EFFECT OF SOIL TYPE AND LOCATION ON THE PROTEIN AND OIL PERCENTAGE OF SOYBEANS (*GLYCINE MAX* L.)

by

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INTRODUCTION

Soybeans were reportedly first cultivated in the United States about 160 years ago having been brought to this country from China and Manchuria. In the early part of the twentieth century, small quantities of soybeans and soybean oil which was used for industrial purposes were imported into this country. During World War I, there existed a world-wide shortage of fats at which time the United States began importing increasing amounts of soybean oil from Manchuria. Most of this was used for edible purposes. Many other countries of which European countries are noteworthy, began to realize the value of soybean oil about the same time. Shortly after World War I, the versatility of the soybean became apparent to world scientists. Since the early 1930's there has been a continual increase in United States soybean production. Present annual production in this country exceeds one billion bushels. Soybeans rank second in value among farm crops in the United States.

The increased demand for and use of soybeans is due to the high oil and high protein content, both having superior quality.

Approximately 90% of the soybean oil consumed in the United States is for human consumption. It is the primary raw material for margarine, shortening and salad oil. The remainder is used primarily in the production of paints, soaps, varnish and drying oils. Consequently, the oil content of soybeans is of major importance. The yield of oil has increased from 9.7 pounds per bushel in 1950 to 11.0 pounds per bushel in 1960. This increase

has been due mostly to changes in the methods used to extract the oil and the use of improved varieties with both high oil and high protein.

While oil has historically been considered the most important ingredient of soybeans, soybean protein is becoming increasingly important. At the present time approximately 95% of the soybean protein consumed in the United States is as animal feed. The development of new food products made from soybeans has created a tremendous potential usage for soybeans as a food both domestically and abroad. The soybean is unsurpassed as a high-protein high-energy food and is being promoted for use in food deficit nations. Soybean protein contains all of the essential amino acids necessary for human nutrition.

Information on factors affecting the oil and protein content of the soybean seed is extremely fragmentary with contradictory statements sometimes appearing in the literature. The genetic makeup probably has more effect on chemical composition of soybean seed than any other single factor. Varieties, strains and plant introductions being grown and utilized in breeding programs in the United States have an extremely wide range in oil and protein content, ranging from approximately 12% to 25% oil and from 33% to 52% protein. Very little effect on the oil and protein content has been noted due to cultural and/or management practices. Temperature during certain critical periods, moisture, day length, seed size and soil fertility are some factors which have been studied

and thought to affect chemical composition in varying degrees. The oil processors in Virginia are continually stating that soybeans produced on the east coast are inferior in oil content to beans produced in the gulf coast area and mid-western states. It is thought that this condition exists because of differences in varieties grown and environmental conditions, including soil type.

The objective of this study was to determine the effect of three soil types and three locations in Virginia on the oil and protein content of different soybean varieties.

LITERATURE REVIEW

Howell (20) reported that the accumulation of most chemical materials in the seed, in general, parallels the accumulation of total dry matter. However, oil synthesis appears to trail somewhat behind the total gain in weight, initially. The oil increases very rapidly from the time seed weight is about 30 mg until about two weeks later, after which oil percentage changes very little (7, 28). The oil percentage, according to Howell and Cartter (11, 12) is influenced by temperatures, especially during a period of about three weeks, beginning shortly after the start of seed development. Oil content also varies, according to Collins and Cartter (4), with position of the seed on the plant and with position of the pod on a raceme. They found that seed produced near the tip of long terminal branches produced less oil than those from points lower on the raceme.

Morse et al. (18) refer to the chemical composition of the soybean as being very complex. They further state "...the chemical composition is governed by the combined forces of heredity of the variety and the environment under which the parent plant is grown." The genotype probably has more effect upon oil and protein content of soybeans seeds than any other factors as indicated by the wide range of oil (12% to 25%) and protein (34% to 52%) in genetic materials available to plant breeders (31).

Garner et al. (8) concluded from their experiments that under most conditions, climate is a more potent factor than soil in

controlling oil content and the size of soybean seed. They grew soybeans in pots of soil brought in from different locations and concluded that the relative effects of different soil types are not specific and constant but depend largely on seasonal conditions. Howell (20) postulates that temperature variations affect soybean composition more than they affect yield of seed.

In 1937, Viljoen (32) studied the relationship of temperature during the growing season to oil content at maturity. These data showed no correlation between maximum temperatures and percentage oil. He did find a highly significant correlation between mean minimum temperature and percentage oil and also between mean temperature and percentage protein. It should be pointed out that these correlations were made with only two varieties of unknown maturity and two growing seasons at nine locations in South Africa. Temperatures, at the different locations, ranged from a monthly mean of 91.3°F. to 46.0°F. Maximum temperature for a single day was 102.2°F. while minimum temperature was 34.5°F. In his experiments, rainfall for the entire growing season ranged from 1.88 inches to 25.67 inches. In the same experiment he observed that the oil content was lower from beans of the same varieties planted late in the season as compared to early planting. He attributed this to the lower mean minimum temperature during the growing season when soybean planting was delayed.

Pahigian (22) studied the correlation between mean monthly temperatures, total precipitation for the growing period and the

mean oil content of soybean seed grown in each of 10 principal production areas of the United States. Although high mean temperatures tended to be associated with high oil content within regions, few correlations were significant. He attributed low correlations within a region to limited observations and to little variability of rainfall from one location to another. He inferred that rainfall probably was a contributing factor. Pahigian (22) also studied the relationship of oil content to day-length and found a positive but low correlation when temperature was held constant.

Using four varieties of flax, Dillman and Hopper (5) correlated oil percentage and July temperature at irrigated and non-irrigated stations. Under non-irrigation, a highly significant negative correlation was achieved with average maximum, average minimum and average mean temperatures and oil percentage. This was true for all four varieties evaluated. Under irrigation the significant correlation coefficients were negative for only two of three varieties with average minimum ($P = .01$) and the same two varieties with average mean ($P = .05$) temperatures.

Weiss et al. (33) studied the effect of mean temperatures during the bean development period on the oil content using five varieties, five planting dates and three mid-western locations for a three year period. They found a significant positive correlation between mean temperature and oil percentage. Howell and Cartter (11) using data from Uniform Nursery Tests in the South

and Midwest (29, 30) studied the relationship between oil content of soybean seed and the maximum and minimum daily temperatures for 10 day periods, beginning 50 days prior to pod maturity. They concluded that maximum temperatures exerted a greater influence than minimum temperatures for Group 0 (early) beans grown in the North. They also found that maximum temperatures 20-30 days before pod maturity were more closely associated with oil content than maximum temperatures, earlier or later. Minimum temperatures early in the pod-filling stage were more closely associated with oil content than maximum temperatures. However, with maturity group VIII (late) varieties, both maximum and minimum temperatures showed a positive correlation with oil content but the highest correlation for maximum temperatures was for the 20-30 day period prior to maturity. This agrees with data obtained when using Group 0 (early) varieties.

In another study, Howell and Cartter (12) concluded that day temperature during the pod-filling stage exerted an effect on oil content of the soybean seed. Increasing the day temperature during the pod-filling stage from 70°F. to 85°F. resulted in an increase in oil content from 19.5% to 22.2%, respectively. Temperature did not exert a significant effect on protein content of the seed in this study. Cartter and Hopper (2) suggest that climatic conditions favorable for the development of high protein are responsible for low oil. They found one notable exception in the case of the variety Peking whose seed consistently had a relatively low oil

and low protein content. In the same study, they found that calcium content of the seed varied directly with maximum temperature.

Some investigators have reported that seed size has an effect on oil and protein content. Weiss et al. (33) showed that delayed plantings after May decreased seed size and oil percentage. These data, however, did not show as clearly as some the apparent inverse relationship which generally exists between oil and protein content, reported by many authors.

Smith et al. (24) in Virginia experiments involving locations, varieties and dates of planting concluded that the protein content of soybean seed of the different varieties used showed no consistent effect due to date of planting. Oil content averaged slightly less from the July 5 (late) seeding, than from earlier plantings. Garner et al. (8) suggested that the environment at the critical period for carbohydrate metabolism in the plant and for oil and protein metabolism in the seed for each variety must play an important role in determining protein composition as well as seed size. They indicated that when the seed of a given variety are large (due to favorable weather conditions) then the protein percentage is likely to be lower and the oil percentage higher. As a parallel, they cited the case of "shrunken" wheat kernels which usually contain a higher percentage of protein. With respect to seed composition, they concluded, that the performance of a variety or strain of soybeans at one location gives an indication of the relative performance that may be expected by it at other locations. Fellers (7)

concluded from his experiments that immature and small seed are lower in oil percentage than mature seed. This may be explained, according to Fellers and others, by assuming that reserve carbohydrates in the seed have not become fully transformed into oil. Feaster (6) working in Southeastern Missouri with five varieties planted at 20 day intervals, reported that varieties react differently at different dates of planting in yield, protein content, oil content and iodine number of the oil. Oil content of relatively late varieties, he reported, was decreased more by delayed plantings than was that of earlier varieties. His implication is that if soybeans mature during relatively high temperatures, the oil content is likely to be higher than if they mature at lower temperatures. Weiss et al. (33) also studied the compositional characters in soybean seed as influenced by variety and time of planting. They concluded that protein content of soybean seed was not affected by date of planting. Although the varieties used in their experiments differed appreciably in protein content, they failed to respond differently to dates of planting. The oil content was decreased slightly by delayed plantings but was not consistent among varieties. Their conclusions concurred with Feaster's (6) in that oil content of the seed of relatively late varieties was decreased more by delayed planting than was that of earlier plantings. They also found that the oil content varied with years and locations.

According to Smith (25) most soybean varieties currently being grown in Virginia were developed south of Virginia and therefore are too late in maturity for best production in the State. These late varieties are often damaged by early frosts, especially when planted after small grains, and tend to have lower oil and protein content than soybeans produced in the Middle West or deep South. He also suggested that when grown in Virginia, full season (late) varieties, which constitutedapproximately 95% of the Virginia soybean acreage, produce appreciably lower oil and in many instances, lower protein, than when grown in states to the south. However, early varieties grown in Virginia have oil and protein content equal to those produced in other areas. Production of soybeans that mature late in the season during cool weather may be one of the big factors for low oil in Virginia grown beans. Decreases in oil content of seed with a delay in date of planting have been reported (5, 11, 12, 21, 34) thus suggesting that later maturity and lower temperatures during seed development are associated with decreases in oil. However, Hartwig (9) found no appreciable effect of planting date on oil content for two southern varieties grown in Mississippi. Smith et al. (24) found some reduction of oil in early varieties (northern types) when planted late but little difference for late varieties (southern types). The oil content of varieties differed in their response to date of planting. Garner (8) suggested that where large geographical areas are included in an experiment which involves a wide range in varietal

characteristics, more variance will be found due to location than to variety.

The influence of soil fertility on chemical composition of soybean seed has been sparsely studied. The early work of Lipman et al. (16) and Fellers (7) reported a fairly consistent increase in protein content of soybean seed resulting from lime application. Several conclusions were made from this work by Fellers:

1. The oil content of soybean seed decreases in direct proportion to the largeness of lime application; conversely, the protein content increases. (He did not mention soil pH).
2. Phosphate application increased oil content on limed plots but had no effect on unlimed plots.
3. Potassium caused a slight decrease in percentage of oil in the seed but had little influence on the protein content.
4. Landplaster in amounts up to 600 pounds per acre caused an increase in oil content in the seed and also stimulated nodule formation.

Stark (27) also showed an increase in protein content of the seed due to adding phosphorus and lime to the soil. He concluded from his studies that the chief factors affecting the composition of soybeans grown in different localities are soil fertility and soil reaction. He was reporting data obtained from fields not over 50 miles apart and in a region of similar climatic conditions. He summarized his conclusions as follows:

1. Application of lime and organic matter increased the seed content of protein and reduced the percent of oil.
2. Application of rock phosphate in addition to limestone and organic matter further increased the protein content and decreased the oil content.
3. Potassium applied in addition to rock phosphate, limestone and organic matter resulted in a decrease in the percentage of protein and an increase in oil content.

Garner et al. (8) concluded that soil fertility had no real effect on chemical composition and that only yield was affected.

MATERIALS AND METHODS

Four soybean varieties were grown on three soil types at each of three Virginia locations in 1964, 1965, 1967, and 1968.

Soil types chosen for this study were Davidson clay loam from the northern Piedmont, Sassafras fine sandy loam from the northern Coastal Plain, and Bertie sandy clay loam from the southern Coastal Plain.

Locations selected for the study were the same three areas from which the soils were selected; namely, Orange, Warsaw and Holland in the northern Piedmont, northern Coastal Plain and southern Coastal Plain, respectively.

At each of the three selected locations, 48 holes were dug, each 42 inches deep and 14 inches in diameter. A 100 mesh copper screen wire was placed in the bottom of each hole to prevent vertical root penetration into the soil below the depth of the hole. Copper toxicity restricted root growth. Each hole was then lined with a double thickness of four mil black plastic to prevent lateral root penetration. A rim made of eight inch wide galvanized metal was placed around the top of each hole to allow retention of rainfall and irrigation water as well as to prevent weed and grass encroachment.

Soil of each of the three types was then transported to each location placed in the holes in a randomized complete block design replicated four times. The top-soil was kept separate from the sub-soil and placed in the holes as nearly as possible to its

original position. The top-soil depth was 0-6 inches, 0-4 inches and 0-9 inches for Sassafras, Davidson and Bertie, respectively. The sub-soil in each case was that portion of the soil profile from where the top-soil ended to the 20 inch depth. Composite soil samples were taken from each soil type for chemical and physical analysis (Appendix Tables I and II).

Soil pH was adjusted to approximately 6.0 by applying dolomitic limestone. P_2O_5 and K_2O were applied to each "pot" at the rate of 80 pounds per acre and worked into the top six inches of soil well in advance of planting the first and third years of the experiment.

Six plants of a variety were grown in each pot and were seeded on or about May 20 of each year. In 1964 and 1965 two early maturing varieties (Clark and Bethel) and two late maturing varieties (Ogden and Lee) were selected for the experiment. Clark and Bethel mature about September 25 and October 1, respectively. Ogden and Lee mature about October 25 and November 1, respectively.

In 1967 Lee and Ogden, which are subject to frost damage at Orange, were replaced by two earlier (mid-season) varieties, Dare and D65-6647 (a high protein line) which mature about October 19 and 20, respectively. Bethel also was replaced by a high protein line, D62-6225 of comparable maturity. In 1968 due to problems involving seed supply and diseases, these two high protein lines were replaced with two moderately high protein lines of similar maturity, D65-2304 and D65-2367.

All varieties also were grown each year on undisturbed soil at each location and seed was harvested for oil and protein determinations.

Seed were hand-harvested as they matured and threshed by a small plot thresher. Sixty-gram samples of seed were submitted to the U. S. Regional Soybean Laboratory, Urbana, Illinois, each year of the experiment for oil and protein determinations.

Certain problems were encountered during the course of the experiment. In 1964 the soil was first placed in the "pots" in April. Plantings were made within six weeks afterwards which did not allow adequate time for the soil to settle. Davidson soil type at Holland settled nine inches below the surrounding soil surface and soybeans growing on this soil type at Holland did not produce sufficient seed for chemical analysis. Even though this soil type settled several inches at the other locations, the soybean plants did survive and produced adequate seed.

In 1965 at the Orange location, additional Bertie top-soil had to be added to the "pots." This soil when taken from Holland inadvertently contained enough of the herbicide, atrazine, to be phytotoxic to the young soybean seedlings. Three plantings were made on this soil in 1965 and each time the plants died. Consequently, no data could be obtained from Bertie soil at Orange in 1965.

In 1966 plantings were made but no data collected because at two of the three locations many of the plots were destroyed by

wildlife. The plots at all locations were then fenced with one inch mesh chicken wire which eliminated this problem in subsequent years.

Only one composite seed sample was drawn from the four replications at each location in 1964 and 1968 for oil and protein determinations. However, in 1965 two treatment samples each being a composite of two replications were analyzed, and in 1967 oil and protein determinations were obtained from each of four replications at all three locations.

Moisture was not a variable since it was kept in adequate supply most of the time by irrigation.

Insect control was applied throughout the growing season as needed. In 1966 the presence of soil-borne diseases, especially Sclerotium rolfsii, began to appear. Consequently, in the spring of 1967 all plots were fumigated with methyl bromide at the rate of one pound per 100 square feet. This prevented further outbreak of diseases in subsequent years and also aided in the control of grass and diseases.

RESULTS AND DISCUSSION

In discussing the results of this study, it should be noted at the out-set that the seed samples for chemical analysis were composited in 1964, 1965 and 1968. Only one analysis was made for each variety and soil type at each location in 1964 and 1968 and two analyses were made in 1965 (composite of replication 1 and 2, and 3 and 4). Only in 1967 were oil and protein determinations obtained from each of four treatment replications.

Protein

Soybeans grown on Bertie sandy clay loam contained a higher protein content than when produced on either Sassafras fine sandy loam or Davidson clay loam when averaged over four varieties and three locations for 1967 and 1968 (Table I). In 1964 no comparison was made with Davidson soil but in that year soybean seed grown on Bertie had a higher protein percentage than seed produced on Sassafras soil. Bertie soil was not used at the Orange location in 1965. Soybean seed grown on Sassafras soil in 1965 were higher in protein than those grown on Davidson soil. Soybeans grown on Davidson also were lower in protein percentage than seed grown on either Sassafras and Bertie in three out of three years tested (Table I). This higher average protein content of soybean seed produced on Bertie and lower average protein content produced on Davidson tends to be rather consistent from year to year and

Table I. Protein and oil percentage of soybeans grown on three soil types for four years.*

Years	1964	1965	1967	1968
Soils		Protein		
Davidson	----	39.5 b	41.7 c	39.0 c
Sassafras	41.8 b†	40.8 a	42.2 b	40.3 b
Bertie	42.9 a	-----	43.1 a	42.9 a
Significance	.01	.01	.01	.05
		Oil		
Davidson	----	21.6	19.8 a	20.8 a
Sassafras	20.0	21.5	19.8 a	21.3 a
Bertie	19.9	-----	19.3 b	19.6 b
Significance	N.S.	N.S.	.01	.01

*Averaged over four varieties and three locations each year.
†Values followed by the same letter within a column are not significantly different.

location to location (Tables I, II, III, IV, V, and VI). Even the locations where difference in protein percentage cannot be considered statistically valid showed the same trend in every instance.

There was a highly significant soil x variety interaction in 1967 (Appendix Table IX), the only year that protein percentage was available from each of the four replications at each location. Thus, under the conditions of this study, in 1967, all varieties did not respond similarly to the three soils at each location with respect to protein percentage. Other examples of variations in protein percentage of the seed by some varieties on different soil types were indicated. Information on this differential variety response with respect to protein percentage of soybean seed due to soil type was not found in the literature and cannot be explained from this study.

The pronounced effect of soil type on the protein percentage of soybean seed is somewhat contrary to the conclusions of other workers who have attributed little or no significance to the effect of soil type on chemical composition (2, 8, 32). Garner et al. (8) grew soybeans in pots with soils from different locations and concluded that the relative effects of different soil types are not specific and constant, but depend largely on seasonal conditions. Viljoen (32) arrived at a similar conclusion from his investigations. Cartter and Hopper (2) concluded "...that climate is the more important in its effects of the two factors, soil and climate, that go to make up the location effect." In studies conducted prior to 1947, United

Table II. Protein percentage of four soybean varieties grown on three soil types at three Virginia locations. 1964.

Varieties	Bethel	Clark	Lee	Ogden	Avg.
Soils			Orange		
Davidson	38.3	42.1	39.1	39.9	39.9 b*
Sassafras	40.9	41.3	40.1	41.9	41.1 b
Bertie	44.2	43.6	41.8	42.9	43.1 a
Avg.	41.1	42.3	40.3	41.6	
	N.S.*	N.S.	N.S.	N.S.	
			Warsaw		
Davidson	41.2	40.7	40.3	39.0	40.3 b
Sassafras	40.9	40.9	41.5	40.7	41.0 b
Bertie	43.1	42.7	41.1	41.6	42.1 a
Avg.	41.7	41.4	41.0	40.4	
	N.S.	N.S.	N.S.	N.S.	
			Holland		
Davidson	----	----	----	----	----
Sassafras	41.6	41.7	44.3	45.2	42.2 N.S.
Bertie	43.3	44.0	42.5	44.3	43.5 N.S.
Avg.	42.4	42.8	43.4	44.7	
	N.S.	N.S.	N.S.	N.S.	
			Orange & Warsaw		
Davidson	39.8	41.4	39.7	39.5	40.1 c
Sassafras	40.9	41.1	40.8	41.3	41.0 b
Bertie	43.7	43.2	41.5	42.3	42.7 a
Avg.	41.5	41.9	40.7	41.0	
	N.S.	N.S.	N.S.	N.S.	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table III. Protein percentage of four soybean varieties grown on three soil types at three Virginia locations. 1965.

Varieties	Bethel	Clark	Lee	Odgen	Avg.
Soils			Orange		
Davidson	37.2	39.9	36.3	39.2	38.1 b*
Sassafras	39.5	41.5	38.8	42.7	40.6 a
Bertie	----	----	----	----	----
Avg.	38.3 b*	40.7 a	37.5 b	40.9 a	
			Warsaw		
Davidson	38.8	40.1	40.9	41.5	40.3 N.S.
Sassafras	40.0	42.4	41.6	42.3	41.6 N.S.
Bertie	39.2	43.3	40.4	43.4	41.6 N.S.
Avg.	39.3 b	41.9 a	40.9 a	42.4 a	
			Holland		
Davidson	40.2	39.7	40.2	40.4	40.1 b
Sassafras	39.9	39.7	41.4	39.8	40.2 b
Bertie	41.3	41.9	43.8	43.1	42.5 a
Avg.	40.5 N.S.	40.4 N.S.	41.6 N.S.	41.1 N.S.	
			Warsaw & Holland		
Davidson	39.5	39.9	40.5	40.9	40.2 b
Sassafras	39.9	41.0	41.5	41.1	40.9 b
Bertie	40.3	42.6	42.1	43.3	42.0 a
Avg.	39.9 b	41.2 a	41.3 a	41.8 a	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table IV. Protein percentage of four soybean varieties grown on three soil types at three Virginia locations. 1967.

Varieties	D62-6225	Clark	D65-6647	Dare	Avg.
Soils			Orange		
Davidson	41.9	39.5	46.4	37.3	41.3 b*
Sassafras	42.7	39.3	44.8	39.5	41.6 b
Bertie	44.0	41.0	47.9	39.2	43.0 a
Avg.	42.9 b*	39.9 c	46.4 a	38.6 d	
			Warsaw		
Davidson	42.5	39.6	48.7	37.5	42.1 b
Sassafras	43.7	40.0	48.7	38.3	42.7 a
Bertie	43.0	39.8	48.5	38.7	42.5 a
Avg.	43.0 b	39.8 c	48.6 a	38.2 d	
			Holland		
Davidson	40.9	40.0	47.3	38.4	41.6 c
Sassafras	42.1	42.3	45.9	38.9	42.4 b
Bertie	43.1	43.0	48.1	40.6	43.7 a
Avg.	42.0 b	41.8 b	47.2 a	39.3 c	
			Orange, Warsaw & Holland		
Davidson	41.8	39.7	47.5	37.7	41.7 c
Sassafras	42.8	40.6	46.6	38.9	42.2 b
Bertie	43.4	41.3	48.2	39.5	43.1 a
Avg.	42.6 b	40.5 c	47.4 a	38.7 d	

*Values followed by the same letter within a column or horizontal average are not significantly different (p=.05).

Table V. Protein percentage of four soybean varieties grown on three soil types at three Virginia locations. 1968.

Varieties	D65-2304	Clark	D65-2367	Dare	Avg.
Soils			Orange		
Davidson	40.9	40.5	40.4	41.3	40.8 b*
Sassafras	41.2	40.9	42.7	39.9	41.2 b
Bertie	46.4	44.3	45.0	44.0	44.9 a
Avg.	42.8	41.9	42.7	41.7	
	N.S.*	N.S.	N.S.	N.S.	
			Warsaw		
Davidson	38.8	37.6	37.0	38.6	38.0 N.S.
Sassafras	42.3	40.5	41.0	35.8	39.9 N.S.
Bertie	42.4	42.3	41.6	39.9	41.6 N.S.
Avg.	41.2	40.1	39.9	38.1	
	N.S.	N.S.	N.S.	N.S.	
			Holland		
Davidson	38.6	38.6	39.6	36.0	38.2 c
Sassafras	39.5	40.4	40.5	38.3	39.7 b
Bertie	42.6	42.7	42.4	41.3	42.3 a
Avg.	40.2	40.6	40.8	38.5	
	a	a	a	b	
			Orange, Warsaw & Holland		
Davidson	39.4	38.9	39.0	38.6	38.9 c
Sassafras	41.0	40.6	41.4	38.0	40.3 b
Bertie	43.8	43.1	43.0	41.7	42.9 a
Avg.	41.4	40.9	41.1	39.4	
	a	a	a	b	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table VI. Protein and oil percentage of soybeans at three Virginia locations for four years.*

Years	1964	1965	1967	1968
Locations		Protein		
Orange	41.3	----	42.0 b†	42.3 a
Warsaw	41.1	41.1	42.4 a	39.8 b
Holland	----	40.9	42.6 a	40.0 b
Significance	N.S.	N.S.	.01	.01
		Oil		
Orange	19.5 b	----	19.5 b	19.1 c
Warsaw	20.3 a	21.3 b	19.5 b	20.7 b
Holland	----	22.0 a	19.9 a	21.8 a
Significance	.05	.05	.01	.01

*Averaged over four varieties and three soil types each year.
†Values followed by the same letter within a column are not significantly different.

States Department of Agriculture workers (20) concluded, "In these studies the inherent characteristic of the variety was the most important factor in determining the protein content. Changes in soil fertility and seasons did not greatly influence the relative standing of the varieties with reference to protein". They also concluded that "Differences in climate were more important in their effects on oil content than differences in soil". They did not conclude that climate was more important than soil on the protein content of soybeans, however. Howell and Cartter (12) in greenhouse experiments concluded that by increasing day temperature from 70° to 85°F. a substantial increase in the oil content of soybean seed would result but that temperature exerted very little influence on the protein or non-protein nitrogen content of soybean seed.

The data in this experiment indicate that soil type does affect protein percentage and that varieties respond differentially to the effect of soil type on protein percentage.

The effect of location on the protein percentage of soybean seed was less pronounced and not as consistent as was the effect of soil type (Table I and VI). Location had little or no effect on protein percentage in 1964 and 1965, but in 1967 soybeans grown at Orange were significantly lower in protein percentage than those grown at Holland and Warsaw. However, the reverse was true in 1968, with soybeans grown at Orange being the highest in protein percentage. This inconsistency at the different locations from

one year to the next may have been affected somewhat by the substitution in 1968 of two moderately high protein lines for two high protein lines that were grown in 1967; but these substitutions would be minor as compared to the effect due to environmental differences.

There was a location x variety interaction in two of the four years (Appendix Tables III and IX). Varieties apparently responded differentially to locations with respect to protein percentage of the seed. Several literature citations indicate that location does affect protein content of soybean seed (2, 8, 12, 20) but in every case except one this location effect was explained on the basis of climate; especially temperature during the pod-filling stage. No reference concerning this effect on oil percentage for varieties grown at different locations was found. "The high protein content ...is attributed in part, to high temperatures during the summer and fall..." (8). Smith et al. (24) working with six varieties, five planting dates at four locations showed an apparent location effect on protein percentage. The low mean protein percentage was obtained at the Orange location while the highest percentage was obtained at Holland. They offered no explanation for these differences.

Varieties used in this study were changed at the beginning of the third and fourth years. Therefore, no direct comparisons of varieties averaged over years can be made. However, in 1967 there was a variety x soil interaction as previously discussed

(Appendix Table IX). Interactions between varieties and locations, temperatures and dates of planting are cited in the literature (11, 20). In this study the D65-6647 strain of soybeans in 1967 produced the least protein percentage when grown on Sassafras soil at two out of three locations while the other three varieties tested were lower in protein when grown on Davidson soil (Table IV).

In 1968 three out of four varieties were very consistent in their response to soil type at all locations. Seed produced on Davidson and Bertie soils contained the highest and lowest protein percentage, respectively, with seed produced on Sassafras being intermediate. The Dare variety with respect to protein content responded similarly to the other varieties at the Holland location; but at Warsaw and Orange, seed of Dare contained the least protein percentage when grown on Sassafras soil. This response of Dare to Sassafras soil at Orange and Warsaw was not obtained in 1967.

Oil

In this study soybeans grown on Bertie soil contained a lower oil and higher protein percentage when averaged over four varieties and three locations than seed grown on Sassafras or Davidson soil (Table I). However, no real difference in oil percentage occurred between seed produced on Sassafras and Davidson soil. This lower oil percentage from seed produced on Bertie was consistent for five out of six observations made in 1967 and 1968 (Tables IX and X); but there was no difference in oil percentage due to soil at

any location in 1964 and 1965 (Tables VII and VIII). Soils had a very definite effect on oil percentage in this study although it was not consistent from year to year. These results generally agree with the literature which usually indicates less influence on the oil content of soybeans by soil than from other factors, including climate and genotype; and soils had less effect on oil percentage than on protein (Tables I and XI).

The effect of location on oil percentage (Table VI) was more consistent than its effect on protein percentage. Soybean seed produced at Holland had a higher oil percentage each year than seed from Warsaw and Orange; and seed from Orange had a lower oil percentage than seed from Warsaw in two out of three years with the oil percentage being equal at the two locations the third year.

Location also had a more consistent effect on oil percentage from year to year than soil type. This consistent location effect from year to year is probably a result of climatic differences. The literature generally credits temperature as being the dominant factor affecting oil percentage from one location to another (2, 10, 11, 12).

The varietal effect on oil percentage was pronounced each year of the experiment (Appendix Tables VII, VIII, IX, and X) and was the most important factor affecting soybean oil percentage. Variety x location interactions occurred in only one out of four years (1964) as did variety x soils (1967). Under the conditions of this study, varieties had a significant effect on the oil

Table VII. Oil percentage of four soybean varieties grown on three soil types at three Virginia locations. 1964.

Varieties	Bethel	Clark	Lee	Ogden	Avg.
Soils			Orange		
Davidson	22.7	20.1	18.2	17.2	19.6 N.S.*
Sassafras	21.9	21.5	18.1	16.9	19.6 N.S.
Bertie	20.5	19.9	18.0	18.3	19.2 N.S.
Avg.	21.7 a*	20.5 a	18.1 b	17.5 b	
			Warsaw		
Davidson	21.1	21.0	18.9	20.8	20.5 N.S.
Sassafras	21.3	21.4	18.6	19.3	20.2 N.S.
Bertie	20.2	21.1	19.5	19.8	20.2 N.S.
Avg.	20.9 a	21.2 a	19.0 b	20.0 ab	
			Holland		
Davidson	----	----	----	----	----
Sassafras	21.8	22.2	18.1	19.2	20.3 N.S.
Bertie	20.5	20.9	19.9	19.4	20.2 N.S.
Avg.	21.2 a	21.6 a	19.0 b	19.3 b	
			Orange & Warsaw		
Davidson	21.9	20.6	18.6	19.0	20.0 N.S.
Sassafras	21.6	21.5	18.4	18.1	19.9 N.S.
Bertie	20.4	20.5	18.8	19.1	19.7 N.S.
Avg.	21.3 a	20.7 a	18.6 b	18.7 b	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table VIII. Oil percentage of four soybean varieties grown on three soil types at three Virginia locations. 1965.

Varieties	Bethel	Clark	Lee	Ogden	Avg.
Soils			Orange		
Davidson	23.6	21.7	21.7	19.9	21.7 N.S.*
Sassafras	22.2	20.8	20.6	18.9	20.6 N.S.
Bertie	----	----	----	----	----
Avg.	22.9 a*	21.2 b	21.1 b	19.4 c	
			Warsaw		
Davidson	23.4	20.6	20.8	20.6	21.3 N.S.
Sassafras	23.0	20.9	20.9	21.1	21.5 N.S.
Bertie	23.0	20.6	21.2	20.1	21.2 N.S.
Avg.	23.1 a	20.7 b	20.9 b	20.6 b	
			Holland		
Davidson	22.6	23.5	20.4	21.1	21.9 N.S.
Sassafras	22.9	23.9	21.1	21.5	22.4 N.S.
Bertie	22.9	22.1	20.6	20.8	21.6 N.S.
Avg.	22.8 a	23.2 a	20.7 b	21.1 b	
			Warsaw & Holland		
Davidson	22.9	22.0	20.6	20.9	21.6 N.S.
Sassafras	22.9	22.4	20.9	21.2	21.9 N.S.
Bertie	22.9	21.3	20.9	20.4	21.4 N.S.
Avg.	22.9 a	21.9 b	20.8 c	20.9 c	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table IX. Oil percentage of four soybean varieties grown on three soil types at three Virginia locations. 1967.

Varieties	D62-6225	Clark	D65-6647	Dare	Avg.
Soils			Orange		
Davidson	17.6	21.8	16.8	22.6	19.7 a*
Sassafras	17.4	21.8	17.7	21.7	19.7 a
Bertie	17.1	20.9	16.4	21.8	19.1 b
Avg.	17.4 c*	21.5 b	16.9 d	22.0 a	
			Warsaw		
Davidson	18.6	21.9	15.9	22.5	19.7 a
Sassafras	17.5	21.6	16.3	22.6	19.5 a
Bertie	17.8	21.3	15.7	22.5	19.3 b
Avg.	17.9 c	21.6 b	15.9 d	22.5 a	
			Holland		
Davidson	19.0	22.1	16.7	22.6	20.1 a
Sassafras	18.5	22.6	16.9	22.5	20.1 a
Bertie	18.1	21.8	16.1	21.6	19.4 b
Avg.	18.5 b	22.2 a	16.6 c	22.2 a	
			Orange, Warsaw & Holland		
Davidson	18.4	21.9	16.4	22.6	19.8 a
Sassafras	17.8	22.0	16.9	22.3	19.8 a
Bertie	17.7	21.3	16.0	21.9	19.2 b
Avg.	17.9 c	21.8 b	16.5 d	22.3 a	

*Values followed by the same letters within a column or horizontal average are not significantly different (p=.05).

Table X. Oil percentage of four soybean varieties grown on three soil types at three Virginia locations. 1968.

Varieties	D65-2304	Clark	D65-2367	Dare	Avg.
Soils			Orange		
Davidson	17.5	21.1	18.3	20.9	19.5 a*
Sassafras	18.1	22.0	17.8	21.6	19.9 a
Bertie	15.2	19.4	16.5	19.9	17.8 b
Avg.	16.9 b*	20.8 a	17.5 b	20.8 a	
			Warsaw		
Davidson	15.7	23.3	20.8	22.9	20.7 N.S.*
Sassafras	19.0	23.5	20.0	23.5	21.5 N.S.
Bertie	17.4	21.3	19.0	22.3	20.0 N.S.
Avg.	17.4 b	22.7 a	19.9 b	22.9 a	
			Holland		
Davidson	18.6	23.7	21.0	25.2	22.1 a
Sassafras	19.3	25.1	20.7	25.0	22.5 a
Bertie	19.1	23.3	19.1	21.9	20.9 b
Avg.	19.0 b	24.0 a	20.3 b	24.0 a	
			Orange, Warsaw & Holland		
Davidson	17.3	22.7	20.0	23.0	20.8 a
Sassafras	18.8	23.5	19.5	23.4	21.3 a
Bertie	17.2	21.3	18.2	21.4	19.5 b
Avg.	17.8 b	22.5 a	19.2 b	22.6 a	

*Values followed by the same letter within a column or horizontal average are not significantly different; "N.S." indicates not significant (p=.05).

Table XI. Protein and oil percentage of soybeans grown on three soil types at three Virginia locations.*

Soil Types	Davidson	Sassafras	Bertie
Locations		Protein	
Orange	40.0	41.1	----
Warsaw	40.2	41.3	41.4
Holland	----	41.9	43.0
		Oil	
Orange	20.2	19.9	----
Warsaw	20.6	20.7	20.2
Holland	----	21.3	20.5

*Averaged over four years and four varieties each year.

percentage of soybean seed and they responded similarly to soil type and location with respect to oil percentage in two of the four years tested. Tables VII, VIII, IX, and X list the oil percentage for each year by individual locations, varieties and soil types. These data indicate that individual varieties differed in oil percentage in two out of four years at all locations and soil type affected oil percentage in only two out of four years (1967 and 1968) except at Warsaw in 1968 where soil type did not affect oil percentage.

Table XI shows the average oil and protein content of soybeans produced on three soils at each of three locations. The highest oil percentage in this study was obtained at the Holland location. At this location soybeans grown on Sassafras were higher in oil percentage than when grown on Bertie. Davidson soil is not included in the average oil percentage in this table although Davidson tended to be lower in oil percentage in the years (1965, 1967 and 1968) at locations on which soybeans were grown on it (Tables VIII, IX, and X).

The oil and protein content for all varieties grown on disturbed and undisturbed Bertie soil at Holland, Sassafras soil at Warsaw, and Davidson soil at Orange in 1965, 1967 and 1968 are given in Table XII. In general, the oil and protein content for seed from the disturbed and undisturbed soils at the three locations compare favorably.

Table XII. Protein and oil percentage for soybeans grown on three disturbed* and undisturbed soils at three Virginia locations. 1965, 1967, and 1968.

Soil type & location	Disturbed				Undisturbed			
	1965	1967	1968	Avg.	1965	1967	1968	Avg.
	Protein							
Davidson @ Orange	38.1	41.3	40.8	40.1	40.8	41.6	41.5	41.3
Sassafras @ Warsaw	41.6	42.7	39.9	41.4	40.9	42.1	41.7	41.6
Bertie @ Holland	42.5	43.7	42.3	42.8	43.0	43.9	42.5	43.1
	Oil							
Davidson @ Orange	21.7	19.7	19.5	20.3	21.8	19.5	19.4	20.2
Sassafras @ Warsaw	21.5	19.5	21.5	20.8	22.0	19.3	20.7	20.7
Bertie @ Holland	21.6	19.4	20.9	20.6	19.5	19.3	19.0	19.2

*Refers to soil that had been moved to each location and placed in "pots" fashioned by digging holes and lining with polyethylene.

SUMMARY AND CONCLUSIONS

A study was conducted for four years to determine the effect of three soils at each of three Virginia locations on the oil and protein content of different soybean varieties. Soybeans were grown in plastic lined "pots" fashioned by digging holes 14 inches in diameter and 48 inches deep. Root growth was restricted to the "pots" by plastic liners on the sides and copper mesh wire covering the bottom of each hole. Each soil was placed in the holes as near to its original position as possible.

Soybeans grown on Bertie sandy clay loam contained a higher protein and lower oil percentage than when produced on Sassafras fine sandy loam or Davidson clay loam. Soybeans grown on Davidson were lower in protein percentage than soybeans grown on Sassafras but there was no difference in oil percentage.

Soybeans grown at Holland contained more oil than when grown at Warsaw or Orange; and soybeans grown at Warsaw contained more oil than when grown at Orange.

The location effect on protein was significant in only two out of four years. In 1967, the protein percentage was significantly lower for soybeans grown at Orange but the reverse was true in 1968 when protein percentage was higher at Orange than at the other two locations. Of the two factors, soils and location, soils had a more consistent effect on the protein percentage. Both soil and location effect on oil percentage was consistent but of lower magnitude than effects on protein.

There was a location x variety and soils x variety interaction for both oil and protein percentage.

Under the conditions of this study both soil type and location affected the oil and protein content of soybeans. Soil type affected protein percentage more than location while oil percentage was affected more by locations. Varieties responded differentially to soil type and location.

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APPENDIX

Appendix Table I. Certain physical characteristics of three disturbed* soil types at three depths.

Depth of sample Inches	Soil separate percentages: Sand sizes VC	C	M	F	VF	Total Sand	Silt	Clay	Bulk density
	Sassafras								
0-10	1.03	12.00	22.70	11.60	2.70	50.00	35.97	14.00	1.44
10-20	.50	6.93	25.26	14.93	4.13	50.83	31.87	17.30	1.59
20-48	.47	6.86	24.53	15.40	4.33	51.63	30.43	17.93	1.58
	Davidson								
0-10	1.23	1.93	3.27	5.20	2.50	14.17	47.30	35.20	1.17
10-20	.74	.80	1.40	2.23	1.53	6.37	28.90	64.73	1.16
20-48	.20	.67	1.37	2.23	1.60	6.06	28.93	65.00	1.16
	Bertie								
0-10	.30	.93	12.97	38.27	6.00	58.50	30.97	10.53	1.26
10-20	.00	.30	10.43	36.93	5.50	53.17	30.60	10.23	1.63
20-48	.00	.30	10.40	38.30	5.30	54.16	30.27	15.57	1.56

*Samples were taken from soil that had been moved to each location and placed in "pots" fashioned by digging holes and lining with polyethylene.

Appendix Table II. Certain physical characteristics of three undisturbed soils at various depths.

Horizon	Depth Inches	Soil separate percentages: Sand sizes VC	C	M	F	VF	Total: Sand	Silt	Clay	Bulk density
					Sassafras					
Ap	0-10	.5	8.0	26.8	15.7	4.3	55.3	33.9	10.8	1.69
B_1	10-16	.5	6.8	23.8	13.6	9.0	48.7	37.0	14.3	1.60
B_{21}	16-30	.5	5.7	19.8	11.7	3.4	41.2	37.5	21.3	1.67
B_{22}	30-38	.4	7.3	29.0	20.1	5.3	62.1	21.2	16.7	1.77
Bx	38-48	.9	10.2	33.3	18.3	6.0	68.7	16.4	14.9	1.78
B_{31}	48-60	.6	7.7	30.9	18.7	6.6	64.5	15.6	19.9	----
B_{32}	60-66	.9	8.0	30.2	19.0	5.9	64.0	13.9	22.1	----
					Davidson					
Ap	0-12	.7	2.2	3.0	3.7	2.7	12.2	47.5	40.3	1.25
B_1	12-30	.6	1.4	1.8	2.3	1.8	7.9	36.2	55.9	1.35
B_{21}	30-46	.4	1.3	1.8	2.3	2.4	8.0	30.2	61.8	1.29
B_{22}	46-66	.7	1.6	1.7	2.2	2.2	8.3	26.8	64.9	----
					Bertie					
Ap	0-8	.04	.62	9.41	51.51	9.58	71.15	20.72	8.12	1.55
B_{21}	8-17	.00	.76	9.33	47.27	9.90	67.26	18.00	14.73	1.82
B_{22}	17-23	.05	.94	10.57	47.30	8.46	67.32	18.51	14.17	1.80
B_3	23-32	.03	1.42	11.36	56.01	8.06	76.88	15.57	7.55	1.80
C_1	32-37	.00	.97	11.93	57.37	8.40	78.66	17.60	3.74	1.78
C_2	- - - - - - - - - - - -				Not sampled			- - - - - - - - - - - -		

Appendix Table III. Analysis of variance for protein and oil percentage, Orange and Warsaw. 1964.

Source of variation	df	Protein		Oil	
		MS	F	MS	F
Variety	3	1.71	2.19	11.99	21.04**
Soil	2	13.29	17.04**	.23	-----
Location	1	.24	----	3.92	6.88*
Location x variety	3	1.35	1.73	2.79	4.89*
Location x soil	2	1.08	1.38	.10	----
Variety x soil within location	12	.78		.57	
Total	23				

Appendix Table IV. Analysis of variance for protein percentage at three locations. 1964.

Source of variation	df	Orange MS	Orange F	Warsaw MS	Warsaw F
Variety	3	2.09	1.88	.97	2.11
Soils	2	10.98	9.89*	3.39	7.37*
Variety x soil	6	1.11		.46	
Total	11				
		Holland			
Variety	3	2.02	1.03		
Soils	1	.21	----		
Variety x soil	3	1.97			
Total	7				

Appendix Table V. Analysis of variance for oil percentage at three locations. 1964.

Source of variation	df	Orange MS	Orange F	Warsaw MS	Warsaw F
Variety	3	11.92	15.28**	2.86	8.17*
Soils	2	.21	----	.12	----
Variety x soil	6	.78		.35	
Total	11				
		Holland			
Variety	3	3.31	3.00		
Soils	1	.04	----		
Variety x soil	3	1.10			
Total	7				

Appendix Table VI. Analysis of variance for protein and oil percentage, Warsaw and Holland. 1965

Source of variation	df	Protein		Oil	
		MS	F	MS	F
Reps within locations	2	.56	----	.80	1.04
Treat. combinations	11	5.15	2.46*	3.84	4.99**
Variety	3	7.55	3.61*	12.63	16.40**
Soils	2	13.52	6.47**	1.05	1.38
Variety x soil	6	1.16	----	.37	----
Locations	1	.47	----	4.56	5.92*
Treat. comb. x loc.	11	3.15	1.51	1.57	2.04
Error within location	22	2.09		.77	
Total	47				

Appendix Table VII. Analysis of variance for protein percentage at three locations. 1965.

Source of variation	df	Warsaw MS	Warsaw F	Holland MS	Holland F
Reps	1	.77	----	.35	----
Treat. combinations	11	4.57	3.68*	3.73	1.27
Variety	3	10.90	8.79**	2.33	----
Soils	2	4.21	3.40	14.66	4.99*
Variety x soil	6	1.53	1.23	.78	----
Error	11	1.24		2.94	
Total	23				

		Orange	
Reps	1	.08	----
Treat. combinations	7	8.71	4.84*
Variety	3	11.60	6.44*
Soils	1	24.26	13.48**
Variety x soil	3	.65	----
Error	7	1.80	
Total	15		

Appendix Table VIII. Analysis of variance for oil percentage at three locations. 1965.

Source of variation	df	Warsaw MS	Warsaw F	Holland MS	Holland F
Reps	1	1.45	2.42	.15	----
Treat. combinations	11	2.50	4.17*	2.91	3.10*
Variety	3	8.65	14.42**	9.06	9.64**
Soils	2	.14	----	1.18	1.26
Variety x soil	6	.22	----	.41	----
Error	11	.60		.94	
Total	23				
		Orange			
Reps	1	1.44	3.69		
Treat. combinations	7	4.26	10.92**		
Variety	3	8.30	21.28**		
Soils	1	4.84	12.41**		
Variety x soil	3	.03	----		
Error	7	.39			
Total	15				

Appendix Table IX. Analysis of variance for protein and oil percentage, Orange, Warsaw and Holland. 1967.

Source of variation	df	Protein		Oil	
		MS	F	MS	F
Reps within location	9	1.14	3.26**	.31	1.72
Treat. combinations	11	144.80	413.71**	30.38	446.55**
Variety	3	509.61	1456.03**	289.86	1610.33**
Soils	2	23.89	68.26**	4.88	27.11**
Variety x soil	6	2.70	7.71**	.82	4.55**
Location	2	5.06	14.46**	2.34	13.00**
Loc. x treat. comb.	22	4.47	12.77**	.86	4.78**
Error within location	99	.35		.18	
Total	143				

Appendix Table X. Analysis of variance for protein and oil percentage at three locations. 1967.

Source of variation	df	Protein					
		Orange		Warsaw		Holland	
		MS	F	MS	F	MS	F
Reps	3	.05	----	.83	2.76	2.55	5.93**
Treat. combinations	11	42.90	138.39**	70.25	234.17**	40.58	94.37**
Variety	3	142.29	459.00**	255.33	851.10**	133.47	310.40**
Soils	2	13.45	43.39**	1.62	5.40*	17.16	39.91**
Soil x variety	6	3.04	9.81**	.58	1.93	1.94	4.51**
Error	33	.31		.30		.43	
Total	47						
		Oil					
Reps	1	1.44	3.69	1.45	2.42	.15	----
Treat. combinations	11	4.26	10.92**	2.50	4.17*	2.91	3.10*
Variety	3	8.30	21.28**	8.65	14.42**	9.06	9.64**
Soils	2	4.84	12.41**	.14	----	1.18	1.26
Variety x soil	6	.03	----	.22	----	.41	----
Error	11	.39		.60		.94	
Total	23						

Appendix Table XI. Analysis of variance for protein and oil percentage, Orange, Warsaw and Holland. 1968.

Source of variation	df	Protein		Oil	
		MS	F	MS	F
Variety	3	6.80	5.40**	52.35	75.87**
Soil	2	47.98	35.08**	9.80	14.20**
Location	2	22.48	17.84**	24.01	37.80**
Loc. x variety	6	1.10	----	.68	----
Loc. x soil	4	1.21	----	.28	----
Var. x soil within location	18	1.26		.69	
Total	35				

Appendix Table XII. Analysis of variance for protein and oil percentage at three locations. 1968.

Source of variation	df	Protein					
		Orange		Warsaw		Holland	
		MS	F	MS	F	MS	F
Variety	3	.93	1.08	4.87	1.86	3.21	10.35**
Soils	2	20.96	24.37**	12.62	4.82	16.80	54.19**
Variety x soil	6	.86		2.62		.31	
Total	11						
		Oil					
Variety	3	13.02	62.00**	20.54	19.75**	20.16	24.89**
Soils	2	5.06	24.09**	2.26	2.17	3.06	3.77
Variety x soil	6	.21		1.04		.81	
Total	11						

Appendix Table XIII. Climatic conditions at three Virginia locations for two months preceding soybean maturity. 1964, 1965, 1966 and 1967.

Location	Orange		Warsaw		Holland	
Months	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.
Years	Average monthly maximum*					
1964	84.1	79.3	84.1	79.5	83.2	80.0
1965	85.8	81.3	86.9	82.8	87.2	83.2
1967	82.4	75.5	83.2	77.4	84.3	77.5
1968	87.2	80.3	88.5	81.6	89.7	82.2
	Average monthly minimum*					
1964	61.9	55.7	63.8	56.8	64.2	60.0
1965	62.8	58.5	64.7	60.1	65.2	61.5
1967	62.7	51.5	65.6	53.5	65.1	53.3
1968	65.6	55.2	66.5	55.6	67.7	56.4
	Monthly average*					
1964	73.0	67.5	74.0	68.2	73.7	69.3
1965	74.3	69.9	75.8	71.5	76.2	65.4
1967	72.6	63.5	74.4	65.5	74.7	72.4
1968	76.4	67.8	77.5	68.6	78.7	70.0
	No. days above 90°F.					
1964	8	6	6	2	4	0
1965	11	5	11	6	8	0
1967	1	0	2	0	5	6
1968	16	0	17	1	20	0

*Degrees Fahrenheit.

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Effect of Soil Type and Location on the Protein and Oil Percentage of Soybeans (Glycine max L.)

Allen H. Allison

Abstract

A study was conducted for four years to determine the effect of three soils at each of three Virginia locations on the protein and oil content of different soybean varieties. Soybeans were grown in plastic lined "pots" fashioned by digging holes 48 inches deep and 14 inches in diameter. Root growth was restricted to the "pots" by plastic liners on the sides and copper mesh wire covering the bottom of each hole. Each soil was placed in the holes as near to its original position as possible.

Under the conditions of this study, both soil type and location affected the oil and protein content of soybeans. Soil type affected protein percentage more than location but oil percentage was affected more by locations. Varieties responded differentially to soil type and location.

Soybeans grown on Bertie sandy clay loam contained a higher protein and lower oil percentage than when grown on Sassafras or Davidson soils. Soybeans grown on Davidson soil were lower in protein percentage than when grown on either Sassafras or Bertie soil.

Location affected protein percentage in two out of four years and oil percentage each year. Soybeans grown on the southern-most location produced more oil and less protein than when produced at the two northern-most locations.