0
Whole cow's milk	88	3.3	3.6	4.7
Human milk	87	1.3	4.6	7.0
Fresh water fish	78	18.0	2.5	-
Lean beef	66	19.0	14.0	-
Egg	74	13.0	11.5	0.5

There has so far been no vegetable source of proteins in Uganda that has a high enough and sufficiently well balanced protein content in a form that can be easy to eat in sufficient quantity to supply the protein needed for a growing child. The traditional vegetable protein suppliers - the beans and cowpeas are mainly eaten as pulse which makes it difficult for young children to eat the large quantities required to supply sufficient daily protein needs whereas the soyabean in a processed form could suffice.

The soyabean, as a dietary constituent is nutritionally comparable with cow and human milk as shown in Table 4, but at the same time is rich in iron and in vitamin C when sprouted. Soyabeans are perhaps the world's oldest protein rich food crop and for centuries nutritionally they have provided major protein rich food products for people of Asia. Because of their great food value, they are now becoming more and more firmly established in the diet of Americans. Thousands of dishes and products are prepared to utilize this most nearly balanced (in the ten essential amino acids as shown in Table 5) of all vegetable proteins.

Table 5: Table of Essential Amino Acid human daily requirements and content from different sources

Amino Acid	Requirements		Amino Acid content per 100 gm protein			
	Infant (gm)1/	Adult (gm)1/	Soya-bean curd 2/	Haro-soy soya-bean 2/	Soya protein concentrates 3/	Content of "balanced protein" 2/
Lysine	5.6	3.2	5.0	6.5	6.6	4.2
Methionine	2.8	0.9	1.2	1.0	1.3	2.2
Cystine	-	-	1.2	1.2	1.6	2.0
Tryptophane	1.0	1.0	1.0	1.8	1.4	1.4
Threonine	2.9	2.0	3.2	3.7	4.3	2.8
Isoleucine	3.0	2.8	4.3	4.2	4.9	4.2
Leucine	14.0	4.4	7.6	8.0	8.0	4.8
Phenylalanine	5.6	4.4	4.8	4.9	5.3	2.8
Valine	5.4	3.2	4.0	4.6	5.0	4.2
Histidine	-	-	1.7	2.6	3.6	2.4

1/ Richard J. Block and Weiss K.W. (1956) Amino Acid handbook. Methods and results of Protein Analysis - Charles C. Thomas.

2/ Evans, R.J. and S.L. Bandemer (1967) Nutritive value of legume and seed protein. Agriculture and Food Chemistry, Vol. 15, No. 3, pp. 439.

3/ E.W. Meyer, Soya Protein concentrates and Isolated (1966).

The soyabean with its about 40% proteins on a dry weight basis in favourable cultivars and a satisfactory amino acid balance should be a possible remedy to Uganda's protein malnutrition. With the good quality and high quantity of soyabean proteins, a smaller amount would be eaten to get the necessary protein requirement as compared to other grain legumes. Soyabeans also have the advantage of being able to be processed into many different edible forms. Soyabean protein foods such as CSM (70% maize, 25% soya protein concentrate and 5% milk) are now being used in child-feeding programmes by UNICEF replacing milk solids. Other protein mixtures, e.g. soya porridge, vita-soya curd, soya paste, soyasauce, soyamilk, etc. are on a commercial scale of production in Asiatic countries and the U.S.A. Soya protein concentrates are also becoming more and more popular. The soya protein concentrates has been defined in the Soyabean Digest vol. 26, No. 6 (1966) as "the product prepared from high quality, sound, clean, dehulled soyabeans by removing most of the oil and water-soluble nonprotein constituents and shall contain not less than 70% protein (N x 6.25) on a moisture-free basis". The major current food uses of soya protein concentrates include comminuted "meat" products, "sausage", luncheon loaves, breading and breakfast cereal.

The soybean has also become a major source of protein foodstuff for poultry, pig and other livestock in many areas of the world within the last 50 years. There is no background of experience in feeding soyabeans to poultry, pigs and livestock in Uganda. In light of worldwide recognition that soyabeans provide the most valuable source of vegetable protein for livestock feeding, such a position is paradoxical in a country that can both grow this crop and which also has a rapidly expanding livestock industry. The possibility of curtailing expensive feed imports by introducing soyabean feedstuffs has a clear economic appeal.

Of course, the value of the soyabean does not lie with the protein content alone but rather in the fact that there is a simultaneous high demand for both oil and protein, either directly or indirectly in human food. The demand for edible oil in this country is so high that recently the railway authorities had to convert some petrol tanks to vegetable oil tanks. These vegetable oils are imported in large quantities from the European Common Market. The demand for the oil and meal has been increasing in recent years and appears to be getting stronger in the coming years. Vegetable oils appear to be in high demand in a number of other countries. According to Hymowitz

(1968) from September, 1965 to the end of 1967, over 200,000 metric tons of soyabean oil was imported into India by the State Trading Corporation and over 28,000 metric tons by International Agencies in the same period. It appears reasonable therefore, to assume that if soyabeans were produced on large scale in this country they would have adequate local and foreign markets which is a very important economic fact in any large scale crop production for commercial purposes.

1.5.2 Previous attempt - History in Uganda and East Africa

Greenway (1945) considers that the first introduction of soyabean into East Africa was made in 1907 and 1909 at Amani with seeds from the U.S.A. Further introductions to Amani were made in 1911 from China, Japan and South Africa. The Uganda Department of Agriculture Annual Report (1913) makes the first reference to soyabean in Uganda in 1913 at a Kampala plantation. From the report it appears that soyabean had already been on the plantation for some time. The plantation itself was established in 1908 and it is therefore probable that soyabeans were introduced to Uganda at about the same time as they were introduced to Amani.

According to the Uganda Department of Agriculture Annual Reports in 1914-1915 soyabeans were planted in young coffee as a catch crop at Kakumiro plantation in Mubende. There was no local demand and prices were not high enough to allow transport elsewhere and so the following crops were used as green manure. By 1920 the botany section of the Department of Agriculture had started conducting field trials at Kakumiro, Bukalasa and Simsa (Teso) plantations and yields of over 400 pounds per acre were recorded at Simsa. Between 1922 and 1930 yield trials were conducted at Serere and consistent yields of over 600 lbs. were reported but again there was no local demand as local people disliked the soyabean finding it unpalatable as a dry pulse. Between 1931 and 1938 the soyabeans on all the Government plantations were mainly used as legume green manure crops the use of which was very fashionable at that time.

In 1938, however, the role of soyabean in Uganda agriculture changed since it became valuable for its seed with the beginning of the second world war. A cultivar of soyabean imported from Imperial College of Tropical Agriculture, Trinidad in about 1930 (Uganda Department of Agriculture Annual Report, 1938) which originally came from Venezuela was giving good seed yields and was tested for its food value. It had 30 - 40% crude protein and about 17% fat.

It was later to become known as "Local" in the variety trials that followed. In the same year numerous cultivars are reported to have been introduced from South Africa and the U.S.A. Small plots of imported types restricted to yellow beans only presumably with a view to production for export mainly for direct human consumption, were planted in both seasons of 1939 for observation and a variety trial was planted at Bukalasa each season to test the more promising types chosen from previous increase plots. The results of the variety trials are shown in Table 6.

Table 6: Table of Variety Trial Yields in pounds per acre for 2 seasons 1939 to 1940: Source: Agriculture Report (1940).

Variety	Country of Origin	1st Rains March sown (lb/acre)	2nd Rains Sept. sown (lb/acre)
Local	Venezuela	922	958
Barberton YI	S. Africa	536	550
Palmetto	U.S.A.	647	733
R 42	S. Africa	819	937
R 51	S. Africa	690	735
R 184	S. Africa	712	966
R 304	S. Africa	635	691
R 42a	S. Africa	851	-
	LSD (P = 0.05)	151	161

Varieties R 184 and R 42 were selected and bulked for distribution in the 1940 seasons. Variety trials continued at all centres (Kampala, Serere, Bukalasa, Kawanda and Kakumiro). From 1941 all work on soyabean was concentrated at Kawanda which then carried on variety trials and seed multiplication. The years 1943 to 1946 saw a boom in soyabean production in the country as shown in Table 7 when larger quantities were required to feed the troops in the 2nd World War.

Table 7: Table of Acreage, Production and Estimated Value of soyabean in Uganda from 1944 to 1958.

Source: Uganda Department of Agriculture Annual Reports (1940 to 1960).

Year	Acreage harvested	Production marketed (tons)	Estimated Value £
1944	32,480	3,000	-
1945	33,936	3,060	-
1946	20,616	-	-
1947	16,339	1,401	12,293
1948	15,990	2,292	27,390
1949	22,443	3,127	37,916
1950	20,282	4,314	38,799
1951	12,251	1,312	20,210

Table 7: (Continued)

Year	Acreage harvested	Production marketed (tons)	Estimated Value £
1952	8,447	169	3,785
1953	3,447	-	-
1954	13,246	-	-
1955	4,816	-	-
1956	4,768	-	-
1957	1,211	-	-
1958	2,769	-	-

Encouragement for soyabean production in Buganda was given throughout 1942 and seed stocks were increased during the year to enable large scale planting to take place in 1943 as the crop was very popular by that time in Buganda. There was a keen demand for all available seeds. This led to the distribution of any seeds available which included "genetic rubbish". The acreage planted was only limited by the seed supply and areas planted justified an estimate of 3,000 tons for sale in 1943 to 1944. Small acreages of soyabeans were also grown in Bunyoro, Toro and Ankole for seed multiplication. The crop gained some favour as a food and small amounts were consumed by growers in the famine period 1943/44 both in Buganda and the Western Region. In 1945 large scale soyabean cultivation was extended to Ankole, Toro, Bunyoro and Lango but significant progress was only recorded in Ankole where the crop grew well and provided a useful cash crop. Also in this year, the multiplication task was finished and then research into spacing, inoculation, time of planting and variety trials started again. The results of these trials are shown in Tables 8, 9 and 10.

Table 8: Table of Spacing Trial at Nawunzu-Busoga (1945). Yield lbs. per acre. Source: Uganda Department of Agriculture Annual Report (1945).

Spacing	Yield pounds per acre
24" x 6"	997
18" x 6"	968
12" x 6"	957
12" x 12"	857
Broadcast	685

No information on cultivar used, replication, plot size and LSD was reported.

Table 9: Table of variety trials carried out at Serere in 1945. Yield in lbs. per acre. Source: Uganda Department of Agriculture Annual Report (1945).

Variety	Yield	Variety	Yield
S 42	553	Hernon 5	453
S 113	462	Hernon 6	745
S 119	379	Hernon 18	671
S 256	531	Hernon 29	571
S 263	505	Hernon 36	523
R 265	244	Hernon 49	640
S 273	301	Hernon 286	375
R 332	318	Dixie	379

No information on standard error, plot size and replication was reported.

Table 10: Table of Spacing - inoculation trial at Kawanda in 1945. Yield in pounds per acre. Source: Uganda Department of Agriculture Annual Report (1945).

Cultivar	Spacing	
	12"	6"
Venezuelan	968	819
S 42 Serere	1204	992

Cultivar	Spacing	
	12"	6"
S 42 Kawanda	1132	1091
S 119 Kawanda	1003	1179
R 184	1122	1297
R 265	1012	993
S 273	1175	1164
S 304	1090	1198
R 332	1031	1169
Dixie	1073	1109

Unfortunately the reports do not describe the work done in full. Such information as plot size, replication, standard error, and the response to or the source of the culture of the *Rhizobium* inoculum are not given. It is not clear whether the spacing given was for between rows or square!

With the end of the war in 1945 the European market for soyabean collapsed and there was little or no commercial contact with Far East until much later, so soyabean production declined accordingly as the crop was mainly a cash crop. The Government increased prices in 1948 from about 9 to 11 cents per pound but this gave inadequate encouragement to prevent the declining trend. Some new importation of several American cultivars was made including Acadian, Volstate, Ogden, Avoyelles and Mamloxi to try and improve yields but this seems to have met with little success. Some interest was taken in the Protein and oil contents of various cultivars in the late 1940's but does not appear to have gone very far as the soyabean steadily lost its place in the agriculture of the country. From 1950 the research centres gave up all serious work on soyabeans until 1965 when Kawanda Research Station started country-wide collection of whatever of the former genotypes had survived - which implies some degree of local adaptation, and these survivors now having lost their original identity and occurring in heterogeneous bulks can be referred to as Uganda land races.

Some of the cultivars that were introduced from various countries of origin are shown in Table 11.

Table 11: Table of a partial list of soyabean cultivars that were introduced into Uganda in the first half of this century. Source: Compiled from Department of Agriculture Annual Reports (1913 to 1960)

Cultivar	Country of origin	Cultivar	Country of origin
Local	Venezuela	Barberton	S. Africa
Palmetto	U.S.A	R 42	S. Africa

Table 11: (Continued)

Cultivar	Country of origin	Cultivar	Country of origin
R 51	S. Africa	R 184	S. Africa
R 304	S. Africa	R 42 a	S. Africa
R 181	S. Africa	S 11	Unknown
Avoyelles	U.S.A.	Ogden	U.S.A.
Acadian	U.S.A.	Macoupin	U.S.A.
Mamloxi	U.S.A.	Hernon 49	Rhodesia
Hernon 29	Rhodesia	Hernon 7	Rhodesia
Hernon 6	Rhodesia	Hernon 18	Rhodesia
Hernon 5	Rhodesia	Black	U.S.A.
Virginia	U.S.A.	Dunfield	U.S.A.
Scioto	U.S.A.	Monetta	U.S.A.
Mammoth yellow	U.S.A.	S 113	Unknown
S 119	Unknown	S 256	Unknown
S 263	Unknown	R 265	S. Africa
S 31	Unknown	S 38	Unknown
S 277	Unknown	S 58	Unknown
Loredo	U.S.A.	S 42 Serere	Trinidad
Hernon 36	Rhodesia	Hernon 39	Rhodesia
Otootan	Nigeria	Clemson	U.S.A.
Bansei	U.S.A.	Willomi	U.S.A.
Imperial	U.S.A.	Jogun	U.S.A.
Seminole	U.S.A.	Wilson Ely	U.S.A.
S 273	Unknown	R 332	S. Africa
Hernon 286	Rhodesia	Dixie	U.S.A.

These cultivars represent only those cultivars that were included in variety trial experiments. It is possible that many more were never thought promising enough to be included in variety trials but may nevertheless have been distributed when seeds were scarce.

It appears probable that the S introductions came from South Africa during the 1938 to 1939 period when numerous introductions are reported into Uganda. At about the same time 64 cultivars were introduced at Amani and cultivars with S all came from South Africa. It is probable that those cultivars in Uganda with similar letter coding might have come from the same source. It is, however, noted that S 42 Serere came from Trinidad and therefore there is a chance that these unknown S coded cultivars might have come from there or that Trinidad may have imported a similar range of S coded cultivars from South Africa and that S 42 came from South Africa via Trinidad.

The first introduction of soyabean into Tanzania appears to have been made in 1907 and 1909 at Amani. Greenway (1945) suggests that nothing much appeared to be known of the history of soyabean in that country from then until 1938 when a collection of 64 cultivars was established again at Amani with further introduction from India, South Africa, the U.S.A., Ruanda and Uganda. According to Auckland (1967) it was not until the inception of the "Ground-nut scheme" by the Overseas Food Corporation in 1947 that any large scale attempt to grow soyabeans in Tanzania was made. This, however, was the time by which the soyabeans were already on their decline in Uganda and the European market had collapsed. The first cultivars tried by the Overseas Food Corporation gave low yield and were unsuited to conditions at Nachingwea where production was attempted. Further introductions were made in 1950 and these showed greater promise and in particular the variety Hernon 237 (ex - Rhodesia) opened up the prospects of profitable soyabean cultivation in the Nachingwea area and became the standard cultivar until 1961. In 1963 there were about 6,000 acres of soyabean growing in the Nachingwea district alone. The Tanzania work has been thoroughly reviewed by Auckland (in press).

Soyabean has never become an important crop in Kenya, although, Graham (1943) reported a large yellow type to grow "exceptionally well" in Nyanza in 1943. In recent years work on soyabean has started at Kitale and Homa Bay in Kisii District but the crop is still regarded as a side line on both stations and collections are only being maintained with limited field experimentation.

1.7.3 Palatability and the need for processing

The soyabean is unpalatable when eaten merely boiled and may cause flatulence and diarrhea. The Chinese, however, have a long tradition in the use of soyabeans for food and with the centuries of experience, they have developed various methods for processing the soyabeans. They have recently been introduced to other parts of the world mainly Americas, Africa and India initially as a crop for export or local processing to oil and cake which is used for livestock feeding. With soyabeans becoming an increasingly important source of high-quality protein in these countries and in the world as a whole, however, knowledge of the nature of constituents in soyabeans that are associated with flavour and flatulence is also increasingly important.

Soyabean requires a long time for cooking to soften and even then it may still cause flatulence and diarrhea. According to Rackis et. al. (1967), Steggerda et. al. have shown that toasted (treated with live steam at 100°C) dehulled full fat and defatted soya flour all still cause flatulence. Rackis et. al. (1967) stated that fermentation of carbohydrates in the colon appeared to be the primary cause of gas production. A high proportion of the carbohydrate in the soyabean is indigestible. It also contains a trypsin inhibitor reported by Bowman et. al. (1944) which cannot be removed easily by boiling the beans and which therefore interfers which normal digestion in the digestive system.

The soyabean meal fractions responsible for the flavour were investigated by Rackis et. al. (1967) using thin-layer chromatography.

Using different tests they came to the conclusion that contituents in both the lipid and non-lipid fractions were responsible for characteristic flavour of soyabean products. They found that the flavours were readily extracted with 95% ethyl alcohol. The obstacles of flavour, flatulence and trypsin inhibitor can now all be removed by different methods of processing.

Two main types of processing have been developed in the Far East, one based on water extraction of soaked and ground beans producing soyamilk and other by the use of a fungus to produce fermented products such as soya-sauce, Natto, Miso temper, etc. There is general improvement in flavour and digestibility by germination. A variety of secondary products is made from soyabean milk such as soyabean curd, aburage (fried bean curd), etc. In the Western countries new processing methods have been developed to utilize the soyabean oil and protein for food and industrial purposes. Types of new soyabean products introduced for human consumption include, defatted soya flour and full-fat soya flour. The soya flour is used in a great variety of food products. An important feature of soya flours is their relative low cost per unit of protein.

1.7.4 Uganda Environment in relation to soyabean culture

According to Radwanski (1960) the soils of Buganda may be divided for land use purposes very broadly into three groups. Upland soil occurring on hill summits, slopes and low land soils found in alluvial plains and in river valleys. This also applies to a large extent over much of Western Region except that there are volcanic soils in the South-West of the Region. The upland soils are more or less free draining. The deepest soils occur on relatively gentle middle slopes. Their texture varies from clay to loamy sand and the surgance humose top soils contain variable amounts of organic matter depending on the type of vegetation. In high rainfall areas and under undisturbed conditions these deep soils usually have a uniform red or brown coloured subsoil exceeding 6 feet. Ollier et. al. (1959) have reported three main soil patterns in the Eastern Region. Fertile soils occur near Mount Elgon with a volcanic parent material which develop into red soils on flattish sites and dark brown soils on the younger steep sites. A second type is found in Busoga which resembles the Buganda soils and the third type is found in the bottom lands with widespread deposits of alluvium which determine the soil types. Ollier (1959) recognised twenty four distinct mapping units, most of them of a complex of catenas, in the Northern Region. In most cases, however, drainage is free on slopes of hills with various kinds of red loam constituting the dominant soil types. On plateaux at an altitude of about 4,000 feet most of the soils are the deep sandy loam, usually of grey or brown colour. On the whole the soils are fairly good and the base and organic matter contents are quite satisfactory but the available phosphate content is less than normally considered desirable.

Although Uganda lies within the equatorial belt both temperatures and humidities typical of such regions are considerably modified over most of the country by a relatively high general altitude ranging from 3,500 to 6,000 feet above sea level with a majority of land area at about 4,000 feet or more. According to the meteorological data the two ten-day moving means of dewpoint at 0900 hours varies between 14 - 18°C for the Southern part, and 14 - 20°C for the Northern parts of Uganda. The maximum temperatures vary between 28° - 32°C for the Northern parts and 26 - 29°C for the Southern parts of Uganda while the minimum temperatures vary between 14 - 17°C and 10 - 17°C respectively. The daily total solar radiation varies between 400 - 450 cal/cm^2/day in the North and 370 - 470 cal/cm^2/day in the South. The annual variation in potential photosynthesis varies between 220 - 250 lbs CH_2O per acre per day for the whole country with peaks in March and September coinciding more or less with the rainfall regime. The rainfall is heaviest (about 60 inches annual average) around Lake Victoria and on the Mountain ranges Elgon in the East, Bufumbira in South West and Ruwenzori in the West. It is characterized by a bimodal distribution in the Western, Buganda and Eastern Regions with the rainy peaks generally falling between mid-March and mid-May and from September to November. The peaks are not well defined and considerable variation occur from one year to another as does the reliability of rainfall with the available pattern of the means. The Western half of the country usually received more rain from August to November and the Eastern half from the rains beginning in mid-March. The Northern Region is generally hotter and drier than the other parts of the country and rainfall is of a monomodal type of distribution falling mainly between April and October. According to Langdale-Brown (1960) the mean annual rainfall ranges from 30 inches in North-East to 55 inches and 60 inches in the West Nile highlands and on the Gulu-Lira ridge respectively.

Owing partly to the great differences in characteristics and growth requirements of the numerous cultivars, the soya-beans adapt to a wide range of climate. They, however, grow best in a humid climate with plenty of rain during the growing season but requires dry weather during the period of ripening. They also will grow on nearly all soil types except extremely deep sands but the best results are obtained on fertile loams, provided that nitrogen fixing bacteria (Rhizobium spp.) are present. Soyabeans are also daylength sensitive but there are many cultivars adapted to Uganda's 12¼ hours daylength. Thus many parts of Uganda with fairly reliable and well distributed rainfall and also in most cases good soils for soyabean requirement appear to be well adapted for large scale soyabean production. In areas with the bi-modal type of rainfall distribution two crops per year can be obtained from the same land which even makes it more attractive to grow the crop. The dry seasons in between the rainy seasons are very useful in soyabean production since the soyabean need dry weather during the ripening and harvesting periods.

1.7.5 Government Policy for Crop Diversification

Uganda is mainly economically dependent upon her agriculture. She has so far depended on two main cash crops, i.e. cotton and coffee to earn her foreign exchange. Export proceeds from these two crops fluctuate widely, due to the vicissitudes of weather and instability of world prices. According to the Uganda's second Five-Year Plan, these proceeds account for more than one-quarter of the monetary growth domestic product. Since the mass of the population are farmers, the development and diversification of agriculture is a very important aspect of the economic development of the country.

The aim of the diversification programme in the Second Five-Year Plan is primarily to reduce dependence on coffee although a relative decline in the importance of cotton is also planned. The diversification programme is concerned with increasing rapidly the output of other crops which are now of minor importance. There is also a need for a bigger range of crops with high food value to feed the rising and increasingly urbanized population of the country. The Government has indicated interest in the soyabean re-introduction into the country's major agricultural crops list. The FAO and UNICEF have also put plans to the Government for grain legume production in Eastern Africa to provide cheap but high-protein foods of which soyabean will play a big part. It is known that the soyabean can be grown under the environmental conditions of many parts of Uganda as the yields in the 1940's were comparable to the yields of other legume crops on a field scale even though not good in terms of what should be obtained under optimum conditions. It is also known that the disappearance of the crop from the country's major agricultural crops list was mainly on account of loss of foreign market as the crop was produced mainly for export. The other of the main reasons inhibiting continuity of production after 1950's was unacceptable flavour of the soyabean. There is now a processing plant in Kampala so that the soyabean does not have to be eaten as a pulse any more and the processed products appear to be gaining acceptability by the local people.

This creates and internal market which will take sometime to be saturated. This encourages the government to re-introduce the soyabeans into the country's agriculture.

2. GENERAL METHODS

2.1 Crude Protein Content Determinations

These are done by the Micro-Kjeldahl Method (Chapman and Pratt, 1961) on a previously dried (at 105°C for 24 Hours) and finely ground sample of 0.2 gm soya flour. 10 ml concentrated sulphuric acid and a little catalyst mixture are added to the sample in a 50 ml Kjeldahl flask and then digested by heating for 2 hours. After digestion and cooling the clear solution is transferred quantitatively to a 50 ml graduated flask and made up. 10 ml samples of this are pipetted into a flask containing about 10 ml of 50% NaOH and distilled into 10 ml of 2% boric acid containing mixture indicator. This is then titrated with 0.02 N.HCl and the titre multiplied by 0.7 to get N content and then by 6.25 to get the crude protein percentage. Routine analysis by this method are carried out by assistants of the Department of Crop Science and Production.

2.2 Oil Content Determination

This is done by soxlet ether extraction method (Horwitz, 1965) on 2 gm samples of full-fat soya flour in an extraction thimble lined with an 11 cm No.1 filter paper. 30 ml of petroleum ether b.pt. 40 - 60°C are put in an accurately weighed extraction flask which had been dried at 100°C and cooled in a dessicator and the sample is extracted for 3 hours in a Butt type extractor. After extraction the solvent is evaporated and the extract heated for 2 hours at 90°C in an oven to constant weight. The gain in weight of the extraction flask represented the oil content in the sample and this was used to calculate the oil content percentage in the soya flour on a dry weight basis. Routine analysis are carried out by assistants of the Department of Crop Science and Production.

2.3 Plant Characteristics and Component of Yield Determination

Data are obtained from either single plants or many plants either from a plot or line. Cultivars are evaluated for seed yield, size, plant flowering and maturity time, height, number of nodes, number of branches and number of pods.

Yield of seed is obtained by weighing threshed air-dried beans and expressed in grams per plant or per plot. The estimated yield in Kg/ha and lb/acre is obtained from total yield in grams from a specified area multiplied by a factor based on this area. Small plot data tend to give overestimated yields by this method.

Seed size was determined by dividing the seed weight from either one or ten plants for single plant and ten plant samples respectively by the number of seeds from the plants.

Pods per plant and average number of seeds per pod were recorded as the average from a count of 10 random plants.

Flowering and maturity time is recorded as the number of days from sowing until the flowers can be seen and until the leaves have dropped and over 95% of the pods are dry.

Height is the average length in inches of 10 plants taken at random within a variety or plot. The measurement is made from the ground to the tip of the stem at the time of maturity.

Nodes and branches per plant are recorded as the average from a count of 10 random plants.

2.4 Statistical methods

2.4.1 Analysis of variance

Various experimental designs have been used in different experiments (see later). Most of the designs used are simple and the analysis of variance on the data is based on standard procedures, e.g. of Snedecor (1946). The only uncommon method of analysis of variance carried out was on data from a criss-cross experimental design. The analysis is shown in Table 12.

Table 12: Table of analysis of variance procedure for data from criss-cross experimental design. Analysis of variance for a 3 cultivar (v) x 4 levels of lime (L) criss-cross design with 4 levels of phosphate (p) on sub-plot, the whole design having 3 blocks (B).

Source of Variation	df	Ss
Blocks (B)	2	B-C (this term included only for completeness)
Main plots (a)		
Varieties (v)	2	V-C
Error (a)	4	BV-B-V + C
Main plots (b)		
Lime (L)	3	L-C
Error (b)	6	BL-B-L + C
Main plots (c)		
V x L	6	VL-V-L + C
Error (c)	12	$BVL(T_1)$-BV-BL-VL + B + V+L-C
Total for main plots	35	T_1-C
Sub-plots (d)		
Phosphate (P)	3	P-C
V x P	6	VP1V-P + C
L x P	9	LP-L-P + C
V x L x P	18	VLP-VL-VP-LP + V+L+P-C
Error (d)	72	T_2-T_1 - VLP + VL
Total for sub-plots	143	T_2-C

In the sums of square T_2 is total uncorrected sum of squares, C is correction factor and all the other terms are uncorrected sums of squares for their appropriate components. All the corrected sums of squares for main plots are divided by 2 as each will require 2 sub-plot totals in calculating the uncorrected sums of squares.

2.4.2 Least significant difference. The procedure followed for the estimation of LSD was as follows:-

(a) LSD for differences among subplot treatments LSD = t (for error (d) df) $\sqrt{\frac{2(\text{mean square for error d})}{(\text{no.reps.})(\text{No. main plot trets.})}}$

(b) LSD for differences among main plots

$$LSD = t\sqrt{\frac{2\,(\text{error mean square})}{\text{no. of reps.}}}$$

2.4.3 Coefficient of variation:

This was estimated by the formula

$$CV = \frac{\sqrt{\text{Error mean square}}}{\text{mean of data}} \times 100$$

3. EXPERIMENTAL WORK AND RESULTS

3.1 Selections from Uganda land races

3.1.1 Bukalasa Selections:

Six plants were selected by Leakey from a Bukalasa soyabean field on the basis of apparent pod yield and habit to be used in a class exercise. They were then shelled separately and seeds from each plant counted and weighed. The number of pods, seed weight and mean seed weight were recorded as shown in Table 13.

Table 13: Table of observation data (data from a 2nd year student practical class)

Plant	No. pods	Seed wt. (gms)	Mean seed weight (gms)
1	76	16.34	0.150
2	87	38.02	0.200
3	92	30.56	0.170
4	110	43.54	0.229
5	73	24.83	0.165
6	112	44.47	0.234

The seeds from each plant were sown in rows of 14 ft. in July, 1966 at a spacing of 24" x 4" for preliminary evaluation and seed multiplication. The time from sowing to maturity was recorded and seed weight, mean seed weight and pods per plant determined. The results are shown in Table 14.

Table 14: Table of mean observation data on the 1st progeny rows of Bukalasa selections

Selection	Days from sowing to maturity	Pods per Plant	Yield per row (gm)	Mean seed weight (gm)
1	120	60	317	0.205
2	121	81	420	0.233
3	129	50	235	0.192
4	127	115	642	0.212
5	116	70	409	0.210
6	125	91	641	0.207

The selections were grown during the first rains of 1967 (March, 1967) in unreplicated progeny rows of 23 ft. long. The standard spacing of 24" between rows and 4" within rows was used. Mean seed weight and total seed yield per progeny row were recorded and protein and oil content determined. The results are shown in Table 15.

Table 15: Table of data from second crop of Bukalasa selections

Selection	Seed wt.(gm.)	Mean seed wt.	Protein %	Oil %
1	630	0.151	28.7	20.6
2	745	0.176	31.3	30.0
3	728	0.172	-	-
4	838	0.197	34.5	18.4
5	454	0.172	31.3	19.4
6	720	0.214	33.4	17.6

The mean seed weight of the original plants and the first progeny were each correlated with the mean seed weight of the second crop. There was a significant correlation coefficient of 0.83 between the mean seed weight of the original plants and the second crop but only correlation coefficient of 0.22 between the first and second crops which was not significant at 5% probability level. This indicates that either the variation in moisture content among the progeny rows in the first crop was unrelated to the variation in moisture content among the original plants and second crop or probably the mean seed weight had an interaction with the environment.

Bukalasa 1, 3 and 5 were relatively short and compact while Bukalasa 2, 4 and 6 were tall, with more and wider-angled branches. The protein content analysis also showed that they had a higher protein content than the other selections. They were, however, liable to lodging under favourable growing conditions. After this there were sufficient seed for a replicated trial which was carried out during the second rains of 1967 in a 6 x 6 latin square design. Each plot measured 14 ft. by 17 ft. and the spacing was 24" x 4". Two guard rows surrounded each plot and all the rows within each plot were harvested. The land used for the experiment was newly opened, had no fertiliser application and proved to be very heterogeneous with a low pH of 5.3 - 5.8. At this time no land suitable for experimental field plots had yet been made available on the farm. The seeds were not innoculated with Rhizobium. The summary of the results of yield and analysis of variance is presented in Tables 16 and 17 respectively.

Table 16: Table of summary data from Variety Trial (2nd Rains, 1967)

Selection	Mean yield (gms.)	Estimated yield - lbs/acre
1	1934	781
2	1876	760
3	1503	607
4	2687	1086
5	1605	650
6	2532	1022

LSD (p = 0.05) = 405 gm

Table 17: Summary table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	35	23.605		
Rows	5	5.983	1.196	2.69
Columns	5	1.666	0.333	0.75
Selections	5	7.051	1.410	3.17
Error	20	8.904	0.445	

CV. = 32.9%

The generally low yields were attributed mainly to the poor land. The analysis as well as field observations indicated great heterogeniety of the land. The upper part of the experiment was more fertile with deeper soil and the depth of soil fell off from the upper to the lower part of the experiment and this accounts for significant row differences. Nevertheless Bukalasa 4 and Bukalasa 6 still showed significant superiority at the 5% level over the other selections. The correlations of the single original plants and the unreplicated progeny rows with the replicated variety trial mean yields were computed and the results are presented in Table 18.

Table 18: Summary table of correlations of mean yields of replicated variety trial with yields of unreplicated progeny rows and single plants

Progeny rows and single plants	Correlation coefficient
Single plants	0.6788
First progeny rows	0.9133
Second progeny rows	0.5954

The correlation coefficients were all significant at 5% level. This suggests that yield results from unreplicated progeny rows could be used to evaluate the relative performance of cultivars if large numbers of cultivars are involved.

3.12 Kakira selections

Twenty plants were selected from a Kakira soyabean field by Leakey in 1966. The selections were shelled separately and the seeds sown in unreplicated progeny rows in July, 1966. In March, 1967 the selections were sown in unreplicated progeny rows, 23 ft. long. The mean seed weight and seed yield per progeny were recorded. The protein and oil contents from the second crop were determined. The results are shown in Table 19.

Table 19: Summary table of data from 1st and 2nd crops

Selection	Sown July '66	Sown March, 1967			
	Mean seed wt.	Protein %	Oil %	Mean seed wt.	Seed wt. per row
1	0.220	29.2	-	0.174	810
2	0.198	28.1	18.5	0.179	733
3	0.226	29.9	19.8	0.206	930
4	0.214	28.8	20.5	0.170	651
5	0.199	-	-	0.170	734
6	0.199	24.4	19.8	0.153	756
7	0.206	-	-	0.164	653
8	0.195	25.6	-	0.170	833

Table 19: (continued)

Selection	Sown July '66	Sown March, 1967			
	Mean seed wt.	Protein %	Oil %	Mean seed wt.	Seed wt. per row
9	0.182	30.3	-	0.153	695
10	0.175	24.1	20.7	0.153	725
11	0.161	26.9	19.3	0.144	723
12	0.172	28.1	10.5	0.155	845
13	0.198	29.4	24.8	0.158	925
14	0.173	27.1	18.6	0.159	678
15	0.192	27.8	-	0.158	640
16	0.172	27.1	23.1	0.162	663
17	0.170	23.1	16.6	0.151	600
18	0.191	26.5	-	0.149	628
19	0.163	20.2	20.0	0.147	543
20	0.193	-	-	0.162	678

These selections all flowered after about 46 - 48 days from sowing and matured about 107 to 114 days from sowing. After the preliminary evaluation of the selections over the two seasons, sufficient seed was available for the more promising selections, i.e. Kakira 1, 3, 8, 12 and 13 to be tested further in replicated trial in a 6 x 6 latin square design together with selection Kawanda 20. The plot size was 14 ft. by 15 ft. at a spacing of 24" x 4". The air-dry seed weight from each plot was recorded and the estimated yield per acre determined. The summary of the results of yield and analysis of variance are presented in Tables 20 and 21 respectively.

Table 20: Summary table of mean and estimated yields

Selection	Mean yield (gms)/plot	Estimated yield (lbs. per acre)
Kakira 1	1193	547
Kakira 3	1095	502
Kakira 8	1148	526
Kakira 12	1086	498
Kakira 13	1287	592
Kawanda 20	1133	519

The very low yields were attributed to low soil fertility and depth (soil was barely 6 inches deep in much of the plot). The analysis of variance was carried out and the results are presented in Table 21.

Table 21: Summary table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	35	5.383		
Rows	5	3.612	0.722	13.37
Columns	5	0.513	0.102	1.88
Selections	5	0.166	0.033	0.61
Error	20	1.091	0.054	

The analysis failed to show significant difference among the selections.

During the second rains of 1968 the selections were each grown in unreplicated rows of 33 ft. long at a spacing of 24" x 4" along with all the other available cultivars on spare strips of fairly uniform land at the margin of the trials land. Some detailed plant by plant observations were made on 10 plants selected from each line at random in areas of good stand. The results are presented in Table 22.

Table 22: Summary table of mean data from observations

Cultivar	Mean No. pods per plant	Mean No. branches	seed Wt/plant (gm.)	Mean seed wt. (gm)	Ratio of seed wt. to whole plant wt.
Kak. 1	96.7	6.8	29.1	0.189	0.617
Kak. 3	97.2	9.7	29.6	0.156	0.513
Kak. 6	54.1	5.0	17.1	0.177	0.459
Kak. 7	66.8	6.9	19.7	0.191	0.574
Kak. 8	63.3	6.5	16.9	0.159	0.529
Kak. 9	54.7	4.9	17.8	0.158	0.534
Kak. 10	83.8	7.1	23.3	0.170	0.508
Kak. 11	45.2	5.4	10.9	0.144	0.534
Kak. 12	39.7	3.9	9.0	0.136	0.508
Kak. 15	62.8	5.6	19.0	0.191	0.508
Kak. 16	49.8	4.5	17.7	0.164	0.550
Kak. 18	67.5	8.0	26.4	0.234	0.584

Table 23: (continued)

Selection	Original plants: No. of pods	Mean seed wt. (gm)	Seed wt. (gm)	First Crop: Mean seed wt. (gm)	Seed	Pro-tein %	Oil %
6	286	0.142	62	0.176	745	-	-
7	193	0.128	35	0.143	440	27.3	20.9
8	193	0.195	78	0.177	630	-	-
9	185	0.162	39	0.160	470	-	-
10	245	0.158	54	0.163		-	-
11	225	0.155	87	0.164	655	27.7	20.6
12	230	0.145	54	0.143	563	-	-
13	243	0.166	56	0.156	633	-	-
14	342	0.173	96	0.152	570	27.9	20.8
15	195	0.145	42	0.144	658	25.4	-
16	250	0.172	60	0.150	658	29.4	20.1
17	199	0.146	39	0.161	663	-	-
18	243	0.188	80	0.150	663	27.1	25.9
19	238	0.166	64	-	-	-	-
20	241	0.181	65	0.156	825	27.1	20.4
21	322	0.148	65	-	-	-	-
22	217	0.146	50	-	-	-	-
23	170	0.200	53	-	-	-	-

During the second rains (September) 1968 those selections which were not entered in replicated variety trials were further evaluated along with other cultivars. They were grown in observation lines 33 ft. long on a fairly even land. The spacing was 24 x 4 . 10 plants were sampled within areas of good stand at random and vario s observations made. The results of the mean data of these observations are presented in Table 24.

Table 24: Mean observation data on ten random plants

Cultivar	Mean no. pods per plant	Mean no. branches	Seed wt/plant (gm)	Mean seed wt. (gm)	Ratio of seed wt. to total plant weight
1	95.7	7.0	26.9	0.178	0.478
2	103.8	7.4	31.9	0.180	0.463
3	55.2	6.1	14.9	0.157	0.474
4	76.9	8.4	16.6	0.159	0.500
5	107.1	9.7	30.8	0.196	0.489
6	66.3	6.1	21.6	0.160	0.501
7	120.1	9.8	32.9	0.159	0.433
8	72.3	6.1	21.2	0.187	0.547
9	88.4	6.7	26.7	0.174	0.537
10	71.0	6.6	20.8	0.172	0.498
11	86.0	6.4	28.6	0.199	0.554

Table 24: (continued)

Cultivar	Mean no. pods per plant	Mean no. branches	Seed wt/plant (gm)	Mean seed wt. (gm)	Ratio of seed wt. to total plant weight
12	91.1	9.0	25.6	0.191	0.614
13	107.2	9.2	34.1	0.182	0.504
14	130.5	10.3	32.0	0.165	0.459
15	72.9	6.8	21.9	0.171	0.498
16	86.1	7.2	25.4	0.193	0.480
17	108.1	7.6	31.6	0.185	0.457
18	74.8	7.2	21.8	0.180	0.497

3.2 Accessions from USA via Kenya

A few seeds of each of twenty-one American cultivars were received in November, 1966 from Nyanza Agricultural Station at Homa Bay, Kenya. These were sent from the USA in 1965 and bulked at Homa Bay. The "Belgian Congo" cultivar which came with them was locally selected at Homa Bay and recommended for Kisii District (above 5,000 ft.). They were grown in observation rows 24" x 4" in first rains of 1967 for seed multiplication and the observations shown in Table 25 were made.

Table 25 Table of observations made on the USA accessions

Cultivar	Days from sowing to flowering	Days from sowing to maturity	Seed colour	Seed mean weight (gm)
Harosoy	34	95	Yellow	0.150
Grant	34	95	Yellow	0.150
Delmar	34	100	Yellow	0.180
Kanum	34	90	Yellow	0.260
Clark	34	95	Yellow	0.150
Kent	34	98	Yellow	0.190
A 100	34	90	Yellow	0.158
Dorman	42	98	Yellow	0.160
Ross	34	85	Yellow	0.164
Hill	34	95	Yellow	0.175
Jogun	34	90	Yellow	0.170
Ford	35	90	Yellow	0.180
Korean	36	100	Yellow	0.210
Adams	34	90	Yellow	0.150
Black Hawk	34	95	Yellow	0.190
Kim	34	90	Green	0.360
Bethel	35	98	Yellow	0.172
Belgian Congo	48	115	Yellow	0.180
Henry	34	95	Yellow	0.150
Mamloxi	60	125	Yellow	0.140
Wills	35	95	Yellow	0.172

Preliminary screening of the cultivars was carried out in small plots with four replications. Each plot had 5 rows of 21 feet each. Each row was divided into three parts of 7 feet thus giving three cultivars to each row. The spacing was

4" within row and 24" between the rows. The cultivars were scored for their susceptibility to *Cercospora kikuchii*. The protein content for each cultivar was determined. The results are presented in Table 26.

Table 26: Summary table of mean yield and protein content data and cultivar susceptibility to *C. kikuchii*

Cultivar	Mean yield/ row (gm)	*C. kikuchii* infection	Protein %
Kanum	197	+	36.3
Belgian Congo	388	-	33.1
Harosoy	240	+	37.1
Delmar	286	-	32.8
Grant	310	+ +	28.0
A 100	183	+	38.0
Henry	253	-	40.2
Kent	363	+	32.9
Black Hawk	207	+	35.3
Dorman	293	-	36.0
Mamloxi	270	-	43.1
Ford	327	+ +	35.0
Korean	331	+	35.3
Bethel	218	+	40.2
Clark	276	+	29.6
Adams	235	+ +	37.8
Hill	320	-	-
Kim	273	-	35.0
Wills	357	-	-
Jogun	155	+	39.3
Ross	190	+	-

N.B.: + + corresponds to heavy infection by *C. kikuchii*

+ corresponds to light infection by *C. kikuchii*

− corresponds to no visible infection by *C. kikuchii*

The cultivars matured in the wet season and some showed heavy infection by *Cercospora kikuchii*. Some cultivars were selected for further evaluation. The selection was based on yield performance for the cultivars that showed less susceptibility to *Cercospora kikuchii*.

During the second rains (September, 1968) the cultivars were further evaluated. They were grown in observations rows of 33 feet long on a fairly even land. The spacing was 24" x 4". Ten plants were sampled from areas of good stand at random and various observations made. The mean data results of these observations are presented in Table 27.

Table 27: Observation mean data on ten random plants

Cultivar	Mean no. pods	Mean no. branches	Seed wt/plant (gm)	Mean seed weight (gm)	Ratio of seed weight to total plant weight
Ford	20.3	1.9	6.90	0.172	0.605
Grant	31.0	2.4	8.22	0.138	0.600
Kanum	32.1	2.3	10.3	0.213	0.606
Adams	28.6	3.2	7.78	0.137	0.613
Henry	52.8	6.6	20.26	0.159	0.592

Table 27: (continued)

Cultivar	Mean no. pods	Mean no. branches	Seed wt/plant (gm)	Mean seed weight (gm)	Ratio of seed weight to total plant weight
Clark	44.4	10.8	15.93	0.151	0.613
Black Hawk	37.2	4.0	11.16	0.140	0.714
Harosoy	27.4	3.7	8.25	0.150	0.602
Delmar	34.3	4.5	10.58	0.165	0.602
Mamloxi	97.0	10.3	20.31	0.112	0.510
Kim	20.7	1.1	7.75	0.263	0.586
Bethel	51.0	4.0	12.62	0.166	0.533
Hill	36.5	6.4	12.50	0.170	0.647
Jogun	10.5	0.9	3.11	0.194	0.607
A 100	16.0	2.3	4.56	0.158	0.570
Wills	40.2	5.4	12.54	0.172	0.702

3.3 Accessions from Tanzania

The introductions acquired from Tanzania came from Auckland's programme and included two hybrid bulks, 3H55 F4/1 and 3H55 F4/9 and cultivar Hernon 237. The first crop showed that hybrid bulks 3H55 F4/9 and 3H55 F4/1 were still heterogeneous and Hernon 237 which was sent as a "pure line" also showed considerable heterogeneity. Both the hybrid bulks and Hernon 237 were in general very tall, laxly branched and easily lodged. They were vegetatively bulky, very late maturing and most of them sparsely podded.

A selection of ten plants from hybrid bulk 3H55 F4/9, eight plants from hybrid bulk 3H55 F4/1 and ten plants from Cultivar Hernon 237 was made. The selection was based on maturity time, habit and the number of pods on the selected plants. Observations data on the selected plants from the hybrid bulks are shown in Table 28.

Table 28: Summary table of observation data on single selected plants from hybrid bulks

Plant	3H55 F4/1		3H55 F4/9	
	No. pods	Mean seed wt. (gm)	No. pods	Mean seed wt. (gm)
1	98	0.101	130	0.143
2	69	0.144	186	0.150
3	104	0.140	97	0.153
4	149	0.134	185	0.162
5	160	0.109	199	0.140
6	131	0.122	185	0.172
7	114	0.107	373	0.176
8	110	0.107	373	0.176
9	-	-	140	0.168
10	-	-	296	0.182

The seeds from the selected plants from both hybrid bulks 3H55 F4/1 and 3H55 F4/9 and cultivar Hernon 237 were sown in replicated progeny rows of 18 ft. long at 24" between rows and 4" within rows, in the second rains (September, 1967). Only one selection in the cultivar Hernon 237, flowering in 70 days after sowing and maturing in about 150 days was able to be harvested, and even then it had shrunken seed but all the other selections in this cultivar were caught by the following dry season (January to March, 1968) and failed to give any crop. Several of the selections from the hybrid bulks, however, gave some crop but even then many of them were very sparsely podded. All the material whether or not they gave any crop, suffered from excessive lodging. They followed about 70 to 80 days and some reached maturity over 150 days after sowing.

It seemed from these preliminary data that as a group the Tanzania cultivars were of no immediate commercial value in this environment. They had been developed for Nachingwea region at 2000 ft. above sea level and failed to tolerate the rise to 4000 ft. This is mainly assumed to be attributable to temperature differences and short growing seasons of Kabalyolo as compared to Nachingwea.

The selections that could give some crop were maintained and some re-selections made within them. During the second rains (September, 1968) these selections were evaluated in observation rows of 33 feet long at a spacing of 24" x 4". The selections matured about 125 - 130 days after sowing. At harvest 10 plants were selected from areas of good stand at random from each selection. Some components of yield were recorded and the relative performance of each cultivar was estimated from the total yield of the 10 plants. The results are shown in Table 29.

Table 29: Mean observation data on ten random plants

Selection	Pods	Branches	Height (in.)	Seed wt(gm)	Mean seed wt (gm)	Ratio of seed wt. to whole plant wt.
3H55 F4/9/3	200.7	16.8	26.3	34.51	0.099	0.387
3H55 F4/9/1	64.0	6.6	29.28	22.10	0.205	0.450
3H55 F4/1/3	133.1	16.7	19.76	25.06	0.092	0.451

The mean seed yield per plant results suggested that these selections might be of some promise in future as possible commercial cultivars especially as selections maturing within the growing season period of this area have been made.

3.4 Accessions from Kitale

Eighteen yellow seeded soyabean cultivars were received from Kitale Research Station, Kenya in the first part of July, 1968. These cultivars were selections from the bybridization programme on the station. They were sown on 9/7/68 on land that previously carried the inoculation - weeding experiment with cultivar Dorman. They were planted in unreplicated rows of varying lengths depending on the quantity of seed received and rows were $1\frac{1}{2}$ feet apart with a spacing of 3 inches within rows. During the initial stages of growth the plants were irrigated by overhead irrigation system and matured in the middle of second rains which caused them to show uneven ripening. All the cultivars had gray pubescence and purple corolla colour. They flowered about 45 - 50 days and matured about 115 - 120 days after sowing.

At harvest 10 plants were selected from areas of good stand at random from each cultivar and observations made on various yield components. The results are presented in Table 30.

Table 30: Table of components of yield mean data on ten plants

Cultivar	No. of pods/ plant	No. of bran- ches	Seed wt./ plant (gm)	Mean seed wt. (gm)	Ratio of seed wt. to whole plant
B/7/1	63.2	6.7	20.8	0.215	0.448
D/1/1	47.9	6.9	14.16	0.210	0.439
XB/1	73.7	7.0	21.10	0.177	0.526
B/1/3	43.2	5.7	15.8	0.250	0.548
B/3/1	56.9	6.7	21.11	0.237	0.467
XB/2	63.2	7.5	13.25	0.166	0.459
B/7/4	43.4	5.7	14.22	0.232	0.427
H/1/3	40.1	5.9	14.70	0.239	0.471
B/1/1	41.1	6.0	12.43	0.240	0.452
A/3/1	48.2	6.0	21.00	0.252	0.518
XB/3	74.5	7.6	23.50	0.209	0.500
F/1/2	52.8	6.5	18.39	0.224	0.444
B/3/2	45.4	5.7	-	-	-
B/7/3	27.4	6.2	-	-	-
F/7/1	47.1	7.1	14.95	0.238	0.426
F/1/1	51.7	7.5	14.73	0.191	0.478
K6573		Nothing germinated			

The relative performance of the cultivars was considered to be expressed by the total seed yield from the 10 plants selected for yield component observations. This was because there were varying total number of plants harvested among cultivars and it was not possible for the total seed yield from each row to indicate the relative performance of the cultivars.

3.5 Accessions from Kawanda

A few seeds of each of about 100 cultivars were acquired from Kawanda Research Station in September, 1968. A few of these cultivars had been collected from the Uganda land races within Uganda while most of the rest had come through Kenya from the USA. This group contained all the American cultivars that were already at Kabanyolo University Farm and new introductions in addition. The cultivars were sown in unreplicated observation lines at a spacing of 24" x 4" on a fairly uniform land. At harvest, ten plants were selected from areas of good stand at random for observation. The time from sowing to maturity for each cultivar was also recorded. The results are shown in Table 31.

Table 31: Observation results from Kawanda material

Code No.	Name	Origin	Seed colour	Maturity period (days)	Yield/ plant (gm)	Mean seed weight (gm)
S3	R 184	Kawanda	Yellow	105	12.77	0.142
S5	Sangalo	Kawanda	"		16.10	0.220
S6	Blyvoor	Kawanda	"	110	17.14	0.181

Table 31: (continued)

Code No.	Name	Origin	Seed colour	Maturity period (days)	Yield/ plant (gm)	Mean seed weight (gm)
S8	Benares	Kawanda	Yellow	110	28.8	0.201
S12	-	Mengo	"	105	13.2	0.176
S15	-	Toro	"	110	19.2	0.175
S16	-	Acholi	"	110	18.1	0.208
S18	Vorster	Kitale	"	110	-	-
S19	Congo 1963	"	"	105	21.7	0.189
S22	-	Mityana	"	110	12.9	0.179
S24	-	Acholi	"	110	19.8	0.200
S25	-	Busoga	"	115	23.5	0.201
S26	-	Busoga	"	110	21.6	0.192
S27	-	Busoga	"	115	22.2	0.210
S41	Flambbau	Kenya (USA)	"	90	4.6	0.159
S43	Manitoba brown	"	Brown	95	-	-
S44	Pagoda	"	Yellow	85	-	-
S45	Comet	"	"	85	-	-
S47	Hardome	"	"	95	13.9	0.154
S48	Kobatt	"	"	90	-	-
S49	Mandarin	"	"	85	-	-
S51	Monsoy	"	"	96	4.9	0.259

Code No.	Name	Origin	seed colour	Maturity period (days)	Yield/ plant (gm)	Mean seed weight (gm)
S52	Norchef	Kenya (USA)	Yellow	100	-	-
S55	Chippewa	"	"	90	15.8	0.180
S56	Habaro	"	"	95	8.9	0.184
S57	Harly	"	"	90	14.06	0.146
S58	Manchuria	"	"	105	-	-
S59	Monroe	"	"	95	12.46	0.165
S60	Ottawa	"	"	95	11.4	0.160
S62	Bansei	"	"	95	7.7	0.237
S63	Kakote	"	Green	95	8.9	0.223
S63	Hawjeye	"	"	90	10.4	0.200
S69	Kanro	"	Yellow	95	-	-
S72	Lindarin	"	"	95	9.2	0.153
S75	Richland	"	"	85	-	-
S76	Funk	"	Brown	1 5	7.0	0.141
S77	Gibson	"	Yellow	95	6.3	0.137
S79	Seneca	"	"	95	6.5	0.164
S83	Kanrich	"	"	95	10.9	0.250
S86	Chief	"	"	95	6.2	0.126
S90	Harbinsoy	"	"	90	5.5	0.149
S91	Higan	"	"	95	6.7	0.213

Table 31: (continued)

Code No.	Name	Origin	Seed colour	Maturity period (days)	Yield/ plant (gm)	Mean seed weight (gm)
S92	Hokkaido	Kenya (USA)	Yellow	90	-	-
S94	Madison	"	"	95	9.1	0.146
S95	Morse	"	Green	105	8.3	0.200
S96	Norredo	"	Black	95	-	-
S97	Patoka	"	Yellow	100	17.0	0.153
S98	Peking	"	"	95	-	-
S99	Perry	"	"	90	6.0	0.149
S100	Roe	"	"	95	9.3	0.132
S101	Scott	"	"	95	5.1	0.163
S102	Virginia	"	Black	90	6.1	0.144
S103	Wabash	"	Yellow	100	11.6	0.156
S104	Wilson	"	"	90	3.7	0.123
S107	Hood	"	"	110	9.3	0.193
S108	Lee	"	"	95	6.2	0.162
S109	Ogden	"	Green	105	-	-
S110	Jackson	"	Yellow	95	7.1	0.218
S111	Biehville	"	Green	95	4.6	0.149
S112	Seminole	"	Yellow	95	6.8	0.245

3.6 Accessions from Japan

Seven acquisitions were received from Japan through the quarantine in Muguga in September, 1968. They were sown on 16th September, 1968 in observation rows for observation and seed multiplication at a spacing of 24" x 4". They flowered about 35 days and matured about 85 - 90 days after sowing. They were stunted due to daylength sensitivity. For some of the cultivars only a few seeds were received and this coupled with the fact that there was poor germination due to the drought that followed after sowing, only a few plants were raised. This meant that for these cultivars there were not enough plants to make a meaningful average for some characters. For the cultivars where enough plants were raised, ten plants were selected from areas of good stand at random from each cultivar and observations made on various yield components. The observation results are shown in Table 32.

Table 32: Summary table of observation

Cultivar	Sowing to maturity (days)	Height (in)	Yield/ plant (gm)	Mean seed wt. (gm)
Tokachinagaha	84	8.5	7.5	0.169
Asumusume	88	6.3	5.24	0.221

Table 32: (continued)

Cultivar	Sowing to maturity (days)	Height (in)	Yield/ plant (gm)	Mean seed wt. (gm)
Shirohacikoku	88	10.0	8.36	0.156
Shirodaizu	90	7.6	6.4	0.223
Ani	84	-	-	-
Norin 2	90	-	-	-
Tachishuzunari	90	-	-	-

3.7 The grouping of available cultivars

Over 150 accessions have been made to the Uganda land races collected at Kabanyolo in 1966. After preliminary evaluation of most of these introductions over several seasons in observation rows, they were classified into major groups according to growth habit (upright with narrow-angled branches and easily lodged with lax branching) and period to maturity (early - less than 100 days from planting to maturity, medium - 100 to 125 days and late - over 125 days).

The period to maturity classification method put all the American and Japanese cultivars into the early maturing group, the Uganda land races selections and cultivars developed in Kenya into the medium maturing group and the

Tanzania accessions into the late maturing group. On a basis of habit classification all the cultivars were in the upright group except the Tanzania acquisitions (the American and Japanese cultivars were mainly daylength sensitive types and therefore stunted owing to excessively early flowering). Some selections that fall into the medium maturity of upright habit have, however, been made from the original Tanzania material and they appear to be fairly promising.

The more promising cultivars from the early and medium maturing groups were selected for more detailed evaulation in variety trials and some were used in agronomic studies (see later).

3.8 VARIETY TRIALS

3.8.1 Work done in East Africa

There was no attempt to carry out systematic selection or breeding programme on soyabean in Uganda in the 1940's and early 1950's when soyabean were then an important crop but many variety trials using some of the available cultivars were carried out in all the growing areas. The Hernon cultivars from Southern Rhodesia are said (Department of Agriculture Annual Reports) to have proved to be the best yielders. Results of the variety trial experiment that gave the highest recorded yield in Uganda during that time are given in Table 33.

Table 33: Table of data from District Variety Trials 1946

Source: Department of Agriculture Annual Report (1946).

Yield pounds per acre.

Cultivar	Toro Kyembogo	Mubende Kakumiro	Ankole Bushenyi	Bunyoro Bulindi
'Local'	762	-	-	-
R 184	1149	1830	1285	937
H 5	1394	1699	1197	784
H 29	1263	1307	980	980
H 49	1568	1919	1219	958
H 36	1416	1525	1219	958

Cultivar R 184 was used as a control in these trials. Hernon cultivars were reported to have had poor germination despite their impressive performance. This may be due to their branched habit which would be expected to allow a high degree of compensation. Before and after 1946 variety trials were carried out but yields were lower than 1919 pounds per acre obtained from Hernon 49 at Kakumiro in Mubende shown in Table 33.

Although soyabean has never been an important crop in Kenya there again various variety trials have been carried out. In 1962 the cultivar Vorster planted early in the season yielded 1,420 pounds per acre on an experimental plot basis (Auckland, 1968). At Kisii, Cray (1967) reported yields of 1,829 pounds per acre from cultivar Belgian Congo which was the highest yielder there.

Many trials were carried out by Auckland during the period 1958 to 1964 in Tanzania particularly in the Nachingwea area in Southern Tanzanyika. There the Hernon cultivars or selections from crosses of Hernon cultivars with other cultivars were the best yielders (Auckland, 1968). Results from some variety trials are shown in Table 34.

Table 34: Table of yields (lbs/acre) of Nachingwea cultivars grown at Stations in Tanzania and in the British Soloman Islands. Source: Auckland, 1968.

Cultivar	STATION AND YEAR				
	Ilonga 1963	Ilonga 1964	Suluti 1963	Mtopwa 1963	Soloman Islands 1962
HLS 219	-	-	2768	-	1655
HLS 147	1624	1999	2662	-	-
HLS 273	-	-	-	1755	-
HLS 239	-	-	-	-	1774
7H/101	2001	2025	-	-	-
Hernon 237	1532	1495	1575	1180	1490
Light speckled	906	1185	1906	1131	1624
R 184	1017	669	-	-	-

Table 34: (continued)

Cultivar	Ilonga 1963	Ilonga 1964	Suluti 1963	Mtopwa 1963	Soloman Islands 1962
LSD					
P = 0.05	444	441	-	-	74
P = 0.01	584	580	53	49	-

The highest yield of 2768 pounds per acre was recorded in 1963 at Suluti sub-station of the Southern Research Station, Nachingwea near to Songea.

Most of the variety trials except the recent ones in Tanzania and Kenya were carried out without inoculating the soyabean with Rhizobium and without application of fertilisers to the land that was used. It is also possible that other husbandry practices were poor. Despite all these setbacks, some cultivars still recorded reasonable results comparable to results obtained in the USA where the crop's genotype has been greatly improved by prolonged selection and breeding and the problems of its production are well understood.

3.8.2 Variety trials (First Rains, 1968)

3.8.2.1 Materials and Methods

After the 2nd rains, 1967 experiments the following

9 entries were selected for further evaluation in a variety trial experiment:

Bukalasa 4 Bukalasa 6	best yielders of Bukalasa selections
Kakira 13 Kawanda 20	best yielders of the Kawanda and Kakira selections
Korean Kent Doman	American cultivars that performed fairly well earlier and did not have significantly purple stained seeds
Hernon 49 -	Good yielding Kawanda cultivar under the code No. S2.

S38 - Kawanda's standard cultivar.

Cultivar S38 was used as a standard cultivar. The experimental design was randomized complete block with 5 replications. Each plot size was 8 ft. by 8 ft. and the distance between rows was 24' and 4" within rows. The land was fertilized by application of lime and single super phosphate by the farm staff at rates not precisely determined. It was impossible to get a Rhizobium inoculum in time and therefore again the trial was carried out without inoculating the seeds.

3.8.2.2 Results

Air dried seed weight in grams was recorded from each plot and the mean yield per plot compared

The analysis of variance for the yields of the cultivars was carried out and the results are shown in Table 35.

Table 35: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	44	21.73		
Replications	4	0.27	0.067	0.76
Cultivars	8	18.63	2.322	26.3
Error	32	2.83	0.088	

CV = 17.7%

The analysis of variance showed a significant difference among cultivars at 5% level. The LSD at 5% level was worked out to separate the cultivar means and the results are shown in Table 36. Also shown in Table 36 are the estimated yields in Kg/ha.

Table 36: Summary table of mean yield (gm/plot) and estimated yield (Kg/ha).

Cultivar	Mean seed yield (gm/plot)	Estimated yield kg/ha
Bukalasa 4	2832	3811
Bukalasa 6	2701	3635
Kawanda 20	2003	2696
Kakira 13	1518	2043

Table 36: (continued)

Cultivar	Mean seed yield (mg/plots)	Estimated yield kg/ha
Hernon 49	1451	1953
S 38	1220	1642
Kent	1151	1549
Dorman	1098	1477
Korean	1094	1472

LSD (P = 0.05) 383 gm

The American cultivars yielded lowest. This may be at least in part to the fact that they are stunted plants and with spacing used of 24" by 4" leave quite a lot of open land. It may be that if they were planted at higher densities so that they cover all the ground, their yields might be considerably improved. They also flower earlier than the local cultivars and therefore have less growing period. The local selections covered the ground fairly well but the yields can still be improved by inoculation and probably increasing the nutrient levels. The yields, however, are very encouraging as this is the first time in East Africa that yields above 3,000 pounds per acre have been recorded even on small plot experiments.

3.8.3 Variety trials (second rains, 1968)

3.8.3.1 Material and Methods

Fifteen entries (see later) were included in this trial. The experiment was carried out on the same land that was used for the variety trial in the first rains of 1968 but 50 pounds per acre of single super phosphate was applied broadcast just before sowing. The experimental design was a randomized complete block with plot size of 8 ft. by 10 ft. and 5 replications. The spacing was 24" x 4". Only areas of good stand in the three inner rows were harvested and the number of plants from each plot recorded. A multiplying factor based on the number of plants harvested and the number of plants expected in the three rows as worked out for each plot. The sum of the recorded yield for each plot and the multiplying factor for the same plot was used in the analysis of variance and estimation of yield in Kilogram per hectare for each cultivar.

3.8.3.2 Results

The air-dried seed yield in grams was recorded for each plot. The analysis of variance for the yields of the cultivars was carried out and the results are shown in Table 37.

Table 37: Table of analysis of variance

Source of variance	df	Ss	Ms	F
Total	74	17.48		
Replications	4	1.00	0.250	2.77
Cultivars	14	11.40	0.814	9.04
Error	56	5.08	0.090	

CV = 23.1%

The analysis of variance showed a significant difference among cultivars at 5% level. The LSD at 5% level was worked out to separate the cultivar means and the results are shown in Table 38. Also shown in Table 38 are the estimated yields in Kg/ha.

Table 38: Table of mean yield and estimated yield of various cultivars

Cultivar	Description	Mean yield (gm) per plot	Estimated yield kg/ha
Hernon 237	Selection from H 237	1806	3240
Bukalasa 6	Bukalasa section	1648	2956
S 7	Yellow Keeble	1649	2940
Kawanda 20	Kawanda selection	1552	2784
S 13	Collected from Gulu	1547	2775
B. Congo	Ex-Kiisi, Kenya	1503	2696

Table 38: (continued)

Cultivar	Description	Mean yield (gm) per plot	Estimated yield kg/ha
Bukalasa 2	Bukalasa selection	1464	2626
Bukalasa 4	Bukalasa selection	1440	2583
S 1	Hernon 29	1373	2463
S38	Ex-Kitale, Kenya	1267	2273
Kakira 13	Kakira selection	1046	1876
Kent	American cultivar	736	1320
Kanrich	American cultivar	538	965
Delmar	American cultivar	520	933

LSD (P = 0.05) = 379 gm

Conversion: gm/plot x 1.794 to kg/ha

The American cultivars again yielded lowest. Bukalasa 4 which previously had always yielded best was outyielded by several cultivars. This might have been a reaction to the drought conditions that prevailed in the first 1½ months after planting. This indicates that Bukalasa 4 shows a high genotype x environment interaction which might be a serious disadvantage.

3.9 AGRONOMIC STUDIES

3.9.1 Spacing trials

There had not been any work done on the optimum plant population per unit area and spatial arrangement under Uganda conditions before the present investigations were started. The spacing recommendations had been based on the work done on French beans (*Phaseolus vulgaris*) at Kawanda, a crop of very different growth habit. The spacing pattern used at Kawanda has been 24" x 3" but spatial arrangement of 24" between rows and 4" within row had previously been adopted for the soyabean at Kabanyolo. In Rhodesia, Arnold (1942) using cultivar Hernon 268 with combinations of 30" and 15" inter-row and 4" and 2" intra-row spacing obtained best yield from a 15" x 4" pattern. Also in Rhodesia Smartt (1960) studying a wide range of planting patterns working with cultivar Hernon 147 got high yields at 18" x 6", 18" x 3" and 12" x 6" giving best yields. In Kenya, Gray (1967) working with cultivar Belgian Congo at high altitude and rainfall studied 3 inter-row width of 24", 12", 18" and intra-row width of 6", 4" and 2" at two densities of 1 and 2 plants per hill and found that inter-row of 12" gave a significant increase in yield over others as also did the greater number of plants per hill. The intra-row spacing did not appear to affect the yields. In Tanzania, Auckland (1967) working with cultivars Hernon 237 (indeterminate) and light speckled (determinate) at low altitude and rainfall found that spacing patterns influenced yields. He found no significant difference at 5% probability level between populations of 128,000 and 64,000 plants per acre with spacing of 7" x 7" and 14" x 7" respectively though the spacing pattern of 7" x 7" gave higher yields. He showed that for narrow inter-row spacing, the pattern of spacing with the same population was not significantly important, but with wide inter-row spacing pattern, the narrower inter-row spacing and wider intra-row spacing pattern produced significantly higher yields with the same population. Work done in U.S.A. and Canada suggests that narrow inter-row and intra-row spacing produced the best yields. Probst (1945) attributed significant variety x spacing interactions obtained for seed yield largely to differential lodging of cultivars across spacing treatments. Lodging increased with increasing density in the row, while height, seed size, and maturity were generally unaffected. Hinson and

Hanson (1962) reported that percent protein and plant height decreased, while yields per plant, percent oil, seed size, node number, and branch number increased under wider spacing. However, significant genotype x spacing interactions were found in most traits.

Wiggans (1939) reported that, within population levels, seed yields increased as the inter-row and intra-row spacings approached a uniform (square) distribution pattern. Increase in population density beyond 6 plants per square food gave little further change in seed yield. Lehman and Lambert (1960) found that 20-inch rows generally out-yielded 40-inch rows, while yield differences due to intra-row spacings were inconclusive. Seed weight and seeds per pod were not affected appreciably by spacing or population change, whereas the number of seeds, pods, and branches per plant decreased with increased plant population. Dovovan et. al. (1962) reported appreciable yield increase for soyabean plants in 7" x 3" arrangements compared with plants in rows 35 inches apart. They suggested that in general, chemical composition of soyabean seed was affected very little by inter- and intra-row plant spacings or by competition.

An experiment was carried out during the first rains of 1968 to study the effects of spacing and populations on yield, agronomic and chemical characters of three cultivars under two different plant nutrient levels at Kabanyolo. The experiment was repeated during the second rains using two cultivars and four plant nutrient levels.

3.9.1.1 <u>Spacing trials (first rains, 1968)</u>

3.9.1.1.1 <u>Materials and Methods</u>

The materials used were Belgian Congo which was the same cultivar used in the experiment by Gray (1967), Kakira 13, a local selection and Delmar, an American cultivar of medium size and maturity. There were 3 populations in 6 different spacing arrangements (see Table 42 for details). The experimental design was a split-plot with plot size of 8 ft. x 8 ft. and three replications. The cultivars were in main plots, the fertility levels in the sub-plot and spacing in the sub-plot. The two fertility levels were "low fertility", i.e. no fertilisers added and "high fertility" with a mixture of 400 pounds per acre of double super phosphate and 2 tons acre of calcium ammonium nitrate applied broadcast. Unfortunately the fertilisers badly affected germination and consequently had poor stand on the part of the experiment that had fertiliser application. This part of the experiment was therefore abandoned for the purposes of analysis of variance thus giving a split plot design for the remaining part of the experiment. However, at harvest the outer rows were discarded and then similar treatment was given to both parts of the experiment for the components of yield observations. Ten plants were randomly samples from parts with good stand from each plot and scored for the various yield components and characters. The seeds from all the ten plants in each plot were later combined for the purpose of protein and fat content analysis. Experimental results were subjected to an analysis of variance. The various characters studied have been summarized by combining and averaging the observation data for each character from each treatment.

3.9.1.1.2 Results

The air-dried seed yield in grams per plot was recorded.

part of the experiment that had fertiliser application. This part of the experiment was therefore abandoned for the purposes of analysis of variance thus giving a split plot design for the remaining part of the experiment. However, at harvest the outer rows were discarded and then similar treatment was given to both parts of the experiment for the components of yield observations. Ten plants were randomly samples from parts with good stand from each plot and scored for the various yield components and characters. The seeds from all the ten plants in each plot were later combined for the purpose of protein and fat content analysis. Experimental results were subjected to an analysis of variance. The various characters studied have been summarized by combining and averaging the observation data for each character from each treatment.

3.9.1.1.2 <u>Results</u>

The air-dried seed yield in grams per plot was recorded.

The data showed no obvious trend of differences in yield among spacing arrangements. The mean yield for each population at different spacing arrangement was computed and the results are shown in Table 39.

Table 39: Summary table of mean yield data (gm)

Spacing pattern	Approximate population plants/hectare			Rectangularity means
	160,000	216,000	344,000	
High rectangularity	2509	2707	2425	2547
Low rectangulatiry	2608	2732	2599	2647
Population means	2558	2719	2512	

The low rectangularity outyielded the high rectangularity for the same population in all the three populations used although the differences did not appear to be significant at 5% probability level.

The analysis of variance was carried out and the results are shown in Table 40.

Table 40: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	53	22.03		
Main plots	8	11.10		
Cultivar	2	1.18	0.591	0.36

Table 40 (continued)

Source of variation	df	Ss	Ms	F
Blocks	2	3.35	1.678	1.02
Error (a)	4	6.56	1.641	
		CV =	46.7%	
Sub-plots	45	10.92		
Spacing	5	0.70	0.140	0.47
Spacing x cultivar	10	1.27	0.127	0.43
Error (b)	30	8.94	0.298	
		CV =	19.9%	

The failure of analysis of variance to show any significant difference among the different spatial arrangements and populations was probably due to low plant nutrient level of the land used. Some of the yields components were examined to try and find out which components were affected most by the treatments. The observation results are shown in Table 41.

Although there was no significant differences in yield for the different spatial arrangements and populations the crop showed its compensation ability thus the wider inter-row spacing of 24" and 18" produced more pods and seed weight per plant than the closer inter-row spacing with the closest inter-row spacing of 6" producing the smallest yield per plant as expected. For mean seed weight, however, such a relationship did not appear to be generally applicable.

Table 41: Table of some yield components

Cultivar	Spacing	Av. no. pods per plant	Av. no. seedless pod per plant	Seed wt per plant (gm)	Mean seed wt. (gm)
B. Congo	24" x 4"	52.8	4.6	12.60	0.159
	18" x 4"	57.5	7.2	11.90	0.153
	12" x 4"	45.4	5.0	10.20	0.172
	12" x 8"	51.0	8.9	9.80	0.149
	9" x 8"	48.6	6.0	10.00	0.148
	6" x 8"	42.9	5.1	8.20	0.150
Kak. 13	24" x 4"	64.5	7.9	20.60	0.174
	18" x 4"	39.6	4.2	8.52	0.164
	12" x 4"	31.4	3.9	6.80	0.162
	12" x 8"	42.5	3.3	9.50	0.162
	9" x 8"	47.1	5.6	10.72	0.177
	6" x 8"	38.2	3.8	8.29	0.170
Delmar	24" x 4"	43.2	2.6	12.94	0.173
	18" x 4"	56.2	3.6	17.58	0.172
	12" x 4"	26.7	2.6	8.48	0.171
	12" x 8"	33.2	0.8	7.02	0.168
	9" x 8"	30.3	1.2	10.25	0.165
	6" x 8"	20.7	0.9	5.51	0.159

The estimated yield in Kg/ha based on yield data recorded was computed. The expected yield in Kg/ha based on intended plants per hectare and seed weight per plant based on thirty sampled plants for each spatial arrangements was also computed and the results are presented in Table 42.

Table 42: Summary table of observed yield and expected yield based on intended population per hectare and yield per plant on the basis of sampled plants

Spacing	Intended population per hectare	Seed wt/ plant on basis of 30 plants (gm)	Observed yield (kg/ha)	Expected yield (kg/ha)
B. Congo:				
24" x 4"	155,150	12.60	1960	1955
12" x 8"	162,200	9.70	1580	1573
9" x 8"	215,120	10.00	1532	2151
18 x 4"	216,270	11.90	1654	2574
12" x 4"	324,410	10.20	1738	3244
6" x 8"	365,840	8.20	1375	3000
Kak. 13:				
24" x 4"	155,150	13.00	1918	2017
12" x 4"	162,200	9.50	1614	1540
9" x 8"	215,120	10.72	1831	2306

Table 42: (continued)

Spacing	Intended population per hectare	Seed wt/ plant on basis of 30 plants (gm)	Observed yield (kg/ha)	Expected yield (kg/ha)
Kak. 13: (contd.)				
18" x 4"	216,270	8.52	1809	1843
12" x 4"	324,410	6.80	1632	2206
6" x 8"	365,840	8.29	1566	3033
Delmar:				
24" x 4"	155,150	12.94	1747	2008
12" x 8"	162,200	7.02	1818	1139
9" x 8"	215,120	10.25	2030	2205
18" x 4"	216,270	10.75	1961	2325
12" x 4"	324,410	8.48	1882	?751
6" x 8"	365,840	5.51	1720	2016

A similar trend for 24" x 4" and 12" x 8" was shown by both the observed and expexted yield data for all the cultivars with pattern 24" x 4" out yielding 12" x 8". The other patterns, however, failed to show consistently similar trend. From the expected yield data, closer inter-row spacing outyielded the wider inter-row spacing arrangements. The fact that this was not reflected in the observed yield data may be due to fewer number of plants harvested from each spatial arrangements than expected due to poor stand. During the second rains experimentation, however, an actual count of the plants harvested from each plot was made and this was taken into account during the various analyses of the data.

Determination of crude protein percentage from each spacing and fertility level treatments were carried out and the means computed. The results are shown in Table 43.

Table 43: Summary table for mean protein percentage (N x 6.25)

Spacing	Protein means for non-fertilised land	Protein means for fertilised land
B. Congo:		
24" x 4"	29.1	-
12" x 8"	30.2	32.9
9" x 8"	27.7	32.8
18" x 4"	29.4	38.1
12" x 4"	29.4	36.3
6" x 8"	29.9	-
Fertility mean	29.2	35.0
Kak. 13:		
24" x 4"	30.4	40.7
12" x 8"	39.1	37.2
9" x 8"	37.3	39.8

Table 43: (continued)

Spacing	Protein means for non-fertilised land	Protein means for fertilised land
Kak. 13: (contd.)		
18" x 4"	33.5	41.6
6" x 8"	31.9	42.2
Fertility mean	33.4	40.3
Delmar:		
24" x 4"	27.8	32.4
12" x 8"	29.2	37.6
9" x 8"	23.8	-
18" x 4"	31.9	34.5
12" x 4"	30.4	33.3
6" x 8"	27.2	31.7
Fertility mean	28.3	33.9

The data appeared to show a significant difference between the two fertility levels but showed no obvious response to spacing treatments.

3.9.1.2 Spacing trials (2nd rains 1968)

3.9.1.2.1 Materials and Methods

The experiment was run in four units. Each experimental unit was a sub-experiment complete in itself with a randomized complete block design and plot size of 8 ft. x 8 ft. The four units corresponded to four levels of fertiliser application. During the first rains of 1968 the four plots each received respectively no fertilisers, 5 cwt/acre, 10 cwt/acre, and 20 cwt/acre of mixed fertiliser (2 parts calcium ammonium nitrate, 2 parts single super phosphate and 1 part potassium chloride) referred to as F_o, F_1, F_2 and F_3. The land had then carried a crop of Phaseolus vulgaris. Before sowing to soyabean in the second rains, application by placement of additional 50 lbs/acre, 80 lbs/acre and 120 lbs/acre of the same mixed fertiliser as used before was made to units that had had 5 cwt/acre, 10 cwt/acre and 20 cwt/acre of mixed fertiliser respectively. Two cultivars, Bukalasa 4 - a tall local selection and Kent - a short American cultivar and 6 spacing arrangements (see Table 44 for details) were used in each experimental unit. The experimental units were regarded as part of one experiment for the purpose of analysis for the effects of nutrient levels and as separate experiments for the purpose of spacing arrangement effects on the yield of the cultivars.

The two outer rows and the plants adjacent to gaps in the inner rows of each plot were discarded at harvest. The number of plants harvested per plot was recorded and later a ratio of plants expected to plants harvested per plot was used in estimating yield per plot based on the observed yield. Ten plants were randomly sampled from areas of good stand from the inner rows for the component of yield observation and protein content determination.

3.9.1.2.2 Results

The air-dry seed yield in grams for each plot was recorded. Then the estimated yields in kg/ha for each cultivar from different nutrient levels for the same spacing arrangement was computed. The results are presented in Table 44.

The results showedaaasharp response by the soyabeans to fertiliser application up to level F_2 and then a decline with application of higher levels of fertiliser. Both cultivars showed a general decline at the highest level of plant nutrients.

Table 44: Summary table of estimated yield data (kg/ha)

Spacing	Cultivar	Nutrient level F_o	F_1	F_2	F_3
24" x 4"	Bukalasa 4	878	1604	2064	2333
	Kent	379	884	1122	741
24" x 3"	Bukalasa 4	1067	1630	2374	2440
	Kent	298	923	1132	974
24" x 2"	Bukalasa 4	1036	1833	2530	2789
	Kent	609	929	1225	1051
12" x 4"	Bukalasa 4	1326	2178	3367	3222
	Kent	574	1271	1710	1672
12" x 3"	Bukalasa 4	1369	2101	3604	2779
	Kent	674	1405	1719	1636
12" x 2"	Bukalasa 4	1920	2666	3405	3623
	Kent	1207	1803	2043	1736
Nutrient level means		994	1602	2191	2083

Conversions: gm/5 plots x 0.4485 for inter-row spacing of 24" and x 0.3844 for inter-row spacing of 12" to kg/ha.

The data from each experimental unit were subjected to analysis of variance. The results are shown below.

The results from the analysis of variance of the yield data from the experimental unit without fertiliser application (F_o) are presented in Table 45.

Table 45: Table of analysis of variance (F_o)

Source of variation	df	Ss	Ms	F
Total	59	7.66		
Replications	4	1.988	0.497	10.35
Cultivars	1	1.472	1.472	30.66
Spacing	5	1.963	0.392	8.16
Spacing x cultivars	5	0.090	0.018	0.37
Error	44	2.151	0.048	

CV = 47.0%

The analysis showed a highly significant difference among the spacing arrangements used at 5% level even with the high coefficient of variation but failed to show significant difference for the interaction of spacing and cultivars. The LSD at 5% level was then computed to separate the spacing arrangement means. The results are shown in Table 46.

Table 46: Summary table for spacing means data (gm/plot)

Cultivar	Spacing arrangement					
	24"x4"	24"x3"	24"x2"	12"x4"	12"x3"	12"x2"
Bukalasa 4	392	476	462	690	713	999
Kent	169	133	271	198	351	628
Spacing means	280	304	366	494	532	813

LSD (P = 0.05) = 280 gm

Doubling the population did not give significant differences except in the case of 24" x 4" and 12" x 2". This might be due to the high coefficient of variation. The analysis of variance results from (F_1) experiment are presented in Table 47.

Table 47: Table of analysis of variance (F_1)

Source of variation	df	Ss	Ms	F
Total	59	7.061		
Replications	4	0.602	0.150	5.769
Cultivars	1	2.247	2.247	86.432
Spacing	5	2.996	0.599	23.038
Spacing x cultivar	5	0.053	0.010	0.38
Error	44	1.163	0.026	

CV = 20.5%

The analysis showed a highly significant difference among the spacing arrangements and the LSD at 5% was computed to separate the spacing means. The results are shown in Table 48.

Table 48: Summary table of spacing means (F_1) (gm/plot)

Cultivar	Spacing arrangement					
	24"x4"	24"x3"	24"x2"	12"x4"	12"x3"	12"x2"
Bukalasa 4	715	727	817	1133	1093	1287
Kent	394	411	414	661	609	938
Spacing means	555	569	616	897	851	1163

LSD (P = 0.05) = 206 gm.

Doubling the population by changing inter-row of 24" to 12" with intra-row of 4", 3" or 2 significantly increased yield.

The analysis of variance results from (F_2) experiment are presented in Table 49.

Table 49: Table of analysis of variance (F_2)

Source of variation	df	Ss	Ms	F
Total	59	17.576		
Replications	4	1.226	0.306	4.135
Cultivars	1	7.031	7.031	95.013
Spacing	5	5.486	1.097	14.824
Spacing x cultivar	5	0.543	0.018	1.459
Error	44	3.290	0.074	

CV = 25.2%

The analysis showed a highly significant difference among the spacing arrangements and the LSD at 5% was computed to separate the spacing means. The results are shown in Table 50.

Table 50: Summary table of spacing means (F_2) (gm/plot)

Cultivar	Spacing arrangement					
	24"x4"	24"x3"	24"x2"	12"x4"	12"x3"	12"x2"
Bukalasa 4	920	1059	1128	1752	1875	1771
Kent	500	505	546	890	894	1063
Spacing means	710	782	837	1321	1384	1417

LSD (P = 0.05) = 347 gm.

Again the results showed a significant increase in yield by doubling the population by changing inter-row spacing from 24" to 12".

The analysis of variance results from (F_3) experiment are shown in Table 51.

Table 51: Table of analysis of variance (F_3)

Source of variation	df	Ss	Ms	F
Total	59			
Replications	4	0.723	0.180	3.00
Cultivars	1	8.512	8.512	141.866
Spacing	5	4.402	0.880	14.666
Spacing x cultivar	5	0.303	0.060	1.00
Error	44	2.652	0.060	

CV = 24.0%

The analysis showed a highly significant difference among the spacing arrangements and LSD at 5% level was computed to separate the means. The results are shown in Table 52.

Table 52: Summary table of spacing means (F_3) (gm/plot)

Cultivar	Spacing arrangements					
	24"x4"	24"x3"	24"x2"	12"x4"	12"x3"	12"x2"
Bukalasa 4	1040	1088	1243	1676	1446	1885
Kent	330	434	469	870	852	903
Spacing means	685	761	856	1273	1149	1394

LSD (P = 0.05) = 313 gm.

Again the results showed a significant increase in yield by changing the inter-row spacing from 24" to 12".

The results thus indicated that the intra-row spacing did not have as much influence on yield as the inter-row spacing.

3.9.2 Fertiliser application trials

The advent of radioactive labelling of elements made possible the precise determination of the contribution of fertilisers to the day by day requirements of the plant. But the exact understanding of the individual fertiliser's contribution is still meagre. Ohlrogge (1960) considers that failure to increase yields consistently through single fertiliser applications to soyabeans probably discouraged detailed studies on individual fertiliser's contribution when it should have had the opposite effect.

Early in the use of radioactive tracers, it was demonstrated by Krantz et.al. (1949) that in the early stages of growth of soyabeans from 70 to almost 100% of the plant phosphorus may be derived from applied fertilisers. Both band and broadcast application could supply this when appropriate rates were applied. Although fertilisers were utilized, they replaced much soil phosphorus, resulting in only slight over-all increases in phosphorus uptake and yield. Their data also showed that the bulk of the fertiliser phosphorus was taken up within the first 2 to 3 months after application by the soyabean crop. Bureau et. al. (1953) working in Ohio reported that the fertiliser phosphorus uptake rates reached a maximum of 0.2 pounds per acre per day for the period 75 to 114 days after planting. Since then quite a lot of work has been done to show the up-take of phosphorus by plants from fertilisers but there is little reported work attempting to relate up-take rates with seed yield. Different cultivars, however, have been shown to respond differently in yield to different levels of phosphorus application. Howell (1964) has shown that soyabean cultivars differ in their response to high levels of phosphorus. He said that some cultivars were tolerant in respect of germination and vigorous growth to high phosphorus, whereas others were not.

In established soyabeans, it is generally agreed that symbiotically fixed nitrogen helps to meet the daily nitrogen requirements but initially the seedling is dependent on what is supplied from the soil via its roots on its own cotyledonary reserves. According to Ohlrogge (1960), Yoshihara found that in effectively nodulated soyabeans an outside source of combined nitrogen was needed only for the first 5 weeks after planting. Allos et. al. (1959) concluded from studies with several legume spp. in general that only about $\frac{1}{2}$ to $\frac{3}{4}$ of the total nitrogen required for yields could be supplied by the fixation process so that even with effective nodulation, nitrogenous fertilisers may be needed to maximise yields of other nutrients are present in sufficient amounts not to impose any limit.

Surprisingly little critical work has been done on the role of Calcium in the production of soyabean and Ohlrogge

(1960) suggests that the abundance and relatively low costs of calcium in the U.S.A. and its general widespread application as a routine measure have been responsible for this. He emphasised that a constant supply of calcium, however, is required by the plant since it is immobilised within the soyabean plant. The positive effects of liming include the raising of pH in acid soils, which in turn affects the uptake of other minerals as well as the direct effect of Ca^{++} availability.

There has been very little work done in East Africa to evaluate the contribution of either individual fertilisers or of mixtures of the different fertilisers on soyabeans. The only reference found was that of Auckland (1967) who reported that in Nichingwea region of Tanzania, 50 pounds of double super phosphate per acre gave "economic returns".

In view of the lack of adequate information on the role of fertilisers in soyabean production in East Africa a fertiliser experiment was run during the first rains of 1968 to try and evaluate the role of lime and phosphorus fertilisers in soyabean production on a typical Buganda catena upperslope brown soil. The experiment was repeated during the second rains of 1968 using the same plots as used in the first rains to evaluate the residual effects of these fertilisers. Another experiment was carried out jointly for fertility levels and spacing effects on soyabean yield per unit area (see 3.9.1.2.2).

3.9.2.1 Materials and Method

The cultivars used in the experiment were Belgian C Congo, Bukalasa 4 and Kent. Belgian Congo was eliminated after planting from the 1st rains experiment because it was found that accidental admixture had occurred with some Bukalasa 4 seeds. The experimental design was a criss-cross (Finney, 1952) with cultivars and lime in main plots, and phosphate in sub-plots. The sub-plot size was 8 feet by 8 feet. There were 4 levels of lime, zero, 1 ton, 2 tons and 4 tons per acre and 4 levels of phosphate, i.e. zero, 100 pounds, 200 pounds and 400 pounds per acre of double super phosphate. The fertilisers were broadcast just before planting. Spacing was 4 inches within row and 24 inches between rows for each cultivar. At harvest the inner three rows were harvested and the two outer rows acted as guard-rows. In the 2nd rains experiment the three inner rows were again harvested but this time the plants adjacent to gaps were discarded and the number of plants harvested per plot recorded. This figure was later raised proportionally to that equivalent to the full stand per plot for the purpose of various analyses. Ten plants were randomly sampled from areas with good stand in the three inner rows in the 1st rains experiment for observation on the components of yield. The experimental results are subjected to an analysis of variance. The various characters studied have been summarized by combining and averaging the observation data for each character from each treatment.

3.9.2.2 Results for 1st rains experiment

The total air-dry seed yield for each treatment was determined and the results are shown in Table 53.

Table 53: Summary table for yield data for each treatment (grams per 3 plots)

Cultivar	Phosphate level per acre	Lime level per acre				
		Zero	1 ton	2 tons	4 tons	Mean
Kent	Zero	3260	3230	3490	3949	3482
	100 lbs.	3276	3129	2274	2862	2885
	200 lbs.	3065	3996	3996	3842	3717
	400 lbs.	3314	3481	3600	3343	3434
	Mean	3228	3459	3590	3499	

Table 53: (continued)

Cultivar	Phosphate level per acre	Lime level per acre				
		Zero	1 ton	2 tons	3 tons	Mean
Bukalasa 4	Zero	4482	4643	4945	4884	4738
	100 lbs.	4378	4892	4495	4173	4484
	200 lbs.	4724	4716	4592	4861	4723
	400 lbs.	4542	4707	4578	5063	4722
	Mean	4531	4739	4652	4745	

From the summary table it appeared that there was no very obvious response either to phosphate, lime or a combination of the two fertilisers by the two soyabean cultivars, but Kent appeared to have significantly responded to phosphate. The analysis of variance for air-dry seed yield per plot was carried out and the results are shown in Table 54.

Table 54: Table of analysis of variance

Source of variance	df	Ss	Ms	F
Blocks	2	0.18		
Main plots (a)				
Cultivar	1	10.43	10.43	37.25
Error (a)	2	0.56	0.28	
		CV = 22.1%		

Table 54: (contd.)

Source of variance	df	Ss	Ms	F
Main plots (b)				
Lime	3	0.28	0.093	0.33
Error (b)	3	0.84	0.028	
		CV	= 22.1%	
Sub-plots (d)				
Phosphate	3	0.23	0.08	2.67
Cultivar x phosphate	3	0.09	0.03	1.0
Lime x phosphate	9	0.29	0.03	1.0
Cultivar x Lime x phosphate	9	0.52	0.06	2.0
Error (d)	48	1.59	0.03	
		CV	= 7.2%	

The analysis failed to show a significant response at 5% level to either phosphate or lime fertilization. It also failed to show any significant interactions either of the first or second order. Some of the yield components were then examined and the results are presented in Table 55.

It was observed that even individual yield components failed to show any obvious response to the treatments. The lack of response to the fertilisers applied might have been due either to relatively high initial fertility of

Table 55: Table of mean data of some of the yield components based on a sample of 30 plants for each treatment.

Lime	Phosphate level	Pods/plant		Mean seed weight(gm)		Yield/plant (grams)	
		Buka-lasa	Kent	Buka-lasa	Kent	Buka-lasa	Kent
Zero	Zero	56.4	42.6	0.216	0.168	22.2	13.1
	100 lbs.	59.5	47.8	0.226	0.195	23.9	20.1
	200 "	56.2	39.1	0.221	0.186	21.4	13.3
	400 "	55.1	51.4	0.221	0.193	24.1	18.9
1 ton	Zero	52.6	39.8	0.229	0.182	2.13	16.0
	100 lbs.	58.7	47.0	0.223	0.181	26.7	20.0
	200 "	62.9	54.6	0.227	0.201	24.9	21.8
	400 "	58.5	46.9	0.231	0.196	23.9	16.6
2 tons	Zero	60.0	41.8	0.229	0.195	24.0	17.0
	100 lbs.	59.6	34.8	0.226	0.176	25.0	17.0
	200 lbs.	55.6	45.0	0.232	0.195	22.8	20.1
	400 lbs.	63.2	57.6	0.225	0.188	25.4	21.7
4 tons	Zero	55.6	50.6	0.231	0.198	23.3	23.2
	100 lbs.	61.1	53.9	0.230	0.196	22.8	23.4
	200 "	53.9	44.0	0.228	0.186	22.9	17.4
	400 "	55.5	41.2	0.220	0.182	20.8	16.7

the land used in terms of available Phosphorus and Calcium as it was coming out of pasture after about 3 years without cropping or a genuine lack of responsiveness to either lime or phosphate or merely to having too many factors out of control on the experimental plots.

The crude protein percentage of the dry seed from each treatment was next determined and the results are presented in Table 56.

Table 56: Summary table of mean data of crude protein percentage (% protein = N x 6.25)

Cultivar	Phosphate level per acre	Lime levels per acre % Protein			
		Zero	1 ton	2 tons	4 tons
Kent	Zero	29.1	29.2	30.3	31.8
	100 lbs.	30.9	30.1	29.9	31.8
	200 "	29.0	20.4	32.3	27.8
	400 "	32.8	30.8	32.9	32.0
Bukalasa 4	Zero	43.1	40.8	39.5	40.5
	100 lbs.	40.8	39.2	40.2	40.8
	200 "	38.5	40.7	38.9	38.4
	400 "	41.0	38.5	37.8	40.0
B. Congo	Zero	29.3	27.9	27.4	27.2
	100 lbs.	26.7	27.1	29.3	27.0
	200 "	28.8	27.9	26.5	27.7
	400 "	27.4	27.6	27.9	28.0

The summary table showed no very obvious response to the treatment. The protein means indicated random variation within each cultivar irrespective of the fertiliser treatments.

3.9.2.3 Results from 2nd rains experiment

The yield data was subjected to analysis of variance and the results are presented in Table 57.

Table 57: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Replications	2	0.948		
Main plots (a)				
Cultivars	2	6.468	3.234	28.543
Error (a)	4	0.453	0.113	
		CV	=	38.0%
Main plots (b)				
Lime	3	0.131	0.043	0.269
Error (b)	6	1.143	0.190	
		CV	=	49.3%
Main plots (c)				
Cultivar x lime	6	0.313	0.052	1.268
Error (c)	12	0.496	0.041	
		CV	=	22.9%
Sub-plots (d)				
Phosphate	3	0.615	0.205	7.321
Cultivar x phosphate	6	0.396	0.066	2.357
Lime x phosphate	9	0.329	0.036	1.285
Cultivar x lime x phosphate	18	0.300	0.001	0.035
Error (d)	72	2.069	0.028	
		CV	=	18.9%

The analysis showed a significant response of the crop to phosphate at 5% probability level. It also showed a significant interaction of cultivar by phosphate at the same level of probability but it failed to show any significant response of the crop to lime.

The LSD at 5% level was computed to separate the phosphate means and the results are shown in Table 58.

Table 58: Summary table for phosphate means (gms. per plot)

Cultivar	Phosphate levels per acre			
	Zero	100 lbs.	200 lbs.	400 lbs.
Kent	461	484	515	490
B. Congo	842	946	970	1043
Bukalasa 4	1120	1139	1164	1426
Phosphate means	807	856	883	986

LSD (P = 0.05) = 50 gms.

The estimated seed yield in kilograms per hectare for each cultivar in the experiment irrespective of the various treatments for both seasons was computed and the results are shown in Table 59.

Table 59: Summary table of estimated yield (kg/ha)

Cultivar	1st rains	2nd rains
Kent	2587	1094
Belgian Congo	-	2132
Bukalasa 4	3842	2720

Conversions: gms/48 plots x .280 to kg/ha for 1st rains results and x .467 for 2nd rains results.

The low yield for the 2nd rains were attributed to the initial dry conditions under which the crop established itself. It may be that a phosphate response is obtainable under these conditions but not when moisture is plentiful at establishment.

3.9.4 Weed control studies

Control of weeds is quite essential for the protection of crop against competition for soil nutrients, water, light and possible poisoning so that the crop can grow with maximum vigour. The loss of vigour of crop and consequently crop yield due to weed competition depends very much on the competitive ability and population of the dominant weed species competing with the crop. In the U.S.A. Caviness and Taylor (1960) reported 900 pound per acre loss in soyabean yield due to moderate infestation of Johnsongrass. Soyabean yields in Mississippi showed yield reduction of 50% from competition from pigweeds and 40% from morning glory competition. This indicated the different competitive ability of the weeds with the soyabeans and this gave the varying yield reduction depending on the type and population of dominant weeds in the particular experiment.

Various weed control practices have been tried to attain maximum soyabean yields in the U.S.A. and elsewhere. The cultural, mechanical and herbicide control methods have all been used. Some workers have questioned the usefulness of mechanical control where this has involved cultivation in the crop to remove the weeds (Burnside et. al. 1964) as hoeing also disturbed the soil and probably injured the roots of the crop. The discovery of pre-emergence herbicides has given the research worker and farmer an important tool for the elimination of weeds in crop without disturbing the soil and crop roots.

Yields of soyabean have been shown in the present investigations and elsewhere (Auckland, 1967) to be increased by reducing the inter-row spacing. Such a change in crop culture to be practiced on a field scale requires weed control practices other than cultivation. Burnside et. al. (1964) working at Lincoln, Nebraska showed that chemical control could be as effective as clean hand-weeding in control of weeds for soyabean production. Their results also indicated the necessity of efficient weed control if high soyabean yields are to be expected.

There is relatively little information in East Africa to indicate the severity of weed competition in reducing soyabean yields and no effort has apparently been made to investigate the use of herbicides that could eliminate or at least considerably reduce cultivation in the crop. Auckland (1968) in Tanzania suggested that the soyabean field should be kept free of weeds until the crop attains adequate size to shade the soil when it is effective in suppressing weed growth. In Rhodesia, Smartt (1960) found that one weeding doubled the yield of control (no weeding) but two, three and four weedings only gave small increases in yield over one weeding. This of course, however, would depend on the weed challenge in terms of population and environmental conditions for weed growth or regrowth.

Information on this important aspect in soyabean production was lacking for Kabanyolo conditions under which several soyabean cultivars were going to be evaluated for their yield potential. Experiments were run in the first and second rains of 1968 to evaluate the effects of weeding frequency on soyabean yield and a preliminary experiment with herbicides was conducted in the second rains. The purpose of the herbicide experiment was to evaluate the effects of different doses of different pre-emergence herbicides on the germination of soyeabeans and early growth of weeds.

3.9.4.1 Frequency of weeding (1st rains, 1968)

3.9.4.1.1 Materials and Methods

Dorman soyabean, an American cultivar, was used in the experiment. The experiment was carried out on a particularly weedy plot that had been cropped with green grams during the previous season and had been continuously cultivated for more than three years. No fertilisers were applied. The major weed species present were: *Galinsoga parviflora* and *Amaranthus* sp. The experiment had two general treatments: weeding at four levels, i.e. control (no weeding) 1, 2 and 3 weedings and inoculation with *Rhizobium* bacteria inoculum at two levels, i.e. inoculated and non-inoculated seeds. The first weeding was carried out at 4 weeks after planting and subsequent weedings at 3 weeks intervals. The experiment was a 2 x 4 factorial with a randomized complete block design and three replications. The plot size was 6 ft. by 6 ft. and a crop spacing of 18" x 3".

At harvest, ten plants were randomly sampled from areas of good stand within the inner three rows of each plot for observations of components of yield. The experimental results were subjected to analysis of variance and differences among treatments were tested for significance.

3.9.4.1.2 Results

The mean air-dry seed yield for each treatment combination was determined and the estimated yield in kilogram per hectare computed. The results are shown in Table 60.

Inoculation	Weeding frequency	Mean yield per plot (grams)	Estimated yield kilogram/hectare
Inoculated seed	No weeding	441	1,055
	1 weeding	1120	2,679
	2 weeding	1443	3,452
	3 weeding	1524	3,647
Non-inoculated seeds	No weeding	192	460
	1 weeding	814	1,948
	2 weeding	947	2,266
	3 weeding	1001	2,395

LSD (0.05) = 308 (gm)

Conversions: gms/plot x 2.392 to kg/ha

The data showed a considerable response to both weeding and inoculation with Rhozobium. In the case where the seeds were not inoculated with the Rhozibium sp. the reduction in yield represented 80.8%, 18.8% and 5.4% on no weeding, one weeding and two weedings respectively as compared to carrying out 3 weedings. In the case of inoculated seeds the corresponding reduction percentages were 71%, 26.5% and 5.3%. The data were subject to analysis of variance and the results are shown in Table 61.

Source of variance	df	Ss	Ms	F
Total	23	5.144		
Replications	2	0.246	0.123	3.96
Weeding	3	3.339	1.113	35.9
Inoculation	1	0.917	0.917	28.5
Inoculation x weeding	3	0.193	0.064	2.06
Error	14	0.447	0.031	

CV = 13.2%

The analysis showed very highly significant differences at 5% probability level for inoculation and weeding frequency. The analysis also showed that soyabean yield was significantly increased by weeding and inoculation with Rhizobium. It, however, failed to show a significant increase in yield for various weeding frequencies after the first weeding.

Some of the yield components were examined to try and find out which components were affected most by the treatments. The observation results are presented in Table 62.

Mean seed weight appeared not to be systematically affected by weeding treatments. All the other components, 3.9.4.2 Chemical weed control (2nd rains 1968)

3.9.4.2.1 Material and Methods

Three herbicides, each at four levels (see table 65 for details) and cultivar Bukalasa 4 were used in the experiment. The experimental design was a randomized complete block with three replications and plot size of 4.5 metres by 1.5 metres. The spacing was 0.5 metre between rows and 7.5 cm within rows. The experiment was carried out on a particularly weedy plot that had been cropped for a long time. The main weeds were *Oxalis latifolia*, several genera of the composite family and African couch grass, *Digitaria scalarum* the latter two groups forming about 40% of the weed population.

A germination count of the inner two rows was taken 3 weeks after sowing and the weeds in the inner strip of 0.5 m x 4.5 m of each plot were harvested 50 days after application of the herbicide treatments. The weeds were dried at 100°C for 24 hours and the dry weight recorded.

3.8.4.2.2 Results

The germination data were subjected to analysis of variance and the results are presented in Table 63.

The analysis failed to show a significant difference among the treatments at 5% probability level. This suggested that the various levels of the herbicides used did not significantly affect the germination of the soyabean crop.

Table 63: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	38	1901		
Replication	2	674	337.0	9.07
Treatments	12	336	28.0	0.75
Error	24	891	37.12	

CV = 33.7%

The weed dry weight data were also subjected to analysis of variance and the results are presented in Table 64.

Table 64: Table of analysis of variance

Source of variance	df	Ss	Ms	F
Total	38	1.956		
Replications	2	0.040	0.020	0.58
Treatments	12	1.091	0.090	2.64
Error	24	0.825	0.034	

CV = 38.3%

The analysis showed a significant difference among the treatments at 5% probability level even with the very high coefficient of variation.

The LSD at 5% level was computed to separate the treatment means and the results are presented in Table 65.

Table 65: Summary table of dry weed yield (gm/plot)

Herbicide	Level/acre	Treatment means (gm)
Amiben	1 lb.	640
	2 lbs.	373
	3 lbs.	235
	4 lbs.	222
Triflan	1 pt.	656
	2 pts.	551
	3 pts.	445
	4 pts.	341
Eptam	1 lb.	665
	2 lbs.	588
	3 lbs.	472
	4 lbs.	322
No herbicide	no weeding	749

LSD (0.05) = 310 gm

No herbicide appeared to show any high superiority over the others in terms of the overall weed reduction, but it was noted that Triflan affected Oxalis latifolia more than the other herbicides.

3.9.5 <u>Time of planting studies</u>

Research workers are almost unanimous on the desirability of early planting of annual crops in tropical monsoon climates, that is sowing as soon after the breaking of the rains after a dry season as the seeds can be planted. Advantages of early planting have been demonstrated by many workers for individual crops in differing environments. Oram (1958) said that studies on groundnuts in the Congo by De Preter, and Tchad by Niqueux showed a linear and highly significant decrease in yield from earliest to latest sowings amounting in some years to 1800 pounds per acre over a 6 week period. Ruston (1962) compiled a table illustrating the effects of late planting of cotton in several African countries, showing that the average yield decline was as much as 62% with a delay in sowing of 8 weeks. Similar results are given by Goldson (1963) for maize in Kenya. For soyabeans, Smartt (1960) reported similar results in Rhodesia and Auckland (1968) recommended planting as soon as possible after the on-set of the rains for the best yeild results for soyabeans in Tanzania. Cartter et. al. (1962) claimed that probably no single cultural factor is more important to soyabean production than planting date in the United States this being, however, in relation mainly to soil temperature and daylength.

The suggested causes of the effects of early planting include rainfall regimes, crop water requirements, nitrate availability, soil air changes, solar radiation values, daylength and pests and disease effects. Different factors are probably of different relative importance in different regions. The day length factor for example would be very important for crops sensitive to daylength in the sub-tropical and temperate areas like U.S.A. where daylength is highly variable and the early planted soyabeans tend to flower at the same time as the late planted soyabeans thus giving the late planted crop a shorter growing period and hence lower yields. In equatorial regions, however, soil air changes might be of greater significance where there is a lot of rain and the soil reaches field capacity or even becomes waterlogged by the middle of the rains and thus the soils may have insufficient oxygen content for good root establishment and growth. The soil borne diseases tend to increase later in the rainy season.

The time of planting experimental trials were carried out in the first and second rains of 1968. The aim was to assess the effects of time of planting on the growth and yield of soyabeans at Kabanyolo University Farm.

3.9.5.1 First rains 1968 studies

3.9.5.1.1 Materials and Methods

Two cultivars, Hernon 49 and Bukalasa 4, were used in the trial. The experimental design was a randomized complete block design with plot size of 8 feet by 8 feet and five replications. The spacing was 24" x 4" and dates of sowing were at two weeks intervals starting with 27th February, 1968. The 10 day weather observation data at planting time and during the active growth period of the crop are shown in Table 66. At harvest, ten plants were randomly sampled from areas of good stand in the inner rows of each plot for observations on various components of yield.

Table 66: Summary table of 10 day weather observation data.

Source: Kabanyolo Weather Station.

Month	Mean temperature	Total rainfall (mm)	Potential evaporation (Penman)(mm)
February	23.3	3.9	46.88
	20.7	88.4	36.10
	22.0	104.0	29.55
March	21.9	61.6	43.57
	21.3	31.1	37.05
	21.9	32.0	48.23

Table 66: (continued)

Month	Mean temperature	Total rainfall (mm)	Potential evaporation (Penman)(mm)
April	22.1	62.3	37.56
	21.9	61.2	42.38
	20.9	94.0	33.69
May	21.4	27.8	39.93
	21.7	21.6	42.70
	21.3	84.4	38.11

3.9.5.1.2 Results

The air-dry seed yield per plot was recorded in grams. The mean yield per cultivar for each date of planting was then determined and the yield in kg/ha estimated. The results are shown in Table 67.

Table 67: Summary table of mean yield data

Cultivar	Date of sowing	Mean yield per plot (gm)	Estimated yield kg/ha
Hernon 49	27.2.68	1477	1986
	12.3.68	1153	1550
	26.3.68	1012	1360
Bukalasa 4	27.2.68	3443	4630
	12.3.68	2660	3578
	26.3.68	1758	2365

Conversions: gm /plot x 1.345 to kg/ha

Table 66: (continued)

Month	Mean temperature	Total rainfall (mm)	Potential evaporation (Penman)(mm)
April	22.1	62.3	37.56
	21.9	61.2	42.38
	20.9	94.0	33.69
May	21.4	27.8	39.93
	21.7	21.6	42.70
	21.3	84.4	38.11

3.9.5.1.2 Results

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	26.3.68	1012	1360
Bukalasa 4	27.2.68	3443	4630
	12.3.68	2660	3578
	26.3.68	1758	2365

Conversions: gm /plot x 1.345 to kg/ha

With a delay in sowing of 4 weeks from the first sowing and 5 weeks from the on-set of the rains, Hernon 49 had a reduction in yield of 31.5% while Bukalasa 4 had a reduction of 48.9%. The analysis of variance was carried out and the results are shown in Table 68.

Table 68: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	29	25.998		
Replications	4	1.168	0.292	2.53
Cultivars	1	14.847	14.847	128.94
Date of planting	2	5.781	2.890	25.10
Date x cultivar	2	1.898	0.949	8.24
Error	20	2.302	0.115	

CV = 17.6%

The analysis showed high significant difference among the different dates of sowing and the date of planting by cultivar interaction. The 5% level LSD was computed to separate the sowing date means and the results are shown in Table 69.

The analysis showed that Bukalasa 4 responded with significant difference in yield to all the three dates of sowing while Hernon 49 failed to show any significant response between the second and third dates of sowing but yields at these two dates were significantly different from those of the first sowing date.

Table 69: Summary table of sowing date mean yield data (gm)

Cultivar	Sowing dates		
	27.2.68	12.3.68	26.3.68
Hernon 49	1477	1153	1012
Bukalasa 4	3443	2660	1758
Sowing date means	2460	1906	1385

LSD (p = 0.05) = 183 gm

In order to investigate further the mechanisms of these responses to early planting some of the yield components were examined and the results are presented in Table 70.

Table 70: Summary table of some yield components

Cultivar	Date of sowing	Av. no. of pods/ plant	Av. no. of seed-less pods	Mean seed wt. (gm)	Av. seed wt. per plant (gm)
Hernon 49	27.2.68	44.6	2.7	0.175	12.0
	12.3.68	46.7	6.3	0.167	9.9
	26.3.68	37.7	4.7	0.167	9.7
Bukalasa 4	27.2.68	51.2	3.8	0.213	20.5
	12.3.68	53.5	4.9	0.206	19.6
	26.3.68	57.9	7.0	0.174	16.8

There was a tendency for the mean seed weight to be reduced by late planting, particularly in cultivar Bukalasa 4. In addition there was a marked reduction in height measured at maturity for both cultivars with successively later planting. The most important effect of late planting appears to be the high incidence of blind pod, suggesting that although the plant has produced sufficient 'sinks' the resources for filling them are limited. Cultivar Hernon 49 had 6.0%, 13.4% and 12.4% while cultivar Bukalasa 4 had 7.4%, 9.1% and 12.0% blind pods of the total pods per plant for the successive dates of planting respectively.

3.9.5.2 2nd rains 1968 studies

3.9.5.2.1 Materials and Methods

Three cultivars, Hernon 49, Bukalasa 4 and Kent, were planted in a randomized complete block design with 4 replications and plot size of 8 feet by 10 feet. The spacing was 24" x 4" and the dates of sowing were at two weeks interval starting with 5th September, 1968. The 10 day weather observation data at planting time and during the active growth period of the crop are shown in Table 71.

Table 71: Summary table of 10 day weather observation data

Source: Kabanyolo Weather Station

Month	Average temperature °C	Total rainfall (mm)	Potential evaporation (Penman) (mm)
September	22.05	18.1	46.32
	22.05	23.4	41.02
	22.15	10.2	44.75
October	22.90	21.6	46.73
	23.30	6.6	50.55
	22.15	68.6	49.68
November	22.25	32.1	41.03
	22.25	46.3	48.03
	21.75	107.1	34.73
December	21.30	120.5	35.60
	22.00	17.8	45.28
	21.65	6.0	52.75

3.9.5.2.2 Results

The air-dry seed yield per plot was recorded in grams. The mean yield per cultivar for each date of planting was then determined and the yield in kg/ha estimated. The results are presented in Table 72.

Table 72: Summary table of yield data

Cultivar	Date of sowing	Mean yield/ plot (gm)	Estimated yield kg/ha
Kent	5. 9.68	694	1246
	19. 9.68	1065	1911
	3.10.68	934	1676
Hernon 49	5. 9.68	1102	1978
	19. 9.68	1448	2599
	3.10.68	1026	1842
Bukalasa 4	5. 9.68	1417	2543
	19. 9.68	1980	3551
	3.10.68	932	1672

Conversions: Mean yield gm /plot x 1.794 to kg/ha.

The data was subjected to analysis of variance and the results are shown in Table 73.

Table 73: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	44	7.634		
Replications	4	0.282	0.070	1.25
Cultivars	2	2.231	1.115	19.91
Time of planting	2	2.390	1.195	21.33
Time x cultivars	4	1.217	0.304	5.42
Error	32	1.796	0.056	

CV = 20.0%

The analysis showed that the cultivars significantly responded to the various dates of planting at 5% probability level. There was also a significant interaction of cultivar by time of planting. The LSD at 5% was computed to separate the time of planting means and the results are shown in Table 74.

Table 74: Summary table of yield data means (gms)

Cultivar	Sowing dates		
	5.9.68	19.9.68	3.10.68
Kent	694	1065	934
Hernon 49	1102	1448	1026
Bukalasa 4	1417	1890	932
Time of planting means	1071	1497	964

LSD (P = 0.05) = 306 gm

The second date of sowing has the highest yield and the latest planted crop gave the lowest yield. The significant interaction of cultivar by time of planting indicates the relative differential fluctuation of the yield of each cultivar to the dates of sowing. The rains were on up to the middle of September and then declined until late October. The first planted crop had enough moisture for germination but then little moisture for establishment while the second sown crop had little moisture for germination but the rains started again when it was establishing itself and the third sown crop was established under excessive moisture in the soil. The mean temperatures did not appear to significantly change during the growing period and the potential evaporation remained high during this period. This caused water stress to the early planted crop as there was little soil moisture and the plants were wilting from about noon each day for about three weeks. This water stress in the initial stages of growth of the early planted crop appears to have caused poor resultant growth and hence poor yield of this crop. The late planted crop was established under high soil moisture but probably poor soil oxygen/carbon dioxide balance conditions which seems to have depressed growth and hence final seed yield.

3.10 Studies of the interactions between genotypes and environment

The presence of interactions between cultivars (genotypes) and environments (seasons and locations) has been recognized for a long time. Vavilov (1935) considered that the question of the interaction of the organisms and the environment is one of the most important branched of breeding. Mutzinger (1963) compared soyabean cultivars at 4 locations in North Carolina over a 3-year period and obtained a significant cultivar x year and cultivar x year x location components. Schutz et. al. (1967) showed that genotype x location interactions were of relatively little importance in selecting material for local adaptation but often assumed a dominant role in selecting for wide adaptation. He cited evidence to suggest that locations may be effectively substituted for seasons in regional tests to permit a rapid turnover of breeding material and that data from 10 to 15 locations in a single season should be sufficient to eliminate low-yielding cultivars. Eberhart (1967) showed that replications and locations were of important considerations in increasing progress from selection in maize in Kenya.

Auckland (1968) has shown seasonal variation in advanced generations of hybrid bulk populations and defined a new term "aggregate homeostasis" as an attribute of components that show a small interaction in cultivars compounded in F5 and F6 generations. In a "bad" year, it was observed that the cultivars compounded in the early generation yielded better in general than the selections in the same family compounded in the F6 generation. In the "very good" years, the more homozygous selections yielded higher than the F5 compounded cultivars while in the "moderate" years there was insignificant difference.

There are several suggested explanations of these interactions. Many of them are of physiological aspect though in crops liable to attack by a large range of diseases, the different effects of environment on different diseases and the different susceptibility of cultivars to each disease may account for much of the genotype x environment interactions. The differences in habit might allow greater overall use of incident radiation and the larger leaves might be an advantage in a "good" year for photosynthesis but might be a disadvantage in the dry season due to too much loss of water by excessive transpiration.

There has not been any reported investigations in the study of these interactions in Uganda on this crop and their implications for the efficiency of selection. The purpose of this study was therefore to estimate the relative magnitudes of these interactions and evaluate their importance in selecting suitable cultivars for the different parts of the country and to investigate whether the country should be subdivided into regions for varietal recommendations. The basic idea is to test the reliability of a cultivar to yield consistently that is to have small genotype x environment interaction as well as to yield highly.

3.10.1 Materials and Methods

A total of fourteen cultivars were involved in the studies. These are shown in Table 75.

Table 75: Table of cultivars

Variety	Origin	Description
S 1	H 29 - Old Kawanda collection	Best yielders of the Kawanda collection at the time the studies started.
S 2	H 49 - old Kawanda collection	
S 3	E 184 - old Kawanda collection	
S 4	42.S.2 - old Kawanda collection	
S 7	Yellow Keeble - old Kawanda collection	
S 13	Gulu - old Kawanda collection	
S 14	Ankole collection	
S 17	Ex-Kenya - old Kawanda collection	

Table 75: (continued)

Variety	Origin	Description
S 30	Makasa collection	
S 38	Ex-Kenya - Kitale	Kawanda standard
Bukalasa 4	Bukalasa selection	Best yielder among Bukalasa selections
Kent	U.S.A. via Homa Bay - Kenya	Best yielding American material
B. Congo	Homa Bay local selection	Good yielding and apparently adapted to Kabanyolo conditions
Kakira 13	Kakira selection	Best yielder among Kakira selection

Five of these cultivars, S 1, 3, 17, 30 and 38 were involved in studies of genotype x season and the rest in genotype x location interactions. The seasons used were from the first rains 1966 to second rains 1968, i.e. 5 seasons, with all the experiments at Kawanda. The locations Nkozi, Kibale and Abi were used in the second rains of 1967 and 5 locations, Abi, Pekelle, Kawanda, Nebbi and Arapai were used in the second rains of 1968 for the location x genotype interaction studies. The experimental design in all experiments was randomized complete block with plot size of 45 feet x 8 feet and a spacing of 24" x 3".

10.2 Results

10.2.1 Genotype x location (second rains 1967)

There was a considerable amount of consistency on the order of performance of the cultivars on the different locations. The analysis of variance on the yield data was carried out and the results are presented in Table 76.

Table 76: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	149	592.36		
Replications	4	11.30	2.82	2.10
Cultivars	9	55.09	6.12	4.56
Locations	2	339.04	169.52	126.50
Locations x cultivars	18	31.76	1.76	1.32
Error	116	155.17	1.33	

CV = 30.9%

The analysis failed to show significant genotype x location interaction at 5% level, i.e. the order of performance of the cultivars was not significantly different on the different locations. This might probably have been due to the large coefficient of variation in the analysis.

10.2.2 Genotype x location (2nd rains 1968)

The results from the analysis of variance on the yield data are presented in Table 77.

Table 77: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	249	2034.15		
Replications	5	10.58	2.116	2.107
Cultivars	9	70.35	7.816	7.784
Locations	4	1636.21	409.052	407.422
Locations x cultivars	36	121.23	3.367	3.353
Error	195	196.7	1.004	

CV = 23.3%

The analysis showed a significant genotype x location interaction at 5% probability level. The results were unlike those obtained in the 2nd rains of 1967 where there was no significant location x genotype interaction. This suggests that evaluation trials should be conducted on centres within each growing region to make it possible to identify cultivars most suited for particular regions.

10.2.3 Genotype x Season studies

The results from the analysis of variance on the yield data are shown in Table 78.

Table 78: Table of analysis of variance

Source of variation	df	Ss	Ms	F
Total	124	1117.62		
Replications	4	5.80	1.450	0.532
Cultivars	4	13.41	3.352	1.231
Seasons	4	773.91	193.477	71.07
Seasons x cultivars	16	63.12	3.945	1.449
Error	96	261.38	2.722	

CV = 25.5%

The analysis failed to show a significant season x cultivar interaction at 5% probability level. The results suggest that seasons might not be of significant importance as far as progress through selection is concerned. There is some variation in the order of performance of cultivars from season to season but the fluctuation is not very large and high yielding cultivars can be identified after a few seasons.

GENERAL DISCUSSION

The genetic base of the present programme was fairly broad. A comprehensive collection of locally adapted Uganda soyabean germplasm was made at Kabanyolo. According to the Uganda Department of Agriculture annual reports (1938) many cultivars were introduced into Uganda (see page 36).. It is likely that a number of these cultivars will have since been lost through the generations of selection but a substantial amount of this introduced soyabean germplasm possibly still exist though by now mixed up by natural hybridization or slightly changed by mutations from the original genotypes and selection over the years. More soyabean germplasm arrived later from U.S.A., Kenya, Tanzania and recently from Japan. It would certainly be desirable to have far wider introductions but the problems of phytosanitary regulations and delays in quarantine will have to be solved first if a full scale breeding programme based upon evaluation and use of the maximum available variability within the species is to be undertaken.

Of the cultivars collected at Kabanyolo for trial, the quick maturity types including many of the present day United States commercial cultivars yielded poorly and are not expected to be of immediate commercial use but nevertheless they have a high seed/biological yield ratio and will probably be useful for a breeding programme. Some of the very longest termed cultivars on the other hand produced a great weight of vegetative growth but did not crop well and in most of them the sowing to maturity period was too long for the 4 to 5 months growing season of Kabanyolo. The highest yielding types were medium to the long term which were mainly collected from Uganda and having persisted over 20 years or so are inevitably well adapted to the growing conditions.

The Hernon series of cultivars introduced from Rhodesia and South Africa were reported to have yielded fairly well in the 1940's (Department of Agriculture Annual Reports 1946). The present investigations included at least two (and some of the new Uganda selections might also have been originally Hernon material) Hernon cultivars, Hernon 49 and Hernon 237. Under the growing conditions of the present investigations the yields of Hernon 49 have been increased by about 30% from those reported in 1946 (from 1919 lbs/acre to 2500 kg/ha) while Hernon 237 has doubled its previously reported best yield in Tanzania by Auckland (from 1532 lbs/acre to 3240 kg/ha). The Hernon materials are still important commercial cultivars in Rhodesia. From their reported performance in this country and Tanzania and the results from the present investigations it would appear to be desirable to introduce as many Hernon cultivars as possible from Central Africa (Rhodesia, Zambia and Malawi) for evaluation under Uganda conditions. This might probably produce some additional suitable cultivars more quickly than a breeding programme at least on a short term basis since there is at present a great need for high yielding seed. The present investigations have produced several cultivars, e.g. Bukalasa 4, that are considered entirely suitable for commercial production around the Lake Victoria shore region but cultivars suitable for the Northern parts of the country still need to be developed. Yields of between 3,000 and 4,000 kg/ha have been obtained at Kabanyolo and this compared favourably with other annual crops and with commercial yields of soyabean obtained elsewhere. But only about a third of this yield has been obtained in the Northern parts of the country using the same cultivars.

Several workers have previously reported that spacing patterns influence yeilds with the same populations.

Gray (1967) in Kenya and Smartt (1960) in Rhodesia reported higher yields from squarer than more oblong rectangular patterns using the same population, and Auckland (1967) also observed that the square patterns yielded better than the rectangular patterns for the same populations. The results from the present investigations have similarly indicated that low rectangularity results in better yield than high rectangularity and this in effect implies that the closer the inter-row spacing the higher the yield per unit area. There is, however, a serious limitation to this because if the inter-row spacing were to become too close mechanical intercultivation would become impossible. It might be hoped that the current research with pre-emergence herbicides will solve this problem and conceivably increase soyabean yields by allowing the adoption of much narrower inter-row spacing than has so far been practicable. Another technical problem is found in mechanised seeding since existing planters cannot easily be used for very close inter-row spacing. The intra-row pattern at least among spacings of one plant per foot or closer has not been reported so far to be of great significant influence but the present investigations have shown that the intra-row spacing below this level might also have considerable influence on yield. There was no significant difference between three or four plants per foot but 6 plants to a foot for the various inter-row spacing showed significant improvement in yield to fewer plants per foot. The general conclusion from literature and present investigations would seem to be that soyabeans should be sown to closer inter-row and intra-row spacing than practised at present if high yields per unit area are to be realized under otherwise good agronomic practices. This conclusion would appear to stand irrespective of the cultivars used. As an economic aspect, however, the cost of seeds at higher populations has some importance. At a spacing of 24" x 3" a total of 50 lbs of Bukalasa 4 per acre are needed. If the spacing was changed to 12" x 3" twice the amount of seed would be required. At the present price of soyabeans it would mean Shs.12/50 in the first case and Shs.25/- for the higher population. This difference in seed cost, however, would be more than offset by the value of the expected higher yields. Also the frequency of expensive weeding would be reduced as the higher population would cover the ground sooner than the lower population thus suppressing the growth of weeds. This would also help to offset the higher seed cost.

Like most other annual crops, soyabeans will respond significantly to applied fertilisers. Different cultivars differ in their response to high levels of different single or mixed fertilisers (Howell 1964). The present investigations have shown that on upper slopes of the Buganda catena that have not been fertilised for at least three years, an application of about 400 pounds per acre of "balanced" mixed fertilisers (N, P, K^{+}, Ca^{++}) will more than double the yield of the soyabeans. From the investigations it would appear that soyabeans respond more to "balanced" mixed fertilisers than to individual fertilisers. This was indicated by their failure to respond to either lime or phosphorus treatments or a combination of the two treatments but showed a significant response to mixed fertilisers at much lower rates. This, however, makes it difficult to investigate the role of individual fertilisers in soyabean production.

Various methods are used in the control of weeds but inter-cultivation still appears to be the usual major control method. Smartt (1960) found that one weeding was quite adequate while Auckland (1967) advocated clean weeding until the crop was big enough to cover the ground. The present investigations have shown that one weeding is adequate but more would be needed for maximum yields to be obtained. This will vary depending on how weedy the land used is and on the types and population of the different weeds. On a very weedy land perhaps one weeding might be inadequate and a second weeding would be necessary.

The preliminary work carried out in the present study on herbicides has shown considerable promise. The various herbicides and the different levels used did not significantly affect the germination of soyabean seeds but they significantly reduced the total weed yield. Further useful research could and should be done with herbicides for use in soyabean production in Uganda.

Soyabeans respond to delayed planting as do many other annual crops by reduced yields. Some cultivars in the present investigations have shown nearly as much as 50% yield reduction with a delay of about 5 weeks from the "break of the rains" after a dry season. Many of the usual factors to which the decline of yields of many crops are attributed with late planting could be discounted in the present investigations. There was for example, no apparent attack of pests or diseases on the late crop at least above ground. The day-length does not vary appreciably throughout the year, the variation being only about three minutes and the solar radiation values also only show small variation of up to 20 cal/cm^2/day within the growing season although the variation might be up to 50 cal/cm^2/day between the dry and wet seasons at Kabanyolo (Kabanyolo Weather Station). There was enough water even for late planted crop in the present investigations as the rains lasted about three to four months. The most important fact affecting the late planted crop would therefore appear to be concerned with excess soil moisture. Russell (1954) has said that in the tropics, soil air in the surface layers of an arable soil contains about 20.3% oxygen, 79% nitrogen and carbon dioxide varies between 0.15 and 0.65% but during the warm rainy seasons the carbon dioxide percentage may rise much higher and the oxygen content fall. This is possible since carbon dioxide is more soluble in water than oxygen and the soils tend to be water-logged after heavy storms. If this was so it might seriously affect root respiration and hence growth which in turn would have an adverse effect on plant growth and this would be reflected by reduction of yield for late planted crop. The early planted crop gets established and makes a good root system before the soils become waterlogged. This might explain the apparent lack of effect on the early planted crop by subsequent waterlogging of the soil. In some cases the late planted crop might in addition to initial waterlogging of the soil suffer from water stress in the later part of growth if the rains go before the crop matures.

The presence of interactions between cultivars (genotypes) and environments (seasons and locations) has been recognised for a long time. Schutz et. al. (1967) showed that in North Carolina, U.S.A., the genotypes x season interactions were generally smaller than estimates of the genotype x location interaction. This suggests that there is less variation in seasons than the locations in North Carolina. The location interaction may be due to change in latitude and therefore daylength and temperatures.

In Uganda, however, the daylength and temperature differences are very small during the growing seasons and do not play a large part in the interactions. The present investigations failed to show significant season x genotype interactions, i.e. there was no sufficient season to season variation to significantly affect the relative performances of the different cultivars. This suggests that less importance would be attached to the number of seasons to be used during the evaluation of introductions and selections in a breeding programme than when a season x genotype interaction was expected. But the investigations showed a significant location x genotype interaction. This means that selection either from new introductions or hybrid bulks would have to be carried out on different centres to ensure that lines suited to different areas are identified. This might avoid a possible risk of discarding lines at one centre that might have been selected at another centre.

The main cause of the genotype x location interaction appears to be the available soil moisture. The second rains 1967 season was a wet season all over the country and the analysis then failed to show significant genotype x location interactions. The second rains 1968 season had less rain than expected and some areas experienced water stress during the growing period and this time the analysis showed significant genotype x location interactions. If this hypothesis is correct, then it would seem necessary to divide the country into different regions representing the different rainfall patterns and then to have at least one trial centre in each region. This would lead to different varietal recommendations to the different regions so set up.

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ACKNOWLEDGEMENTS

I wish to acknowledge with gratitude the unfailing guidance and encouragement given to me by my supervisor, Mr. C.L.A. Leakey and Professor K. Oland's keen interest in the project and encouragement. I am most grateful to Mr. S.K. Mukasa of Kawanda Research Station for making available the data that I used to study the genotype x environment interactions, his willingness to agree to co-operate and run joint up-country experiments and letting me have many of his soyabean collections and new introductions. I am also grateful to Dr. G.H. Freeman for his advice on the analysis of the criss-cross experimental data, Mr. R. Paul for typing this thesis and to the assistants of the Department of Crop Science and Production who helped in the collection of data.

This project was financially supported by the Pulse Crop Improvement Grant from the Rockefeller Foundation to the Faculty of Agriculture, Makerere University College for which I am very grateful.