PRELIMINARY STUDIES IN SOYBEAN (*GLYCINE MAX* (L) MERRILL) PRODUCTIVITY ON THE ACCRA PLAINS

A THESIS PRESENTED TO THE
FACULTY OF AGRICULTURE
UNIVERSITY OF GHANA

IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE
MASTER OF SCIENCE
(AGRICULTURE)

BY
KOFI BONSU BOAKYE-BOATENG, B.Sc. (Hons) Agric.

DECEMBER, 1974

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DECLARATION OF ORIGINALITY

I hereby declare that the work presented in this thesis is the result of my own original research conducted while enrolled in the Department of Crop Science at the University of Ghana, Legon. This thesis has neither in whole nor in part been previously submitted to another University for the award of a degree.

References to work of other researchers have been duly cited.

SIGNED:.......................

DATE:....................

K.B. BOAKYE-BOATENG
(C A N D I D A T E)

DATE:..................

....
DAVID J. HUME
(SUPERVISOR)

DATE:..................

....
ROBERT B. DADSON
(MEMBER, SUPERVISORY COMMITTEE)

DATE:..................

....
EMMANUEL V. DOKU
(MEMBER, SUPERVISORY COMMITTEE)

SUMMARY

Experiments on mulching, temperature, storage and inter-row spacing were conducted in the field and laboratory during the major and minor seasons of 1973, with 21 introduced soybean varieties including Hill, Kent, CES 486 and Amsoy 71.

1. Mulching Experiments

Three varieties (Hill, Kent, CES 486) were grown in two field trials and a pot experiment with and without mulch applied after planting in 1973. Mulching decreased maximum soil temperature; maintained higher soil moisture content; improved seedling emergence; increased plant height, seed size and grain yield in the major season. In the minor season, mulching increased nodes and pods per plant, seed size and lodging. Grain yield was not increased most likely due to the increased lodging and pest infestation. In the pot experiment, mulching hastened flowering; increased stem diameter, plant height, flowers, nodes and pods per plant; the percentage of flowers which formed pods and seed yield. Mulching appeared beneficial particularly when seed viability was low and soil temperatures were high.

2. Temperature Experiments

Twenty-one varieties were sown in trays and kept in incubators at 20, 30, 40 and 50°C. Germination and emergence were high but slow at 20°C. There was no germination at 50°C. Doubling the temperature from 20 to 40°C reduced days to first emergence and days to maximum emergence by 50%, however, maximum number of seedlings that emerged

as well as hypocotyl elongation were reduced by approximately 40% and 30% respectively. Hypocotyl elongation was better at 30°C than at 20 or 40°C by 20% and 30% respectively. Based on their ability to consistently germinate and emerge well at the higher temperature (40°C), the varieties Cutler 71, Semmes, Hark and Dare were found to perform well, while Hutton, Hill, Clark 63 and Jupiter were the poorest.

3. Storage Experiments

Soybean (cv. Amsoy 71) seed of initial moisture content 11.2% was stored in cloth or polythene bags at ambient temperature and relative humidity (27°C, 76% RH), in an air-conditioned room (22°C, 59% RH) and in a walk-in cold room (2°C, 89% RH). Seed at 14.5 and 17.8% moisture also was stored in the air-conditioned room. Seed samples stored at high temperature and moisture contents rapidly lost their ability to germinate and emerge after 9-10 weeks. Lowering temperatures or moisture content preserved seed viability longer. Seed in polythene bag at 22 or 2°C and 11.2% moisture did not lose viability during 50 and 55 weeks respectively of storage.

4. Inter-row Spacing Experiments

Two varieties (Hill; CES 486) were sown in the field in rows 25, 50 and 75cm apart during the major and minor seasons of 1973. The number of main-stem branches and pods per plant significantly increased with increasing row spacing. The tall variety, CES 486, lodged more than the short variety, Hill. Seed size was not significantly affected, however, seed yield tended to be higher in rows 25cm apart for the short determinate variety (Hill), and in rows 75cm apart, for the tall indeterminate variety CES 486, the latter outyielding Hill, which matured earlier.

5. It was concluded from the results of these studies that soybean production on the Southern part of Ghana, at least on small holdings, would be possible.

ACKNOWLEDGEMENT

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K. BONSU BOAKYE-BOATENG

UNIVERSITY OF GHANA
LEGON.

DECEMBER, 1974

DEDICATION

Dedicated to Dad and Mum - Boakye and Obenwaa - peasant farmers.

K.B. B-B

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INTRODUCTION

Soybean (Glycine max (L) Merrill) has a high content of oil (17-22%) and plant protein (32-45%). Crude soybean oil has a high keeping quality and a high content of essential fatty acids (linoleic and linolenic acids) while the protein has an amino-acids composition comparable to that of animal protein, methionine being the only limiting factor. The climatic and soil adaptations of soybean fit well into areas that suitably support maize production. Its demand, value and volume in world trade is also increasing. Soybean could therefore be conveniently and cheaply used to meet the ever increasing local need for more raw materials for oil and animal feed production; for diversification of cash crop production and for the provision of a cheaper source of protein for human consumption.

Renewed interest recently shown by Ghanaians for the possible uses of soybean in the country's economy and diet calls for work into some of the production problems that may face the Ghanaian farmer. These include suitable agronomic practices, storage and maintenance of seed viability; pest and disease control.

In this thesis some of the basic problems likely to be encountered in a large-scale production of soybean on the Accra Plains were studied.

SECTION A

SECTION A

REVIEW OF LITERATURE

I. GENERAL

1. Origin, Early History and Dissemination

Soybean (*Glycine max* (L) Merrill) is a native of the Orient. Its domestication dates back beyond 2838 B.C. Nagata (1960) concluded that *Glycine max* must have originated in the Northern and Central China, but Hymowitz (1970) has suggested the Eastern half of North China as the area where soybean was first domesticated. Some aspects of the origin, early history and dissemination have been reviewed by Doku (1973). At present, soybean has assumed worldwide importance due to the demand for both soybean oil and protein. The major producing countries are the USA, China, Japan, Brazil, Indonesia and Korea.

Soybeans were introduced into South Africa in 1903 (Piper and Morse, 1923). The first effort to establish the crop in Tanganyika (now part of Tanzania) appears to have been made at Amani in 1907 and further introductions were made in 1909 (Auckland, 1970). In Uganda, it was first introduced from America and South Africa in 1938. Graham (1943) reported that a 'large yellow' type grew 'exceptionally well' in Nyaza, Kenya in 1943. Rhodesia, Zambia, Malawi, the Congo and the French speaking West African states produce small amounts of soybean. There is at present a steady increase in production in Nigeria. The International Institute of Tropical

Agriculture established in July 1967 at Ibadan, Nigeria (IITA 1973 Report) has also initiated intensive research programme into grain legumes, including secondary responsibility for soybeans.

Soybean has been known in the Gold Coast Colony (Ghana) on Government experimental stations since 1909 (Piper and Morse, 1923), but it has never been a familiar crop to the farmers. Lynn (1937) listed twenty-three crops commonly grown in the North Mamprusi. Four legumes were recorded as grown but no mention was made of soybean. Geurts (1959) also never mentioned soybeans in his countrywide enquiry into 'the extent to which some leguminous crops other than groundnuts are already grown by farmers in Ghana'. Snow (1961), however, indicated that between 1909 and 1956 over seventeen annual trials spread over more than 12 locations in Ghana were conducted with about 40 soybean varieties. Some efforts have since been made to popularise the crop both as an addition to the local diet and as a possible export crop but without much success (Snow, 1961). Geurts in 1961 made introduction of 29 soybean varieties from Nachingwea, Tanganyika but they had all lost viability by 1963 when trials were made at Legon. According to Mercer-Quarshie (1973), S.H. Evelyn did some work on soybean at Kwadaso from 1967 - 1972. Adansi, in 1966, found that some 12 varieties planted at Bunso, were promising. In October 1967, Evelyn began adaptability trials with seven of these 12 varieties received from Adansi but results of these are not available. Nsowah (1973) carried out trials with the varieties 'Improved Pelican', 'Clark 63', 'Davis' and 'Bragg' in 1969 and with 'Hardee', 'Jupiter', 'Biloxi' and 'Otootan' in 1972 at the University of Science and Technology, Kumasi. Yields of all varieties except Hardee and Jupiter were not encouraging. Since 1970 there have been over 70 have been introduced varieties. Some of the best adapted varieties the Legon Crop Science Department has tested appeared to be those from the Phillipines (CES 486, CES 407), USA (Davis, Hardee, Hill, Improved Pelican) and Canada (Amsoy).

2. Taxonomy

Soybean, also called Chinese pea, Manchuria bean, soja bean and soya bean, has been called by different botanical names. These include *Glycine soja* (L) Sieb. and Zucc.; *Glycine hispida* (Moench) Maxim.; *Soja max* (L) Piper; *Dolichos soja* L.; *Phaseolus max* L. etc. According to Lawrence (1949), perhaps no plant has been subjected to more name-changing than has the soybean. Most taxonomists, however, now seem to share the contention of Ricker and Morse (1948) that the correct name for soybean, according to international botanical rules, should be *Glycine max* (L) Merrill. Soybean then is classified as belonging to the family Leguminosae, sub-family *Papilionoideae*, and genus *Glycine*.

3. Botany

Soybean is erect, bushy and leafy herbaceous annual. It may be of a height of 20cm to 180 cm depending on the variety and environment

(Poehlman, 1959). The leaves are usually trifoliate and the leaflets may range from linear to ovate or oval in shape. Most varieties have a dense tawny or gray colored pubuscence on the stem, pods and leaves. Some varieties of soybean produce determinate, while others produce indeterminate type of growth. This depends on whether or not at flowering in each case, the terminal bud develops into a terminal inflorescence and thereby curtails further vegetative growth (Poehlman, 1959).

Soybean flowers are perfect, completely self-fertile and normally self-pollinated. The color may be purple or white or rarely a combination of these colors. Many of the flowers drop off without forming pods. The pods are borne on short stalks at the nodes in clusters. The seeds are round to elliptical and the number per pod may vary from one to five but most commercial varieties are usually 2 - 3 seeded (Poehlman, 1959; Purseglove, 1968). The testa color may be yellow, straw, cream, green, brown or black, or a mottled in combination of these colors (Doku, 1973). The color of the cotyledon may be either yellow or green.

Germination is epigeal and under favourable condition of temperature and moisture, seedling may emerge from 4 to 7 days after planting (Howell, 1963). The developed tap root may penetrate as deep as 150cm. However, the bulk of the root dry weight usually concentrates in the upper 7.5 to 15cm of the soil (Mitchell and Russell, 1971; Doku, 1973). Inoculated plants may bear root-nodules.

Vegetative growth ceases completely about the time of seed development and dry weight of leaves, stem and root decrease thereafter (Borst and Thatcher, 1931; Doku, 1973).

4. Culture and Cultivation

Soybean is a plant primarily adapted to temperate regions with fairly humid warm summers. It is very sensitive to changes in its environment (Doku, 1973) but in general, the climatic adaptation of soybean is about the same for maize. Soybean is susceptible to drought particularly at germination and during flowering and early pod setting.

Soybean requires fertile soil, generally a sandy or clay loam containing fair quantities of potash, lime and phosphorus (Piper and Morse, 1923). It will usually thrive on soils that reasonably support maize. Provision of suitable *Rhizobia* spp is of great advantage for yield (Sorwli, 1974) especially in soil with marginal nitrogen levels. Under nearly all conditions, soybean must be grown in rows.

Weed competition affects soybean yields (Weiss, 1967) more than maize. Weed control should be effected particularly within the first 30 - 35 days when most varieties are about to flower. By 60 days, most soybean crops should have developed enough to shade out weeds (Weiss, 1967; Hume, 1973: Personal Communication).

A number of pests and diseases attack soybean especially in large scale production (Piper and Morse, 1923; Weiss, 1967; Robertson, 1969). However, no pests or diseases of economic importance have so far been recorded in Ghana, except a few insignificant cases of attack by leaf-rollers e.g. larvae of the moth, Eucrysops malathana, mice and Cercospora leaf spot (Nsowah, 1973; Mercer-Quarshie, 1973).

Maturity period ranges from 75 days (very early), to 200 days or more (very late) (Piper and Morse, 1923).

The average yield of beans per hectare varies between 500 and 2500kg depending on variety, harvesting and the manner of cultivation.

II. SPECIFIED TREATMENTS

1. Effects of mulching on emergence, growth and yield of soybean

In the humid tropics soybean often emerge poorly after planting because seeds lose their viability rapidly in storage and because the large cotyledons have difficulty in penetrating the crusted soil surface. This crusting could be broken up by hoeing, by the use of mechanical cultivation equipment or by mulching (Verma and Kohnke, 1951; Adams, 1965; Greb, 1966). In the use of mulch of plant residue, micro-organisms usually multiply during decomposition and these help pulverise the surface soil. Plant growth and development, in general, are influenced by soil temperature and soil moisture both of which are influenced by mulching. Even though all the changes in the soil caused by mulching may improve soybean stands, few experiments to test these effects on soybean have been reported.

Various mulching materials have, however, been used to investigate their effects on soil conditions and plant growth. These include mulches of plant residue, animal dung, synthetic materials like glass-wool, soil set and turfiber, and inert materials like rock, gravel and sand (Stephenson and Schuster, 1945; Choriki, Hide, Krall and Brown, 1964; Fairbourn, 1973). Mulching the soil surface with plant material can lower soil temperature, decrease crusting, conserve soil moisture and reduce soil erosion (McCalla and Duley, 1946; Verma and Kohnke, 1951; Hanks, Bowers and Bank, 1961; Adams, 1965; Greb, 1966; Fairbourn, 1973). Early work in the U.S.A. was reviewed by Verma and Kohnke (1951), who cited seed yield responses ranging from increases of 390kg/ha to decreases of 81kg/ha following mulching. They also tested plant residue and an inorganic mulch of glass-wool and had consistent yield increases during 2 years. Burrows and Larson (1962) reported that as little as 2510kg/ha of chopped corn (*Zea mays* L.) stalk mulch materially reduced the growth of corn as indexed by plant height and dry matter production in the North Central States, U.S.A. This has been explained as due to the reduction in soil temperature in the cool wet early season (Willis, Larson and Kirkham, 1957; Burrows and Larson, 1962). Fairbourn (1973) used gravel and maize (*Zea mays* L.) stalk mulches on four crops, including soybean in the U.S.A. Mulching increased soybean yield by over 300kg/ha. In a recent trial in Nigeria (IITA, 1973) mulching with rice straw decreased maximum mean soil temperatures at 5-cm depth and improved percent establishment of two varieties of soybean - ('Kent' and '280-3') - by as much as 30-66% over unmulched plots. No yield responses were given. Yield increases after mulching with plant material also have been reported for potatoes, cowpeas and groundnuts grown in the tropics (Blane, 1949; Miller, 1955; Nye, 1952; Ashrif and Thornton, 1965).

2. Effects of Temperature on Germination and Emergence of Soybean

Soybean is sensitive to temperature and daylength (Garner and Allard, 1920, 1923; Parker and Borthwick, 1939; Brown, 1960; Hartwig, 1970). Temperature provides both a working condition for nearly all plants and the energy necessary for their vital processes. Temperature also can have a modifying effect on plants' response to daylength (Garner and Allard, 1920, 1923; Van Schaik and Probst, 1958; Doku, 1973; Breuer, 1974). Daylength variation in Ghana is very slight, hence temperature and rainfall are the two most important variable environmental factors which may affect varietal establishment and performance. Observations of poor and erratic seedling emergence of soybean resulting in poor stands have been reported (Snow, 1961; Grabe and Metzer, 1969; IITA 1973 Report). Such poor stands may result from the use of seeds with low viability due to improper timing of harvest (IITA 1973 Report) and improper storage. It can also be due to varietal causes (Ayers, 1952; Grabe and Metzer, 1969; Wien, 1973). The effects of high soil temperatures on the vigour of emerged seedlings have also been suggested to be a possible cause of poor stands (IITA 1973 Report) since high soil temperatures over 40°C are not uncommon on the Accra Plains (Gbeckor-Kove, 1965) and at Ibadan (IITA 1973 Report).

Most of the newly introduced soybean varieties in Ghana and in Nigeria (IITA 1973 Report, Ibadan) were developed in the temperate regions especially the USA and Canada. Some of these varieties do not do well under local conditions (Nsowah, 1973) and at other subtropical and equatorial areas (Leng, 1973). Furthermore, information on emergence characteristics on soybean seedlings in Ghana is virtually non-existing. Such information may help in identifying genotypes that carry the poor emergence characteristics and thus help in the exclusion of such genotypes in future breeding programme.

Soybean varieties differ in their temperature responses (Brown and Chapman, 1960; Doku, 1973) and the temperature optima and minima also vary according to the stage of growth as well as for different plant organs. In spite of these varietal differences, Fukui, Mutsuo and Watanabe (1965) observed a general trend of response for apparent photosynthetic rates for soybean varieties that had then been studied. The rate was found to reach a maximum around 15°C, remain high up past 20°C to about 35°C after which there is a sharp drop. This trend seems to support earlier report by Early and Cartter (1945) that the height of soybean plants increased with increasing temperature from 2°C to about 17°C, remained uniform from 17°C to about 27°C and decreased rapidly at 37°C. They added that root temperature from about 22°C to about 27°C appeared to be most favourable for maximum dry weight production of top and roots of soybean plants. Howell (1963) also observed that generally, higher temperatures over 38°C early in the season reduced the rate of node formation and internode elongation leading to a reduction in plant size.

Brown (1960) Brown and Chapman (1960) used a temperature range between 10 to 32°C to develop a Soybean Developmental (Heat) Index, however, probably, due to the narrow range of temperature adopted in the derivation of the equation, it is rarely used. The Average Rate of Soybean Development, Y (i.e. the reciprocal of the number of night hours from planting to flowering: $Y = \frac{10^4}{\text{Night Hours to Flowering}}$) showed a curvilinear relationship with temperature. They suggested that probably 10°C (50°F) was the threshold temperature for development and 25°C the optimum. However, Early and Cartter (1945) had shown earlier that growth (height) of soybean was possible at root temperature around 2.2 and 7.2°C (mean 4.7°C). They agreed, however, that root temperature as low as 12°C and as high as 37°C restricted production of dry weight of soybean (cv. Dunfield and Manchu). In four of their five experiments also, root temperature as low as 17°C prevented maximum plant development.

In terms of germination percentage and the development of secondary and primary roots, the optimum temperatures for soybean (cv Improved Pelican, L.Z. and Pennsoy) were found to be 30°C and 20/30°C alternating temperature (Aquino and Bekendam, 1969). Grabe and Metzer (1969) reported that hypocotyl elongation of dark grown 'Ford' soybean seedling was severely inhibited at 25°C but was normal at 15, 20 and 30°C while that of 'Hawkeye' soybean was normal at all four temperatures. They concluded that the distinct varietal difference in emergence ability appeared to be genetically controlled. Recently at IITA, Ibadan, soybean (Kent) germination experiments at four temperatures of 21, 27, 32 and 38°C have indicated interaction between seed quality and soil temperature. Germination percentage decreased from 81.3% at 21°C to 65, 50, and 3.8% at 27, 32 and 38°C respectively (IITA 1973 Report). It was deduced that somewhere between 32 and 38°C is a critical temperature above which even the best quality seed available may not germinate well. Other preliminary studies at Ibadan with soybeans (cv Kent and 280-3) and cowpea (cv Prima) have also indicated that high temperature can significantly inhibit the elongation of hypocotyl (Wien 1973). Grabe and Metzer (1969) used the ability of germinating seeds to emerge from 10cm depth of sand at 25°C to classify twenty-five soybean varieties at Ames, Iowa, USA. Based mainly on the mean of variety yields in trials at 2 locations in Nigeria (IITA Ibadan and Bende) and one location in Ghana (Kpong), Camacho (1973) concluded that the soybean varieties Improved Pelican, Bossier, CES 486, Kent and Ching Hsing No.1 were suitable for those and other similar environments.

3. Effects of Storage conditions on Soybean Seed Viability

Soybean production in Ghana could be hampered by the rate at which seeds lose their viability when exposed for long periods to warm, moist air. Seeds which normally look healthy fail to germinate. The seed quality characters of soybean are influenced by environmental conditions both during seed formation and during storage. Viability in stored good seed is conditioned partly by humidity and temperature of storage, and partly by the moisture content of the stored product. These factors may be influenced by the type of material used as containers for the product during storage.

The effects of storage conditions on soybean seed viability, together with additional data on longevity have been reviewed by Owen (1956) and Barton (1961). Suitable storage conditions for soybean seeds require low moisture content (%), low temperatures and suitable relative humidity (%). Toole and Toole (1946) found low moisture content and low temperature to be important factors in retaining viability of stored soybean seed. Grabe (1965) listed moisture content, temperature and past field history of the seed (particularly in relation to mechanical damage) as the main factors affecting longevity and viability of soybean seed in storage. Dorworth (1967) found soybean germination percentage to decrease with increase in initial moisture content and the temperature in storage. He observed that the germination percentage of seed remained above 90% during 24 weeks of storage at the lowest used moisture content (12.1%) and temperature (15°C). Increasing the storage temperature or seed moisture content has also been found to shorten the period before germination percentage begins to decline (Dorworth and Christensen, 1968; Mayeux, Esphahani, Loewer and Johnson, 1970). Gvozdeva and Zhukova (1971) found soybean seed with high initial moisture content to be very susceptible to deterioration resulting from long term storage in open containers. They attributed the high sensitivity of soybean seeds to storage conditions to the structure of the seed epidermis which is not firm and breaks up easily. In a study of germinability in seeds of some 18 field crops, including soybeans, stored in sealed or open containers, Khoroshailov and Zhukova (1971) found seeds with higher moisture content (%) and those stored in open containers to lose their germinability faster and to a greater degree than drier seeds and seeds stored in sealed containers. Hukill (1963) has computed an 'age index' for soybeans for estimating viability, based on seed moisture content and storage temperature, (i.e. Age Index = storage time in months x 10^{x+y}, where x = 0.143 times percentage moisture and y = 0.0645 times storage temperature in °C). He found that germination percentage was a fairly precise though complex function of the age index. Soybean germination began to decrease after an age index of 15,000 was reached.

Most workers have found polythene bags and other moisture-resistant containers to be more suitable than cloth or paper bags for safe storage and transportation of high quality seeds under various climatic conditions (Ching, Taylor and Rowell, 1960; Toole, Toole and Nelson, 1961; Harrington, 1963; Helmer, Caldwell and Bunch, 1963; Clark, 1963; Mackay and Flood, 1970). Ching and Abu-Shakara (1965) found polythene bag of 10-mil thickness to maintain the viability of crimson clover seed longer (6 months) in storage than 2-mil polythene bag (2 months). Seeds in cloth bag lost viability in one month. Andrews (1970) found no advantage after 18 months of controlled storage conditions (6°C, 30% RH) in the use of polythene bags over paper bags for soybean seeds at high initial moisture contents (13%) if the RH of the controlled storage atmosphere is low enough to cause the stored seed to lose moisture. However, seeds with lower initial moisture content (7%) in polythene bag maintained germination capacity and vigour.

Hanfenricher, Foster and Schwendiman (1965) have reported that the geographical location where seed was stored had a pronounced and definite effect on longevity and viability. They concluded that the viability of seeds of 4 legumes and one forb was greatest in cool dry climate and least in the warm, humid environment. Mandy and Szabo (1970) working in Tapioszele, Hungary, found seeds of 13 soybean cultivars stored in paper bags in uncontrolled condition to retain their germination capacity for 3 - 4 years.

Edje and Burnis (1970) studied some physiological and biochemical changes in deteriorating soybean (cvs Amsoy and Hawkeye) seeds which were aged artificially by storage in sealed jars at 40°C and 13% moisture content for up to 20 days. They reported that respiratory rate, carbohydrate and nitrogen contents decreased with storage; and that the contents of non-reducing sugars fell more than those of reducing sugars.

Green, Pinnell, Cavanah and Williams (1965) working on three varieties of soybean concluded that soybean seed viability and vigour may be measured by visual ratings of seed character, laboratory germination test and field emergence trial.

4. Effects of Inter-row spacing on performance of Soybean Varieties

Spacing and its relationship to yield sometimes present a problem to the management of field crops newly introduced to any locality. Plants with different habits of growth may differ in their manner of response to the pattern of distribution in space which in turn may influence their yield. Also most crops have optimum density for yield beyond which no significant increase would occur with further increase in density. Soybean which under nearly all conditions need be grown in rows, is a relatively new crop to Ghanaian farmers most of whom practice mixed-cropping.

When soybeans are grown under conditions of adequate moisture and fertility the seed yield usually increases as inter-row distances become narrower until practically all the incident sunlight is intercepted by the time of flowering (Shibles and Weber, 1965; Weber, Shibles and Byth, 1965). As plant densities increase beyond those intercepting nearly all the sunlight, yields usually decrease (Hinson and Hanson, 1962). Soybean yields at high plant densities under good growing conditions often are limited because plants lodge severely (Cooper, 1970; 1971a; 1971b). With increasing plant densities and decreased inter-row distances plants become more etiolated, less branched and have fewer pods and less seed yield per plant. At optimum plant spacing, the product of seed yield per plant and plants per hectare is maximised. The inter-row distances and plant populations at which optimum seed yields are obtained depend largely on plant height and size. More small-statured plants at narrower row widths usually are required to achieve high yields.

Snow (1961) has summarised some experimental work on soybean in Ghana since 1909. He mentioned that some comparisons on yield, planting distance and spacing, optimum time of planting and place in rotation have been done but in all cases no concrete recommendations were made. Lehman and Lambert (1960) used two inter-row spacing of 50.8 and 101.6cm and four within-row spacings with the two varieties 'Mandarin' and 'Blackhawk'. They concluded that seed yield tended to be higher at the narrower spacing between rows. According to Reiss and Sherwood (1965) different workers have found seed yield of soybean to be highest at the narrower row widths used in different trials. Using five inter-row spacings and four seeding rates at Southern Illinois, they found that row-width spacing of 61cm consistently produced highest seed yield followed in decreasing yield order by 40.1, 20.3, 81.3 and 101.6cm row widths. Gray (1967) reported that yields of the variety 'Belgian Congo' grown in Kenya in 1965 were 1863, 2001 and 2351 kg/ha at 61, 45.7 and 30.5cm inter-row spacings respectively. In other trials in East Africa (Weiss, 1967; Auckland, 1970), decreasing inter-row spacing from 71.1 to 17.8cm increased seed yield of two varieties of soybean. In field trials during 2 years in Illinois with soybean cv 'Harosoy 63' and 'Wayne' sown in rows 25.4, 50.8, 76.2 and 101.6cm apart, Wax and Pendleton (1968) reported that seed yields increased with decrease in distance between rows. Wayne yielded more than Harosoy 63 at all row spacings. Bastidas *et al.* (1971) used three soybean varieties, including 'Hill' at inter-row spacing of 60cm and different intra-row spacings of 2 to 12cm which resulted in six densities ranging from 138,333 to 833,333 plants/ha. They found 'Hill' to give the highest yields at the narrower spacings.

If fertility, moisture or disease are limiting, inter-row spacing may have little effect on soybean yield. Gray (1967) found that yields of the variety 'Belgian Congo' grown in Kenya in 1964 at 61, 45.7 and 30.5 inter-row spacing did not differ. He noted that the trial was deficient in P, had received no fertilizer or inoculation, and suffered virus disease and bacterial blight (*Pseudomonas glycinea*). Using inter-row spacings of 25, 50, 75 and 100cm and densities of 8, 16, 24 or 32 plants/m of rows, Val *et al*. (1971) reported that as inter-row spacings decreased to 25cm, grain yields increased to a maximum of 5.2 and 3.6 tons/ha for 'Hardee' and 'Improved Pelican' respectively. The trial had adequate P and K. Oba *et al*. (1961) found lower plant populations to result in greater pod set and increased dry matter production of leaves and stem.

Greater and more consistent yield increases from reduction in inter-row spacings have also been reported for other row crops like groundnut (Cox and Reid, 1965) and cowpeas (Haizel, 1972).

Reiss and Sherwood (1965) reported that wider row width produced the heaviest seed and narrower row width the lightest seed. Probst (1945) working on four soybean varieties at a constant inter-row spacing of 76.2cm but five different intra-row spacings concluded that generally the distance between the plants in the row had little effect on height of plant and size of seed. However, thick planting was found to increase lodging and also delayed maturity. Lehman and Lambert (1960) reported that the number of branches increased as spacing between plant increased. Hinson and Hanson (1962) found that percentage protein and plant height decreased while seed yield per plant, percentage oil, seed size, node and branch number increased under wider row spacing. Weber, Shibles and Byth (1966) working with the variety 'Hawkeye' at four inter-row spacings and four populations ranging from 65,556 to 516,447 plants/ha, reported that plant height and lodging were relatively unaffected by row width, but tended to increase at the higher population. Protein percentage decreased slightly in the wider row width and with lower population while percentage oil increased.

Most tropical grown soybeans are short-statured compared with varieties grown in temperate climates. Lodging at high densities is less of a problem in the tropics and optimum row width are often as narrow as 15-30cm. By contrast, most soybeans grown in the Midwestern USA are grown at inter-row spacings of 60-100cm (Scott and Aldrich, 1970). Cooper (1971b) observed that the tendency of soybean plants to lodge was greater in rows 17cm than in rows 50cm apart. Bastidas et al. (1971); Val et al. (1971) reported that plant height, height of lowest pod and lodging increased, and branching decreased as plant density increased and/or inter-row spacing was reduced. Pods per plant increased as inter-row spacing increased (Val et al., 1971).

Light interception and LAI increased with increase in plant density (Hanson, Brim and Hinson, 1961; Weber et al., 1966; Bastidas et al., 1971), and seed size is generally independent of row width.

In general, chemical composition of soybean seed, which is more of a varietal characteristic, is little affected by inter-row and intra-row spacing (Hanson et al., 1961; Weber et al., 1966).

III. THE ACCRA PLAINS

1. Location and Size

The Accra Plains region lie in the south-east of Ghana between parallels 06° 14'N and 05° 29'N, and the meridians 00° 23'W and 00° 41'E. It is the area lying between the Akwapim Ridge, the lower Volta River and the sea. The total area is slightly over 1,500 square miles (3,900 sq.Km.) or almost 1,000,000 acres. It forms part of the South Eastern Coastal plains (Brammar, 1967). Ghana has a total surface area of approximately 92,000 square miles (approx. 240,000 sq.Km).

2. Rainfall and Temperature

The Accra Plains experience two peak rainy seasons. The major rains start from March - April to mid-July and the second, the minor rains, start from mid-September to early December. The second rainy season is less reliable than the first. Mean annual rainfall increases from around 76.2cm in the Coast to 101.6 - 127.0cm in the extreme north. The greater part of the Plains, however, probably receive less than 88.9cm (Brammar, 1967). At Legon, Accra, the annual mean total is 75.1cm, with May - June and September - October being the periods when relatively high monthly totals occur (Fig.1).

Air temperatures are highest during the main dry season (December - February) and lowest during the short dry season (July - August). Soil temperatures which are usually higher than air temperatures, follow similar trend over the year (Gbeckor-Kove, 1965)

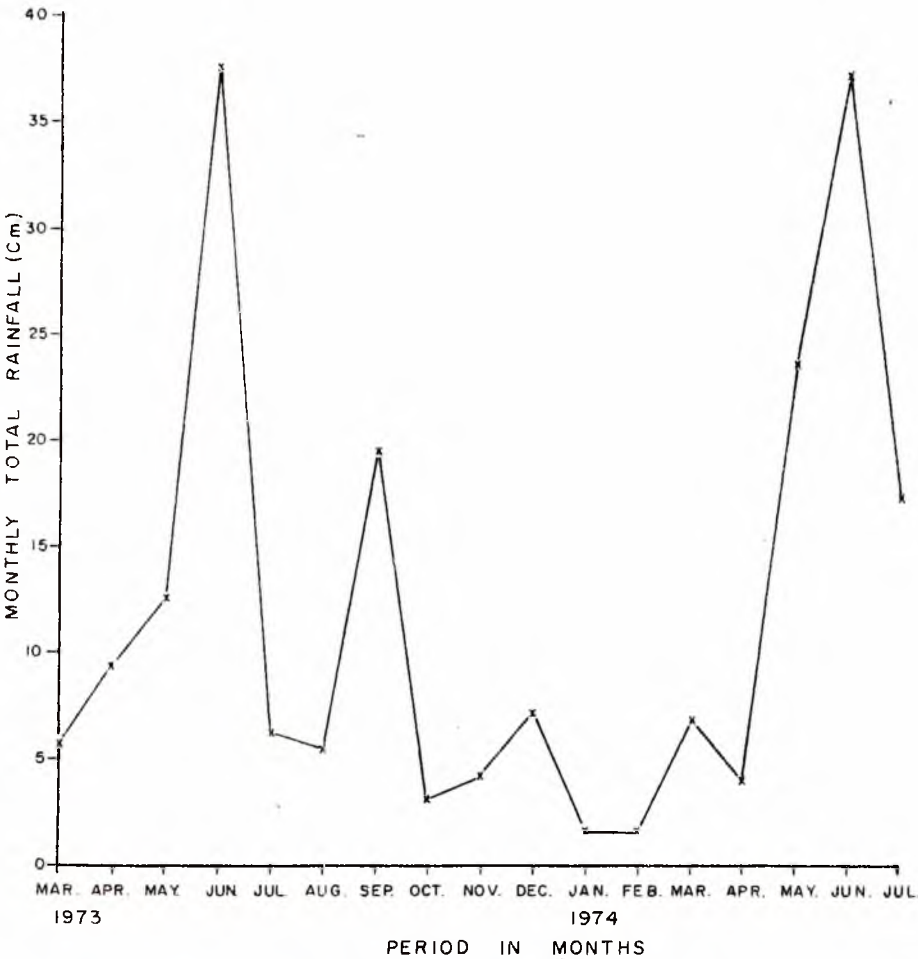


FIG. I MONTHLY TOTAL RAINFALL MARCH 1973 – JULY 1974
(Compiled from Data at University Farm, Legon)

SECTION B

SECTION B

E X P E R I M E N T A L

IV. EFFECTS OF MULCHING ON EMERGENCE, GROWTH AND YIELD OF SOYBEAN

1. MATERIALS AND METHODS

In these studies experiments were conducted both in the field and in pots, using the varieties 'Hill', 'Kent' and 'CES 486'. (PLATE 1).

Field Experiment

The two field experiments were conducted at the University Farm, Legon, during the major and minor rainy seasons of 1973. The soils are slightly acid (pH = 6.0) free-draining light sandy, silty loams with a tendency to crust badly after rains. Each experiment was arranged in a randomized block design with four replications, each of the three varieties being grown with and without a grass mulch.

In the major season experiment, planted 14 May 1973, slightly chopped Guinea grass, (*Panicum maximum*, Jacq.) at 5400 kg/ha was applied immediately after planting. In the minor season experiment, planted November 1, 1973, similar rates of pyramid dropseed, (*Sporobolus pyramidalis*, Beauv.), were used as mulch. Plot sizes were 4.5 x 2.0m with 50cm inter-row spacing. Seeds from previously grown crops were used in the major season experiment. Seed harvested from this first experiment was used to plant the minor season experiment. All seeds were treated with commercial inoculant prior to sowing by hand at a 2.5cm planting depth. A distance of about 5cm between seeds was used in the major season. The minor season experiment was sown at 1.5cm

Three Soybean varieties - CES 486, Kent and Hill - grown in boxes. (Note: relative heights; branching in CES 486; compact pod set in Hill). (Sown 22 May, 1973: Picture taken 20 August, 1973).

PLATE 1

between seeds and later thinned to an average of 82 plants/m^2. No fertiliser was applied in both seasons. However, residual fertility could have been moderately high, particularly in the minor season experiment which was grown following a crop of maize which received 80, 40 and 40kg/ha of N, P and K respectively. All weeding was by hand hoeing, but no pest or disease control measures were applied. Sprinkler irrigation was applied as necessary.

Measurements taken included initial stand, days to first flowering and maturity, plant apex height at first flowering and maturity, 100-seed weight and seed yield. Plants from 8m of the centre two rows in each plot were pulled by hand after dates of maturity (when 95% of the pods were brown) had been recorded. Shelling was done by hand. Seed moisture content was recorded with a grain moisture tester (Dickey John Corp;, Auburn, Illinois, U.S.A.) and yields were converted to 13% moisture. In the minor season experiment, nodule counts were made on 10 plants selected at random from the fourth rows of each plot at the pod-filling stage (21 Dec.). Ten-plant samples also were harvested from the fourth rows of each plot for total dry weight when bottom leaves were beginning to senesce. Lodging scores at maturity were recorded for this experiment, based on the rating of 1 (erect) to 5 (flat i.e. completely lodged). At harvest, pods per plant and main stem nodes also were recorded.

Soil temperatures at 2.5cm depth were measured in all plots within 1h of application of the mulch, using soil thermometers. Subsequent daily soil temperatures were taken at 1500h over the first 8 days in the major season experiment. On May 17, soil temperatures were taken at 2-h intervals from 600h to 1800h. Beginning at 600h on May 22, temperatures were taken at 1- or 2-h intervals for 24h. Soil temperatures in the mulched and unmulched plots during the minor rainy season were measured on three different days after planting (Fig.2).

Soil moisture contents of samples at 12.5cm depths in each plot were taken after mulching and 10 days later during the minor season. No precipitation occurred during this 10-day period. No soil moistures were recorded for the major season experiment because precipitation was frequent after planting.

Pot Experiment

This experiment was started on 25 August, 1973 to collect detailed information on plant response to mulching. Seeds of the three varieties (Hill, Kent and CES 486) were planted in 15cm diameter x 15cm-deep black paper-pulp pots containing a 1:2:1 mixture of sand: loam: humus. A randomized block design was used with four replications. Seeds were sown at five seeds per pot and a mulch of dry grass (*Sporobolus pyramidalis*, Beauv.,) was applied at 11.0gm per pot (about 5500 kg/ha). Seedlings were thinned to one per pot by the tenth day from planting. Plants were grown in the open on raised wooden platforms and watered twice daily with 250ml tap water. Data collected included plant heights, stem diameters, days to first flowering and maturity, number of flowers and pods set, numbers of matured pods, nodes and branches on main stems and seed yield. Final harvest was on 30 November, 1973.

2. RESULTS AND DISCUSSION

Field Experiments

Soil temperatures at 2.5cm depth following the major season planting did not differ among varieties and values were averaged across varieties. Temperatures were consistently about 3.5°C cooler under the mulch during the warmest daily periods (Fig.2). In the few cases where night-time or early morning temperatures were measured, mulched plots appeared to have slightly higher minimum temperatures. Similar temperature differences between unmulched and mulched plots occurred after planting in the minor season, although the data suggested maximum soil temperatures were lower during the latter season.

Soil moisture contents in all mulched plots in the minor season, averaged 14.9% immediately after mulching, compared to 13.9% in unmulched plots. After 10 days without rain, mulched plots averaged 10.5%, compared to 8.7% for unmulched plots. Even though mulched plots had slightly more moisture at planting, the unmulched plots dried more in the 10 days after mulching.

Mulching consistently increased the number of plants which emerged for each of the three varieties grown during the major rainy season (Table 1), even though emergence of all varieties was very poor. The seed had been stored for over 5 months at ambient temperatures and viability was low. Mulching appeared beneficial in improving stands when seed quality was marginal.

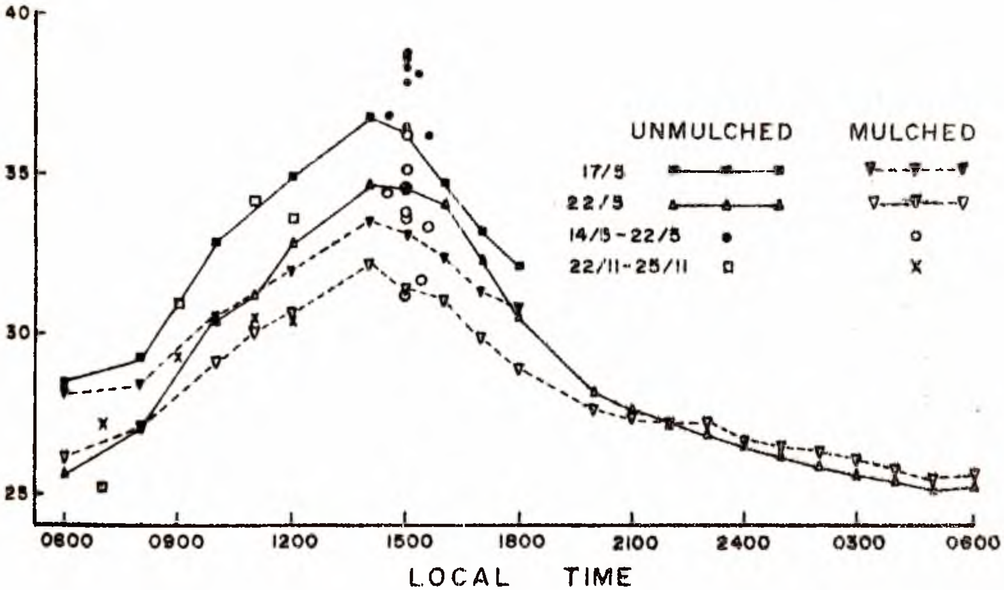


FIG.2. DIURNAL FLUCTUATION IN SOIL TEMPERATURE AT 2·5 cm DEPTH IN MULCHED AND UNMULCHED PLOTS. DATA ALSO ARE SHOWN FOR INDIVIDUAL DAYS AFTER PLANTING IN THE MAJOR AND MINOR RAINY SEASONS.

Mulching did not affect flowering dates of any of the varieties but did cause consistent increases in plant height (Table 1). This increase in height was not caused by etiolation of plants at the higher population in the mulched plots because all populations were so low that little inter-plant competition for light would have occurred. Also in the other two experiments in this study, plant height at flowering was greater in mulched than unmulched plots, and the plant populations for the two treatments were similar.

Plant population at maturity was lower than the initial population, but there still were consistently more plants in the mulched plots. The short, determinate Hill variety responded less than the taller indeterminate varieties, Kent, and CES 486. The time to maturity was unaffected by mulching (Table 1).

Seed yields of all three varieties were markedly increased by mulching. Yields of Kent were low because of the poor stand, since this variety was observed to pod well. Plants of CES 486 grew taller and bushier, and yielded well inspite of the poor stand (Table 1). Most soybean varieties, especially the indeterminate types, branch profusely if given sufficient space (Poehlman, 1959) under suitable conditions. The plant populations of Hill were higher and, although plants were short and small (Plate 1), seed yields in mulched plots were quite high (Table 1). Seed moisture content (%, wet basis) was higher at shelling in mulched plots, probably because drying in mulched plots did not occur as rapidly as in unmulched plots. Seed size in Kent and CES 486 also was greater in mulched plots (Table 1).

Table 1 Effects of mulching on emergence, growth and yield of three soybean varieties grown during the major rainy season of 1973

Variety	Treatment	Initial stand Plants/m^2	Days to Flower	Plant height at first flower (cm)	Stand at maturity plants/m^2	Plant height at maturity (cm)	Days to Maturity	Grain yield kg/ha @ 13% Moisture	% Moisture content at shelling	100-seed wt(g)
Hill	Control	12.9	27.0	23.1	10.0	25.2	90	1026	11.9	17.4
	Mulched	19.4	27.0	25.2	15.8	26.6	91	1914	12.2	17.4
Kent	Control	3.7	23.8	21.1	2.3	38.6	103	641	11.5	20.9
	Mulched	8.0	23.3	23.6	5.7	44.6	100	1334	11.7	22.1
CES 486	Control	5.8	41.0	36.8	3.9	82.4	120	1840	8.6	18.5
	Mulched	11.9	40.8	41.8	7.7	90.3	120	2551	9.2	19.8
Source of Variation										
Varieties (V)		**	**	**	**	**	**	**	**	**
Mulching (M)		**		**	**	**		**	**	**
V x M						*				
C.V. (%)		31.2	1.8	5.4	34.3	4.0	2.4	27.9	3.1	4.5

* ** Significant at P = 0.05 and 0.01, respectively.

A disadvantage of mulching in the major season experiment was that more damage from Sclerotium rolfsii occurred on mulched than on unmulched plots, but yields appeared to be very little affected. It was also observed that there were more purple-stained seeds in mulched than unmulched plots.

Minor Season

Mulching did not affect plant populations during the minor rainy season (Table 2). The seeds for these plots, which had been harvested 2 to 3 months before planting and stored in polythene bags, had good germination and vigour. Also, soil crusting was not as severe as in the major season. Mulching affected plant development and growth as much as it did in the major season trial. Days to flower were decreased slightly by mulching in two varieties, but increased slightly in CES 486 (Table 2). Plant heights at first flower increased with mulching, as did nodes on the main stem and pods per plant. Although there were more pods per plant and seeds were larger (Table 2), grain yields were not significantly increased by mulching and in Hill there was a decrease. These results suggest that mulched plants averaged fewer seeds per pod than unmulched plants. Total plant dry weights at the pod-filling stage of development also were not appreciably increased by mulching. Two factors may partially explain this lack of yield response to mulching; (i) lodging, which was increased considerably by mulching, and occurred particularly early and severely in CES 486 variety (Table 2). As observed by Cooper (1971) lodging

Table 2. Effects of mulching on emergence, growth and yield of soybean varieties grown during the minor rainy season of 1973

Variety	Treatment	Initial Stand Plant/ m^2	Days to Flower	Plant height at first flower (cm)	Total Plant dry wt. at late pod-filling (g)	Stand at maturity Plants/ m^2	Height at maturity (cm)	Days to Maturity	Nodes per Plant	Pods per Plant	Lodging score 1(erect) to 5 (flat)	Grain yield kg/ha @ 13% Moisture	% Moisture at shelling	100-seed wt (g)
Hill	Control	126	27.0	21.8	2.96	77	36.3	78	8.2	11.0	2.5	1264	8.9	13.6
	Mulched	110	26.0	25.4	4.86	79	39.3	84	8.6	12.4	2.9	1168	9.0	15.2
Kent	Control	75	23.3	17.8	5.26	59	46.2	85	11.0	15.9	1.3	1678	9.0	17.0
	Mulched	67	23.0	22.3	5.80	66	55.8	85	12.0	17.9	2.5	1859	9.1	17.7
GES 486	Control	124	32.3	29.8	3.83	79	64.5	94	10.7	12.9	3.4	1076	8.4	15.4
	Mulched	141	33.0	35.3	4.34	83	80.8	95	12.6	18.4	4.6	1328	8.6	16.9
<u>Source of Variation</u>														
Varieties (V)		**	**	**	*	**	**	**	**	*	**	**		**
Mulching (M)				**			**		**	*	**			**
V x M			**											
C.V. (%)		18.1	1.7	7.3	26.0	11.5	9.8	2.6	7.3	23.1	16.9	21.8	6.6	5.2

* ** Significant at P = 0.05 and 0.01, respectively.

can decrease soybean yields by as much as 20%; (ii) mice damage, which caused many immature green pods to drop off in mulched plots. The problem was particularly severe in the mulched plots of the short, densely podded Hill variety, (Plate 1), which may explain why mulching was not beneficial for seed yield in this variety.

Seed yields of the indeterminate, late-maturing CES 486 grown during the minor season were much lower than those for the same variety during the major season. The late planting date in the minor season resulted in seed development during December and January when normally there is very little or no precipitation and the atmosphere is dry. Although irrigation was applied, plant heights at maturity for CES 486 were less in the minor season than in the major season. The other varieties grew taller in the minor season, probably because of more etiolation under the higher plant population. All three varieties matured earlier and had smaller seed size when they were grown during the minor season (Table 2).

Pot Experiment

Plants grown in pots in the open responded more to mulching than those grown in the field. Mulched plants in pots flowered earlier than unmulched plants (Table 3), whereas this response was not consistent in field grown plants. In all three experiments in this study, plant heights at first flowering and maturity were increased by mulching, although Kent and CES 486 plants were much shorter in pots than they were in the field. Probably, much restriction was placed on the growth of the root system of these two varieties

Table 3. Effects of mulching on growth, flowering and yield of three varieties of soybeans grown in pots

	Treatment	Days to flower	Plant height at first flower (cm)	Flowers per plant	Stem diameter at first trifoliate node (mm)	Total No. of main stem nodes	Plant height at maturity (cm)	No. of branches per plant	Total pods per plant	Pods/plant at maturity	Flowers which formed mature pods (%)	[illegible]
	Control	[illegible]	[illegible]	44.8	5.6	8.8	27.5	4.8	22.8	14.3	30.3	[illegible]
	Mulched	[illegible]	[illegible]	[illegible]	6.6	9.1	29.6	5.8	34.1	28.0	47.3	[illegible]
	Control	26.5	13.2	25.9	5.0	8.5	24.3	5.0	11.3	8.4	33.0	2.3
	Mulched	26.0	17.3	[illegible]	6.7	10.1	31.9	6.8	22.5	17.4	38.5	5.5
[illegible]	Control	[illegible]	24.0	51.9	6.4	10.9	31.4	5.5	19.0	17.4	30.2	3.1
	Mulched	[illegible]	30.2	90.4	8.3	14.1	40.8	6.8	34.8	28.4	30.2	6.7
[illegible]												
[illegible]		[illegible]	[illegible]	**	**	**	**		*			
[illegible]		[illegible]	[illegible]	**	**	**	**		**	**	*	**
						*						
[illegible]		[illegible]	[illegible]	28.0	13.4	8.6	11.9	38.3	35.9	43.7	22.2	36.6

*, ** Significant at P = 0.05 and 0.01, respectively.

with the indeterminate growth habit, by the size of the pots used. The bulk of soybean root dry weight is usually concentrated in the upper 15cm of the soil but the fully developed tap root may penetrate as deep as 150cm (Mitchell and Russell, 1971; Doku, 1973). Mulching greatly increased total flowers per plant in all varieties (Table 3) and in Hill and Kent, increased the percentage of flowers that formed pods. Stem diameters, main stem nodes and branches, pods per plant and seed yield were consistently increased by mulching.

Mulching appeared to improve soybean stands when seed viability was poor. This probably occurred because the soil under the mulch developed less of a crust (Verma and Kohnke, 1951). The soil temperatures observed (Fig. 2) were probably not high enough to inhibit emergence of the seedling. Wien (1973), however, found that hypocotyls of Kent elongated very little at 42°C. An attempt was made to separate temperature and moisture effects on emergence by growing the three varieties in plots covered with white wheat flour, black charcoal and with bare soil. Although differences in soil temperatures as large as for mulched and unmulched plots were measured, treatments had no significant effect on emergence. It seems from the results of the study that soil moisture conservation and reduced crusting under a mulch appeared more important than decreased soil temperatures in improving soybean emergence and stand.

There is an indication from the results of all three experiments that mulched soybean plants grow taller, often large and bear more pods than unmulched plants. These invariably result in increased seed yield as was generally observed in these experiments and which also seem to support the results reported by Verma and Kohnke, (1951); and Fairbourn, (1973). No attempt was made to determine whether high soil moisture or lower maximum temperature is more important in causing these effects. After soybeans have developed a complete leaf canopy, however, mulching would be unlikely to cause much lower soil temperature. If therefore lower soil temperatures aid soybean development, this effect would be most important during early growth of the crop.

Some mulches may act as sources of disease for the soybean crop. The increased incidence of damage from Sclerotium rolfsii in the major season mulched plots may have occurred because the disease was present on the Panicum maximum, Jacq., mulch. No symptoms of the disease were apparent in the minor season experiment, although some mulched plants in pots showed the same disease symptoms as mulched plants in the field during the major season.

If soybeans are grown in Ghana by small-scale farmers, mulching could help in obtaining good emergence and establishment of seedlings. With large-scale mechanized production of soybean, however, the use of grass or other transported mulch applied after planting may not appear economically feasible. However, incorporation of plant residues such as chopped maize (Zea mays L.) stover into the soil, if maize precedes soybeans in the rotation, would be desirable to reduce crusting and increase soil water-holding capacity.

3. SUMMARY OF RESULTS

Three varieties (Hill, Kent, and CES 486) were grown in two field and a pot experiment with and without grass mulch applied after planting in 1973. In the field experiments mulching decreased maximum soil temperatures and maintained higher soil moisture contents during the minor rainy season.

Mulching greatly improved seedling emergence during the major rainy season, increased plant height and seed size. Grain yield was increased by an average of 78% over unmulched plots. In the minor season field experiment, percentage emergence of the seedlings in all varieties and treatments was high. Mulching increased plant height, nodes and pods per plant and seed size, and also lodging. Grain yield was not increased, possibly because of more lodging and some rodent damage in mulched plots. In the pot experiment mulching hastened flowering; increased plant height, stem diameter, number of flowers, nodes and pods per plant; the percentage of flowers which formed pods and the seed yield.

Mulching appeared beneficial in soybean production, particularly when seed viability was low and during the major rainy season when maximum soil temperatures were high.

V. EFFECTS OF TEMPERATURE ON GERMINATION AND EMERGENCE OF SOYBEAN VARIETIES

1. MATERIALS AND METHODS

For this experiment, seed lots of twenty-one varieties were obtained by air from the Department of Crop Science, University of Guelph, Canada in early May 1973, and were stored in a walk-in cold room (2 ± 2C; 89% RH) in 5-mil polythene bags tied with strings. The emergence studies, started on 7 June 1973, were conducted in medium size 'IH-280 Gellankemp' incubators at four temperatures of 20, 30, 40 and 50°C. Perforated plastic trays measuring 32 x 21 x 5cm (internal) were used as substrate containers which were filled to 4.5cm depth with steam-sterilized sandy loam soil.

A tray was sown with 10 seeds each of four varieties in four rows spaced 5cm apart. The seeds, which were not treated (with insecticides or fungicides), were 3cm apart within row and placed at 2.5cm depth. There were four replications in a randomized complete block design. The trays, incubated in the dark, were watered at regular interval with adequate tap-water in beakers kept in incubators at the appropriate temperature.

Emergence counts were made daily (1600hr) for the day of first emergence till no more seedlings emerged. Germination (and emergence) as considered here was for sprouted seeds whose cotyledons have emerged above the soil surface (Doneen and McGillivray, 1943, slightly modified). Hypocotyl elongation was measured from the soil surface level for seedlings at 20, 30 and 40°C on days 10, 7 and 6 respectively after sowing. Other records taken were days to maximum emergence and maximum seedlings that emerged (absolute value expressed as percentage). Seeds of two of the varieties, CES 486 and Chippewa 64, were available in very small quantities only enough for one and three replicates respectively. Data on them were therefore excluded from any group analysis.

Data for maximum seedlings that emerged were also re-calculated and expressed as percentages using the corresponding emergence at 30°C (which averaged the highest) as a base. This comparison is used to assist in an attempt to classify the varieties into groups based on their emergence ability at the higher (40°C) temperature.

2. RESULTS AND DISCUSSION

There were no emergence for any of the varieties at 50°C, most of the seeds were found to be charred after 4 days, therefore this treatment was discontinued.

Germination and emergence were slow at 20°C for all varieties. Days to first emergence and to maximum emergence were shortened as temperature increased from 20°C to 30 and 40°C (Table 4). For all varieties which germinated, days to first emergence and to maximum emergence were significantly reduced by about 50% when the temperature was doubled from 20 to 40°C (Table 4; Appendix 9) indicating an accelerated rate of germination under the high temperatures. This was, however, of no advantage because the higher temperature (40°C) was also found to reduce the maximum number of seedlings that emerged.

Table 4. Effect of Temperature on Days to First Emergence and to Maximum Emergence of 19* Soybean Varieties Grown in Incubators at Legon, 1973.

Variety	Days to First Emergence			Days to Maximum Emergence		
	20°C	30°C	40°C	20°C	30°C	40°C
Cutler 71	6.0	3.0	3.5	8.8	7.0	4.4
Dare	7.0	3.5	2.5	10.8	9.5	5.3
Semmes	7.3	4.3	3.3	10.8	7.5	5.8
Hark	8.0	3.5	2.8	10.3	9.5	5.3
Bragg	6.5	3.5	3.0	10.3	7.0	5.3
Improved Pelican	6.8	3.3	3.0	10.0	6.3	5.3
Harosoy 63	7.0	3.5	3.0	11.0	6.8	4.8
Coker Hampton 266A	7.0	3.3	3.0	11.5	7.5	5.5
Pickett 71	6.5	3.3	3.0	11.5	7.3	6.3
Amsoy 71	7.0	3.3	2.8	10.5	6.0	4.8
Clark 63	6.3	4.8	2.8	11.0	6.5	4.0
Davies	7.8	4.3	3.0	10.8	8.5	4.0
Hardee	7.3	3.3	2.8	11.8	6.8	4.8
Lee 68	7.8	3.8	3.3	11.3	8.0	6.8
Calland	7.5	3.8	3.8	11.5	9.5	5.5
Bonus	7.8	3.8	3.0	10.5	7.3	4.8
Hutton	8.5	5.0	3.8	13.0	7.5	4.3
Jupiter	8.0	5.0	3.5	11.0	6.8	5.8
Hill	8.8	5.0	3.5	12.3	9.0	6.3
MEAN	7.3	3.9	3.1	11.0	7.6	5.2
Chippewa 64*	5.7	3.7	3.0	10.7	6.3	4.7
CES 486*	6.0	3.0	3.0	7.0	7.0	3.0

* Chippewa 64, CES 486 excluded from group analysis of data (See Text).

Went (1957) using Brassica arvensis; Aquino and Bekendam (1967) using soybean, reported slow but complete germination at cool temperature, but accelerated and complete germination at 30°C. The days to maximum emergence for all varieties at 30°C averaged 7.6. 'Hill', 'Hutton' and 'Jupiter' seem to take longer time to emerge at all temperatures (Table 4) probably partly because Hill and Jupiter averaged the lowest initial germinability of 85%. Sorwli (1974) reported that full emergence of 'Amsoy 71' soybean occurred 5 days after sowing in the field at Legon. In the present work, Amsoy which seems to emerge early averaged 3.3 and 6.0 days at 30°C (Table 4).

There were significant differences in maximum seedling emergence among temperature treatments and varieties, however, no significant interaction was found between temperature and varieties (Table 4; Appendix 9), as varietal responses to temperature were similar. Mean seedling emergence percentage at 20 or 30°C was significantly greater than that at 40°C (Table 5) indicating reduced seed germinability at the higher temperature. Some of the seeds were found to have sprouted but failed to emerge, possibly due to lack of enough vigour which could have resulted from dissipation of energy as a result of accelerated respiration at the higher temperature. Though overall mean showed a slightly higher seedling emergence percentage at 30°C (74.2%) than that at 20°C (70.8%), there were nearly as many varieties (9 varieties excluding CES 486 and Chippewa 64) which had higher emergence percentages at 20°C than at 30°C,

Table 5. Effect of Temperature on Maximum Seedling Emergence and Hypocotyl Elongation in 19 Soybean Varieties Grown in Incubators at Legon, 1973.

Variety	Maximum Seedling Emergence (as percentage of absolute values) (%) 'A'			Maximum Seedling Emergence (as percentage of corresponding emergence at 30°C)(%) 'B'			Hypocotyl Length (taken at days 10, 7, 6) (cm)		
	20°C	30°C	40°C	20°C	30°C	40°C	20°C	30°C	40°C
Cutler 71	100	95	68	105.3	100	69.4	18.0	14.6	14.6
Dare	93	98	58	94.9	100	59.2	10.8	12.1	10.2
Semmes	88	93	65	94.6	100	69.9	9.2	13.5	9.8
Hark	75	90	58	83.3	100	72.2	7.4	18.5	10.6
Bragg	78	90	50	86.7	100	55.6	11.2	13.1	4.5
Improved Pelican	98	93	35	105.4	100	37.6	7.9	12.9	7.4
Harosoy 63	95	85	40	111.8	100	47.1	7.6	13.9	7.7
C. Hampton 266A	85	83	45	102.4	100	54.2	6.5	14.4	7.8
Pickett 71	65	80	53	81.3	100	66.3	8.8	11.3	6.5
Amsoy 71	58	83	55	69.9	100	66.3	8.2	13.6	7.5
Clark 63	80	73	28	109.6	100	38.4	14.5	11.9	14.0
Davies	75	63	38	119.0	100	63.3	9.5	11.5	10.5
Hardee	60	70	38	85.7	100	54.3	6.9	16.7	8.5
Lee 68	70	68	38	102.9	100	55.9	7.7	13.7	7.8
Calland	45	63	48	71.4	100	76.4	14.3	14.6	4.3
Bonus	45	53	35	84.9	100	66.0	18.4	13.5	11.8
Hutton	58	55	20	105.5	100	36.4	5.9	15.2	9.0
Jupiter	38	40	30	95.0	100	75.0	8.4	14.7	12.9
Hill	40	35	28	114.3	100	80.0	3.4	8.5	4.4
MEAN	70.8	74.2	43.7	96.0	100	60.0	9.7	13.6	8.9
Chippewa 64*	90	73	50	123.3	100	68.5	+	+	+
CES 486*	100	90	40	111.1	100	44.4	14.8	15.6	8.5

* Excluded from group analysis of data (See Text).

\+ Results not available.

as those (10 varieties) which had higher emergence percentages at 30°C than 20°C (Table 5 Column 'B'). The variety 'Calland' had a higher emergence percentage at 40° than at 20°C, however, hypocotyl elongation was greatly reduced at 40°C. Improved Pelican, Harosoy 63 and Clark 63 which had high emergence at both 20 and 30°C, had a comparatively reduced emergence at 40°C.

The emergence results indicate that the optimum temperature for soybean germination and emergence lies somewhere between 20 and 30°C. Similar findings have been reported by Went (1957), Brown (1960), Aquino and Bekendam (1969), Grabe and Metzer (1969). At IITA, Ibadan, germination percentage in 'Kent' soybean decreased from 81.3% at 21°C to 3.8% at 38°C (IITA 1973 Report).

Generally, hypocotyl length increased as temperature increased from 20°C (mean 9.7cm) to 30°C (mean 13.6cm) and then became sharply reduced at 40°C (mean 8.9cm). A similar trend of temperature effect on the development and growth of soybean has been reported for dry matter production of soybean top and roots (Early and Cartter, 1945), rate of node formation and internode elongation (Howell, 1963), apparent photosynthetic rate (Fukui, Mutsuo and Watanabe, 1965) and hypocotyl elongation (Wien, 1973). Three varieties: Bonus, Cutler 71 and Clark 63, had greater hypocotyl elongation at 20°C than at 30°C (Table 5). Clark 63 also had a greater hypocotyl length (14.0cm) at 40°C than at 30°C (11.9cm).

Reduced hypocotyl elongation may limit soybean emergence in the field because the elongation pushes the cotyledons and the growing point of the germinating seed above the soil surface (IITA 1973 Report). Seedlings at 20°C were observed to be bigger and healthier than those at 40°C, which were poorly developed.

The varieties were classified into three groups (Table 6), based mainly on their ability to germinate and emerge at the higher temperature. Cutler 71 and Semmes in 'Group A' (mean maximum emergence at 40°C equal to, or greater than 55%) showed consistent high performance while Hutton, Hill, Clark 63 and Jupiter in Group C' (mean maximum emergence at 40°C less than 40%) consistently performed poorly under the experimental condition. Also performance was not found to fall into any trend with the 'maturity grouping', (i.e. 00 to X Groups as found in U.S.A. and Canada), perhaps this is due to the comparatively constant daylength variation in Ghana. Perhaps, it is worth commenting that hypocotyl length of all varieties in 'Group B' (mean maximum emergence less than 55% but equal to or more than 40%) were comparatively short (below 8.0cm). In Groups A and C, except in one and three varieties respectively, all others had hypocotyl length above 8.0cm. Wien (1973) obtained hypocotyl length of 8.5 and 9.1 (mean 8.8cm) and 11.5cm for Kent and '280-3' soybean and Prima cowpea respectively, grown on agar in test-tubes at 30°C. Recent field trials at Legon with most of the varieties seem to show some promise in yield (Dadson 1974: Personal Comm.), however,

Table 6. Emergence Ability and Hypocotyl Elongation of 19 Introduced Soybean Varieties Grown at 40°C in Incubators - 1973.

Group And Variety	Maturity Group	Maximum Seedling Emergence at 40°C (%)	Hypocotyl length at 40°C* (cm)
'Group A' (Emergence > 55%)			
Cutler 71	IV	68	14.6
Semmes	VII	65	9.8
Hark	I	58	10.6
Dare	V	58	10.2
Amsoy 71	-	55	7.5
'Group B' (Emergence < 55 > 40%)			
Pickett 71	VII	53	6.5
Bragg	VII	50	4.5
Calland	III	48	4.3
Coker Hampton 266A	VIII	45	7.8
Harosoy 63	II	40	7.7
'Group C' (Emergence < 40%)			
Davies	VII	38	10.5
Hardee	VIII	38	8.5
Lee 68	VI	38	7.8
Bonus	IV	35	11.8
Improved Pelican	VIII	35	7.4
Jupiter	IX	30	12.9
Clark 63	IV	28	14.0
Hill	V	28	4.4
Hutton	VIII	20	9.0
MEAN		43.7	8.9
Chippewa 64**		50	-
CES 486**		40	8.5

* Observations made 6 days from sowing

** Omitted from group analysis of data (See Text).

earlier reports (Mercer-Quarshie, 1973; Nsowah, 1973) indicated inconsistent performance. Leng (1973) stated that under less favourable condition, the modern varieties from the United States do not always do well in tropical areas.

3. SUMMARY OF RESULTS

Twenty-one introduced varieties were sown in trays at temperatures of 20, 30, 40 and 50°C in incubators in 1973. There were no germination at 50°C.

Germination and emergence were slow at 20°C in all varieties. Doubling the temperature from 20°C to 40°C reduced the days to first emergence and to maximum emergence by about 50%, however, maximum number of seedlings that emerged and hypocotyl elongation were disadvantageously reduced at 40°C. Hypocotyl elongation was significantly higher at 30°C than at 20 or 40°C. In three varieties (Cutler 71, Clark 63 and Bonus), however, hypocotyl elongation was greatest at 20°C.

Maximum seedling emergence was higher at 20°C than at 30°C in about half the varieties studied, and the others showed maximum seedling emergence at 30°C than at 20°C. Generally, seedling at 20°C were observed to be bigger and healthier while those at 40°C were poorly developed.

Nineteen of the 21 varieties were put into three groups on the basis of their ability to germinate and emerge consistently well at the higher temperatures. The varieties Cutler 71, Semmes, Hark and Dare consistently performed well at higher temperature while Hutton, Hill, Clark 63 and Jupiter were the poorest.

VI. EFFECTS OF STORAGE CONDITIONS ON SOYBEAN SEED VIABILITY

1. MATERIALS AND METHODS

Seed of the soybean variety 'Amsoy 71', obtained by air from the University of Guelph, Canada, was divided into 454g lots and packed in either cloth or 3-mil polythene bags tied tightly with string. Initially, four samples were tested for moisture content and germination. Moisture contents were determined by oven drying to constant weight at 80°C. Germination was tested by placing 25 seeds from each sample on blotter paper moistened with distilled water on a germination plate in the laboratory. A seed was considered germinated when a radicle 1 cm long penetrated the seed coat.

Seed lots were allocated to eight treatments, each replicated four times. Treatments were: storage at ambient temperature in the laboratory, in an air-conditioned room and in a walk-in cold room. Samples in each room were stored in cloth or 3-mil polythene bags. Initial seed moisture contents of the four samples tested averaged 11.2%. The two further treatments were seed stored in polythene bags in the air-conditioned room, but sufficient distilled water was added to each bag, assuming initial percentage moisture of 11.2, to bring the moisture contents up to 14.5 or 17.8%.

The temperatures and humidities of the rooms (Table 7) were measured between 1430-1500h once a week for the first 8 weeks.

Table 7. Temperatures and relative humidities (RH) in the three types of storage.

Room Type	Temperature (°C)	RH (%)
Open laboratory	27 ± 1	77 ± 1
Air-conditioned	22 ± 1	59 ± 1
Walk-in Cold Room	2 ± 2	89 ± 1

Table 8. Effects of condition and duration of storage on Field emergence (%) of soybean seed.

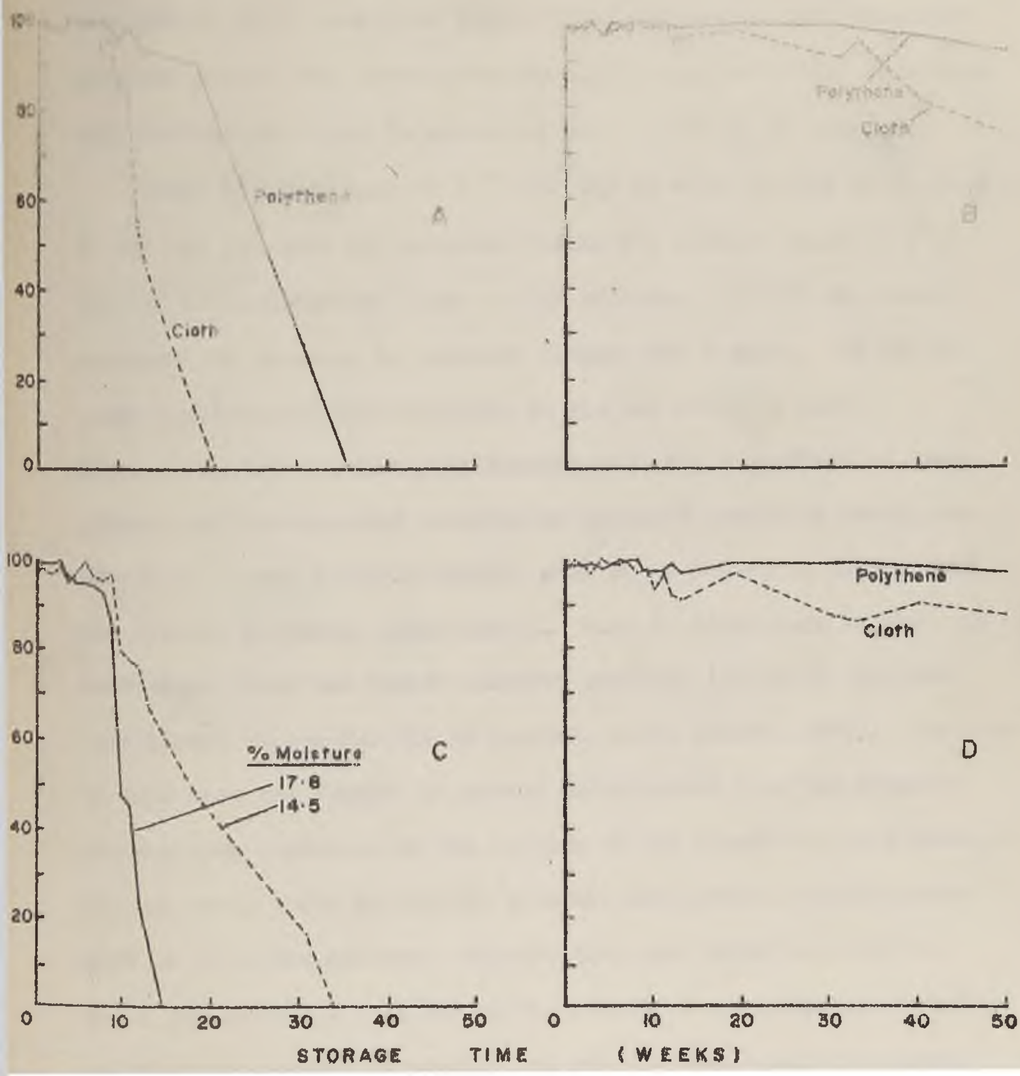
Treatments		Initial Seed Moisture (%)	Weeks of Storage			
Room Type	Bag		0	8	40	50
Open laboratory	Cloth (C)	11.2	96	88	0	0
	Polythene (P)	11.2	96	95	4	0
Air-conditioned	C	11.2	96	95	88	57
	P	11.2	96	98	96	93
	P	14.5	96	65	0	0
	P	17.8	96	59	0	0
Walk-in Cold Room	C	11.2	96	86	49	32
	P	11.2	96	95	96	98

Subsequent measurements were made once every month. Means and standard errors were calculated using all readings.

The experiment was began 25 June 1973. Germination tests were conducted, as previously described, on each sample after weeks 1-13, 19-31, 33, 40, 50 and 55. Seed moisture contents were measured after weeks 1-4, 8 and 50. Percentage emergence from soil was measured after weeks 8, 40 and 50 by planting 20 seeds from each sample in 84cm rows, 20cm apart and counting plants 10 days after planting.

2. RESULTS AND DISCUSSION

Temperatures and humidities remained fairly constant over the 55 weeks of the experiment (Table 7). All stored seed retained its germination ability for 7 weeks (Fig. 3). The high moisture seed samples in air-conditioning (Fig.3:C) lost viability first, followed by samples stored in cloth bags at ambient temperature (Fig.3:A). After 55 weeks (Appendix 3) the samples in polythene bags in either air-conditioned or the cold room retained their viability, although the seeds from the cooler temperature appeared more vigorous during germination and emergence. Losses in germination ability under the various conditions were very similar to those reported by Dorworth and Christensen(1968) who used combinations of four initial moisture contents of 12.1, 14.7, 16.5 and 18.3% and four storage temperatures of 15, 20, 25 and 30°C. Seeds which were stored in polythene bags maintained their viability longer than comparable ones in cloth bags



G.3. EFFECT OF CONDITIONS AND DURATION OF STORAGE ON SOYBEAN SEED GERMINATION. SAMPLES AT INITIAL MOISTURE CONTENTS OF 11·2% WERE STORED IN CLOTH OR POLYTHENE BAGS IN AN OPEN LABORATORY (A), AN AIR-CONDITIONED ROOM (B), OR A COLD ROOM (D). SAMPLES IN C WERE STORED IN POLYTHENE BAGS IN AIR-CONDITIONED ROOM WITH INITIAL MOISTURE CONTENTS OF 14·5 AND 17·8 %.

at all temperatures (Fig.3 and Appendix 3). Similar results were obtained in field emergence trials (Table 8) except that emergence declined sooner than germination on plates (Appendix 3). Some seeds with sufficient vigour to germinate were too weak to emerge.

Seeds in cloth bags at 27°C and 76% RH equilibrated with moisture in the air at about 15% moisture (Table 9), whereas those at 2°C and 89% RH equilibrated close to 19% moisture. At 76% RH, seeds continued to increase in moisture content for 8 weeks. At 89% RH seeds equilibrated with moisture in the air within 4 weeks. Soybean moisture content equilibrates with RH, regardless of temperature, and the observed equilibrium moisture levels at the higher RH values (Table 9) agree closely with those listed by Milner (1950) for similar RH values (Appendix 4). Seed in cloth bags in the air-conditioned room had higher moisture contents (Table 9) than the equilibrium values for 59% RH (approx. 9.6%; Milner, 1950). The door to this room was frequently opened and moisture from the outside air may have condensed on the surface of the relatively cool seeds. Soybean seed, which is high in both oil and protein, equilibrates with RH at higher moisture contents than most other agricultural seeds (Appendix 4). The oil is essentially non-hygroscopic but the relative proportions of protein and soluble carbohydrate strongly influence water absorption (Milner, 1950).

The loss of viability of seed stored in cloth bags compared with those in 3-mil polythene bags in the cold room indicates that

Table 9. Effects of condition and duration of storage on soybean seed moisture content (%).

T r e a t m e n t s		Weeks of Storage			
Room Type	B a g	0	4	8	50
Open Laboratory	Cloth (C)	11.2	13.2	14.9	14.6
(27°C, 76% RH)	Polythene (P)	11.2	11.0	11.2	11.0
Air-conditioned	C	11.2	10.5	10.8	12.5
(22°C, 59% RH)	P	11.2	9.7	10.7	11.0
	P	14.5	13.9	14.6	14.4
	P	17.8	15.7	16.9	17.1
Walk-in Cold Room	C	11.2	19.2	19.3	19.2
(2°C, 89% RH)	P	11.2	10.4	10.1	12.3

seed should be stored in moisture-proof containers. Seeds of most soybean varieties stored for 18 months in paper bags in the same cold room lost all of their ability to germinate. This seems to lend support to the conclusion of other workers on agricultural seeds (Ching et al., 1960; Toole et al. 1961; Harrington, 1963; and Helmer et al., 1963) that packing dry seeds in moisture resistant containers is the simplest and best method for safe storage or shipping of seed under any climatic conditions occuring around the world.

In all cases in this experiment, storage in moisture-proof containers appeared advantageous (Fig.3). However, Andrews (1970) has reported that soybean seeds at moisture content of 13% stored for 18 months under storage condition of 30% RH and 6°C were of slightly poorer vigour in polythene than in paper bag containers. At lower values of 7 and 10% seed moisture contents, however, germination capacity and vigour were maintained regardless of bag type. It seems from Andrews' observations and the results here that storage in a moisture-proof container is advantageous, but may be a disadvantage only when the storage atmosphere has a RH low enough that the seeds will continue to lose moisture.

Hukill's (1963) 'age index' computed for estimating viability is: Age index = (storage time in months) (10^{x+y}), where x = 0.143 times percentage moisture and y = 0.0645 times storage temperature in °C. His calculation suggested that with normal ambient temperatures and humidities in Southern Ghana, viability of soybean seeds would decline rapidly, beginning at about 8 weeks after harvest if moisture content is high. Hukill's age index was applied to the conditions of this experiment, assuming seed was at 11.2% moisture and an average temperature of 15°C during the 8-month period from harvest (Oct. 1972) in Canada until this experiment began (June 1973). The age index predicted storage times for each set of storage conditions before germination would start to decrease (Table 10). In most cases, the observed number of weeks before germination began to decrease (became consistently less than 90%) was close to the predicted value. Seeds in cloth bags at ambient temperature and in cold room, and seed in air-conditioning in polythene bags at an initial moisture content of 14.5% deteriorated more rapidly than predicted (Table 10) although in all cases, germination percentages dropped slowly until approximately the time when the age index predicted that deterioration would begin. Thus Hukill's age index predicted reasonably accurately the time for which soybean seed at a given moisture content and temperature could be stored before it began to lose viability.

In a recent study in Nigeria (IITA, 1973), soybean seed of six varieties were stored at ambient temperatures (25-28°C) in open or sealed 4-mil polythene bags. After open storage for 5 months, five of the six varieties had less than 10% germination, but one variety, 1Gm-393, retained 51% germination. The initial germination percentages for three of the varieties, however, were already low (51-74%)

Table 10. Predicted and observed time periods for soybean seed, stored under various conditions, to begin to decline in germination percentage.

Treatments: Room Type	Treatments: Bag	Storage temperature (°C)	Ave. Seed moisture content(%) until germination decline began	Time to Germination decline (Week): Predicted	Time to Germination decline (Week): Observed
Open laboratory	Cloth (C)	27	13.1	12	9
	Polythene(P)	27	11.1	24	19-31
Air-conditioned	C	22	11.5	44	40
	P	22	10.9	54	>55
	P	22	14.5	17	9
	P	22	17.0	7	8
Walk-in Cold Room	C	2	19.2	69	50
	P	2	11.2	959 ?	>55*

* No appreciable decline in germination percentage (See Appendix 3).

and only 1Gm-393 had average germination of more than 97%. The storage period before germination of the six varieties began to decline were not reported, but the germination percentages after 3 and 5 months of open or sealed storage were similar to results obtained in this experiment (Appendices 3 and 5).

Soybean seed, harvested at the end of the minor rainy season on the Accra Plains, an area with a bimodal rainfall pattern, would be stored for up to 5 months before the rains become regular at the beginning of the major rainy season. Hukill's 'age index' formula predicts that at ambient temperatures averaging 27°C, high quality seed would need to be dried to 12% moisture and stored in moisture-proof containers to store for 5 months. Sun drying of soybean at Legon during the dry months resulted in soybean seed moisture contents as low as 8-9%. Thus seed could be stored at ambient temperatures long enough to maintain viability from harvesting to planting provided two crops per year are grown. If high quality seed is to be stored for longer periods, refrigerated storage facilities will be necessary.

If soybeans are grown in Ghana on any large scale, the seed must be stored carefully otherwise viability will be a problem. The use of a combination of cloth bag lined with polythene (bags) of higher thickness is being suggested for sealed storage.

3. SUMMARY OF RESULTS

Soybean seed cv 'Amsoy 71' was stored in cloth or polythene bags at ambient temperature and relative humidity (27°C 76% RH), in an air-conditioned room (22°C, 59% RH), and in a walk-in cold room (2°C, 89% RH). Initial seed moisture content averaged 11.2%. Seed at 14.5 and 17.8% moisture also was stored at 22°C and 59% RH. Seed in each treatment was tested regularly for moisture content, germination and field emergence.

Seed samples stored at high temperatures and moisture contents rapidly lost their ability to germinate and emerge after 9-10 weeks. Lowering storage temperatures or moisture contents preserved seed viability longer. Seed in polythene bags at 22° or 2°C and 11.2% moisture did not lose viability during 50 and 55 weeks of storage respectively.

The storage time before loss of germination began could be predicted by an 'age index' formula, based on storage temperature and seed moisture content. The formula and observed values indicate that soybean seed in southern Ghana will lose viability too rapidly to sustain commercial production, unless the seed is stored below 12% in moisture-proof containers, and kept under refrigeration.

VII. EFFECTS OF INTER-ROW SPACING ON PERFORMANCE OF (EARLY - AND LATE-MATURING) SOYBEAN VARIETIES

1. MATERIALS AND METHODS

Two experiments were conducted, one during the major and the other during the minor rainy season of 1973 at the University Farm, Legon. Two varieties were used: the short, determinate, early-maturing US variety, 'Hill' and the tall, indeterminate, late-maturing Phillipine variety, 'CES 486'. The crops were grown on free-draining, slightly acid (pH = 6.0) light sandy loams (Brammer, 1967). Each experiment consisted of six treatments (i.e. 2 varieties x 3 inter-row spacings) arranged in a randomized block design. The inter-row spacings were 25, 50 and 75cm with 8, 6 and 4 rows per plot respectively. Each plot was 4.5m long. There were four replications in each case. All seeds were moistened and inoculated with commercial inoculum immediately before planting by hand.

The experiment in the major rainy season was planted May 21, 1973. Planting rate was 375,000 seed/ha but poor germination, erratic emergence and erosion caused by heavy rains in June reduced stands. Measurements taken included plant apex height at flowering and maturity, days to first flowering and maturity, final seed yield, seed moisture content and 100-seed weight. Final harvests were in mid-August for 'Hill' and in late September for 'CES 486'.

Seed of the two varieties harvested from the major season experiment was sown in an identical experiment on October 28, 1973. Seeds were inoculated and thickly planted with about 2cm between seeds and sprinkler irrigated immediately after covering the seed. Very good emergence was obtained and the stands were thinned within 8 days of emergence to approximately 562, 500 plants/ha in all plots. Days to first flowering and maturity, and plant heights were measured as before. Ten plants from second row in each plot were sampled on 4th January 1974. Nodules were counted and leaf area (for LAI calculation) was measured by the leaf-punch technique. At maturity, numbers of nodes and branches on the main stem and pods per plant were recorded. The degree of lodging was scored at maturity on the basis of a 1 (erect) to 5 (flat i.e. completely lodged) scale (Probst, 1945; Weber et. al., 1966). Final harvesting was in mid-January 1974 for 'Hill' and late-January for 'CES 486'. In plots with 25, 50 and 75cm inter-row spacing, which had 8, 6 and 4 rows, 4m of 6, 3 and 2 centre rows respectively were harvested. Pods were shelled by hand. Moisture content was measured with a Dickey-John Grain Moisture Tester, 100-seed weight was determined and seed yields at 13% moisture were calculated.

No chemical analysis of plants or seeds were made.

2. RESULTS AND DISCUSSION

MAJOR SEASON, 1973

Seeds available for planting this experiment were of marginal viability (55-60%, plate germination), resulting in poor erratic germination and emergence with subsequent reduction in stand (Table 11). Heavy rains in June also reduced stand. The significant higher initial stand and stand at maturity for the narrower inter-row spacing could therefore be due more to these reasons than to row width effect *per se*.

Inter-row spacing did not affect days to flower. 'Hill' flowered earlier than CES 486. Days to maturity also were not affected by row width. Hill matured in 90 days and CES 486 in 125 days. Both varieties matured earlier in the minor season (Table 12) than in the major season (Table 11). Row width effects on plant height at flowering and at maturity were not significant, even though at maturity rows spaced 25cm apart gave the tallest plants and the 50cm-rows, the shortest. Varietal differences in plant heights were significant.

Seed size was not significantly affected by inter-row spacing. Probst (1945) found little effect of the intra-row spacing on soybean seed size but Hinson and Hanson (1962) and Reiss and Sherwood (1965) reported increases in seed size with wider row spacing. Haizel (1972) and Asamoah (1974) summarising earlier works on the relationship between plant spacing, plant density and crop yield, pointed out that

Table 11. Effects of Inter-row spacing on plant stands, height and days to flowering and maturity and yield of two varieties of soybean grown during the major season of 1973.

ariety	Row Width (cm)	Initial Stand Plants/m2	Days to Flower	Plant Height at flowering (cm)	Stand at maturity Plant/m2	Plant height at maturity (cm)	Days to maturity	100-Seed weight (g)	Seed moisture at shelling (%)	Seed Yield kg/ha @ 13% moisture
111	25	50	30.5	21.0	42	34	89.3	16.3	11.9	2251
	50	24	30.5	20.7	20	27	91.0	19.0	11.2	1524
	75	20	30.8	20.3	18	29	90.3	18.7	11.1	1312
CES 486	25	23	42.5	29.8	17	45	124.5	19.8	11.8	2530
	50	9	42.5	29.9	8	38	124.5	19.2	12.2	1904
	75	11	42.8	30.9	6	42	124.5	19.4	11.5	1673
<u>Source of Variation</u>										
Varieties		**	**	**	**	**	**	*		
Row widths		**			**					**
Var. x Row Width										
C.V. (%)		48.2	1.9	4.1	49.7	17.4	1.6	6.9	9.7	25.9

* ** Significant at P = 0.05 and 0.01, respectively.

different plant parts may respond differently to density stress, the seed size often being unaffected.

The narrower row spacing gave significantly higher seed yields than the wider spacing in both varieties. Reiss and Sherwood (1965) concluded from their own work and those of earlier workers that narrower row widths gave highest seed yield but the result here must be viewed with caution. Higher seed yields at narrower row spacing are generally due to the higher plant stands at maturity (Table 11).

MINOR SEASON, 1973

In the minor season experiment, days to flower and to maturity and plant height at flowering and at maturity were not significantly affected by row width (Table 12). In CES 486, plant height tended to be slightly higher at the wider inter-row spacing. Lodging was higher at all row spacings in the tall-indeterminate CES 486 variety than in the short, determinate Hill variety (Table 12). A lodging score below 2 (Probst, 1945; Weber *et al.*, 1966) was not considered serious. Hicks *et al.* (1969) found plant height and lodging to increase with decrease in inter-row spacing. Short-determinate plant types did not lodge. Sorwli (1974) found the medium-height variety, Amsoy 71, (35-45cm at maturity) grown during the major season of 1973 to show considerable resistance to lodging. Rows 50cm apart were used with plants 5cm apart within rows and the highest lodging score was 1.28.

Table 12. Effects of Inter-row spacing on growth, development and yield of two varieties of soybean grown during the minor rainy season, 1973.

Variety	Row Width (cm)	Days to First Flower	Plant height at flowering (cm)	Nodule number per plant	Leaf Area Index (LAI)	Number of nodes/ main stem	Number of main stem branches	Pods per plant at maturity	Height at maturity (cm)	Days to maturity	Lodging Score 1 (erect) to 5 (flat)	100-Seed weight (g)	Seed Yield kg/ha @ 13% moisture
Hill	25	28.3	20.6	5.1	0.79	8.4	2.0	9.6	31.7	83.3	1.5	13.7	758
	50	28.0	20.9	6.1	0.75	8.4	2.0	10.0	31.4	83.0	1.6	13.2	653
	75	28.3	20.3	7.8	0.73	8.3	2.5	13.1	31.5	83.3	1.9	13.9	735
CES 486	25	36.0	27.1	8.3	2.00	11.3	1.8	11.2	55.7	94.8	1.6	16.1	929
	50	36.0	29.7	5.6	1.64	11.6	2.8	14.4	57.6	94.8	2.3	15.2	957
	75	36.0	31.6	8.3	2.30	13.6	3.5	23.4	61.6	95.5	2.9	16.5	991
Source of Variation													
Varieties		**	**		**	*		*	**	**	*	**	*
Row Widths							*	*					
Var. x R. Widths													
C.V. (%)		0.82	12.0	57.5	46.7	10.6	28.6	34.4	16.7	2.1	31.5	8.1	34.1

* ** Significant at P = 0.05 and 0.01, respectively.

Nodule numbers per plant were not significantly different among varieties and row widths, even though more nodules were formed in CES 486 (Av.7.4 nodules/plant) than in Hill (Av.6.3), and at wider inter-row spacing (Av.8.1) than at narrow spacing (Av.6.7). In Kanpur, India, Mishra and Singh (1968) reported that decreasing inter-row spacing from 75cm (133, 333 plants/ha) to 25cm (400,000 plants/ha) resulted in increase in the length of main roots of soybean cv T.49 but a decrease in number and weight of nodules/plant. Sorwli (1974) reported that non-inoculated soybean cv Amsoy 71 grown at the University Farm produced virtually no nodules, indicating that the rhizobia might not be indigenous to the soil. He obtained an average of 24.6 nodules/plant from soybeans inoculated with three times the recommended rate of commercial R. japonicum.

Leaf area index (LAI) was higher in CES 486 than in Hill, but no significant effect resulted from inter-row spacing within the varieties (Table 12). Hickes et al., (1969) at Illinois, found LAI to be greater and earlier in rows 25cm apart than in rows 76cm apart, and increased with increase in seed rate. At the time (pod filling stage) plants were sampled, the lower leaves of Hill were yellowing with a few leaves already fallen while CES 486 had a fully closed canopy in most plots.

Number of nodes per main stem was not affected, however CES 486 had more nodes at wider row width spacing (Av.13.6) than at narrower row spacing (Av.11.3). Wider inter-row spacing resulted in significant increase in the number of main stem branches and pods/plant at maturity, the increase being greater in the tall, indeterminate CES 486 variety than in Hill (Table 12). Seed size was significantly higher in CES 486 (Av.15.9g/100-seed) than in Hill (13.6g/100-seed). The wider inter-row spacing tended to produce heavier seeds (Av.15.2g/100-seed) than rows spaced 25 or 50cm apart (Av.14.9g; 14.2g/100-seed respectively) but the differences were not significant.

Differences in seed yield caused by inter-row spacing were not significant. Lack of rainfall and a temporary water shortage during pod filling stage (late-December 1973) could be responsible for this. Singh and Singh (1968) in Kanpur, India, reported that grain yield of the cultivar T.49 was not significantly influenced by inter-row spacings of 25, 50 or 75cm. Hicks et al. (1969) also reported that yields of 4 soybean types were not affected by row spacing of 25 or 75cm or by seed rate, but yields were 4.6% higher in tall-determinate than in normal plant types.

Seed yields in the minor season (Av.837 kg/ha) were lower than yields in the major season(Av. 1866 kg/ha). CES 486 outyielded Hill in both seasons. According to Mercer-Quarshie (1973), S.H. Evelyn planted twenty-four and twenty-three soybean varieties in the minor seasons of 1971 and 1972 respectively at Kwadaso and obtained mean yields of 836.6 kg/ha in 1971 and 2286.8 kg/ha in 1972.

On the basis of mean yield over the two seasons and data provided by earlier workers (Mercer-Quarshie 1973), it seems that the tall, long-maturing varieties would do better both under wider inter-row spacing and in the major season than the short early-maturing ones. The variety Hill is probably the one to recommend at narrower spacing and for the minor season. Furthermore, narrower spacings which seem to suit Hill and other short varieties have been found to result in greater water use efficiency and soil erosion protection than wider rows (Timmons, Holt and Thompson 1967; Mannering and Johnson, 1969).

3. SUMMARY OF RESULTS

In field trials at the University Farm, Legon during the major and minor rainy seasons of 1973, two soybean cv 'Hill' (short-determinate) and 'CES 486' (tall-indeterminate) were sown in rows 25, 50 and 75cm apart. Seeds were inoculated with commercial inoculants just before sowing by hand.

Inter-row spacing had no significant effect on days to flower, height at flowering, days to maturity and height at maturity in both seasons.

In the minor season only, LAI and main-stem nodes/plant were not affected by row spacing. Nodules/plant were higher (Av. 8.1) at the wider spacing than at the narrower spacings (Av. 6.7) but the differences were not significant. Number of main-stem branches and pods/plant significantly increased with increasing row spacing, and the tall variety lodged more than the short variety.

Seed size was not significantly affected by row spacing. Seed yield tended to be higher in rows 25cm apart for the short-determinate variety but in rows 75cm apart for the tall-indeterminate variety. Generally, plants yielded higher (Av. 1866 kg/ha) and matured later (Av. 107 days) in the major season than in the minor season (Av. 837 kg/ha; 89 days). CES 486 outyielded Hill while Hill matured earlier than CES 486 in both seasons.

VIII. CONCLUDING REMARKS

1. "MULCHING EFFECTS"

The beneficial effects of mulching on soybean (*Glycine max* (L) Merrill) performance obtained in this study is due mostly to the ability of the mulch to influence both the physical and chemical properties of the soil on which the plants depend. These include reduction of maximum soil temperatures and conservation of moisture depending on the climatic condition of the area. In local large scale production of soybean, it may not be economically feasible to transport mulches of plant residue into the farm. However, a cropping rotation system could be feasibly adopted where, for example, maize (*Zea mays* L.) preceding soybean can have the stover ploughed into the soil during land preparation. Mulching materials of plant residue could be carriers of disease, and a thick spread of mulch may, in fact, neutralize its beneficial effect by physically impeding emergence and proper elongation of the hypocotyl, and also causing much etiolation. In this experiment about 5400 kg/ha of grass mulch was used. Mulching effects on weeds, soil nutrient level and soybean nodulation also need attention.

2. "TEMPERATURE EFFECTS"

The results of the screening of some twenty-one introduced soybean varieties with respect to their ability to germinate and emerge well at high temperatures were not very conclusive. However, using these results and others elsewhere (e.g. IITA, Ibadan) as broad base guidelines, further trials need be made at narrower temperature intervals (e.g. 15, 20, 25, 30 , 35 and 40°C) to help determine suitable varieties best adapted for the two different seasons and other localities. There are varietal differences in response to temperature; it appears varietal performance also differs according to season. The importance of temperature in the development of a soybean ideotype of high economic yield has been stressed by Doku (1973) who attributed the high yield of the variety Ross to its high temperature tolerance. Soybean germination is epigeal and successful hypocotyl elongation, at higher temperatures, can be a factor to good emergence and possibly to subsequent establishment.

3. "STORAGE CONDITIONS' EFFECTS"

Storage of soybean seeds with low initial moisture content and at low temperatures using moisture resistant containers like polythene bags were found to prolong seed viability. It was also found that sun-drying on the Accra Plains would be suitable to bring moisture contents of seeds produced in the major and minor seasons to below 12%, - i.e. low enough for safe storage at ambient temperatures to retain viability of seeds meant for planting the following season. Cold storage facilities, which are necessary for long periods of storage, are not readily available to many Ghanaian farmers.

A combination of lining cloth bag with polythene of suitable thickness is being suggested for use. Other factors of storage worth paying attention to are microflora built up and 'sweating' in stored soybean. Soybean germplasm also needs to be screened to identify lines with superior ability to maintain germination during storage.

4. "INTER-ROW SPACING EFFECTS"

The results of the inter-row spacing effects on performance of short, early - and tall late-maturing soybean varieties during the major and minor season trials were slightly conflicting. However, a trend was clearly established. Short, early-maturing varieties (e.g. Hill) may do well at closer spacing and also in the minor season when water and the short growing period available may tend to be limiting plant growth. On the other hand, performance of the tall, late-maturing varieties (e.g. CES 486) seemed encouraging at wider spacing and during the major season. Longer periods of experimentations over the two main seasons and also at different locations would provide more meaningful data for recommendations.

5. The overall results of these studies and those of earlier workers indicate that soybean production on the southern part of Ghana, at least on small holdings, would be possible.

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A P P E N D I C E S

Appendix 1 Mean soil Temperature (°C) at 5-cm depth in mulched and unmulched plots, 15-18 May 1973 IITA*

TIME (GMT)	Mulched	Unmulched	Difference**
800	27.6	27.3	- 0.3
1100	30.6	32.1	+ 1.5
1400	32.6	36.9	+ 4.3
1700	30.6	35.2	+ 4.6

* Source: Grain Legume Improvement Program 1973 Report p.58 Table 42. Ibadan: IITA.

** Temperature (°C) lower (-) or higher (+) than mulched plot.

Appendix 2 Hypocotyl Growth Inhibition by High Temperatures. Seed were germinated at 30°C continuously or with various exposure periods daily of 42°C. Observation made after 5 days.**

Daily period of 42°C temp. Exposure (hrs)	Kent soybean hypocotyl length (mm)	280-3 soybean hypocotyl length (mm)	Prima Cowpea hypocotyl length (mm)
0 (Control)	85 ± 18.6*	91 ± 25.2*	118 ± 23.8*
2	23 ± 7.0	45 ± 17.6	71 ± 13.6
4	17 ± 7.9	28 ± 10.9	62 ± 18.2
6	11 ± 4.6	14 ± 7.2	58 ± 18.2
8	14 ± 4.2	10 ± 2.8	63 ± 13.4

* Standard error (SD) of the mean

** Source: Wien, 1973 p.113 Table 4.

Appendix 3. Effect of condition and duration of storage on laboratory Plate Germination (%) of soybean (cv Amsoy) Seed.

Treatments: Room Type	Treatments: Bag	Initial Seed Moisture (%)	Weeks of Storage: 0	1	2	3	4	5	6	7	8	9	10	11	12	13	19	31	33	40	50	55
Open Laboratory (27°C; 75%RH)	Cloth (C)	11.2	98	99	97	100	100	100	98	100	93	96	84	84	54	45	12	0	0	0	0	0
	Polythene (P)	11.2	98	100	98	97	100	100	100	99	99	98	95	98	95	93	90	28	15	0	0	0
Air-conditioned (22°C; 59% RH)	C	11.2	98	98	100	100	97	98	99	100	100	99	99	100	95	97	99	93	97	84	76	80
	P	11.2	98	99	99	100	97	100	100	98	100	100	99	100	99	99	100	100	99	98	95	94
	P	14.5	98	98	97	99	95	97	100	97	95	97	80	78	77	68	47	16	5	0	0	0
	P	17.8	98	99	99	100	96	95	95	94	93	87	48	45	23	15	0	0	0	0	0	0
Walk-in Cold Room (2°C; 89%RH)	C	11.2	98	100	99	97	100	99	100	100	97	98	93	97	92	91	97	87	86	90	88	84
	P	11.2	98	99	99	99	98	99	99	100	100	97	97	98	99	97	99	99	99	98	97	100

Appendix 4. Equilibrium moisture contents for soybeans, sunflowerseed and flaxseed at various relative humidities at 25°C*

Relative humidity (%)	Moisture Content at equilibrium (%)		
	Soybean	Sunflowerseed	Flaxseed
31.0	6.1	5.2	5.3
35.0	6.5	-	-
43.0	7.4	6.3	6.4
50.0	8.0	-	-
51.0	8.3	8.3	6.9
60.0	9.6	-	-
62.0	10.4	8.1	8.2
70.0	12.4	-	-
71.2	12.4	9.5	9.5
81.1	16.4	11.7	11.6
85.0	18.4	-	-
93.0	25.1	16.9	17.1

* Source: Milner, M (1950) In: Soybean and Soybean Products. (Ed. Markley, K.S.), Interscience Publishers Inc., N.Y. pp484-501.

Appendix 5. Changes with time, in germination percentage and moisture content of soybean seeds of six cultivars stored at ambient conditions in open or sealed plastic bags.+

Cultivar	Treatment in Polythene bags	Initial		After 3 months		After 5 months	
		Germination (%)	Moisture (%)	Germination (%)	Moisture (%)	Germination (%)	Moisture (%)
Bossier	Open	51	15.24	62	16.49	3	15.70
	Dried, Sealed*	60	7.75	59	9.79	34	9.76
Grant	Open	69	14.40	63	15.82	2	16.05
	Dried, Sealed*	63	-	62	9.31	51	9.36
Kent	Open	72	15.37	53	16.54	5	15.98
	Dried, Sealed*	74	9.30	63	9.82	46	10.43
I.P.	Open	95	16.17	92	16.52	8	16.10
	Dried, Sealed*	89	9.12	86	8.99	76	9.59
Hale-3	Open	96	13.47	43	18.43	0	22.09
	Dried, Sealed*	87	8.53	97	10.93	81	12.64
IGm-393	Open	99	14.31	97	15.98	51	18.88
	Dried, Sealed*	98	8.60	98	10.05	96	11.69

\+ Source: IITA (1973): Grain Legume Improvement Program. 1973 Report. p.72 Table 51. Ibadan: International Institute of Tropical Agriculture.

* Seeds harvested in April-May 1973, dried at 40°C for 48 hours then sealed in 4-mil polythene bags.

Appendix 6. Analysis of Variance for the Effects of Mulching on initial stand, days to flower, plant height at first flower, stand at maturity, height at maturity, days to maturity, grain yield, moisture content at shelling and 100-seed weight of three soybean varieties grown during the Major Rainy Season of 1973.

MEAN SQUARES (MS)

Source of Variation	Degree of Freedom	Initial Stand Plants/m^2	Days to flower	Plant height at first flower(cm)	Stand at maturity plants/m^2	Plant height at maturity(cm)	Days to Maturity	Grain Yield kg/ha @ 13% moisture	Moisture content at shelling (%)	100-Seed weight (g)
Replications	3	20.16	0.3	9.91*	8.85	7.76	3.33	486908	0.35*	2.14
Treatments	5	130.43**	270.4**	291.32**	94.20**	3187.52**	729.40**	1893582**	9.56**	14.67
Variety	2	227.92**	675.5**	692.46**	175.38**	7869.44**	1810.00**	2959747**	23.42**	33.62
Mulching	1	190.97**	0.4	61.44	113.54**	155.00**	4.00	3502176**	0.70**	4.24
V x M	2	2.68	0.3	5.44	3.36	22.00*	11.50	23120	0.13	0.95
Error	15	10.28	0.3	2.39	6.81	4.20	6.40	187694	0.11	0.74
Coefficient of Variation (%)		31.2	1.80	5.4	34.3	4.0	2.4	27.9	3.1	4.5

* ** Significant at P = 0.05 and 0.01, respectively.

Appendix 7. Analysis of Variance for the effect of mulching on Initial S
Total Dry Weight, Stand at Maturity, Height at Maturity, Day
Lodging Score, Grain Yield, Moisture (%) at shelling and 100
the Minor Rainy Season, 1973.

Source of Variation	Degree of Freedom	Initial Stand plants/ m^2	Days to Flower	Plant height at flowering (cm)	Total plant dry wt. at late pod-filling (g)	Stand at maturity plants/ m^2	Height at maturity (cm)
					MEAN SQUARES (MS)		
Reps.	3	1173	0.33	11.92*	23.39**	288*	421**
Treatments	5	3522**	75**	156.93**	4.19*	343**	1135**
Variety	2	8204**	186**	328.91**	6.32*	796**	2472**
Mulching	1	24	0.33	123.31**	5.79	104	554**
V x M	2	590	1.84**	1.76	1.27	11	90
Error	15	377	0.20	3.43	1.37	73	28
Coefficient of Variation(%)		18.1	1.7	7.3	26.0	11.5	9.8

* ** Significant at P = 0.05 and 0.01, respectively.

tand, Days to Flower, Height at First Flower,
s to Maturity, Nodes per plant, Pods per plant,
-Seed weight of three soybean varieties grown during

Days to maturity	Nodes/ Plant (main stem)	Pods per plant (at maturity)	Lodging score 1(erect) 5(flat)	Grain Yield kg/ha at 13% moisture	Moisture at shelling (%	100-Seed weight (g)
3	6.60**	122.41**	2.57**	734,744**	0.39	9.81**
167**	12.54**	37.87*	4.99*	375,576*	0.28	9.20**
389**	26.73**	57.91*	9.20**	833,854**	0.62	17.37**
24	7.26**	53.40*	5.51**	75,825	0.09	10.22*
17	1.00	10.06	0.51	67,174	0.03	0.52
5.27	0.58	11.56	0.24	92,221	0.34	0.69
2.6	7.3	23.1	16.9	21.8	6.6	5.2

Appendix 8. Analysis of Variance for the effect of mulching on Days to Flower, Height at First Flower, Flowers/plant, Stem diameter, Nodes/Main Stem, Height at maturity, Branches/main Stem, Total pods formed/plant, Pods/plant at maturity, Flowers which formed mature pods per plant and Grain yield of three soybean varieties grown in Pots at Legon (1973).

MEAN SQUARES (MS)

Source of Variation	Degree of Freedom	Days to flower	Plant Height at flowering (cm)	Flowers per plant	Stem diameter at first trifoliate node (mm)	Total No. of nodes per main stem	Plant height at maturity (cm)	No. of branches/main stem	Total pods per plant	Pods/Plant at maturity	Flowers which formed mature pod/plant (%)	Grain yield g/plant
Reps.	3	1.56	9.40	1299**	4.85**	2.94**	74.03**	6.69	612.17**	420**	216.39*	28.50**
Treatment	5	144.50**	143.78**	1822**	5.08**	17.60**	125.68**	2.90	327.75*	248*	189.40*	17.41**
Variety	2	356.38**	287.29**	2575**	5.03**	30.66**	162.17**	1.63	314.57*	228	152.82	10.51
Mulching	1	7.83**	138.24**	3197**	14.45**	18.38**	243.84**	10.67	983.04**	759**	337.50*	65.67**
V x M	2	0.96	3.05	383	0.45	4.16	30.00	0.29	13.29	12	151.93	0.18
Error	15	0.52	3.03	215	0.74	0.78	13.60	4.93	75.05	69	60.24	3.35
Coefficient of Variation (%)		2.3	8.0	28.0	13.4	8.6	11.9	38.3	35.9	43.7	22.2	36.6

* ** Significant at P = 0.05 and 0.01, respectively.

Appendix 9. Analysis of Variance for the effects of Temperature on Days to first emergence, Days to maximum emergence and maximum seedling emergence of 19 soybean varieties grown in incubators at Legon, 1973.

Sum of Squares (SS) and Mean Squares (MS)

Source of Variation	Degree of Freedom	to first seedling emergence		Days to maximum Seedling emergence		Maximum Seedling emergence (mean absolute values)		Required F	
		SS	MS	SS	MS	SS	MS	5%	1%
Replications	3	8.33	2.78*	73.00	24.33**	116.04	38.68**	2.67	3.91
Treatments	56	841.48	15.03**	1424.88	25.44**	1093.54	19.53**	1.44	1.66
Varieties	18	52.15	2.90**	87.05	4.84	532.87	29.60**	1.71	2.12
Temperatures	2	760.16	380.08**	1241.91	620.96**	415.28	207.64**	3.06	4.76
V x T	36	29.17	0.81	95.92	2.66	145.39	4.04	1.54	1.84
Error	168	171.92	1.02	520.00	3.10	818.46	4.87		
Coefficient of Variation (%)		21.3		22.3		35.2			

* ** Significant at P = 0.05 and 0.01, respectively.

Appendix 10. Analysis of Variance for the effect of Inter-row spacing on Initial Stand, Days to Flower, Plant Height at Flowering, Stand at maturity, Plant height at maturity, Days to maturity, 100-seed weight, Seed moisture at shelling and Seed yield for two varieties of soybean grown during the Major Rainy Season, 1973.

MEAN SQUARES (MS)

Source of Variation	Degree of Freedom	Initial Stand Plants/ m^2	Days to Flower	Plant height at flowering (cm)	Stand at maturity plants/ m^2	Plant height at maturity (cm)	Days to maturity	100-Seed weight (g)	Seed Moisture at shelling (%)	Seed yield kg/ha @ 13%
Replications	3	412*	0.11	13.20**	220	28	9.46	4.17	1.03	813091*
Treatments	5	896**	168.17**	109.41**	613**	207**	1415.77**	6.33*	0.74	840891*
Varieties	1	1786**	839.16**	543.40**	1520**	812**	7072.66**	13.53*	1.26	693600
Row Widths	2	1178**	0.17	0.18	684	110	1.55	2.95	0.65	1749624**
V x Rw.	2	168	0.67	1.64	126	2	1.54	6.11	0.58	5804
Error	15	123	0.46	1.08	89	39	3.07	1.69	1.26	234250
Coefficient of Variation (%)		48.2	1.9	4.1	49.7	17.4	1.6	6.9	9.7	25.9

* ** Significant at P = 0.05 and 0.01, respectively.

Appendix 11. Analysis of Variance for the effect of Inter-row spacing on Days to Flower, Height at Flowering, Nodule number per plant, LAI, Nodes per main stem, Branches per Main Stem, Pods per plant at maturity, Height at maturity, Days to maturity, Lodging score, 100-seed weight, and Seed yield for two varieties of soybean grown during the Minor Rainy Season, 1973.

MEAN SQUARES (MS)

Source of Variation	Degree of Freedom	Days to Flower	Plant height at flowering (cm)	Nodule Number per plant	Leaf Area Index (LAI)	No. of Nodes/ main stem	No. of branches per main stem	No. of Pods/ plant at maturity	Plant height at maturity (cm)	Days to maturity	Lodging Score 1(erect) 5(flat)	100-Seed weight (g)	Seed Yield kg/ha @ 13% moisture
Replications	3	0.17	40.90*	30.05	2.03*	4.14*	0.17	88.59*	408.93**	28.28**	4.63**	10.41**	941928**
Treatments	5	73.67**	102.05**	8.44	1.98**	19.89**	1.67*	105.58**	868.46**	168.37**	1.09	7.55**	77648
Variety	1	368.16**	496.05**	7.15	9.01**	87.02**	1.49	177.13*	4269.30**	840.16**	2.04*	32.69**	356240*
Row Widths	2	0.05	9.10	9.95	0.22	2.69	2.55*	136.22*	17.75	0.55	1.33	2.31	6950
V x Rw.	2	0.04	11.52	7.57	0.22	3.43	0.88	39.17	18.75	0.29	0.38	0.23	9050
Error	15	0.07	8.95	15.76	0.41	1.18	0.47	21.86	55.96	3.61	0.38	1.42	72394
Coefficient of Vatiation (%)		0.82	12.0	57.5	46.7	10.6	28.6	34.4	16.7	2.1	31.5	8.1	34.1

* ** Significant at P = 0.05 and 0.01, respectively.