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A Study of the Relative Adaptation of Certain Varieties of Soybeans

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J. M. Poehlman

INTRODUCTION

It is well known that a particular variety of a crop plant may grow well in one locality but poorly in another. This observation has led to extensive variety tests and to the accumulation of a great deal of information on varieties best adapted to particular localities. The selection of a variety suitable for (adapted to) the locality may determine the difference between success and failure or profit and loss in growing the crop. It is unnecessary to cite examples of this broad fact.

Although variety testing is practiced at all experiment stations, relatively little is known of the basic causes determining varietal adaptation except in relatively simple cases. For example, earliness of maturity or resistance to cold may be the decisive factor in determining varietal adaptation near the northern limits for a particular crop. In the majority of cases, however, the factors which determine why one variety grows better than another in a particular environment are not known; and unless we have more definite information of the fundamental causes of varietal adaptations, the selection of adapted varieties must continue to be a matter of trial and error.

With these considerations in mind, two varieties of soybeans, (*Soja max,* Piper), the Virginia and the Morse, were selected for study. Previous observations indicate that in some localities the Morse outyields the Virginia while in others the performance is reversed. This difference in the adaptation of two varieties so nearly alike in many features offers an opportunity to attack the general problem of varietal adaptation.

Why does the Virginia variety outyield the Morse under one set of conditions and Morse outyield Virginia under another? Can the differences in their relative yields be ascribed to particular soil conditions or climatic factors? Are they due to differences between the responses of these two varieties to levels of soil fertility? Soil moisture? Light? Temperature? Soil acidity? Or to the reaction of the variety and some other single factor or group of environmental factors?

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It is recognized that the problem is complex and that a solution for the varieties of soybeans used may not apply to other varieties and other localities. Nevertheless the whole broad problem of varietal adaptation is highly important and a beginning can be made in its solution by a study of a limited number of specific examples.

REVIEW OF LITERATURE

The adaptation of crop varieties to general soil and climatic factors has been widely studied. The soybean has received its share of such attention. Morse[17]* attributed the rapid increase since 1898 of the soybean to a crop of major importance in the United States to the development of new varieties adapted to a greater range of soil and climatic conditions. He states that with few exceptions soybean varieties are particularly sensitive to changes of soil or climate. Differences in the behavior of the same seed in various places are often so striking, he says, it is difficult to believe that they represent the same variety. These observations by Morse are based on his studies in the Orient as well as in the United States. The United States Department of Agriculture has collected over 7,000 samples of soybeans from the Orient, representing more than 2,000 distinct types which range from 75 to 200 days in reaching maturity.

Hollowell[13] observed that the Minsoy variety of soybeans at Ames, Iowa, grew to a height of twelve or fifteen inches and was very erect, while this same variety at St. Paul, Minnesota, grew three or four feet in height and did not develop as stiff a central stem as it did at Ames.

Etheridge and Helm[6] in testing soybean varieties on a wide range of soil types and fertility levels in Missouri, found a differential response of varieties in different localities. On the less productive Lintonia fine sandy loam in the southeastern part of the state (Dunklin County), Virginia and Wilson varieties were superior to Morse and Mikado for both seed and hay. The growth of the Morse and Mikado was short and stemmy and their seeds were borne so near the ground that considerable loss occurred in harvesting. On the Lebanon silt loam in Crawford County, a soil type extremely low in organic matter and natural fertility, Virginia was superior to Midwest, Morse, and Mikado in hay and seed yields. With the exception of Wilson, Virginia was the the only variety that grew tall enough to be harvested by machinery.

In Adair County, Missouri, on the fertile Grundy silt loam, Wilson, Mikado, Morse, Midwest, and Virginia yield in the order named. The same rank was found on Summit silt loam in Johnson County, a dark soil of high productivity. On the highly fertile

*Numerals refer to "references cited" on page 42.

Marshall silt loam of Nodaway County Mikado, Morse, and Midwest were superior to Wilson and Virginia. In general Virginia grew almost as tall on the less productive Lintonia and Lebanon soils as on the more fertile soils—Grundy, Summit, and Marshall—but the yields were not as high. A special fault of Morse, Mikado, and Midwest on the less fertile soils, viz., their low growth, was not apparent on the more productive soil types. The results indicate that Virginia is the most desirable variety tested on soils of medium and low fertility but is inferior to Morse or Mikado on soils of higher fertility.

Morse[17] reports that the Virginia has a greater range of adaptation than most other varieties and that it excels on the less productive types of soils. Kinney and Roberts[15] state that the Virginia gives excellent yields of hay and seed in Kentucky and grows larger on thin land than do most other early varieties. Hackleman[12] at the Illinois Agricultural Experiment Station reports that the Virginia is an excellent hay variety, especially on thin soils, but that it lodges badly on fertile soils. Woodworth[25] has observed that soybean varieties differ greatly in their adaptation. Some varieties are adapted to good soils, while others grow well on poor soils and do not respond to the better soils. He believes that the Morse is affected more by a change in growing conditions than is the Virginia. The Morse growing on brown silt loam at Urbana, Illinois averaged 42 nodes per plant while on Cisne silt loam, a gray silt loam on tight clay at the Toledo, Illinois, experiment field, it averaged 17.5 nodes per plant. These figures he contrasts with 32.8 and 17.8 respectively for the Virginia variety.

Thatcher[23] reports the idea to be prevalent among Ohio soybean growers that the Virginia yields well on thin land. Tests at the Ohio Field Experiment stations[1] support this idea. MeHarry[16] in a report on "Soybeans in Indiana" characterizes the Virginia as a variety which is among the best on rather unproductive soil but becomes unsuitable on rich soils because of lodging. Mulvey[19] states that both Morse and Virginia are too late in maturing for conditions at Lafayette but are generally considered adapted to southern Indiana.

Hughes and Wilkins[14] in an early publication describe the Virginia as the best variety for poor soils and suggest that it may be desirable for such soils in the southern part of Iowa. Later Wilkins[24] stated that Virginia and Morse had been eliminated from yield tests because they were too late in maturing.

At the Rice Branch Experiment Station, Stuttgart, Arkansas, on a soil type classified as Crowley silt loam, Banks[4] reports the Virginia as a good quality hay bean but not as satisfactory a yielder as many others. The growth of Morse is low and bushy, similar to that on the

Lebanon soil at Cuba, Missouri. In 1935 seedings, the Morse ranged from 31 to 34 inches in height while the Virginia averaged from 37 to 39 inches. However, the yields of hay for the six-year period, 1930 to 1935 inclusive, showed the Morse to average 1.43 tons per acre and the Virginia 1.29 tons.

According to York[26] at the Delta Experiment Station in Mississippi, the Virginia is well adapted to their conditions but it does not produce as good yields as some other varieties. Morse matures early, is not adapted and is grown only in observation plots.

The relative differences in yields of Morse and Virginia varieties of soybeans, particularly as observed at the Missouri Agricultural Experiment Station, exemplifies the problem of varietal adaptation. It is a problem which involves possible response of the varieties to a large number of edaphic and climatic factors. The results from a study of the response of these two varieties to different soil and climatic factors may be applicable to the whole problem of varietal adaptation. An investigation was, therefore, undertaken to confirm or disprove earlier observations on their soil and climatic adaptation as measured primarily by yield and to study the relation of various aerial and edaphic factors to their adaptation.

BASIC EXPERIMENTS

In the consideration of this problem, the first objective was to confirm or disprove earlier observations regarding the soil and climatic adaptation of Morse and Virginia varieties of soybeans. Accordingly these varieties were grown in the field on a number of soil types. Certain factors, which observation had indicated might be important in influencing the adaptation of these varieties, were then selected and further study made of each in greenhouse and laboratory experiments. These factors included soil fertility, soil moisture, temperature, and light. Descriptions of the field and pot experiments follow. An analysis, discussion and interpretation of the data presented here is given later.

Field Experiments.—The two varieties were grown in 1932 in rod row plots replicated five times at Columbia (Putnam silt loam), Green Ridge (Oswego silt loam), Cuba (Lebanon silt loam), Sni-A-Bar (Summit silt loam) and Elsberry (Wabash heavy clay). These soils represent a wide range in texture and fertility. At Columbia, Cuba, and Green Ridge, fertilizers were applied as follows: Range I, sodium nitrate, 100 pounds per acre; Range II, no treatment; Range III, 16 per cent superphosphate, 300 pounds per acre; Range IV, 4-16-4, 250 pounds per acre; lime (100 mesh), 400 pounds per acre; Range V, muriate of potash, 100 pounds per acre; Range VI, no treatment; Range VII, lime (100 mesh), 400 pounds per acre. Standard rates of planting and methods of cultivation were used throughout all of the field experiments. Yields of hay were secured by harvesting at an early pod stage and securing air dry weights of the samples.

In 1933 the tests were repeated at Columbia, Cuba, Green Ridge, and Grain Valley. The same fertilizer treatments were made at Columbia, Cuba, and Green Ridge as in the preceding year. At Columbia the test and fertilizer applications were repeated on the same plats as in the preceding year. A poor stand was secured at Cuba and none of the plats were harvested, but appropriate observations were made throughout the growing season. At Green Ridge only one "no treatment" range was harvested. The following season the varieties were planted only at Columbia and Cuba. Observations and results from tests made the two preceding years indicated that no important differences in relative adaptation of the two varieties of soybeans could be found which were not evident when grown on Putnam and Lebanon soils. It was therefore decided to concentrate future work largely on these two types.

In 1934 fertilizers were not applied at Columbia on the Putnam silt loam but at Cuba, on the Lebanon silt loam, treatments were made as follows: Range I, no treatment; Range II, phosphate; Range III, "miscellaneous treatment." The phosphate was applied as chemically pure disodium phosphate ($Na_2HPO_4 \cdot 12H_2O$) at the rate of 20 ppm PO_4 or 11.96 gms. of sodium phosphate per rod row. The "miscellaneous treatment" was a mixture of rare elements as used by Haas and Reed[11]. The elements applied consisted of aluminum, boron, copper, lithium, manganese, bromine, iodine, strontium, and zinc. These were used dry, at the rate of 5.0 ppm. each, in the bottom of the furrow in which the soybeans were planted. Methods of planting and harvesting were the same as in preceding years.

Results of the comparative hay yield tests of Morse and Virginia at Columbia, Cuba, Green Ridge, and Grain Valley and Elsberry are recorded in Tables 1, 2, 3, and 4 respectively.

TABLE 1.—FIELD PLAT YIELDS—COLUMBIA, MISSOURI. YIELDS OF HAY IN POUNDS PER ACRE (AIR-DRY WEIGHTS) OF MORSE AND VIRGINIA SOYBEANS, 1932, 1933, and 1934.

Soil Treatment	Rates of Treatment	1932		1933		1934	
		Morse	Virginia	Morse	Virginia	Morse	Virginia
	lbs.						
Sodium nitrate	100	5726	4836	3913	3482	----	----
None	----	5336	4396	3651	3260	2232	2849
Superphosphate	300	5441	4815	3590	3186	----	----
4-16-4 Fine lime (100 mesh)	250 400	5386	4253	3635	2967	----	----
Muriate of potash	100	5639	4332	3461	3089	----	----
None	----	5676	4248	3348	3102	----	----
Fine Lime (100 mesh)	400	5489	4715	3762	3366	----	----

TABLE 2.—FIELD PLAT YIELDS—CUBA, MISSOURI. YIELDS OF HAY IN POUNDS PER ACRE (AIR-DRY WEIGHTS) OF MORSE AND VIRGINIA SOYBEANS, 1932 and 1934.

Soil Treatment	Rates of Treatment	1932		1934	
		Morse	Virginia	Morse	Virginia
	lbs.				
Sodium nitrate	---	1113	1544	----	----
	100	1568	1877	507	638
Superphosphate (16%)	300	2316	2496	----	----
4-16-4 Fine Lime (100 mesh)	250 400	2260	2443	----	----
Muriate of potash	100	2260	2375	----	----
None	---	2100	2508	----	----
Fine Lime (100 mesh)	400	1886	2020	----	----
Phosphate*	---	----	----	564	615
Misc. treatment*	---	----	----	206	446

*Rates of treatments explained in text.

TABLE 3.—FIELD PLAT YIELDS—GREEN RIDGE, MISSOURI. YIELDS OF HAY IN POUNDS PER ACRE (AIR-DRY WEIGHTS) OF MORSE AND VIRGINIA SOYBEANS, 1932 and 1933.

Soil Treatment	Rates of Treatments	1932		1933	
		Morse	Virginia	Morse	Virginia
	lbs.				
Sodium nitrate	100	2866	2556	----	----
None	---	3290	2884	3063	2961
Superphosphate (16%)	300	3168	2859	----	----
4-16-4 Fine lime (100 mesh)	250 400	3225	3017	----	----
Muriate of potash	100	2933	2801	----	----
None	---	3121	2725	----	----
Fine lime (100 mesh)	400	3744	3008	----	----

TABLE 4.—FIELD PLAT YIELDS—GRAIN VALLEY AND ELSBERRY, MO. YIELDS OF HAY IN POUNDS PER ACRE (AIR-DRY WEIGHTS) OF MORSE AND VIRGINIA SOYBEANS, 1932 AND 1933.

Year	Grain Valley		Elsberry	
	Morse	Virginia	Morse	Virginia
1932	4520	4184	5285	4742
1933	4269	3832	----	----

Pot Experiments.—Studies of the growth and development of Morse and Virginia on different soil types under the same climatic conditions were started in 1932. Soils corresponding to those used in the field experiments for that season (Putnam silt loam, Lebanon silt loam, Oswego silt loam, Summit silt loam, and Wabash heavy clay) were transported to Columbia and placed into four-gallon glazed jars, both surface soil and subsoil being used. Three replications of each variety were planted on each of the soil types and harvested after the seed pods were well formed. The pots were kept in an open pit out of doors, and moisture was kept near the optimum for each soil by the addition of tap water when needed to supplement water supplied by rain. The yields of air-dry matter in grams per pot are recorded in Table 5.

TABLE 5.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN OUTSIDE AT COLUMBIA IN POTS FILLED WITH DIFFERENT SOIL TYPES DURING THE SUMMER OF 1932.

Soil Type	Variety	Pot No. (replication)			Average
		1	2	3	
Putnam silt loam	Morse	68.3	58.2	66.7	64.4
	Virginia	65.4	61.5	58.2	61.7
Lebanon silt loam	Morse	26.2	29.3	29.2	28.2
	Virginia	23.5	23.9	24.2	23.9
Oswego silt loam	Morse	55.1	62.4	58.7	58.7
	Virginia	52.5	58.7	62.6	57.9
Wabash heavy clay	Morse	56.8	49.2	57.9	54.6
	Virginia	58.1	51.1	50.4	53.2
Summit silt loam	Morse	82.2	81.9	73.7	79.2
	Virginia	74.2	63.1	75.8	71.0
Lintonia loam	Morse	47,7	51.6	51.7	50.3
	Virginia	55.7	39.5	50.9	48.7

All yields in grams dry matter per pot.

The effects of different soil moisture levels on the comparative growth of Morse and Virginia growing on Putnam and Lebanon soil types were studied in the greenhouse during the winter of 1932-33. Surface soil was secured from the field plats at Columbia and at Cuba where these varieties had been grown the preceding summer and placed in three-gallon glazed jars. Six replications of each variety and treatment were maintained. Two-hundred-watt electric light bulbs placed two to three feet above the plants were used to increase the day length to fifteen hours. Temperature of the greenhouse was maintained at approximately 70° Fahrenheit. The moisture levels were maintained by weight as follows: Putnam silt loam, low, 15 per cent; medium, 21 per cent; high, 25 per cent; and Lebanon silt loam, low, 13 per cent; medium, 16.5 per cent; and high, 20.5 per cent. Optimum moisture for the Putnam soil type is 22.5 per cent and for the Lebanon soil type, 18 per cent, optimum being considered as one-half of the water holding capacity of the soil as determined by a Hilgard moisture cup. The soybeans were harvested after sixty-five days growth at which time the pods were just beginning to form. The total dry weights in grams per pot were obtained and the results are recorded in Table 6.

TABLE 6.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN THE GREENHOUSE AT COLUMBIA (WINTER 1932 AND '33) IN POTS FILLED WITH PUTNAM AND LEBANON SILT LOAMS AND WITH VARYING LEVELS OF SOIL MOISTURE.

Pot No. (Replication)	Putnam Silt Loam Soil Moisture Level			Lebanon Silt Loam Soil Moisture Level		
	Low	Medium	High	Low	Medium	High
Morse						
1	11.3	19.4	28.3	16.6	26.0	21.4
2	15.0	21.5	23.7	20.4	25.7	24.1
3	15.8	18.0	23.0	18.4	22.8	27.2
4	9.0	26.1	37.3	18.0	29.7	39.5
5	9.9	23.9	42.4	18.6	30.0	39.8
6	12.1	28.6	39.6	20.2	33.2	38.4
Average	12.2	22.9	32.4	18.7	27.9	31.7
Virginia						
1	10.1	18.6	18.3	15.7	24.1	20.7
2	9.3	20.3	18.8	16.0	22.1	22.1
3	11.2	18.7	20.4	14.3	21.4	23.9
4	9.2	25.7	38.2	16.5	28.8	32.7
5	8.5	22.4	34.0	13.9	28.2	31.8
6	9.3	24.6	38.3	16.1	29.5	30.7
Average	9.6	21.7	28.0	15.4	25.7	28.3

All yields in grams dry matter per pot.
Soil moisture levels given in text.

TABLE 7.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN POTS FILLED WITH DIFFERENT SOIL TYPES AND KEPT AT LOW AND HIGH SOIL MOISTURE LEVELS UNDER CELL-O-GLASS AT COLUMBIA (SUMMER, 1933).

Pot No. (replication)	Soil Types				
	Putnam Silt Loam	Lebanon Silt Loam (unfertilized)	Lebanon Silt Loam (fertilized)	Oswego Silt Loam	Union Silt Loam
Morse—Low Moisture					
1	22.8	22.8	30.6	25.9	13.9
2	19.7	18.1	22.2	24.7	13.5
3	20.8	20.4	29.0	25.3	14.3
Average	21.1	20.4	27.3	25.3	13.9
Virginia—Low Moisture					
1	12.1	19.2	33.2	27.0	15.8
2	12.5	23.4	29.5	26.2	16.9
3	14.5	18.7	28.2	25.4	16.3
Average	13.0	20.4	30.3	26.2	16.3
Morse—High Moisture					
1	70.4	68.5	125.7	98.9	36.2
2	66.0	69.2	124.6	100.6	36.8
3	71.1	68.2	131.4	102.3	35.6
Average	69.2	68.6	127.2	100.6	36.2
Virginia—High Moisture					
1	71.7	67.1	113.5	98.5	28.8
2	64.9	67.4	104.4	89.6	31.4
3	66.8	56.5	112.4	94.0	33.1
Average	67.8	63.7	110.1	94.0	31.4

All yields in grams dry matter per pot.
Fertilizer and soil moisture treatments given in the text.

During the summer of 1933, the two varieties were grown at both high and low moisture on Putnam silt loam, Oswego silt loam, Lebanon silt loam (fertilized and unfertilized), and Union silt loam. The Putnam, Oswego, and Lebanon soils were obtained from the field plats being used that season at Columbia, Green Ridge, and Cuba respectively, the Union soil from a poor, eroded area near Columbia. Liberal amounts of sodium nitrate, superphosphate, potassium chloride and hydrated lime were applied to the fertilized series of the Lebanon soil. Both subsoil and surface soil were used. The pots were kept outdoors in a pit which was protected from rain by a framework covered with cell-o-glass. The high moisture levels, which were optimum for the soil types being used, were as follows: Putnam, 22.5 per cent; Oswego, 22.5 per cent; Lebanon (fertilized and unfertilized), 18 per cent; and Union, 26.2 per cent. The low moisture levels maintained were: Putnam, 12.5 per cent; Oswego, 12.5 per cent; Lebanon (fertilized and unfertilized), 10 per cent; and Union, 15 per cent. Moisture levels were maintained by the addition of tap water. Plantings were made on June 12 and the plants harvested on September 10, at which time the pods were well filled. Air-dry weights of the plants, as grams of total weight per pot, are recorded in Table 7.

The test was repeated the following winter in the greenhouse on Putnam and Lebanon soils. Day length was increased to fifteen hours by the use of 200-watt electric lights and temperature was kept at approximately 70° Fahrenheit. Instead of maintaining the low moisture content by weighing, the plants were used as an index. The soil moisture was kept just above the permanent wilting point of the plant by

TABLE 8.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN POTS IN THE GREENHOUSE AT COLUMBIA ON PUTNAM AND LEBANON SILT LOAMS AT LOW AND HIGH MOISTURE LEVELS (WINTER 1933-'34).

Pot No. (replication)	Putnam Silt Loam		Lebanon Silt Loam	
	Low Moisture	High Moisture	Low Moisture	High Moisture
Morse				
1	4.75	9.20	4.20	9.45
2	3.65	9.35	4.30	9.55
3	3.15	9.70	3.00	8.75
Average	3.85	9.42	3.50	9.25
Virginia				
1	4.35	12.20	2.10	9.20
2	3.00	6.90	3.10	7.10
3	2.95	4.45	3.35	7.20
Average	3.43	7.85	2.85	7.83

All yields in grams dry matter per pot.
Moisture levels given in the text.

watching the plants carefully and adding tap water as the lower leaves began to wilt. Weights of total dry matter per pot are recorded in Table 8.

Recovery from deficient soil moisture in the early stages of growth was studied in the greenhouse in two pot experiments during the winter of 1934-35. The two varieties were grown on Putnam and Lebanon soils, one series being maintained at low moisture level (determined by the wilting of the lower leaves) for the entire growth period, while one series was restored to optimum moisture conditions after being grown at low moisture for 34 days. Day length was increased to fifteen hours by the use of 200-watt electric lights and the temperature was kept at approximately 70° Fahrenheit. Tap water was used for watering. The results of the two experiments are recorded in Tables 9 and 10.

TABLE 9.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN THE GREENHOUSE AT COLUMBIA IN POTS ON PUTNAM AND LEBANON SILT LOAMS WITH VARYING SOIL MOISTURE TREATMENTS (WINTER 1934-'35).

Pot No. (replication)	Low Moisture cut 34 days	Low Moisture cut 60 days	Low Moisture (34 days cut 60 days
	Putnam Silt Loam		
Morse			
1	3.20	4.38	6.25
2	3.34	3.89	7.69
3	3.75	5.84	7.70
Average	3.43	4.70	7.21
Virginia			
1	1.20	2.55	4.15
2	1.50	3.06	3.22
3	1.30	2.77	2.85
Average	1.33	2.79	3.41
	Lebanon Silt Loam		
Morse			
1	3.56	5.90	8.52
2	3.26	3.90	7.60
3	3.90	5.87	9.52
Average	3.57	5.22	8.55
Virginia			
1	2.00	2.29	3.94
2	2.25	2.27	4.32
3	2.05	2.30	4.75
Average	2.10	2.25	4.34

All yields in grams dry matter per pot.
Soil moisture treatments explained in text.

TABLE 10.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN THE GREENHOUSE AT COLUMBIA IN POTS ON PUTNAM AND LEBANON SILT LOAMS WITH VARYING SOIL MOISTURE TREATMENTS (WINTER 1934-'35).

Pot No. (replication)	Low Moisture cut 34 days	Low Moisture cut 60 days	Low Moisture (34 days) cut 60 days
	Putnam Silt Loam		
Morse			
1	3.95	5.07	7.60
2	3.52	4.68	5.61
3	3.39	5.55	6.78
Average	3.62	5.10	6.68
Virginia			
1	1.82	2.21	3.97
2	1.67	1.80	4.10
3	1.30	2.61	3.40
Average	1.60	2.21	3.82
	Lebanon Silt Loam		
Morse			
1	2.36	3.92	5.80
2	3.22	3.25	6.94
3	3.25	4.42	5.88
Average	2.94	3.86	6.21
Virginia			
1	1.52	1.78	2.80
2	1.87	1.65	3.05
3	1.61	1.87	2.72
Average	1.67	1.77	2.87

All yields in grams dry weight per pot.
Soil moisture treatments explained in text.

The effect of fertility level on the comparative yields of Morse and Virginia was studied in the greenhouse by mixing Putnam silt loam with clean white quartz sand in varying proportions. The mixtures used were (1) soil; (2) soil (50%) plus sand (50%); (3) soil (25%) plus sand (75%); and (4) soil (10%) plus sand (90%), thus giving four distinct fertility levels. The milli-equivalents of total exchangeable bases and the water holding capacity of these soil and sand mixtures were determined and are recorded in Table 11.

TABLE 11.—WATER HOLDING CAPACITY AND EXCHANGEABLE BASES IN SOIL AND SAND MIXTURES.

Soil Fertility Level	Water Holding Capacity	Exchangeable Bases
	Percentage	*M.E. per 100 gms.*
Soil	25.00	15.60
Soil (50%) + Sand (50%)	16.15	9.42
Soil (25%) + Sand (75%)	14.25	7.32
Soil (10%) + Sand (90%)	13.91	5.76

Soil moisture was maintained at optimum for each mixture by addition of tap water, and day length was increased to fifteen hours by the use of electric lights as in previous experiments. The plants were harvested after 64 days at which time the pods were just beginning to form. The yield data are recorded in Table 12.

TABLE 12.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN THE GREENHOUSE AT COLUMBIA AT DIFFERENT FERTILITY LEVELS (WINTER 1935-'36).

Soil Fertility Level	Pot Number	Morse	Virginia
		gms.	*gms.*
Soil	1	19.6	10.9
	2	16.6	9.6
	3	15.5	10.7
	Average	17.2	10.4
Soil (50%) + Sand (50%)	1	13.6	10.7
	2	15.4	10.6
	3	14.3	9.3
	Average	14.4	10.3
Soil (25%) + Sand (75%)	1	16.5	7.8
	2	11.0	10.3
	3	13.1	7.8
	Average	13.5	8.6
Soil (10%) + Sand (90%)	1	12.1	6.2
	2	11.2	8.5
	3	11.7	9.6
	Average	11.7	8.1

The effect of length of the day on Morse and Virginia was also studied in the greenhouse during the winter of 1935-36. The two varieties were grown in Putnam silt loam at optimum moisture (by addition of tap water) with 15-hour and 7-hour days. Eight replications of each variety were planted with both long and short day conditions but it was necessary to discard several replications because of insect injury. The day lengths of those grown under conditions of long day were increased to 15 hours by the use of electric lights (200-watt bulbs). Those grown under conditions of short day were removed from a dark house at eight o'clock in the morning and returned to it at three in the afternoon. The soybeans were harvested 60 days after they had emerged from the ground, at which time both varieties grown under the conditions of long day were in full bloom while those grown under short day conditions were just beginning to form pods. Yields of dry matter per pot were weighed and the lengths of the internodes measured. The results are reported in Table 13.

TABLE 13.—POT EXPERIMENT YIELDS. YIELDS OF DRY MATTER IN GRAMS (AIR DRY WEIGHTS) OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN IN THE GREENHOUSE AT COLUMBIA WITH SEVEN AND FIFTEEN HOUR DAY LENGTHS (1936).

Day Length	Pot Number	Morse	Virginia
		gms.	gms.
7 hour day	1	6.58	6.23
	2	6.15	6.40
	3	5.70	5.70
	Average	6.14	6.11
15 hour day	1	16.50	14.60
	2	19.00	12.60
	3	14.70	11.80
	Average	16.83	13.00

AVERAGE LENGTHS (CENTIMETERS) OF INTERNODES OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS GROWN WITH SEVEN AND FIFTEEN HOUR DAY LENGTHS

Day Length	Variety	Number of Internodes from Cotyledons							
		1	2	3	4	5	6	7	8
		cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
7 hours	Morse	5.5	2.6	1.7	1.6	1.0	---	---	---
	Virginia	7.3	3.2	3.0	2.5	1.3	---	---	---
15 hours	Morse	9.2	6.7	6.4	10.1	10.2	7.6	6.9	4.1
	Virginia	11.9	5.8	7.0	12.1	16.3	16.2	8.3	---

Plant Juice Studies.—The concentrations of nitrates, phosphorus, and potassium in the expressed plant juice of the two varieties were studied in connection with their nutritional relations. For this study field plats of each variety were grown on all of the soil treatments described at Columbia, Cuba, and Green Ridge in 1932 and 1933. The expressed plant juice was analyzed for nitrates, phosphorus, and potassium. The details of the methods of procedure as well as a complete discussion and summary of results have been previously published.[21]

DIFFERENTIAL RESPONSE OF MORSE AND VIRGINIA VARIETIES OF SOYBEANS

To determine the correctness of the observations reported by previous investigators to the effect that the relative yield of the Morse and Virginia soybeans varies with soil and climatic factors to such an extent that under one set of conditions Virginia exceeds Morse in yield, while under a different set Morse exceeds Virginia, the yields observed elsewhere and those obtained by the writer are summarized here.

Observations at the experiment stations of Missouri,[6] Arkansas,[2, 3] Indiana[19], Iowa[14], and Kentucky[15] show in general that the two varieties studied do not produce the same relative yields under all conditions. At Columbia, Missouri; Stuttgart, Arkansas; and Ames, Iowa, Morse generally outyields Virginia. At Marianna, Arkansas; and Goodwell, Oklahoma, Virginia usually outyields Morse. The results at Maryville, Warrensburg, and Cuba, Missouri are variable and for the two latter places do not agree with observations made over a period of years to the effect that Morse generally surpasses Virginia at Warrensburg and Virginia is superior to Morse at Cuba. However, the relative yields may be reversed at a particular station in different seasons. These facts are evident from the data in Table 14 in which the yields of the two varieties, available from the work of previous investigators, are summarized.

The writer's experiments on the response of these two varieties show that the Morse variety outyielded the Virginia in field plats on Putnam soil at Columbia, on Oswego at Green Ridge, on Summit at Grain Valley, and on Wabash at Elsberry in all years, except 1934 at Columbia, when Virginia outyielded Morse. The Virginia outyielded the Morse on Lebanon soil at Cuba in all seasons. In pot experiments

TABLE 14.—COMPARATIVE HAY YIELDS OF MORSE AND VIRGINIA.
MISSOURI DATA (a)

Year	Yields of Hay in lbs. per acre							
	Columbia		Warrensburg		Maryville		Cuba	
	Morse	Virginia	Morse	Virginia	Morse	Virginia	Morse	Virginia
1918	4200	3800	----	----	----	----	----	----
1919	4400	5200	2600	3200	3400	4400	400	600
1920	6000	5600	5000	4600	4200	4000	1800	1600
1921	4600	4800	2200	2400	4000	3600	1920	1740
1922	2400	2400	----	----	----	----	1760	1200
1923	----	----	----	----	----	----	620	800

OTHER DATA.

Year	Marianna,(*b*) Arkansas		Stuttgart,(*c*) Arkansas		Ames,(*d*) Iowa		Goodwell,(*e*) Oklahoma	
	Morse	Virginia	Morse	Virginia	Morse	Virginia	Morse	Virginia
1917	----	----	----	----	4180	4300	----	----
1918	----	----	----	----	2640	2260	----	----
1919	----	----	----	----	5700	5320	----	----
1920	----	----	----	----	4400	3960	----	----
1921	----	----	----	----	5260	4160	----	----
1922	----	----	----	----	5320	5940	----	----
1923	----	----	----	----	5100	6120	----	----
1924	----	----	----	----	6660	5260	----	----
1926	1380	2600	----	----	----	----	663	1098
1930	1960	1660	----	----	----	----	375	338
1931	2200	3520	----	----	----	----	331	512
1932	1860	2680	----	----	----	----	----	----
1935	----	----	3060	2860	----	----	----	----
3 yrs. ave. (1925-'27)	----	----	5000	4580	----	----	----	----
5 yrs. ave. (1930-'34)	2820	2520	----	----	----	----	----	----

(*a*) Etheridge and Helm.[6]
(*b*) Cotton Branch Exp. Sta.[3]
(*c*) Rice Branch Exp. Station [2, 4]
(*d*) Hughes and Wilkins.[14]
(*e*) Daniel.[5]

Morse exceeded Virginia in all tests and on all soil types tested, including the Lebanon and the soil and sand mixtures, except in one experiment with the shortened day length when the yields were equal. In the field experiments where Virginia outyielded Morse the growth of the Morse variety was characterized by shortened internodes. The same growth character was observed only in the pot experiments with shortened day length.

The results of the field plat tests (from "no treatment" plats only) are summarized in Table 15.

TABLE 15.—COMPARATIVE HAY YIELDS OF MORSE AND VIRGINIA.

Soil Type	Yields of Hay in lbs. per acre					
	1932		1933		1934	
	Morse	Virginia	Morse	Virginia	Morse	Virginia
Putnam silt loam	5506	4322	3500	3181	2232	2849
Lebanon silt loam	1834	2192	----	----	507	638
Oswego silt loam	3205	2804	3063	2961	----	----
Summit silt loam	4520	4184	4269	3832	----	----
Wabash heavy clay	5285	4742	----	----	----	----

The Morse variety was superior to the Virginia in yields of dry matter on all of the soil types on which they were tested in 1932, except the Lebanon, where the Virginia was superior. This is in agreement with earlier work at the Missouri Experiment Station[6] where hay yields of Morse exceeded Virginia at Columbia on Putnam silt loam. This also agrees with the prevailing idea that the Virginia variety is adapted to soils of low fertility.

In 1933 the yields of hay of Morse exceeded those of Virginia on Putnam, Oswego, and Summit soil types. The plats on the Lebanon were not harvested because of poor stands and plats were not planted on the Wabash that season. The results agree with those of the preceding year on the same soil types.

In 1934, the field test plats were limited to the Putnam and Lebanon soil types. The yields of hay of Virginia exceeded those of Morse not only on the Lebanon soil type at Cuba, as in previous years, but also on the Putnam at Columbia. The 1934 season was characterized by extreme drought in the early part of the growing season, which continued until about the middle of August. This drought was accompanied by extremely high temperatures in June, July, and the first half of August.

It is recognized that yields reported for three years cannot in themselves be taken as indicative of the yielding ability of the two varieties

Fig. 1.—Plant of Morse variety produced on Putnam Silt Loam at Columbia in 1934 showing type of growth with shortened internodes produced in that season.

on the soil types studied. However, they confirm previous yield reports, and with the exception of the yields on the Putnam in 1934, are in accord with the earlier results and observations of the Missouri Experiment Station extending over a long period of years.

In addition to differences in the relative yields of Morse and Virginia on the Lebanon as compared to the other soils, important differences in the comparative growth types were also observed. On the Lebanon the plants of the Morse variety were low and bushy with decidedly shortened internodes rather than upright and branching as on the Putnam, Oswego, Summit, and Wabash soils. The type of growth of the Virginia variety was the same on all soils. On Lebanon the plants of Virginia were almost as tall although the total yield was not as great as on the more productive soils. The low, bushy type of growth made by the Morse on the Lebanon confirms earlier observations of Etheridge and Helm[6] on that soil. It also agrees with Woodward[25] who states that Morse is affected more by a change in growth conditions than is Virginia.

Under the conditions of the 1934 season, in which relative yields of Morse and Virginia at Columbia were reversed in comparison with previous seasons, a reversal in growth type also occurred. The plants of the Morse variety were low and bushy, characteristic of those produced on the Lebanon soil. The Virginia, on the other hand, although not as tall as in favorable seasons, produced a type of growth comparable to that produced in previous years. The distinctly shortened internodes of a plant of Morse grown on the Putnam soil in 1934 are illustrated in Fig. 1.

The character of growth of these varieties on the Putnam in 1934 in comparison with the character of growth made on the Lebanon strongly indicated that the reversal in yield of these varieties on the Putnam was not merely an experimental variation but that it truly reflected their growth and yield in that particular season. The differences in characters of growth may be illustrated by the average length of internodes of a large number of representative plants grown under field conditions. Table 16 lists the average length of the internodes in centimeters for the two varieties growing on Putnam and Lebanon soils in 1933 and 1934.

TABLE 16.—LENGTH OF INTERNODES OF MORSE AND VIRGINIA.

Soil Type	1933		1934	
	Morse	Virginia	Morse	Virginia
	cm.	cm.	cm.	cm.
Putnam	4.39	5.49	2.73	3.52
Lebanon	2.57	3.29	2.53	3.18

The average length of the internodes of the Morse variety on the Putnam in 1933 was longer than in the 1934 season and longer than those of the Morse on the Lebanon in either the 1933 or 1934 season.

From these observations it seems clear that the Virginia and Morse varieties of soybeans do not respond in the same way under all conditions. This is shown not only by the relative yields of these two varieties but also to some extent by the character of their growths at different stations. It would appear from the observations of others that on fertile soils the Morse variety outyields the Virginia. This impression is supported in part by a comparison of total yields of the two varieties.

TOTAL YIELDS AND RELATIVE YIELDS OF MORSE AND VIRGINIA

From the results of field plat tests reported (Tables 1 to 4) it may be observed that when Virginia exceeded Morse the yields of both varieties were usually low. Is there then a relation between the total yields and the relative yields of these two varieties? May the Virginia variety be regarded as more resistant to unfavorable soil or climatic factors and therefore able to outyield Morse whenever conditions for growth are unfavorable? If so, how much must the yields be reduced before Virginia may be expected to outyield Morse?

From this point of view consideration has been given to three sets of data: (1) the writer's experiments, (2) all data available from Missouri, and (3) the data from Missouri together with those from other states (Tables 14 and 15). In each case differences between yields of Morse and Virginia were compared with yields of Morse. The results for ten field experiments performed by the writer are shown in Figure 2. In every case where Morse exceeded Virginia the total yield of Morse was more than 2400 pounds of hay per acre. When environmental conditions were so unfavorable that the total hay yield of Morse dropped below 2400 pounds, then Virginia outyielded Morse. The significance of this trend is attested by fitting a straight line to the data by the method of least squares. This means that whenever soil or climatic conditions are so unfavorable that the total hay yields of Morse are small, Virginia may be expected to outyield Morse. As the growth conditions become more favorable and the total yields increase, the superiority of Morse over Virginia increases.

The results for all experiments available from Missouri are shown in Figure 3. These data show three exceptions only to the general statement that Virginia outyields Morse in Missouri when the yield of Morse is 2400 pounds or less of hay per acre. Again a straight line fitted to the data confirms the generality that as growth conditions

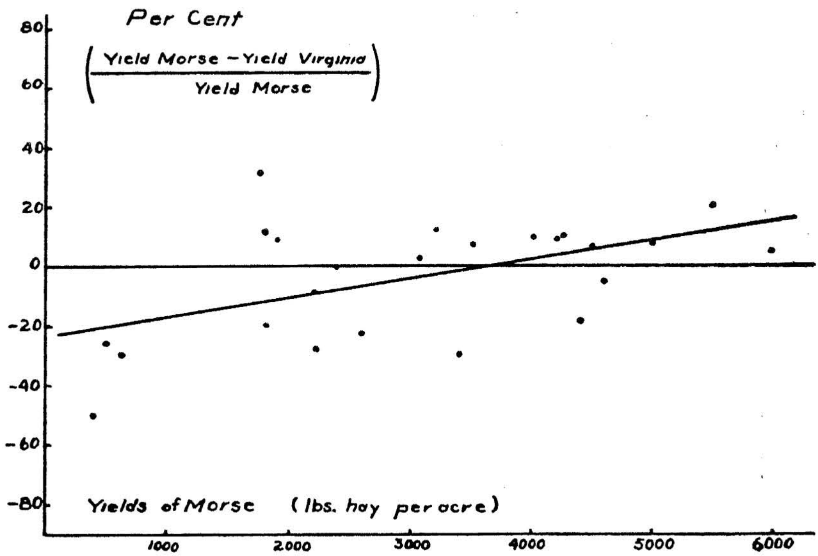

Fig. 2.—Relation of relative yields (expressed as per cent) to the total yields of Morse. Data from author's experiments.

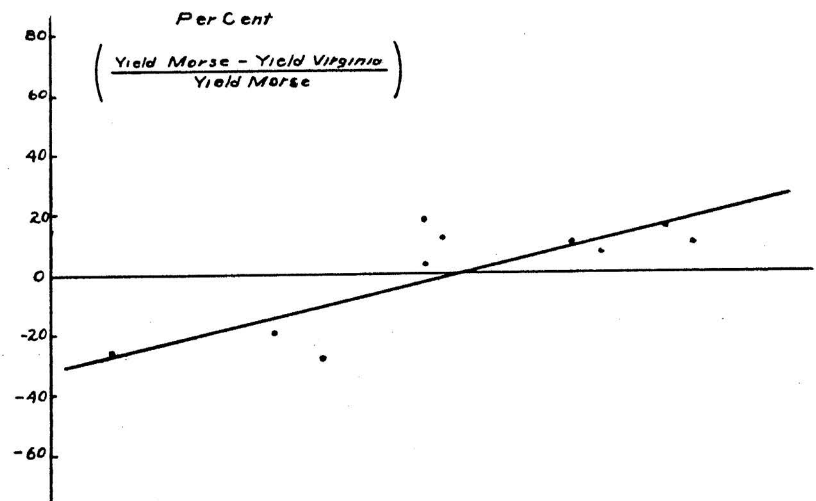

Fig. 3.—Relation of relative yields (expressed as per cent) to the total yields of Morse. Data from Missouri experiments.

improve the effect is more marked on Morse than on Virginia, though certain exceptional cases may be noted.

The results for all field experiments available to the writer are shown in Figure 4. Here are five exceptions to the generality that Virginia outyields Morse when the yield of Morse is 2400 pounds or less of hay per acre and several cases where Virginia outyields Morse at the higher yields. However, a straight line fitted to the data confirms the general tendency discussed above.

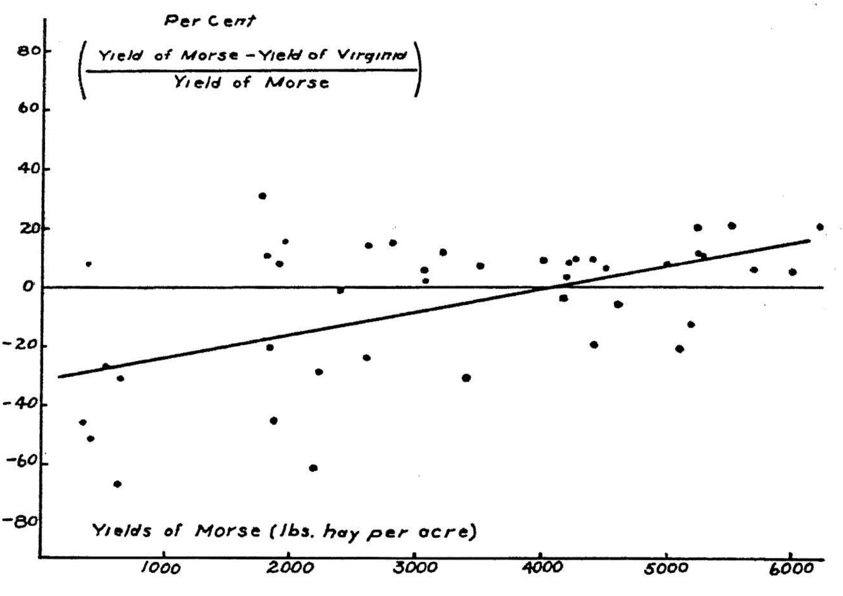

Fig. 4.—Relation of relative yields (expressed as per cent) to the total yields of Morse. Data from all available experiments.

To what is this general tendency due? Can it be ascribed to the interaction of the varieties and any single factor or complex of factors such as soil type, soil fertility, season, soil moisture, temperature, or light? These relations will be discussed in the following topics.

SOIL TYPE AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA

The importance of soil type in determining the relative yields of Morse and Virginia has been suggested by others[6, 17, 25]. Results of experiments performed by the writer indicate that soil type may not be sufficient to explain differences in the relative yields of these varieties.

Morse and Virginia were grown in pots filled with the various soils used in field experiments during the summer of 1932 and the plants were kept under uniform environmental conditions. The results of the experiment are reported in Table 5 and are summarized in Table 17.

TABLE 17.—YIELD OF MORSE AND VIRGINIA ON DIFFERENT SOILS. (AIR DRY WEIGHT IN GRAMS).

Soil Type	*Morse*	*Virginia*
Putnam silt loam	64.4	61.7
Lebanon silt loam	28.2	23.9
Oswego silt loam	58.7	57.9
Wabash heavy clay	54.6	53.2
Summit silt loam	79.2	71.8
Lintonia loam	50.3	48.7

In this experiment Morse was superior to Virginia on every soil type. However, pot experiments are not always comparable with field experiments since it is not possible to reproduce entirely in a pot the natural conditions of a soil as it occurs in the field. Even though both subsoil and surface soil were placed in the pots in positions and depths corresponding to those found in the field, the physical condition of the soil was disturbed in filling the pots.

That soil type is not sufficient to explain the differences in adaptation of these varieties of soybeans, even when in its natural position, is indicated by the results on the Putnam soil at Columbia in successive seasons (Table 18). In 1932 and 1933, the Morse variety was superior to the Virginia on this soil. In 1934, a season characterized by extreme drought and high temperatures, the Virginia was superior to the Morse.

TABLE 18.—YIELDS OF MORSE AND VIRGINIA ON PUTNAM SILT LOAM AT COLUMBIA IN DIFFERENT SEASONS.

Season	*Morse*	*Virginia*
1932	5506	4322
1933	3500	3181
1934	2232	2849

The differences in yields were accompanied by the differences in types of growth previously described. These data illustrate a change in growth type and a reversal of relative yields by these varieties on the same soil with different seasonal conditions. Five subsequent pot experiments in which both varieties were grown on several different soils with varying soil moisture levels failed to show any relation between the comparative yields of the varieties and the soil type.

It should be remembered that "soil type" is a broad term classifying soils with respect to general resemblance of a complex of physical and chemical characteristics. To use soil type to explain differences in the adaptation of these varieties of soybeans does not clearly define the problem. It should be possible to find some particular characteristics of the soils used in the field experiments which are correlated with the comparative yields of these varieties.

Furthermore, the field experimental plats on the various soil types are located at widely different parts of Missouri and climatic conditions between the experimental fields vary. Any variation in yield due to climatic difference between the fields would be confounded with difference due to soil type.

SOIL FERTILITY AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA

Differences in soil fertility have been generally offered as an explanation for the fact that under some conditions Virginia outyields Morse and under other the reverse performance occurs. A relation between soil fertility and the relative yields of Morse and Virginia has been indicated by several investigators. The opinion that Morse is superior on soils of high fertility and Virginia on soils of low fertility is confirmed, with one exception, by the writer's field experiments but not by his pot experiments. The writer's observations and evidence pertaining to the relation of soil fertility to this phenomenon may be divided as follows: (1) observations and yields from field and pot experiments with soil types of different productivity, (2) fertilizer trials and relative yields of Morse and Virginia, (3) comparative plant juice analyses, and (4) yields on soil and sand mixtures.

Results on Soil Types of Varying Productivity.—Morse and Virginia were grown in field plots on several soil types that varied widely in fertility levels (Table 19). Methods of soil analysis have been previously described.[21]

Evidence on the differences in productivity of the soil types used may be derived from the yields. Table 20 gives the average yield in pounds of hay per acre on the different soils used in 1932.

TABLE 19.—PARTIAL ANALYSIS OF SOILS USED IN FIELD EXPERIMENTS.

Soil Type	pH	Organic matter	Ex-change-Bases	Available*		
				N	P	K
		%	M.E.	lbs.	lbs.	lbs.
Putnam silt loam	5.8	4.18	14.50	32.2	5.1	2022
Oswego silt loam	5.1	3.43	9.58	16.7	12.9	1674
Lebanon silt loam	5.7	2.21	6.18	4.8	6.8	1812

*Nitrogen, lbs. per acre as N; Phosphorus, lbs. per acre as P_2O_5; Potassium, lbs. per acre as K_2O.

TABLE 20.—YIELDS OF MORSE AND VIRGINIA ON DIFFERENT SOIL TYPES IN 1932. (POUNDS PER ACRE, AIR DRY WEIGHT).

Soil Type	Morse	Virginia	Average
Putnam silt loam	5506	4322	4914
Wabash heavy clay	5285	4742	5013
Summit silt loam	4520	4184	4352
Oswego silt loam	3205	2804	3004
Lebanon silt loam	1834	2192	2013

These data indicate a decided range in soil fertility as measured by organic matter content and exchangeable bases and in productivity as measured by yield. The greatest correlation to be noted is that between the yield and the milli-equivalents of exchangeable bases. On the Lebanon, the soil having the lowest productivity, the Virginia outyielded the Morse. On the more fertile soils the Morse outyielded Virginia. These results indicate that Virginia excels on soils of low fertility and low productivity.

An exception to this conclusion is found in the yields on the Putnam in 1934, when the relative yields as well as the growth types were reversed. This reversal must be explained by other than soil fertility conditions unless we conclude that high temperature and low water content of the soil affected the availability of mineral nutrients or affected some other element determining soil fertility.

Furthermore, Morse outyielded Virginia on all of these soils in pot experiments at Columbia (Table 5) even though the range in productivity was great. As in field experiments the lowest yield was produced on the Lebanon but even on this soil type the Morse variety was superior to the Virginia. Three explanations are possible: first, the differences secured in the field plats were due to factors other than soil fertility; second, the soil when transported to Columbia and placed in pots had its physical or chemical character changed so that its productivity no longer could be compared with its productivity in the field; or third, the mineral constituents of the tap water* used in watering affected the fertility of the soils in the pot experiments.

Fertilizer Treatments and the Relative Yields of Morse and Virginia.—If Morse is superior to Virginia on soils of high fertility, then fertilizer treatments should increase yields of Morse relatively more than they increase yields of Virginia. With soils of low fertility on which Virginia usually outyields Morse, the comparative yields of these varieties might even be reversed by the application of sufficient fertilizer. Occasionally in the writer's experiments, yields of Morse were increased more than those of Virginia by the use of fertilizers, but in no instance were the relative yields reversed.

Fertilizer treatments consisting of sodium nitrate, superphosphate, 4-16-4 and lime, potash, and fine lime were applied to Putnam, Oswego, and Lebanon soils in 1932 and to the Putnam in 1933. On the Putnam soil Morse was definitely superior to Virginia on all treatments both in 1932 and 1933. On the Oswego also Morse produced with all treatments greater yields than the Virginia, but on the Lebanon Virginia outyielded Morse with all treatments.

Application of sodium nitrate produced a small increase in yield over the check on the Putnam in both 1932 and 1933 but decreased the yields on the Oswego and Lebanon. Superphosphate and 4-16-4 plus lime increased yields on the Lebanon but not on the other soil types. Potassium had no significant effect on any soil type. Fine lime decreased yields on the Lebanon but increased them slightly on the other soils. The only evidence that fertilizer applications will increase the yields of Morse more than the yields of Virginia is from the applications of phosphorus on the Lebanon and Putnam in 1932 and application of 4-16-4 on the Lebanon. In these instances yields of Morse were increased more than those of Virginia.

Fertilizer applications (with one exception on the Lebanon) were not made to pot experiments since Morse always outyielded Virginia on unfertilized soil in the pot experiments.

A change in growth type of certain plants by the use of "rare" elements has been reported[11]. As the shortened internodes produced by the Morse at Cuba were somewhat similar to some of these deficiency diseases, plots of Morse and Virginia at Cuba in 1934

*Analysis of tap water, University of Missouri well No. 1, 700 feet; and well No. 2, 970 feet Dearborn Laboratories, Chicago, 8/11/31.

	Mg. per liter		Mg. per liter
SiO_2	12.77	Na_2 and K_2CO_3	109.50
Fe and Al oxides	0.787	Na and KCl	29.10
$CaCO_3$	139.97	Na and KNO_3	Traces
$CaSO_4$	None	Loss, etc.	5.68
$MgCO_3$	13.32	Total mineral	377.91
Na_2 and K_2SO_4	66.78	Organic matter	Trace

were treated with a mixture of the "rare" elements. Either the method of application or the concentrations used injured most of the plants. However, no effect of the treatment on the type of growth could be observed. Treated plants of the Morse variety which were uninjured by application of the elements produced a low bushy growth type with short internodes characteristic of the plants in the untreated plots.

Studies of Expressed Plant Juice.—Analyses were made of the expressed juice of Morse and Virginia varieties of soybeans to determine if differences between the varieties could be found in the nitrate, phosphorus, or potassium concentrations of the juice. Differences in the concentrations of these elements might indicate differences in the feeding power of the varieties in question. Nitrogen, phosphorus, and potassium concentrations were studied in view of the important position of these elements in plant nutrition.

For plant juice analyses Morse and Virginia soybeans were grown on a series of fertilizer plats on Putnam, Oswego, and Lebanon soil types in two seasons. Complete details of this investigation, including the plant materials used, methods of procedure, methods of analyses, and results of analyses have been previously published[21].

An analysis of variance covering all varietal differences and interactions have been applied to the data on the concentrations of the mineral elements studied in the expressed plant juice. The results are given in Table 21.

TABLE 21.—ANALYSIS OF VARIANCE OF EXPRESSED PLANT JUICE DATA.

Source of Variance	Degrees Freedom	Sum of Squares	Mean Square	F*
P.P.M. Nitrates in Expressed Plant Juice—				
Between Means of Varieties	1	78	78	1.25
Interaction:				
Variety—Season†	1	--	--	---
Variety—Soil	2	257	129	2.06
Variety—Treatment	4	3877	969	1.58
P.P.M. Phosphorus in Expressed Plant Juice—				
Between Means of Varieties	1	82	82	.27
Interaction:				
Variety—Season	1	33	33	.11
Variety—Soil	2	75	38	.12
Variety—Treatment	4	304	76	.61
P.P.M. Potassium in Expressed Plant Juice—				
Between Meams of Varieties	1	612	612	.89
Interaction:				
Variety—Season	1	8	8	.003
Variety—Soil	2	55	28	.11
Variety—Treatment	4	4855	1214	1.66

*Ratio of larger mean square to mean square of error.
†Plant juice analyzed for nitrates in one season only.

From this table it may be observed that there are no significant differences between varieties or for the interaction of variety with season, interaction of variety with soil, or interaction of variety with treatment. Thus no significant differences between these two varieties were found in the concentrations of nitrates, phosphorus, or potassium in the expressed juice.

Relative Yields of Morse and Virginia on Soil and Sand Mixtures.—A valid objection to using different soil types as a criterion for measuring the effect of fertility levels on yields is that the soils do not vary uniformly in their fertility. For example the Putnam is superior to the Lebanon with respect to exchangeable bases, but is actually lower in the amount of available nitrogen and phosphorus present. In addition there is a wide variation in the physical character of these soils. The confounding of seasonal conditions with soil type has already been mentioned in connection with field experiments carried on at different places or in different years.

In order to secure a soil which would vary uniformly in mineral nutrients in the different fertility levels, white quartz sand was mixed in varying proportions with Putnam silt loam. The method of procedure has been described and the results are recorded in Table 12. The comparative yields of dry matter (air-dry weights) are shown graphically in Figure 5.

In this experiment Morse was superior to Virginia at all fertility levels studied but particularly at the higher levels. In view of the low level of fertility originally present in the mixture of soil (10%) plus sand (90%) it would seem that further reduction of the level of nutrition would not result in the crossing of the yield curves (Figure 5). However, the soil in this experiment was watered with tap water which, as has been pointed out, contains considerable calcium and other bases. It is possible, therefore, that during the experiment the level of some essential mineral element was raised sufficiently high by the addition of the tap water to permit Morse to outyield Virginia.

The plants in this experiment showed a decided potassium deficiency. Symptoms first appeared in the Morse variety on the low fertility series after about twenty days growth, and later on the next two fertility levels. They appeared in the Morse before they did in the Virginia. This may have ben due to the loss of the cotyledons by the Morse variety a few days before they were dropped by the Virginia. In view of the condition of the plants and the composition of the tap water it seems probable that potassium, nitrogen and phosphorus were little affected by the tap water addition.

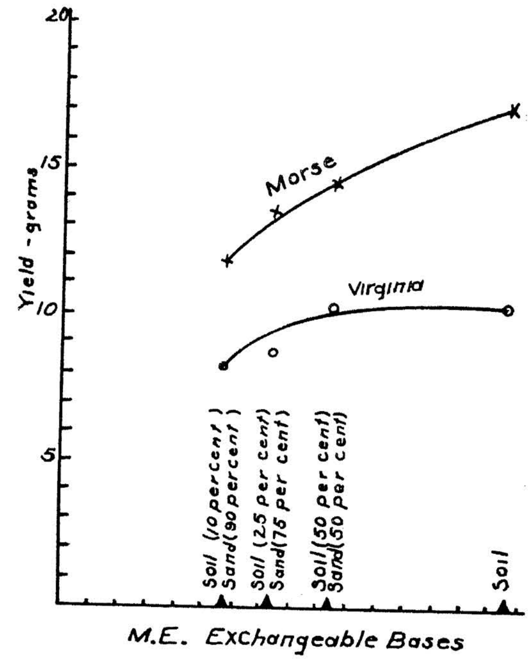

Fig. 5.—Relation of yield to the M.E. of exchangeable bases in sand and soil mixtures.

The situation with regard to calcium is another matter. It would be desirable to carry this type of investigation further both in soil and in water culture, determining the relative response of these two varieties to deficiencies of various essential elements, calcium in particular. Some support to this suggestion is given by a comparison of the exchangeable bases in the sand-soil mixtures and in the soils used in the field experiments summarized in Tables 11 and 19. The milli-equivalents per 100 grams of dry soil in the Lebanon silt loam on which Virginia outyielded Morse is about the same (6.18) as that in the least fertile soil-sand mixture (5.76). In the latter Morse outyielded Virginia. If exchangeable bases are significant in determining relative yields of Morse and Virginia soybeans the fertility in the least fertile soil-sand mixture might have been raised by the addition of the tap water to a level above the critical point.

The studies made by the writer on the relation of soil fertility to the relative yields of the Morse and Virginia soybeans show the following:

1. With one exception Morse outyielded Virginia on soils of high fertility.
2. On the less fertile soils the difference in yield between the two varieties diminished.
3. In the field Virginia outyielded Morse on soils of low fertility. Application of fertilizers did not reverse this order of yields.
4. In pot experiments Virginia did not outyield Morse even on soils of very low fertility.

It appears that soil fertility will not account completely for differences in yield between the two varieties, but it may be an important factor in their adaptation. Further experiments should be performed on soil in which various of the essential elements are deficient, particularly calcium.

SEASON AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA

In the discussion of soil type and its relation to the relative yield of these varieties of soybeans, two important results were noted: first, when soils were brought to Columbia, placed in pots, and the two varieties grown under the same environmental conditions Morse was superior on all types, contrary to the results of that season on the same soil types in the field; second, over a period of three seasons on the Putnam soil type at Columbia, a reversal in comparative yields occurred in one season. This seems to indicate that season may have an important bearing on the comparative yields.

The importance of season is difficult to measure for it is impossible to obtain a random sample of seasons with the few years data available. To say that season is responsible for the character of growth and relative yield does not clearly define the problem since season is determined by a number of variable conditions, chief of which are temperature and rainfall. Furthermore, extreme conditions of temperature and rainfall which may occur in any season may have a greater influence in determining the comparative growth and yield than the average of these conditions for a number of seasons. The season in which the reversal in yield was obtained on the Putnam was marked by extremely high temperatures and deficient rainfall. These particular factors, therefore, were studied in more detail.

SOIL MOISTURE AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA

Precipitation, as reflected by soil moisture content, is one of the important seasonal characteristics which materially influences crop growth. This suggested the relation of soil moisture to the relative yields of these varieties. Two methods of investigating this question are possible: first, a correlation of field plat varietal yields with precipitation, and second, an experimental study of the relative yields of these varieties under controlled soil moisture conditions.

Although soil moisture is a result of precipitation, the total amount that may be held by any soil type as well as the amount available to the plants is modified by the physical characteristics of that soil. The wide range in water holding capacity of the respective soil types used in field experiments may be observed in Table 22. (Water holding capacity was determined by the use of a standard Hilgard moisture cup.) The Lebanon soil which has the lowest

TABLE 22.—WATER HOLDING CAPACITY OF SOIL TYPES USED IN FIELD EXPERIMENTS.

Soil Type	Water Holding Capacity (Percentage)
Lebanon silt loam	36.0
Putnam silt loam	45.0
Oswego silt loam	45.0
Summit silt loam	50.0
Wabash heavy clay	66.0

water holding capacity is low in organic matter, has a tight compact subsoil, and is regarded as being less drought resistant than the Putnam or Summit. Since the Lebanon was the only soil on which Virginia consistently outyielded Morse, the possibility of the superiority of Virginia on this type being due to its better ability to withstand drought conditions was considered. This consideration was supported by the observation that Virginia outyielded Morse on the Putnam soil at Columbia in 1934. In this year the precipitation at Columbia during May, June, and July totaled 5.58 inches in contrast with 10.50 inches for the same months in 1933 and 11.34 inches in 1932.

To determine the effect of soil moisture on the comparative yields of these varieties several pot experiments were performed. These have been described in the topic "Basic Experiments" and the results recorded in Tables 6 to 10. In the first experiment in which the two varieties were grown on Lebanon and Putnam soils at low, medium, and high moisture content, Morse was superior to Virginia in yields of dry matter with all treatments on each of the soil types. No interaction of varieties with soil moisture treatment was observed. In the next experiment, the two varieties were grown at high and low moisture levels on five soil types. In this experiment, Morse was again superior to Virginia on all of the high moisture but not on all of the low moisture treatments. This may be observed from the summary in Table 23.

TABLE 23.—RELATIVE YIELDS OF MORSE AND VIRGINIA AT LOW AND HIGH SOIL MOISTURE.

Soil Type	Grams (air dry weights) per Pot			
	Low Moisture		High Moisture	
	Morse	Virginia	Morse	Virginia
Putnam	21	13	69	67
Lebanon (unfertilized)	20	20	68	64
Lebanon (fertilized)	27	30	127	110
Oswego	25	26	101	94
Union	14	16	36	31
Average	21.4	21	80.2	73.1
Standard Error 1.74				

From Table 23 the following observations may be made: first, Morse was significantly superior to Virginia at high moisture on all soil types; second, Morse was superior to Virginia at low moisture in this experiment on the Putnam but not on the other soil types.

In the above experiments soil moisture was controlled by weighing, but this method was not entirely satisfactory. In later experiments the soil moisture was controlled by the condition of the plant, water being added to the low moisture series just as the plants began to wilt. In these experiments Morse was superior to Virginia on all soil moisture treatments on each soil type.

In the low moisture series of all the above experiments, the plants were grown with deficient moisture from the time the plants were well established until time of harvesting. Examination of weather data for the individual seasons and localities in which Virginia outyielded Morse revealed that the precipitation was usually low in the early part of the growing season but was increased sufficiently to insure nearly optimum soil moisture in the latter part. Much growth was made in the latter part of the season after soil moisture conditions became more favorable. This suggested that the superiority of the Virginia in such seasons might be due to its ability to resume growth after periods of drought.

Accordingly the two varieties were grown in two experiments in which part of the plants were kept at low moisture for 60 days while the remainder were kept at low moisture for 34 days and the soil moisture then increased to optimum for the remaining 26 days. In these experiments Morse was again superior to Virginia on all soil moisture treatments and this superiority was increased with an increase in soil moisture during the latter part of the growth period, contrary to our field observations. This is shown by the data in Table 24.

TABLE 24.—RELATIVE YIELD OF MORSE AND VIRGINIA WITH SOIL MOISTURE TREATMENTS.

Soil Moisture Treatment	Grams (air dry weight) per Pot			
	First Experiment		Second Experiment	
	Morse	Virginia	Morse	Virginia
Low Moisture (60) days)	4.96	2.52	4.48	1.99
Low Moisture (34 days); High Moisture (26 days)	7.88	3.87	6.44	3.34
Standard Error 0.36				

These experiments were performed to answer the question of the effect of soil moisture on the relative yields of Morse and Virginia. In appraising the experiments with that in view, several observations may be made:

1. In all except two of the experiments Morse was superior to Virginia on all soil moisture treatments on each of the soil types.

2. The yield of Virginia equalled or exceeded that of Morse in one experiment only and that on but part of the soil types. On none of these "soil types" were the yields of Virginia significantly superior to yields of Morse. Criticism may be directed at the maintenance of the low moisture content of the soil. The moisture content could not be kept low as consistently as had occurred in the field in certain years. Between watering periods it would drop to a low level while upon the addition of water the soil moisture would rise, so that a constant low level was not maintained.

3. In most of the experiments, the superiority of Morse over Virginia was so pronounced at both low and high moisture levels that it is doubtful whether varying only soil moisture would cause Virginia to outyield Morse.

TEMPERATURE AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA

One of the important climatic factors affecting plant growth is temperature. The reversal in relative yields at Columbia in 1934 occurred during a season marked by low precipitation and extremely high temperatures. Subsequent pot experiments did not produce reversals in relative yields by deficient soil moisture treatments. Is temperature then a factor in determining the relative yields of Morse and Virginia? Did the reversal in 1934 at Columbia result from continued high temperatures? To answer these questions it is necessary to give consideration to the effect of temperature.

The relation of temperature to relative yields may be studied by two methods: first, by comparing field plat yields with temperatures recorded by nearby weather bureau stations; and second, by growing these varieties at controlled temperatures and studying relative yields. Lack of temperature-controlled chambers prevented the use of the latter method so that only correlations of temperature and field plat yields may be made.

The yield results for 1932, 1933, and 1934 at Columbia and Cuba were chosen for these comparisons. During these seasons the Morse was superior in hay yields at Columbia in 1932 and 1933 but inferior to Virginia in 1934. The Virginia variety was superior in hay yields at Cuba in all three years.

Temperature records at Columbia were secured from the United States Weather Bureau. Temperature records from the United States Weather Bureau station at Rolla, Missouri, were used for Cuba, Rolla being the nearest official weather bureau station. Maximum and mean daily temperatures in degrees Fahrenheit were recorded for the period May 15 to August 31 for each of the years, this period being considered as the approximate growing season for the soybean varieties. Five-day averages were made of these daily temperatures and the sums of the five-day averages calculated. The sum of these five-day averages of maximum and mean daily temperatures give a comparative value for the heat received by the soybeans during the growing season of 1932, 1933, and 1934.

It is evident that such methods of studying the effect of temperature on the yield of plants are only approximate. They do not measure accurately the effect of extremes in temperature, such as those in 1934 at Columbia when the maximum was 108 to 111 degrees Fahrenheit, and which may have had a pronounced influence on the plants. It may be assumed, however, that if the yield of either variety is superior under conditions of high temperature it should be superior in those seasons which show a high "heat value" as determined by the above method.

The "heat values" as determined by the sum of the five-day averages from May 15 to August 30 for the different seasons are recorded in Table 25.

At Columbia, a higher value is noted for 1934 than for either 1932 or 1933. In 1934 at Columbia, Virginia outyielded Morse, the reverse of results in 1932 and 1933. This indicated that Virginia at Columbia may be superior under conditions of high temperature.

TABLE 25.—"HEAT VALUES" AT COLUMBIA AND CUBA, MISSOURI.

Year	"Heat Value" from Mean Daily Temp.		"Heat Value" from Maximum Temp.	
	Columbia	Cuba	Columbia	Cuba
1932	1381	1395*	1572	1574*
1933	1369	1393*	1593	1592*
1934	1477*	1459*	1696*	1654*

*Indicates years in which Virginia outyielded Morse in pounds of dry matter per acre.

At Cuba considerable variation may be found in the "heat values" but Virginia outyielded Morse each year. Comparisons from mean daily temperatures show that the "heat value" at Cuba is only fourteen degrees larger than at Columbia in 1932 and is three degrees less in 1933. Yet in both of these years Morse was superior at Columbia and Virginia at Cuba.

From these results two observations may be made: first, Virginia outyielded Morse at Cuba at "heat values" which did not produce the same relative yields at Columbia; and second, comparisons between Columbia and Cuba showed reversals in relative yield in seasons when the differences in "heat values" between these places were negligible.

LIGHT AND THE RELATIVE YIELDS OF MORSE AND VIRGINIA SOYBEANS

Light is a climatic factor that greatly influences crop growth. It affects both the total growth and the form of the plant. In the cases where Virginia outyielded Morse the latter was characterized by a definite type of growth. Could this be accounted for by the effect of light? The influence of light is determined by its intensity, quality and duration. What effect do each of these factors have on the relative yields of Morse and Virginia soybeans?

In all pot experiments performed in winter and spring light conditions were decidedly different from those in field experiments. The plants were grown in glass greenhouses and the short winter days were lengthened by the use of electric lights. Many of the days during this season were cloudy and electric lights were used throughout the entire day. In the pot experiment performed in the summer of 1933 the plants were in an open shed covered with cell-o-glass, which resulted in some shading and which also altered the quality of the light. In none of these experiments did Virginia outyield Morse and in none of them did the Morse variety produce the type of growth produced in the field at Cuba or in the field at Columbia in 1934.

Judging from the results of a pot experiment performed in the summer of 1932, it is not believed that the failure to secure in the greenhouse a growth of the Morse variety typical for the Lebanon soil at Cuba is due to reduced light intensity. This experiment was performed out of doors at Columbia with different soil types including the Lebanon and the plants were exposed to the direct sunlight as in adjacent field plats. In both pot and field experiments the Morse was superior in yield to the Virginia and in neither case did it make the type of growth which it made at Cuba in the same season.

The effect of a decrease in intensity of light on the comparative growth and yield for these two varieties was studied at Cuba in 1934. One rod-row of each variety was shaded with a single thickness of burlap throughout the entire growing season. A 6½-foot portion of each row was harvested for yield and measurement of growth. General observation showed that shading did not materially affect the character of growth of the Morse variety. The plants of both varieties grown under the shade were taller than those grown in the direct sunlight but the low type of growth with shortened internodes which characterized the Morse plants grown without shade was characteristic also of those grown with shade. The yields in pounds (air dry weight) of the rows harvested are given in Table 26.

TABLE 26.—EFFECT OF SHADE ON YIELDS OF MORSE AND VIRGINIA.

	Morse *lbs.*	*Virginia* *lbs.*
Shade	.23	.29
No shade	.27	.37

These results indicate Virginia to be superior in production of total dry matter in both shade and direct sunlight at Cuba. These yields represent six and one-half foot portions of a single row with no replication. The length of the internodes of these plants was measured and the results are shown in Fig. 6. These measurements indicate that the varietal differences in type of growth, as measured by internode length, cannot be accounted for by a reduction in intensity of light.

The possible relation of length of day to the relative yields of Morse and Virginia was suggested by the short, bushy plants of Morse with shortened internodes which were similar in appearance to those secured by Garner and Allard[7, 8, 9, 10] when they grew soybeans with decreased length of day. Similar differences in growth habits were observed by Hollowell[13] with the Minsoy variety when it was grown in different latitudes.

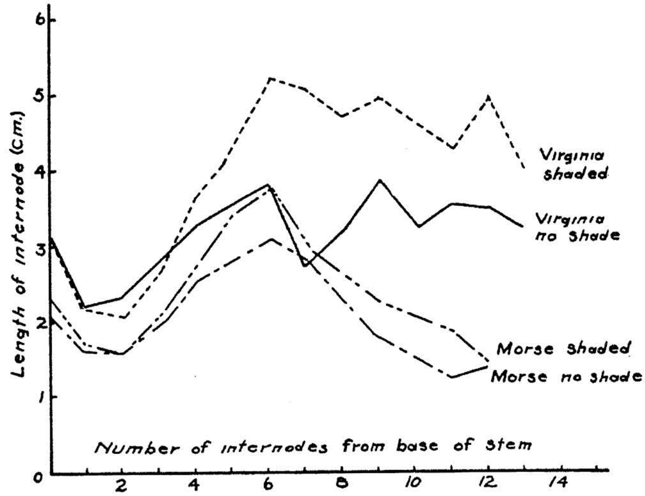

Fig. 6.—Effect of shade on the length of the internodes.

The short bushy type of the Morse consistently occurred on the Lebanon soil at Cuba, which is located farther south than any of the other field test plats. The daylight period at this latitude is shorter during the growing season than at the other experimental fields where the varieties were compared. This suggested that the differences in adaptation of Morse and Virginia may result from differences in the duration of the daylight period and that the superiority of Virginia at Cuba may result because it is less sensitive to a shortening of the daylight period.

To test the effect of day lengths experimentally, the two varieties were grown in the greenhouse at 7 and 15-hour day lengths. With the 15-hour day both varieties produced a tall, sparsely branching growth similar to that produced at Columbia in the 1932 and 1933 seasons. When the light period was reduced to seven hours, the growth of both varieties was materially reduced. The height of the Morse, however, was suppressed more than that of Virginia. This decrease resulted

TABLE 27.—EFFECT OF DAY LENGTH ON YIELDS OF MORSE AND VIRGINIA.

Day Length	Yield of Dry Matter (Air dry weights)	
	Morse	Virginia
	gms.	*gms.*
7 hours	6.14	6.11
15 hours	16.83	13.00

from reduction in both number and length of internodes. The lengths of the internodes together with the yields of dry matter are recorded in Table 13 and the yields are summarized in Table 27.

The yield of Morse was definitely superior to the yield of Virginia with a 15-hour day but not when the light period was reduced to seven hours. With the 7-hour day, the growth type of the Morse was similar to the type produced under those conditions where Virginia outyielded Morse in the field. This was the only pot experiment in which the type of growth of the Morse was similar to the type secured in the field at Cuba. This suggests that length of day may be a factor in the adaptation of these varieties.

There are two important negative observations, which must not be overlooked; first the small difference in day length between Columbia and Cuba; and second, the results obtained in the 1934 season at Columbia. The latitude of Cuba and Columbia is 38 degrees and 3.5 minutes, and 38 degrees and 57 minutes, respectively. The difference in day length between the experimental fields located at Cuba and Columbia during the normal flowering period for soybeans (August 1 to 15) is six minutes. The difference in the daylight period in the above experiment was eight hours, and even then a complete reversal in relative yield was not secured. In the 1934 season at Columbia a reversal in relative yield and growth type occurred with no alteration in day lengths from previous seasons.

There are certain aspects of this problem which have not been investigated. It is possible that the effect of short daylight periods may be intensified by other unfavorable growing conditions such as low soil fertility, unfavorable soil moisture, or high temperature. Interaction of such factors with a shortened light period might accentuate its influence but the small difference in the daylight period between Cuba and Columbia does not seem to offer a complete explanation for the reversal in relative yields.

DISCUSSION

In this paper attention is called to the following:

The relative yields of Morse and Virginia grown under similar conditions in the field change from a situation where Morse outyields Virginia to one where Virginia outyields Morse. This reversal in relative yields is associated with a change in type of growth in the Morse. This is of practical importance because of its relation to the general problem of varietal adaptation as measured by yield.

What factors or complex of factors are responsible for this phenomenon? Several factors associated with soil and climate may be suggested, including: soil type, soil fertility, season, soil moisture, temperature, and light. What is the importance of each?

This phenomenon is associated with soil type; nevertheless, the association is not consistent. For example, on the Putnam soil at Columbia Morse outyielded Virginia only two of three years in which they were tested by the writer. Furthermore, in pot experiments Morse outyielded Virginia regardless of the soil type used. It is recognized that soil type is neither a constant nor a specific factor. A particular soil type may vary widely in its fertility, to a certain extent it may vary in physical properties, and in the field its effect is influenced by climatic factors.

The relative yields and the growth type of Morse and Virginia varieties of soybeans are associated to some extent with seasonal conditions also, since the relative yields vary on a particular soil type with different seasons, as occurred on the Putnam at Columbia. Season also is a complex of factors which may affect plant growth through its effect upon the soil as well as directly.

To investigate systematically all of the factors which may be involved in the relation of soil type and climate to growth has not been possible in this work. Those factors which appeared to merit the most consideration were soil fertility, since it may cause an important difference between the soil types used; water content of the soil, because its variation may be an important factor in growth between seasons; temperature, for the same reason; and light, because it is an important formative factor in plant growth and because the growth type in Morse associated with those instances where Virginia outyielded Morse is a formative change.

Can this phenomenon be ascribed to differences in soil fertility? A survey of the field results would suggest this, since Morse usually outyields Virginia on the fertile soil types while Virginia usually outyields Morse on the less productive soil types. The relation, however, cannot be stated with certainty since conditions other than soil fertility vary in the field. Furthermore, pot experiments using these soil types under controlled conditions do not duplicate field results.

The pot experiments in the greenhouse were performed with 15-hour day lengths. The failure to duplicate field results may be due to the effect of the longer day. However, in two seasons both the Lebanon and the Putnam soils were used in pot experiments at Columbia with day lengths corresponding to those of the growing season. If length of day was a factor of significance in the pot experiments, it must have been a very small factor, since the difference in day length between Columbia and Cuba during the growing season is only about six minutes. It would be desirable to perform pot experiments at Cuba in addition to those carried on at Columbia.

The results of pot experiments may have failed to duplicate results of field experiments because of the disturbance of the soil in moving it from its natural position. It is impossible to overcome this entirely. Lebanon soil in some cases yielded as well as Putnam soil in pot experiments, which suggests that the disturbance in potting a soil changes its yielding capacity. However, the soil and sand mixtures in which fertility was reduced to a very low level failed to produce conditions under which Virginia outyielded Morse. In this case the deficiency as indicated by the appearance of the plants was probably a potassium deficiency. The Lebanon soil is low in phosphorus, but applications of phosphorus to field plats on this soil type did not reverse relative yields nor alter the growth type of the Morse. The Lebanon soil is also low in calcium. The pot experiments may have failed to duplicate the field experiments because the former were watered with tap water rather than distilled water, thereby adding a considerable quantity of calcium. It is true that additions of fine lime to the field plats at Cuba did not increase the yield of either variety. However the seasons in which these fertilizers were applied were extremely dry so that they may not have been effective in modifying the soil or may not have been efficiently used by the plant. It would be desirable to perform experiments in which calcium and other essential elements were deficient to determine whether it might not be posible to find reproducible conditions which would cause Virginia to outyield Morse. If the phenomenon is due to a deficiency of one or more of the essential elements, then it should be possible to cause Virginia to outyield Morse and to produce the change of growth form in Morse by growing the two varieties in cultures deficient in those elements. Furthermore, it should be possible to cause Morse to yield as much as Virginia and to change the growth form of Morse by adding to the Lebanon soil at Cuba sufficient of the element or elements in question.

Although season seems to be correlated in some way with the phenomenon under investigation, its effect cannot be ascribed to either precipitation, as evidenced by soil moisture, or to temperature. However, no controlled experiments on temperature were performed and the effects of this factor, particularly on short or critical periods of growth, may be significant.

Light intensity does not appear to be related to the phenomenon since shading at Cuba had no effect on relative yields nor on the characteristic growth form of Morse. Length of day may be of some importance though no experiments were performed in which the difference in day length between Columbia and Cuba (6 minutes) was approximated. It is difficult to see how this small difference can be effective, although the only case in which the short bushy growth of Morse soybeans was produced in pot experiments was with materially shortened days.

In general Virginia outyields Morse under unfavorable growth conditions, indicating that its superiority may be due to characteristics which make the variety more resistant to such conditions than is the Morse. Nevertheless, this was not true for low moisture conditions in the pot experiments performed nor for the limited fertility conditions produced in sand and soil mixtures as used by the writer.

It is obvious that the problem is a complex and important one and that it requires more extended and complete study of the various factors involved. Careful field observations at many stations and extending over a period of years supplemented by laboratory and greenhouse studies under controlled conditions seem necessary for its solution.

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