SOME PRELIMINARY EFFECTS OF FERTILIZERS AND HARVESTING TREATMENTS ON THE GROWTH OF ASPARAGUS IN SOUTHWESTERN ONTARIO

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Thesis

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by

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THESIS

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INTRODUCTION

PRODUCTION IN CANADA

The acreage devoted to asparagus in Canada in the year 1921 amounted to 177 acres (38). The most recently published statistics (6) show that this figure has been increased by over 800 per cent, as the total acreage in 1936 amounted to almost 1700 acres. This expansion in asparagus production has been brought about largely by the interest which the processing industry has shown recently in Canadian-grown green asparagus, for it is estimated (28) that 74 per cent of the asparagus produced in Ontario is handled by the canning industry. In 1934, the Dominion Outlook (6) reported that 56,000 cases of asparagus were processed in Canada, and in 1936 the same source reported that this figure had increased to 123,000 cases. (see table 1 below):

Table 1.--Acreages of asparagus in Canada and Ontario and the amount processed and exported

Year	Acreage		Packed (Canada)	Exported to United Kingdom
	Canada	Ontario		
			cases	cases
1921	177	-	-	-
1931	1,383	1,212	-	94
1932	-	-	-	-
1933	-	-	-	1,700
1934	-	1,050	56,000	6,400
1935	-	1,250	86,000	7,300
1936	-	1,345	123,000	-
1937	1,698	1,479	-	16,200

Note.--Figures given where available.

Sources:

H. H. Ponton (30)
Monthly Crop Report (35)
Dominion Outlook (6)
Ontario Outlook (28)
Canada Trade Census (7)
Agricultural Census (38)

PRODUCTION IN ONTARIO

An important factor which has contributed to the increase in acreage of asparagus is undoubtedly the possibility of export trade under the Empire Preference Scheme set up in 1932. The total exports to the United Kingdom (table 1) during 1937-38 amounted to 16,200 cases as compared with 94 cases in 1931-32. The Provincial Monthly Crop Report, 1938, (35) listed a total of 12 countries which received shipments of asparagus from Ontario in 1937-38. The proportion shipped for export is still small, but recent increases in acreage in Southwestern Ontario are being made to process asparagus almost exclusively for the export trade.

Over 82 per cent of the total acreage devoted to asparagus in Canada is found in Ontario, the remainder being divided between Quebec and British Columbia. The acreage in Ontario has increased almost 25 per cent during the past six years, and this increase has been accompanied by expansion in previously unimportant areas of production. Estimates prepared by Mr. H. H. Ponton (30) in 1937 show a total of 1,479 acres of asparagus in Ontario which were distributed in the following way: Niagara 43 per cent, Burlington 17 per cent, Essex-Kent-Lambton 15 per cent, Peel-York 12 per cent, and the remaining 13 per cent distributed among eight counties (see table 2). The yields per acre according to Mr. Ponton's figures of 1937 vary from 1.5 tons in Elgin-Oxford district to as low as 0.5 tons in the less important counties; the average production figure being approximately one ton per acre. This average figure (one ton per acre) is based on the total acreage estimates which would include nursery plantations and plantations of varying age, so that it does not represent conditions in mature plantings.

Figure 1.--Acreage and production of asparagus in Southern Ontario in 1937

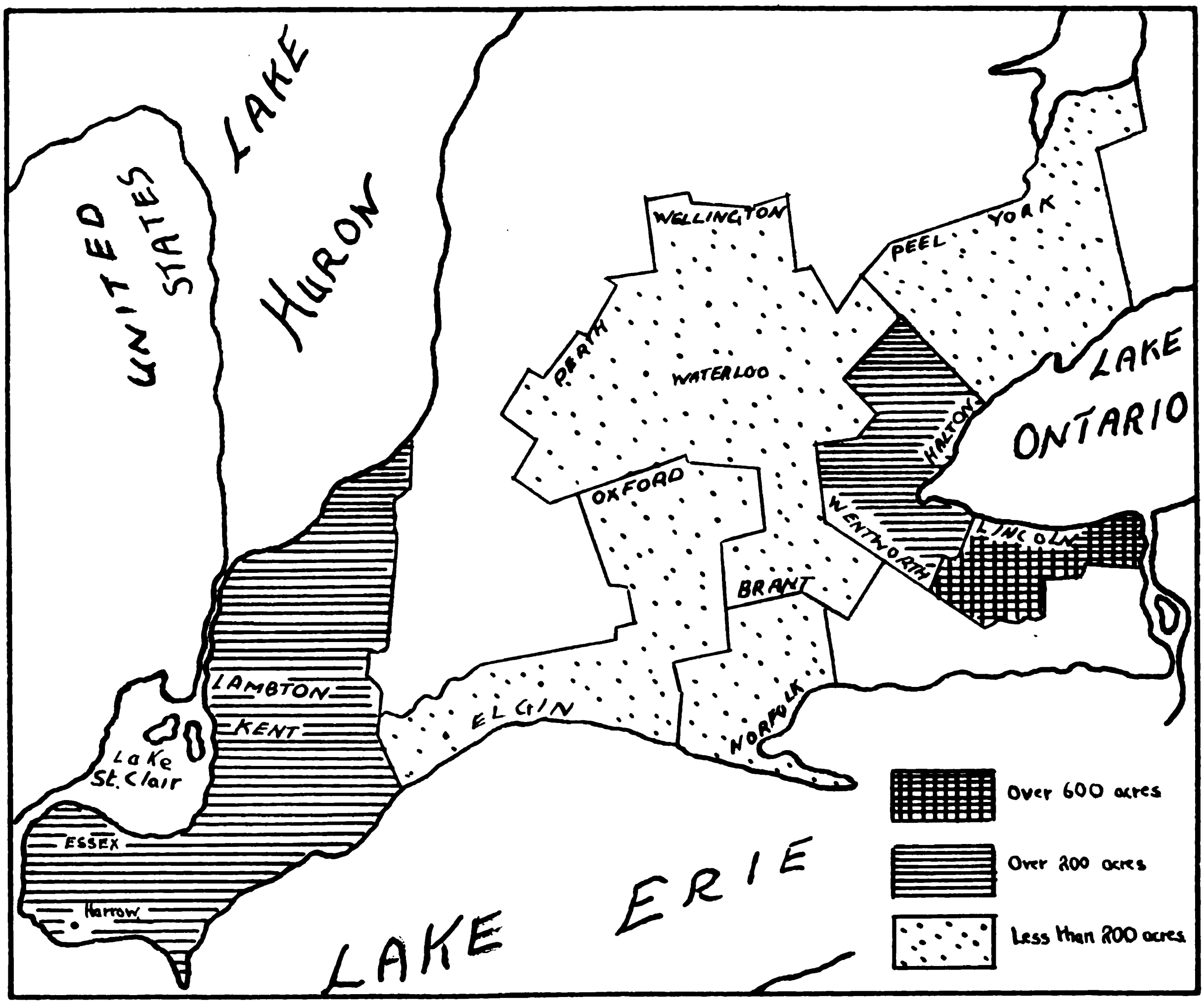

Table 2.--Acreage and production of asparagus in Southern Ontario in 1937

District	Acres	Acreage	Production	Production	Production per acre
		%	tons	%	tons
Lincoln	640	43	640	43	1.0
Halton-Wentworth	245	17	245	16	1.0
Essex-Kent-Lambton	229	15	244	16	1.07
Peel-York	175	12	175	12	1.0
Elgin-Oxford	75	5	112	8	1.5
Norfolk	60	4	50	3	0.8
Perth-Wellington-Waterloo-Brant	55	4	30	2	0.5
	1479	100	1496	100	1.01

Source: H. H. Ponton (57)

PRODUCTION IN SOUTHWESTERN ONTARIO

The area known as Southwestern Ontario included in the title of this thesis covers the Counties of Essex, Kent, Lambton, Elgin, and Oxford, which in 1937 accounted for 27 per cent of the total acreage planted to asparagus in Ontario. (figure 1). Southwestern Ontario is the earliest-producing area in Canada and only occasionally experiences severe frosts after growth begins. The soils along the shores of Lakes Erie and Ontario are also admirably suited to the culture of asparagus in that they are deep, fairly well drained, and are easily cultivated regardless of the time of year. They range in texture from pure sand to clay loam underlain by clay or sand.

STATEMENT OF THE PROBLEM

Harrow is located in Essex County in an area where the most important horticultural crop grown is tobacco. During the past 15 years fruit and vegetable crops have increased in importance and are being grown to some extent on soils which formerly grew tobacco. The type of soil best adapted to the culture of tobacco is a yellow to brown sand which has a tendency to be low in potash, available nitrogen, and organic matter, and with a medium reserve of phosphorus. The culture of tobacco demanded very careful adherence to the most up-to-date fertilizer recommendations and the Experimental Station at Harrow was in a position to assist the tobacco grower. There was, however, a lack of available information as to the best method of fertilizing these soils for the production of asparagus, and it was with the intention of obtaining more information regarding the fertilization and culture of asparagus that the experiments reported here were begun at Harrow in 1931. Information regarding fertilizer practices based on experiments carried out elsewhere, either in Canada or in the United States, could only be of general interest as the soils of this immediate area are slightly different from those described by other investigators as typical asparagus soils. The treatments, therefore, were designed to include comparisons of chemical fertilizers alone, manure alone, various combinations of manure and chemical fertilizers, and time of application of nitrogen, together with one plot to demonstrate the danger of extending the cutting season during the early years of growth.

REVIEW OF LITERATURE

FERTILIZERS

The edible spears of the asparagus plant have been held in high regard ever since the Romans gave this vegetable the publicity which later introduced it into Northern Europe. On looking into Johnson's History of English Gardening 1829 (18) mention of asparagus is found in Grecian and Roman literature. Cato is cited in 150 B. C., in his suggestions regarding the culture of asparagus, as writing that an "easily worked, deep, rich, moist soil" to which sheep dung should be applied annually during the life of the plantation, is preferred. In the year 1842 attention was drawn in the Gardeners' Chronicle (4) to the poor quality of asparagus grown in England, and a reference was made to a report presented to the Horticultural Society by Captain Churchill on the culture of asparagus at San Sebastian in northern Spain. The area where the Spanish asparagus beds lay was on a sandy island in the River Urumea where it was subject to flooding with salt water occasionally during the year. The beds were fertilized with "night soil" obtained from the city of San Sebastian, and the size of the edible stalks was stated to attain a circumference of three to six inches! The English asparagus soils, especially the clay types, were criticised by contrast as being too heavy and cold and prone to become hard and dry when rainfall became scarce.

The situation seems to have changed by 1860 for Loudon in his Encyclopedia (21) mentions the "sandy, light

and deep soils well enriched with animal manure" which were utilized for asparagus culture in the vicinity of London. This observation was supported by travellers who had seen the asparagus plant growing wild along the sandy seashores of Great Britain, Europe, and on the sandy steppes of Russia. At this time a definite lack of quality was known to exist in asparagus shoots where it was grown on the cold, heavy clay soils surrounding London. Loudon cited the practice of Scottish gardeners who regularly applied fresh stable manure mixed with sea-weed and obtained excellent results. Experience in fertilization at Ulm and Augsburg in Germany had shown that the asparagus plant preferred a deep coarse sand which had been well-trenched with manure and salt (NaCl). In France, excellent asparagus was reported to grow on a sandy island in the River Oise quite close to Paris.

Hexamer, in his monograph (12) on the culture of asparagus written in 1901, stressed the importance of providing a medium in which asparagus could grow rapidly, because earliness, tenderness, and size depended on rapid growth which in turn could only occur under proper conditions. Temperature and rainfall could not be controlled, but an open, easily warmed soil, rich in organic matter, would respond to favourable weather conditions much more efficiently. At the time of writing, however, Hexamer observed a definite reaction against the use of manure because of the high handling expenses, the extra care required to control weeds, and the low level of phosphorus and potash in its chemical analysis. P. H. Rolfs is cited, however, as recommending for asparagus the application of 1,500 pounds of a 4-7-5 analysis fertilizer, and whenever possible 20 to 40 tons of vegetable or animal manure. W. F. Massey, on the other hand, is cited as stating that 1,000 pounds of a 5-6-8 analysis fertilizer were sufficient. Experiments carried out in North Carolina, and cited by Hexamer, demonstrated that excellent results were obtained when 1,000 pounds of a 4-5-8 fertilizer alone were used. It should be mentioned that it was a general practice at this time to return the "tops" to the soil in the fall or spring, which may account for the indifferent results obtained with manure. In concluding, the author did not feel that the application of sodium chloride was worthy of consideration, particularly where ordinary fertilizer practice was followed.

Myers (26) conducted some variety tests in Pennsylvania, U.S.A., during the years 1908-1915, and used at first the following fertilizer: 900 pounds of 2-8-12, 10 pounds of bone meal, and 10 tons of manure; changing this eventually in 1912 to 1,900 pounds of 4-8-10 and 10 tons of manure. In a small fertilizer experiment which was being run at the same time, manure at the rate of 24 tons per acre as a treatment and 480 pounds of bone meal per acre as a second treatment were compared with the complete fertilizer and manure used in the variety test. It was found that the largest, but not the most profitable, yield was obtained from the application of 24 tons of manure (manure @ $2.00 per ton), and a decreased yield resulted from the use of bone meal alone.

In an asparagus fertilizer experiment conducted during the years 1906-1915 in Massachusetts, U.S.A., under the direction of Brooks and Morse (2) over 40 different fertilizer treatments were compared. These treatments included various amounts and analyses of complete chemical fertilizers, combinations of manure and complete chemical fertilizers, or nitrogen alone, and were also designed to determine the effect of chlorides and sulphates on yield. The soil in the area used for this experiment was a light sand, two feet deep and underlain by an open gravel. Only one plot of each treatment existed so that it was difficult to estimate the effect of soil variation and an epidemic of rust disease. The maximum yield was obtained in the sixth year on a plot fertilized with 1,000 pounds of a 7-4-13 fertilizer. Manure at the rate of 10 tons per acre did not yield as well as the best chemical fertilizer plot, even where nitrate of soda was added also. No cumulative effect of the organic matter added in the manure was observed, probably because all "brush" or "tops" were disced into the soil in the fall, and possibly removed the necessity of extra organic matter. The plots designed to find out when nitrogen should be added to the soil showed that in combination with manure it might be split into two applications--before and after cutting--but no very significant differences were obtained where chemical fertilizers only were used. Brooks concluded that the most economical fertilizer for asparagus should consist of 1,000 pounds of a mixture approximating a 6-6-12 ratio to which it was unnecessary to add manure.

H. C. Thompson in his text (36) published in 1931 reported that growers in the eastern part of the United States were using 2,000 pounds of a fertilizer approximating a 5-7-6 analysis, with an occasional grower applying manure also. These practices no doubt grew out of the experimental evidence obtained by Myers (26) and Brooks and Morse (2). He cited also work done at Maryland from 1905-1911 (5), which indicated that 20 tons of manure did not increase the yield profitably as compared with an application of 2-3-3 fertilizer at 1,000 pounds per acre. Where one element was omitted from the complete fertilizer, the yield obtained was lower than that of the check. These results would indicate that the location was initially in a high state of fertility, and that the level of organic matter was maintained by discing in the "tops."

The leading State in the production of asparagus in the United States today, according to figures given by various workers (15,32,37,41), is California. Jones and Robbins (15), in their very comprehensive study of the cultivation of this plant in California, regret the lack of local experimental work on fertilizers. An excellent review of literature, however, concerning experimental and practical results obtained in the Eastern United States, England, France, and Germany, is given. Warren in an experiment carried on in New Jersey from 1897-1906 is cited as having obtained the largest yields where 20 tons of manure were used in a comparison with 1,000 pounds of a 2-4-7, a 2-5-9, and a 3-5-9 fertilizer. In reviewing the experience of continental asparagus growers, Jones reports that in France and Germany "manure cannot be replaced entirely by commercial fertilizers." In the Yonne district, France, growers apply annually six or seven tons of manure, and in the Loir-et-Cher district a fall application of 12 tons of manure is accompanied by basic slag, potassium chloride, and gypsum. In the Cote d'Or, growers faced with an economic scarcity of manure favour 1,000 pounds of a 3-3-8 complete fertilizer and seven tons of manure which are applied in the fall. It was suggested that the nitrate of soda be added in the spring before growth begins. Rousseaux and Brioux are reported to be in favour of early applications of phosphorus because of the high proportion of phosphorus utilized by the plant, which is found in the edible stalks. This observation was not supported by any experimental work. Jones and Robbins (15) in discussing the use of fertilizers in Germany state that Meyer advocates the use of stable manure and artificial fertilizers at the rate of five tons of manure and 1,000 pounds of approximately a 2-3-4 complete fertilizer.

Experimental work on the fertilization of asparagus was begun in Maryland in 1905 and first reported in 1911 (5). A second series of experiments was reported in 1929 by White and Boswell (43) and compared the effect of five treatments: (a) check, (b) 10 tons of manure applied in the spring and (c) after cutting, (d) 1,000 pounds of approximately an 8-5-8 applied in the spring and (e) after cutting. In order to ascertain accurately the amount of variation brought about by the treatments, an "outcome" was established for three years during which the plots received a uniform treatment. Nine years' observations were made after the "outcome" had been established and an increase of 35.99 per cent over check occurred where chemical fertilizers were used as compared with a 28 per cent increase in the case of the manure treatments. No significant difference was found between the spring and summer treatments. Sand culture experiments were conducted in the same way and a definite response to the use of organic fertilizers was obtained, which would be expected because of the low organic content of the sand. The most successful sand culture treatment was 12 tons of manure and 400 pounds of kainit, which was followed closely by 12 tons of manure alone. Inorganic fertilizers, when applied to sand, failed to bring about any significant increases in yield over check. No difference was observed in the time of application of the fertilizers used; a fact which was also demonstrated in the field experiments.

In an extension leaflet prepared by workers in

Massachusetts (39) a good soil for asparagus is described as containing plenty of humus, neutral or alkaline in reaction, and sandy in nature. A liberal application of manure, up to 30 tons per acre, is suggested preparatory to planting, and an additional annual application up to 2,000 pounds of a 5-8-7 fertilizer to be applied after planting. This application can be split with advantage into two applications--before and after cutting. Additional amounts of nitrate of soda and muriate of potash are advised in the spring application if the "tops" turn yellow prematurely in the fall.

Seaton (33) reports the results of six fertilizer treatments in Michigan during the years 1926-1932 in which a complete fertilizer of a 4-10-6 analysis applied at 600 pounds summer application, 1,200 pounds summer application, 1,200 pounds spring and summer application, 1200 pounds summer application and cover crop, and 1,800 pounds summer application were compared. No organic fertilizers were included in these treatments, but the "tops" were allowed to remain over winter and were disced into the soil in the spring. The largest yield was obtained where 1,200 pounds of 4-10-6 fertilizer were divided into spring and summer applications, and this yield was significantly greater than where 1,800 pounds of fertilizer were applied in the summer. Seaton suggests as a result of these experiments in Michigan and elsewhere that some fertilizer should be applied in the spring because of the danger of unavailability caused by dry weather in midsummer. On very light

sandy soils a deficiency of potash has been known to spoil the appearance of the spears so that higher applications of potash are advised, and he recommends under these conditions 400 to 600 pounds of a 2-8-10 or a 3-9-18 fertilizer.

T. Jones (17) in making general fertilizer recommendations for asparagus in Ontario suggests a fertilizer of a 6-8-12 analysis on sandy soils applied preferably in two applications, making a total of 1,500 pounds per acre. He recommends also the addition of nitrogen at the rate of 30 to 60 pounds of sodium nitrate during the cutting season. Experimental work carried on at Guelph in 1931-1932 indicated that 250 to 500 pounds per acre of calcium cyanamid proved beneficial in controlling weeds and promoting growth during and after the cutting season. Hoare reports (13) that no recent experimental work on the fertilization of asparagus has been carried on in England. After an analysis of the practices employed by the leading asparagus growers, together with what has been published elsewhere, the following recommendations were made: Before planting an application of 15 tons of manure, 300 pounds of muriate of potash, and sufficient lime to neutralize the soil is considered necessary. During growth an annual application of 20 to 25 tons of manure and 1,000 pounds of approximately a 6-6-11 analysis of chemical fertilizer, in which the nitrogen should be divided and applied in the spring and during cutting, is suggested. Only very large yields and a high price for the edible spears would justify as elaborate a fertilizer programme in Canada or the United States--in fact, experimental results on this continent have rarely justified the use of even 20 tons of manure.

Robb (31) in a discussion on the culture of asparagus in Ontario, Canada, stressed the need of liberal amounts of manure and advocated an annual application of 1,500 pounds of a 4-8-10 analysis fertilizer with the addition of extra nitrogen, as cyanamid or nitrate of soda, during the cutting season. A light sandy soil was recommended to which it was suggested that the "tops" be returned to the soil in the spring as an extra source of organic matter. Thompson at Washington, in a recent cultural discussion (37) of the fertilizer requirements of asparagus, stated that chemical fertilizers cannot replace animal manure entirely unless the soil contains ample organic matter. Green manures, previous to planting and as a late cover crop, were also suggested as methods whereby a supply of organic matter might be ensured.

An outstanding fertilizer experiment on Long Island, which was begun in 1923 and completed in 1934, is reported by Wessels and Thompson (42). The soil of the location used was described as "an almost level field of Sassafras silt loam underlain with sand and gravel at a depth of three feet." Twelve treatments, replicated five times, were laid down and compared with a basal treatment of 1,000 pounds of a 10-12-16 analysis fertilizer.

Treatments were included to observe the effect of sulphates and chlorides on yield; and in these treatments nitrate of soda, sulphate of ammonia, superphosphate, treble superphosphate, sulphate of potash, and muriate of potash were used as sources of nitrogen, phosphorus, and potash. The standard treatments received nitrogen, phosphorus, and potash in the form of equal parts of sulphate of ammonia and nitrate of soda, 16 per cent superphosphate, and 50 per cent muriate of potash. Manure was applied in combination with 128 pounds of superphosphate at the rates of 10 and 20 tons per acre. The treatments were divided into six series entitled nitrogen, phosphorus, potash, chlorine, sulphur, and manure, in which only the factor under consideration was varied. The authors found that applications of nitrogen and potash applied at 60 pounds and 80 pounds, respectively, brought about increases in yield almost as large as where double the amount was used, but it was necessary to supply 128 pounds of phosphorus in order to observe any significant effect. Muriate of potash outyielded the sulphate of potash treatments quite significantly, but no consistent difference was observed between sulphur and no sulphur treatments.
The largest yields during the later years of the experiment were obtained where 10 and 20 tons of manure and phosphorus were applied, which seems to point to a definite cumulative effect of the organic fertilizers. Unless manure can be obtained at less than $2.00 per ton, the authors do not consider its use as economical. This study is similar in

experimental design to the experiment reported herein, so that their method of presentation has been followed closely in the present paper.

In a series of questions and answers on asparagus production prepared in New Jersey (32) in 1938, 1,000 to 1,500 pounds, and later 2,000 pounds, of a 5-8-7 analysis fertilizer in two applications are recommended for the fertilization of asparagus. Manure is suggested previous to planting, but its use is not stressed when the bed becomes established. No statement is made regarding the handling of the "tops," although it is intimated that their return might assist in adding organic matter. Great stress was laid, however, on the fundamental importance of a proper nitrogen, phosphorus, and potash balance in support of which the plant symptoms of a lack or excess of these elements as manifested by the "tops" in autumn were also given. Bryan (3) reported in 1938 the results of some fertilizer investigations in South Carolina in which the basal treatment consisted of 2,000-pound application of 5-7-5 fertilizer applied after harvest with half the nitrogen reserved as a side application for later application. Several fertilizer treatments in which N, P, and K were omitted or varied were laid down for comparison. It was found that asparagus could not utilize to advantage more than five per cent nitrogen and five per cent potash and, although the need for phosphorus did not appear directly, a seven per cent level was found necessary after

three years. The form of nitrogen suggested by the experiment was nitrate of soda because of its neutral effect on the pH and, tentatively, as a source of the sodium ion.

A review of the literature on the fertilization of asparagus as collected from European and American sources is in complete agreement on one point only--the need of some fertilizing material in the culture of asparagus. Depending on the type of soil, the need of nitrogen, potash, and some phosphorus is also emphasized although there is little or no agreement as to the relationship of these elements. The value of organic matter in the form of manure was a well-established fact in the nineteenth century, but some of the more recent experimental work indicates that it is not essential under all conditions.

HARVESTING

The necessity of permitting the young asparagus plant to become well-established before removing any edible spears was well-known to the Romans, and their methods of harvesting have only been modified slightly in recent years. Johnson (18), in discussing the culture of asparagus as it was carried on by the Romans, cites the experience of Cato who recommended that the new plantation should not be cut until the fourth year of growth. Captain Churchill (4) observed in Northern Spain, about the year 1812, that cutting of the new plantation began in the third year of growth. Loudon (21), however, in 1860 suggested that the first cutting should be delayed until the fourth year of

growth. Barnes and Robinson (1) about the year 1870 recommended that the plantation "should not be cut until the second year (third year of growth) after planting, and then only sparingly." They continued by advising against cutting after the middle of June even when the plantation was fully established which, together with wide spacing and heavy fertilization, might possibly account for spears which were described as being more than seven inches in circumference. An essay on the culture of asparagus in France prepared by M. Leboeuf is included (1) and the main facts regarding the culture of this vegetable are similar to those given by Barnes and Robinson (1). Hexamer (12), writing on the culture of asparagus in the United States in 1901, suggested that a light cutting lasting approximately two weeks should be given in the third year of growth, which could be doubled in the following year.

Some of the first experimental work designed to investigate the effect of the length of harvesting in the early years of an asparagus plantation was reported in 1926 by Jones and Robbins (16), and later by Jones (14), Hanna (11), and Haber (8,9). Jones and Robbins (16) presented in 1926 an experimental report on the effect of cutting asparagus in the second year of growth on the yield obtained in the third year. The authors report that this practice is quite common in California as the growers do not believe that it is harmful provided that the young plants have made good growth. It was found that cutting in the

second year resulted in a yield of 300 pounds of asparagus per acre which was followed by a yield, in the third year, of 2,046 pounds from the early harvested plot as compared with 1,940 pounds where no harvesting was done in the second year. This preliminary report was followed in 1932 by the publication of a bulletin (14) after the two treatments had entered full bearing. It was found that the early harvesting treatment gave a greater total yield, but the spears were of poorer grade than those harvested from the later harvested treatment.

Haber (8) reports an experiment which was prepared in 1927 and in 1929, the third year of growth, a series of harvesting treatments was begun. In discussing the effects of these treatments on the basis of two further seasons of cutting, Haber found that cutting until July 15 did not bring about an increase in yield. In reporting further at a later date (9), the author found after six years of cutting that harvesting until June 15 increased the yield and quality of spears as compared with the July 1 treatment which was declining in yield. Haber (9) included also a trial in which a comparison of yields obtained in the third year of growth was made between two plots, one of which had been harvested until June 15 in the previous year. His results showed that the early harvesting treatment was extremely severe, and later observations indicated that the damaging effect of the treatment could be detected after a period of six years.

Hanna (11) carried on an investigation in California, and reported it in 1932, which was designed to determine the effect of over-harvesting in an established plantation, such as might occur where early spear growth was induced by flooding with water. A seven-year-old plantation was selected and a series of treatments varying only in the amount of harvesting given was laid down. In the following year a normal harvesting was made, and it was found that the yields obtained in the eighth year varied inversely as the length of harvesting period in the previous year.

Lewis (19) and Lloyd and McCollum (20) reported in 1934 and in 1938, respectively, an experiment to show the effect of severe cutting of asparagus in Illinois, in which comparisons were made between treatments where cutting began in the second, third, and fourth year of growth. It was found that cutting during the second year of growth lowered the yield quite significantly as compared with the performance of a treatment which received a light cutting in the third year of growth. Delaying the time of first harvest until the fourth year did not prove to be of any benefit even though the observations were made over a period of ten years. It was concluded that the best method of harvesting under the conditions of the experiment consisted in cutting the third year of growth for two weeks, the fourth year for four weeks, and during and after

the fifth year for a period of eight weeks.

Thompson (37) in discussing the harvesting practice of asparagus growers in the United States concluded that the most generally accepted practice consisted of a short cutting of three to four weeks in the third year of growth, which was increased to five to six weeks in the fourth year, and raised again to a full cutting of eight weeks in the fifth year of growth. A perusal of the literature on the harvesting of asparagus agrees very closely with the conclusion of Thompson (37), with the exception of that pertaining to California which does not appear to apply to the Eastern States and Canada.

MATERIALS AND METHODS

LOCATION OF EXPERIMENT

The Experimental Station is situated about three miles north of Lake Erie at an altitude of 625 feet above sea level. The experimental plot is located in Field I and covers an area of approximately 1.5 acres. The soil used for the experiment has not been surveyed recently, but in a rough soil survey made over ten years ago the area was placed in the Fox or Berrien sand group (23). It is sedimentary in origin, rather flat, poorly drained if underlain by clay, and with a pH of 5.5 to 7.0. The main fertility requirements of this soil according to the survey (23) are organic matter, phosphate, potash, and lime.

The experimental area consists of an apparently uniform sandy soil yellow in colour, which becomes reddish yellow at two to three feet, and at four feet appears to be almost pure white sand. These diggings were made in 1938 and healthy asparagus roots were found three feet below the surface of the soil, which would indicate that natural drainage is efficient. A test of soil acidity made in 1931 gave a pH of 5.4, which is lower than the level usually recommended for asparagus (32).

FERTILIZER AND MANURE TREATMENTS

When the experiment was planned (24) it was intended to have 18 treatments replicated three times, of which 16 were designed to investigate the effect on yields of asparagus of the three important elements (nitrogen, phosphorus, and potash) alone and in combination with manure. The numerals preceding the symbols N, P, and K, as in 2N2P2K, are used to designate the actual quantities of the three important fertilizer ingredients. The letter M refers to barnyard manure and the numeral preceding it refers to the actual tons of manure used. The letters Sp. and Su. refer to the time of application, spring and summer, respectively, of nitrogen. The symbols used and their explanation are tabulated below:

1N	-	30 lbs. of nitrogen per acre (N)
2N	-	60 " " "
2.7N	-	80 " " "
1P	-	32 " phosphoric acid per acre (P_2O_5)
2P	-	64 " " " "
1K	-	48 " potash per acre (K_2O)
2K	-	96 " " " "
5M	-	5 tons manure
10M	-	10 " "
20M	-	20 " "
Sp.	-	spring application
Su.	-	summer "

The nitrogen was supplied throughout in the form of nitrate of soda (15 per cent); phosphoric acid by superphosphate (16 per cent); and potash by muriate of potash (50 per cent). The manure used throughout the experiment was obtained from the dairy barn on the Station. It can be seen in table 3 that the nitrogen, phosphoric acid, and potash series each contained the basal treatment (2N2P2K) and two or three treatments in which the element under consideration was varied in order to observe its effect when the other elements were supplied in apparently sufficient amounts. The four remaining series included a comparison of

the quantities of fertilizer used, the effect of manure and a complete fertilizer, the effect of manure alone, and the effect of the time of application of nitrogen when used with manure. The total plot area to which fertilizer was applied measured 69 x 16 feet, or approximately 1/40-acre in area.

Table 3.--Summary of experimental procedure

Series No.	Series	Symbol	Plot letter	Commercial designation 1000# per ac	Manure per acre ton
		Fertilizer Treatments			
I	Nitrogen	2.7N2P2K	Q	8-6-10	-
		2N2P2K	C	6-6-10	-
		1N2P2K	B	3-6-10	-
		2P2K	A	0-6-10	-
II	Phosphorus	2N2P2K	C	6-6-10	-
		2N1P2K	E	6-3-10	-
		2N2K	D	6-0-10	-
III	Potash	2N2P2K	C	6-6-10	-
		2N2P1K	G	6-6-5	-
		2N2P	F	6-6-0	-
IV	Quantity of basal fertilizer	2N2P2K	C	6-6-10	-
		1N1P1K	I	3-3-5	-
		0-0-0	H	-	-
V	Manure (M) and complete fertilizer	2N2P2K5M	L	6-6-10	5
		1N1P1K5M	K	3-3-5	5
		2N2P2K	C	6-6-10	-
		5M	J	-	5
VI	Effect of manure alone	2N2P2K	C	6-6-10	-
		20M	N	-	20
		10M	M	-	10
		5M	J	-	5
		0-0-0	H	-	-
VII	Effect of time of application of nitrogen plus manure	2N2P2K	C	6-6-10	-
		2N10M(Sp.)	O	6-0-0(spring)	10
		2N10M(Su.)	P	6-0-0(summer)	10
		Harvesting Treatment			
I	Extended vs. normal cutting	2N2P2K	C	6-6-10	-
		2N2P2K(Ext.)	R	6-6-10	-

HARVESTING TREATMENTS

When the experiments were begun, two harvesting series--extended cutting and short cutting--were to be compared with the normal cutting as carried out in the basal treatment. In 1933, after one short cutting treatment (see table 5) it was decided to discontinue this series and convert it into a high nitrogen treatment in the nitrogen series. The extended cutting series, however, was not discontinued until 1938.

DESIGN OF EXPERIMENT

The experimental area was laid out in seven ranges 128 feet deep and 63 feet wide, which were separated from one another by a roadway nine feet wide running east and west (figure 2). Each range contained eight plots, making a total of 56 plots of which 54 were used for fertilizer and harvesting experiments. The remaining two plots were planted to five standard varieties of asparagus and used for variety observation only. The plants were spaced three feet apart in the row and four feet apart between the rows (3,630 plants per acre), making a total of 33 rows running north and south at right angles to the roadways between the ranges. Nine rows, occurring at every fourth row, were left as "guard" or "border" rows between adjacent plots and the yield was obtained from the three remaining rows (66 plants), an area of 1/55-acre within the plot. The 18 treatments were laid down in similar order in each replication as illustrated in figure 2 and table 4, for no attempt was made to randomize within blocks.

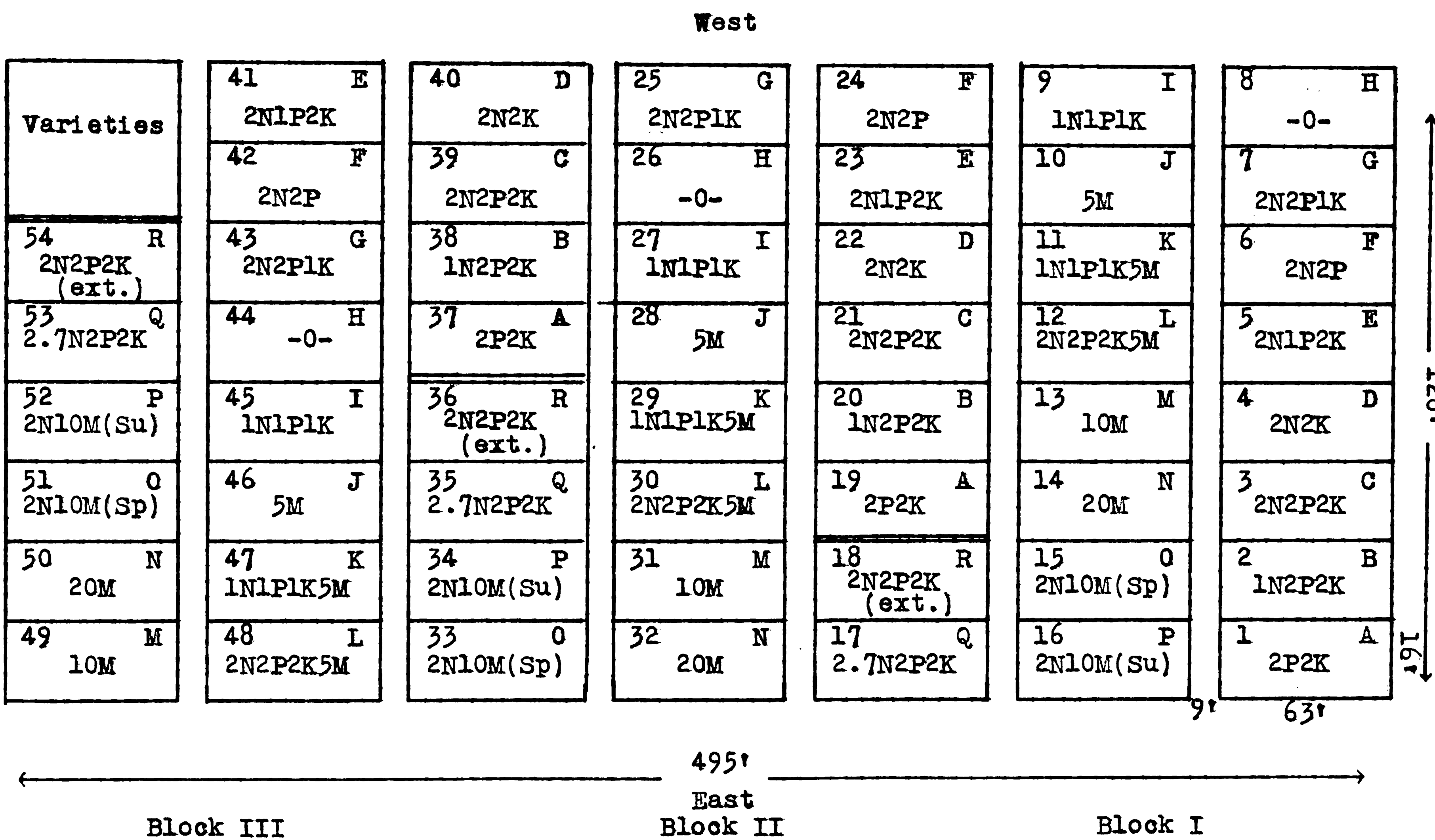

Figure 2.--Plan of asparagus experiment; 18 treatments, unrandomized, in three blocks, total of 54 plots.

Table 4.--Details of treatments showing the plot numbers, the designations used, and the actual amount of nutrients applied per acre

Plot letter	Plot numbers	Commercial designation 1000 lbs.	Experimental symbol	Nutrients per acre N lb.	P2O5 lb.	K2O lb.	Manure ton
A	1,19,37	0-6-10	2P2K	-	64	96	-
B	2,20,38	3-6-10	1N2P2K	30	64	96	-
C	3,21,39	6-6-10	2N2P2K	60	64	96	-
D	4,22,40	6-0-10	2N2K	60	-	96	-
E	5,23,41	6-3-10	2N1P2K	60	32	96	-
F	6,24,42	6-6-0	2N2P	60	64	-	-
G	7,25,43	6-6-5	2N2P1K	60	64	48	-
H	8,26,44	0-0-0	-	-	-	-	-
I	9,27,45	3-3-5	1N1P1K	30	32	48	-
J	10,28,46	-	5M	-	-	-	5
K	11,29,47	3-3-5	1N1P1K5M	30	32	48	5
L	12,30,48	6-6-10	2N2P2K5M	60	64	96	5
M	13,31,49	-	10M	-	-	-	10
N	14,32,50	-	20M	-	-	-	20
O	15,33,51	6-0-0	2N10M(Sp.)	60	-	-	10
P	16,34,52	6-0-0	2N10M(Su.)	60	-	-	10
Q	17,35,53	8-6-10	2.7N2P2K	80	64	96	-
R	18,36,54	6-6-10	2N2P2K(Ext.)	60	64	96	-

CULTURAL METHODS

The nursery plants of variety Mary Washington were grown from especially selected seed at the plant of W. Clark Limited, Harrow, during the season of 1930. Tobacco was the crop grown in the experimental area in 1930, and

since it is a heavy feeder a general fertilizer application of 300 pounds of a 3-8-4 analysis was applied in the spring of 1931. The one-year-old asparagus plants were transplanted in April, 1931, to the permanent bed into furrows eight inches deep. The bed was cultivated sufficiently to keep down weeds, and on June 24 the first application of the fertilizer treatments was made. In November the "brush" or asparagus "tops" were removed from the plot and burned, which is the general practice in this district. In the spring of 1932 the first applications of manure and spring nitrogen were made and the area was disced lightly. No harvesting was done in 1932, and on June 24 the summer fertilizer applications were repeated. This method of culture was followed carefully after 1932, except that the summer fertilizer applications were delayed each year until the harvesting season was over. In the fall of 1933 a count was made of the missing plants in each plot, and the plot yields were adjusted for stand. At the same time a plot-to-plot count of the male and female plants was made. The average number of plants per plot was found to be 61, of which 33 were male and 28 female. The dead plants were replaced with one-year-old replants in the spring and fall of 1934, but no further counts were made. In 1934, lime at the rate of one ton per acre was applied to the experimental area.

The time of first cutting, the number of cuttings, and the length of cutting for each year from 1933-38,

inclusive, are shown in table 5 below:

Table 5.--Time of first cutting, number of cuttings, and length of cutting, 1933-38

Year	Treatment	Dates of Cutting	Harvesting period (days inclusive)	Difference from normal	Number of cuttings
1931	Planted	-	-	-	-
1932	No cutting	-	-	-	-
1933	Normal	May 4-May 22	19	-	7
	Short	May 4-May 16	14	-5	5
	Extended	May 4-May 27	23	4	9
1934	Normal	May 5-June 12	39	-	21
	Extended	May 5-June 22	49	10	26
1935	Normal	May 7-June 17	42	-	17
	Extended	May 7-June 26	51	9	20
1936	Normal	May 8-June 20	44	-	21
	Extended	May 8-June 30	54	10	25
1937	Normal	May 5-June 28	55	-	25
	Extended	May 5-July 6	63	8	28
1938	Normal	April 22-June 24	64	-	22
	Extended	April 22-June 24	64	0	22

The extended harvesting series applies to the one treatment which was consistently cut about nine days longer than the normal except in 1938. The short cutting plots were discontinued after 1933 and converted into a high nitrogen treatment in the nitrogen series. It will be noticed that the first cutting made in 1933 lasted almost

three weeks, and this was doubled to six weeks in 1934 until the maximum of nine weeks was reached in 1938. The average date of first cutting occurred about May 6, if the abnormally early cutting of 1938 is disregarded. The spears appeared in 1938 on April 22 before the applications of manure were made and very severe damage was done by frost, so that it was decided to disc the whole experimental area.

The harvesting of asparagus requires constant attention as the time and amount of cutting vary with temperature and rainfall. It was impossible, however, to make the required number of cuttings because of scarcity of labour; so instead routine cuttings were made on Monday, Wednesday, Friday, and occasionally Saturday, if the weather was very warm. The crop was harvested from the three middle rows of each plot, an area of 1/55-acre or 66 plants, and carried to the packing shed where each plot yield was weighed and the number of spears determined by counting. No attempt was made to grade the crop from each plot so that only the gross yield of untrimmed spears is available. In the early part of the season the crop was shipped in baskets to the Toronto market, and later to the canning factory when processing began.

STATISTICAL ANALYSIS

The experiment was laid down in 1931 in the form of a randomized block consisting of 18 treatments replicated three times, making a total of 54 plots of 1/55-acre size.

The data, available for analysis, comprised the weight and the number of spears for each season of cutting between the years 1933 and 1938. By dividing the number into the weight, an expression of the size of spear entitled "the average weight per 100 spears" has been obtained. Two sets of data, the annual yield per plot and the average weight per 100 spears, consisting of a total of 324 recordings are included in the analysis.

Annual Yield per Plot.--The necessary difference for significance between the yield of the 18 treatments under observation was obtained by Fisher's Analysis of Variance Method (29,34), using Snedecor's "F" tables and values of "t" (34). The method followed for the analysis of variance applied to separate results from each year and the average 1933-38 was obtained from page 21, Snedecor's Text (34) as two criteria and a single item in each class were available. The criteria used were three blocks or replications and 18 treatments, which allowed 34 degrees of freedom for error and subsequently for "t" when determining the necessary difference between treatments (see table 6). The variance for treatments was in every case significantly larger than that for error according to Snedecor's table for "F" (34), which justifies the use of a standard error based on the variance for error obtained in the analysis. The variance for blocks or replications in 1933, 1934, and 1935 was not significantly larger than the variance for error, but in 1936, 1937, and 1938 the "F" for blocks was even larger than that for

treatments. This was caused by Block III which, for instance, in 1936 gave a total yield almost 30 per cent higher than that of Blocks I and II. There does not appear to be any justifiable reason for this lack of uniformity because the area seems to possess a soil of uniform texture and even drainage, and any direct fertility difference should have shown this block difference in 1933 and 1934. Where only two criteria of classification are used it can be seen from a perusal of tables 6 and 10 that in the later years of the experiment a very large difference between treatments is necessary for significance--particularly is this true when the average annual treatment yields for 1933-38 are considered. When a consistent difference occurs between certain treatments over six years, there is some justification in drawing conclusions as regards the superiority of one treatment over another, but this method of statistical analysis does not permit it.

Table 6.--"F" values and annual and average annual necessary differences between treatments

Year	"F" values: Treatments	"F" values: Blocks	"F" values: Age & season	Necessary difference--acre basis between six yr. mean of treatments: 5% Point lb.	1% Point lb.
Data: Annual yield per plot -					
Two Criteria of Classification/					
1933	4.12☆☆	1.50		149	200
1934	3.33☆☆	2.26		435	585
1935	3.45☆☆	2.18		599	805
1936	5.90☆☆	13.40☆☆		703	944
1937	5.05☆☆	9.134☆☆		997	1339
1938	4.82☆☆	6.84☆☆		795	1068
1933-38	4.629☆☆	7.104☆☆		580	780
Three Criteria of Classification//					
1933-38	71.01☆☆	108.99☆☆	1205.33☆☆	85	91
Data: Average weight per 100 spears -					
Three Criteria of Classification//					
1933-38	27.93☆☆	17.36☆☆	266.35☆☆	0.111	0.118

/ Two criteria of classification--3 blocks, 18 treatments, degrees of freedom of "t" = 34.
// Three criteria of classification--6 ages & seasons, 3 blocks, 18 treatments, degrees of freedom of "t" = 170.
☆☆ Significant to the 1% point.

It was decided, therefore, to use the method outlined on page 57, Snedecor's Text (34) and on page 19, Paterson (29), where three criteria and a single item in each class are utilized. Paterson, in discussing the possibility of applying three criteria to the analysis of perennial crops which in this case are six seasons, three blocks, and 18 treatments, draws attention to the fact that seasons may combine the effect of age and weather. Age, it is assumed, is responsible for a steady but not necessarily uniform increase in yield of asparagus regardless of treatment, but age cannot be separated from the effect of the season. It is not permissible, therefore, to use the standard error obtained to test differences between treatments in any specific year; but a much more accurate and smaller necessary difference can be obtained to test the average annual yield or total six-year yield of each treatment because it is based on 170 degrees of freedom. The necessary differences for significance were computed to the 5% point (☆) and the 1% point (☆☆) according to Snedecor (34). It is generally agreed among agricultural statisticians (34) that odds of 20:1 can be applied with safety to results obtained in field experiments, but when 170 degrees of freedom are used to determine the value of "t" there is only a very small difference between the 5% point and the 1% point. This is shown in table 6 where an analysis based on two criteria 1933-38 shows a necessary difference of 580 pounds ☆ and 780 pounds ☆☆ as compared with three criteria in which 85 pounds ☆ and 91 pounds ☆☆ per acre are considered significant.

The table of the analysis of variance is included in table 7 from which it can be seen that a standard error term of 15.8198 pounds per plot was obtained. The enormous variation introduced by season, age is shown by the large "F" which amounted to 1205.23; the "F" for treatments is also large despite the conflicting variation caused by the fertility difference of the blocks.

Table 7.--Analysis of variance of annual plot yield of asparagus in pounds obtained from 18 treatments on three blocks in six years, 1933-38

Source of variation	Degrees of freedom	Sum of squares	Mean square	"F" value
Total	323	137,857.3275		
Between means of treatments	17	19,097.6824	1,123.39	71.01**
Between means of blocks	2	3,448.5337	1,724.2	108.99**
Between means of age and season	5	95,333.7119	19,066.74	1205.23**
Interactions				
Treatment - block	34	8,252.0797	242.71	15.34**
Treatment - age, season	85	7,335.4865	86.30	5.46**
Block - age, season	10	1,700.4730	170.05	10.75**
Remainder	170	2,689.3603	15.8198	

Standard deviation = $\sqrt{15.8198}$

Degrees of freedom for "t" = 170

Necessary differences for significance -		5% point	1% point
Between means of treatments(avg.yield):			
	Plot basis	1.543	1.652
	Acre basis	84.865	90.860
Between means of treatments(total yield):			
	Plot basis	3.7800	4.0464
	Acre basis	207.9	222.55

Average Weight per 100 Spears.--Since this expression is a ratio of the weight and the number of spears, and is not directly related to the age of the plantation, a complex analysis will supply a standard error term that can be used in comparing every possible combination (table 11). The same procedure was followed as in the case of the annual yield per plot and a standard error of 0.08121 was obtained. Since the mean square or variance of each variation was significantly larger than the variance of error according to Snedecor (34), the significant difference derived can be applied in all comparisons within the sources of variation. (table 8).

Table 8.--Analysis of variance of plot average weight per 100 spears in pounds of 18 treatments on three blocks in six years, 1933-38

Source of variation	Degrees of freedom	Sum of squares	Mean square	"F" value
Total	323	218.7152		
Between means of treatments	17	38.5656	2.2686	27.934**
Between means of blocks	2	2.8200	1.4100	17.362**
Between means of age and season	5	108.1529	21.6305	266.352**
Interactions				
Treatment - block	34	39.7362	1.1687	14.235**
Treatment - age, season	85	10.4989	0.1235	1.521
Block - age, season	10	5.1353	0.5135	6.323**
Remainder	170	13.8063	0.08121	

Standard deviation = $\sqrt{.08121}$

Degrees of freedom for "t" = 170

Necessary differences for significance -	5% point	1% point
Between means of treatments over six years disregarding blocks and age, season	0.111	0.118

COSTS OF FERTILIZERS

It is not only necessary to obtain a statistically significant difference between treatments in a fertilizer experiment in order to draw a correct conclusion. Some attempt should be made to estimate whether the fertilizer, from the standpoint of increased returns, is sufficiently better to defray the differences in cost of fertilizers.

Since in this particular experiment no attempt was

made to grade the spears of asparagus according to their marketability, it has been necessary to apply an estimate of 75 per cent marketable to the yield of every treatment. Brooks and Morse (2) estimated that four-fifths of the total yield of a plantation was marketable. Wessels and Thompson (42), however, found that it varied with the vigour of the treatment--the better yielding treatments producing almost 100 per cent marketable material. The blanket estimate, therefore, is quite unfair to the best treatments and too lenient to the low-yielding treatments, as indicated by the range in the weight per 100 spears which varied from 5.321 pounds to 3.937 pounds and was closely correlated with yield (table 12).

The cost of harvesting and care of the plantation were not included in the cost of production. The cost of barnyard manure was estimated at $1.50 per ton throughout the experiment as this is the figure used in the cost of production studies at the Station. The asparagus growers of Essex County are not faced with any difficulty in obtaining manure, as the County is partly devoted to diversified farming. The cost of application and the extra expense required in controlling weeds have tended to discourage the use of manure, but these disadvantages have not been taken into consideration.

In figure 3 and table 9 the cost per ton of nitrate of soda (15 per cent), superphosphate (16 per cent), and muriate of potash (50 per cent) are shown for each year during the period of the experiment. The graph (figure 3) depicts a definite trend towards lower costs of fertilizing materials furnishing nitrogen and potash. The cost of superphosphate, however, remained quite steady throughout the period of the experiment. It is interesting to notice that the cost of the materials for a 6-6-10 fertilizer closely approximated that of a commercial 6-8-10 in spite of the higher content of phosphorus, so that the total cost of materials has been used throughout in obtaining the "net loss or gain" of each treatment over the basal treatment.

Table 9.--The cost per ton of fertilizer materials in Ontario, Canada, during the years 1931-38≠

Fert. material	1931	1932	1933	1934	1935	1936	1937	1938	Avg.
	$	$	$	$	$	$	$	$	$
$NaNO_3$	60.00	65.00	66.00	58.00	47.00	47.00	48.00	49.00	55.00
P_2O_5 16%	24.00	20.00	22.55	22.50	22.00	21.50	22.00	23.00	22.20
KCl	52.00	65.00	66.00	62.00	37.00	42.00	45.00	47.00	52.00
Home mixed 6-6-10	44.00	47.00	48.64	44.60	35.00	37.80	39.00	38.20	41.78
Commer-cial 6-8-10	58.00	47.55	51.35	46.85	40.50	40.50	41.00	-	46.54

≠ Costs of chemical fertilizers supplied by National Fertilizers, Ingersoll, Ontario.

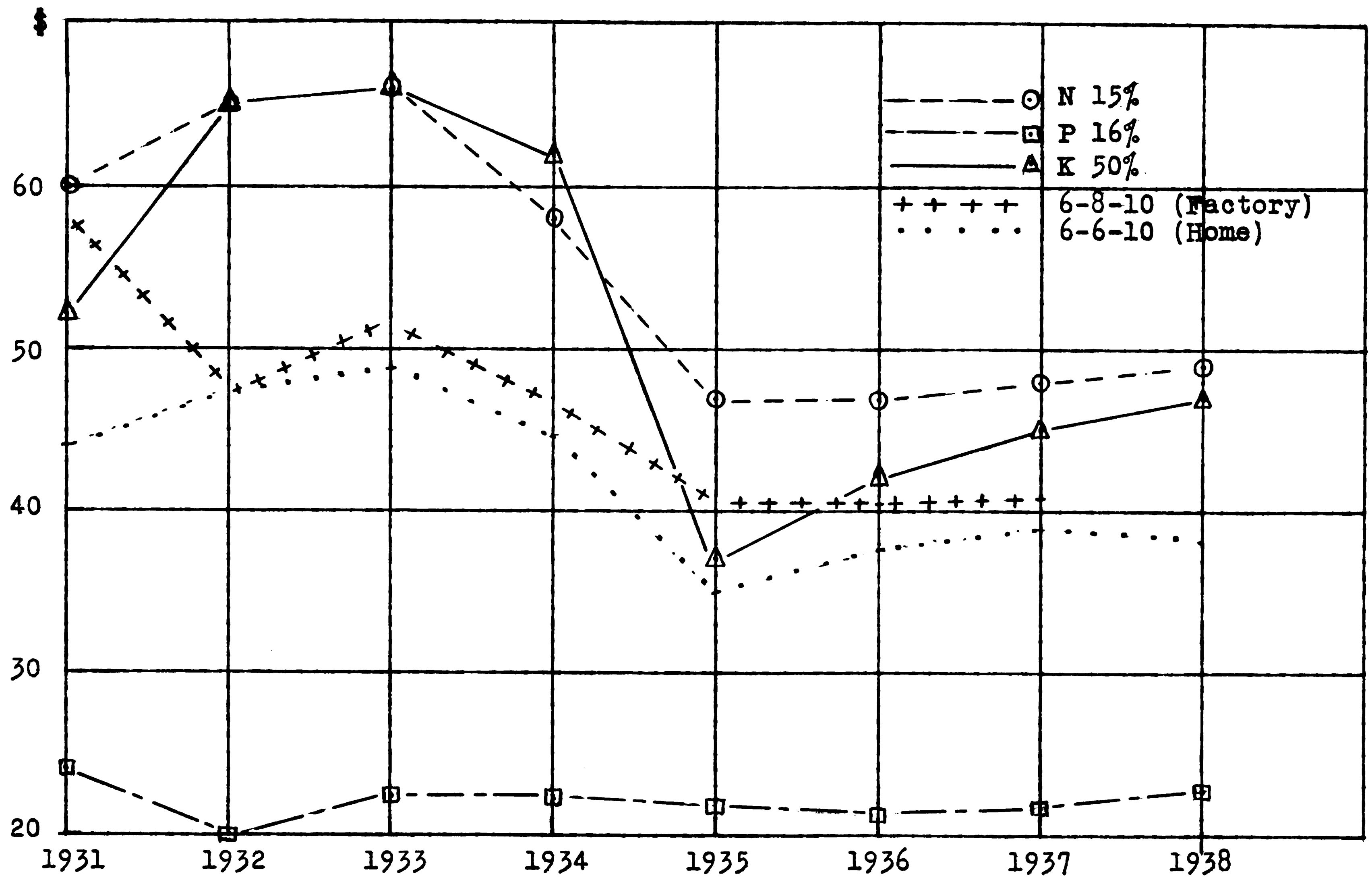

Figure 3.--Cost per ton of chemical fertilizers in Ontario, Canada, during the years 1931-1938
(as supplied by National Fertilizers, Ingersoll, Ont.)

EXPERIMENTAL RESULTS

The experiment was planned to answer pertinent questions as to the effect of various fertilizers and methods of harvesting on the growth of asparagus in Southwestern Ontario. In presenting these preliminary results as obtained from the first six harvesting seasons on 18 treatments they will first be considered generally. A more careful analysis will then be made by breaking up the effects of fertilizers into the effects of the fertilizing elements N, P, and K, the amounts of chemical fertilizer alone and in combination with manure, the amount of manure alone, and the time of application of nitrogen when used with manure. The harvesting treatments together with some general observations on the effect of age and climatic conditions will also be considered. In order to assist in discussing these effects the average yield 1933-38 per acre, the average yield in each year, the total six-year yield per acre, the average annual weight per 100 spears ("size"), and the net monetary loss or gain per acre over the basal treatment will be used.

Average Yield.--Since asparagus is a perennial plant with the capacity to increase in yield up to the tenth year of cutting the average yield, based on only six years' observations is a "middle value," and comparable only with the average yield in the third year of cutting. A horizontal bar chart (figure 4) has been prepared, however, of the average yield per treatment and the necessary difference for significance has been incorporated.

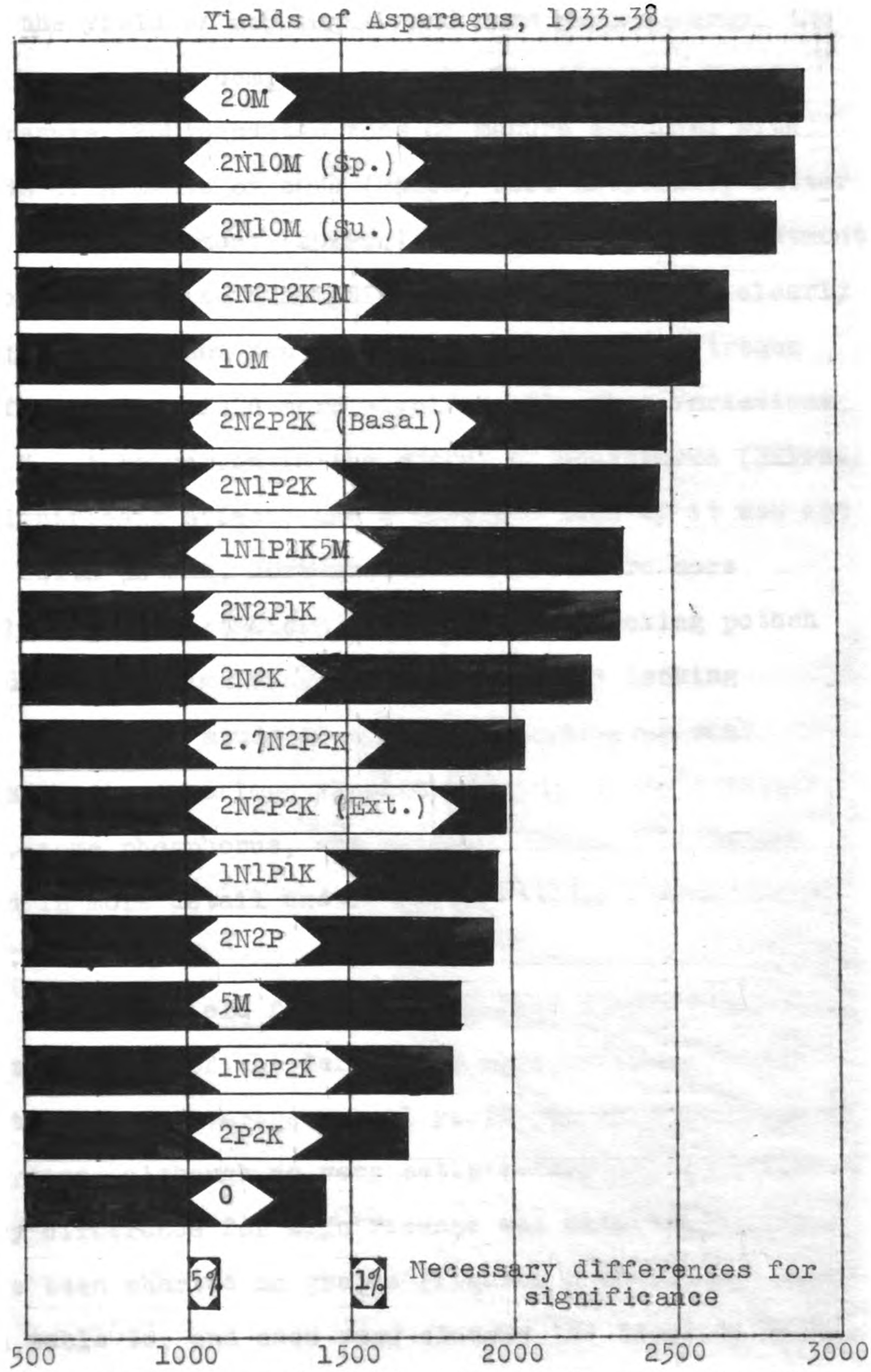

Fig. 4. Average annual yields, in pounds per acre, from various Manure, Fertilizer, and Harvesting Treatments, together with the necessary differences for significance.

This chart shows graphically the effect of fertilizer on the yield of asparagus, and more particularly, the value of manure as a component of the fertilizer. Twenty tons of manure (20M) and ten tons of manure combined with 400 pounds of nitrate of soda (2N10M) were noticeably better than the basal treatment (2N2P2K). Below the basal treatment the effects of varying quantities of N, P, and K are clearly shown. It can be seen that the reduction of the nitrogen level affected the yield more significantly than variations of P and K. A reduction in the amount of phosphorus (2N1P2K) had no significant effect, and a complete lack of it was not drastic. With potash, however, the effects were more noticeable but, nevertheless, the treatment lacking potash (2N2P) outyielded significantly the treatment lacking nitrogen (2P2K). A study of this chart indicates that asparagus on the experimental plot required organic matter, nitrogen, some phosphorus, and potash. These effects are discussed in more detail under the Effects of the different elements.

Average Yield for each Year.--In attempting to compare the effect of the fertilizer constituents, it was decided to use the average annual yield per acre for each of the six years, although no very satisfactory expression of the necessary difference for significance was obtainable. This data have been charted on graphs (figures 6 to 12) and tabulated in table 10, and show very clearly the trend of each treatment over the experimental period.

Table 10.--Effect of fertilizers, manure, and cutting on yield

Letter	Treatment	Total yields per acre (lbs.) 1933 /	1934	1935	1936	1937	1938	Total yield 1933-8	Avg. 1933-8	Avg. difference //
A	2P2K	497	1232	1815	1678	2635	2272	10124	1687	809 ★☆
B	1N2P2K	495	1260	1876	1898	2855	2547	10930	1822	674 ★☆
C	2N2P2K(basal)	695	1887	2706	2552	3586	3548	14975	2496	--
D	2N2K	677	1654	2398	2486	3289	2992	13493	2249	-247 ★☆
E	2N1P2K	702	1896	2503	2745	3641	3328	14815	2469	-27
F	2N2P	671	1595	2068	2068	2800	2508	11710	1952	-544 ★☆
G	2N2P1K	656	1841	2272	2552	3454	3240	14016	2336	-160 ★☆
H	0	504	1157	1645	1480	2024	1819	8628	1438	-1058 ★☆
I	1N1P1K	526	1309	2118	1887	3085	2849	11715	1953	-543 ★☆
J	5M	447	1164	1958	2046	2822	2591	11029	1838	-658 ★☆
K	1N1P1K5M	567	1507	2453	2481	3669	3381	14054	2342	-154 ★☆
L	2N2P2K5M	644	1745	2805	3069	4021	3727	16011	2668	172 ★☆
M	10M	605	1696	2591	2981	4213	3416	15499	2583	87 ★
N	20M	627	1947	2794	3482	4813	3813	17474	2912	416 ★☆
O	2N10M (Sp.)	651	1890	2926	3410	4719	3780	17376	2896	400 ★☆
P	2N10M (Su.)	592	1811	2805	3344	4587	3790	16925	2821	325 ★☆
Q	2N2P2K(Short) 2.7N2P2K	355	1379	2079	2497	3036	2893	12212	2035	-461 ★☆
R	2N2P2K (ext.)	688	1553	2217	2343	2893	2284	11977	1996	-500 ★☆
Necessary diff.	5%	149	435	599	703	997	795	208	85	
"	" 1%	200	585	805	944	1339	1068	223	91	

/ Corrected yield, based on 100 per cent stand.
// Difference from basal treatment (2N2P2K).
★☆ Significant to the 1% point.

Total Yield 1933-38.--The actual yield per acre over the period of six years is important from a monetary standpoint; consequently, this figure has been used to compute the net gain or loss of each treatment in dollars and cents (table 12). It was possible to obtain a statistical expression of the necessary difference for significance, and this is incorporated in the table.

Average Weight per 100 Spears ("Size").--The average annual weight per 100 spears was obtained by dividing the number of spears into the total annual weight per plot, from which the average annual weight per 100 spears and the average weight per 100 spears for each of the six years was obtained. This criterion was combined in the form of a complex experiment, and the necessary difference for significance has been obtained in order to determine if the treatments had any effect. The weight per spear is an easily obtained figure but it can not replace proper sizing and grading. It is used in presenting these results (table 11) to demonstrate the effect of the treatments on the size of spear since more accurate information is not available--and is referred to as "size" throughout the paper.

Table 11.--The effect of fertilizers, manure, and cutting on the spear-weight of asparagus ("size").

Letter	Treatment	Avg. weight of 100 spears (lbs.) 1933	1934	1935	1936	1937	1938	Avg. 1933-8	Difference
A	2P2K	5.250	4.127	5.167	3.943	4.237	3.270	4.332	-0.349 ☆☆
B	1N2P2K	4.957	3.833	4.907	3.843	4.240	3.570	4.225	-0.456 ☆☆
C	2N2P2K	5.393	4.407	5.787	4.257	4.377	3.867	4.681	--
D	2N2K	5.507	4.210	5.500	4.457	4.270	3.763	4.618	-0.063 ☆☆
E	2N1P2K	5.307	4.187	5.133	4.237	4.243	3.533	4.440	-0.241 ☆☆
F	2N2P	5.580	4.183	5.287	3.920	3.940	3.347	4.376	-0.305 ☆☆
G	2N2P1K	5.380	4.187	5.213	4.217	4.480	3.727	4.534	-0.147 ☆☆
H	0	4.713	3.740	4.983	3.643	3.680	2.860	3.937	-0.744 ☆☆
I	1N1P1K	5.217	5.027	5.657	4.083	4.470	3.887	4.723	0.042
J	5M	4.720	3.863	5.380	4.233	4.377	3.820	4.399	-0.282 ☆☆
K	1N1P1K5M	4.987	4.020	5.430	4.127	4.437	3.860	4.477	-0.204 ☆☆
L	2N2P2K5M	5.147	4.080	5.350	4.483	4.463	3.843	4.561	-0.120 ☆☆
M	10M	5.760	4.787	6.047	4.927	5.047	4.247	5.136	0.455 ☆☆
N	20M	5.760	4.740	6.130	5.337	5.320	4.637	5.321	0.640 ☆☆
O	2N10M (Sp.)	5.670	4.610	5.903	5.030	5.007	4.140	5.060	0.379 ☆☆
P	2N10M (Su.)	5.550	4.480	5.587	4.850	5.047	4.260	4.962	0.281 ☆☆
Q	2.7N2P2K	4.350	3.903	5.300	4.317	4.393	3.750	4.336	-0.345 ☆☆
R	2N2P2K(Ext.)	4.757	3.943	5.113	4.250	4.067	3.370	4.250	-0.431 ☆☆
Season average		5.222	4.240	5.437	4.342	4.450	3.764		

Necessary difference for significance -	5% point	1% point
Between treatments in each year (lb.)	.271	.290
" " avg. six years (lb.)	0.111	0.118
" seasons (lb.)	.064	.068

Correlation between Yield and "Size" of Spear.--The processing industry in Ontario demands a spear with a minimum length of five and one-half inches, and a minimum diameter of three-eighths of an inch. As the increase in growth is removed in trimming, the grower is interested in producing spears which are heavy for their length and, therefore, attempts to increase the diameter of spear. That this can be accomplished without resorting to any special treatment is shown graphically in figure 5, which shows the high correlation that existed at Harrow between the average yield and the average weight per 100 spears ("size"). In analysing this relationship by covariance (34), a correlation coefficient of 0.8464 was obtained within the 18 treatments, which is highly significant. The coefficient of regression for "Size" of spear on Yield, obtained in the same way, was 0.00069, from which the linear relationship shown in figure 5 was computed from the equation:

$$X = 4.576 + 0.00069 (Y - 2250)$$

where X equals the "size" of spear and Y the average yield 1933-8.

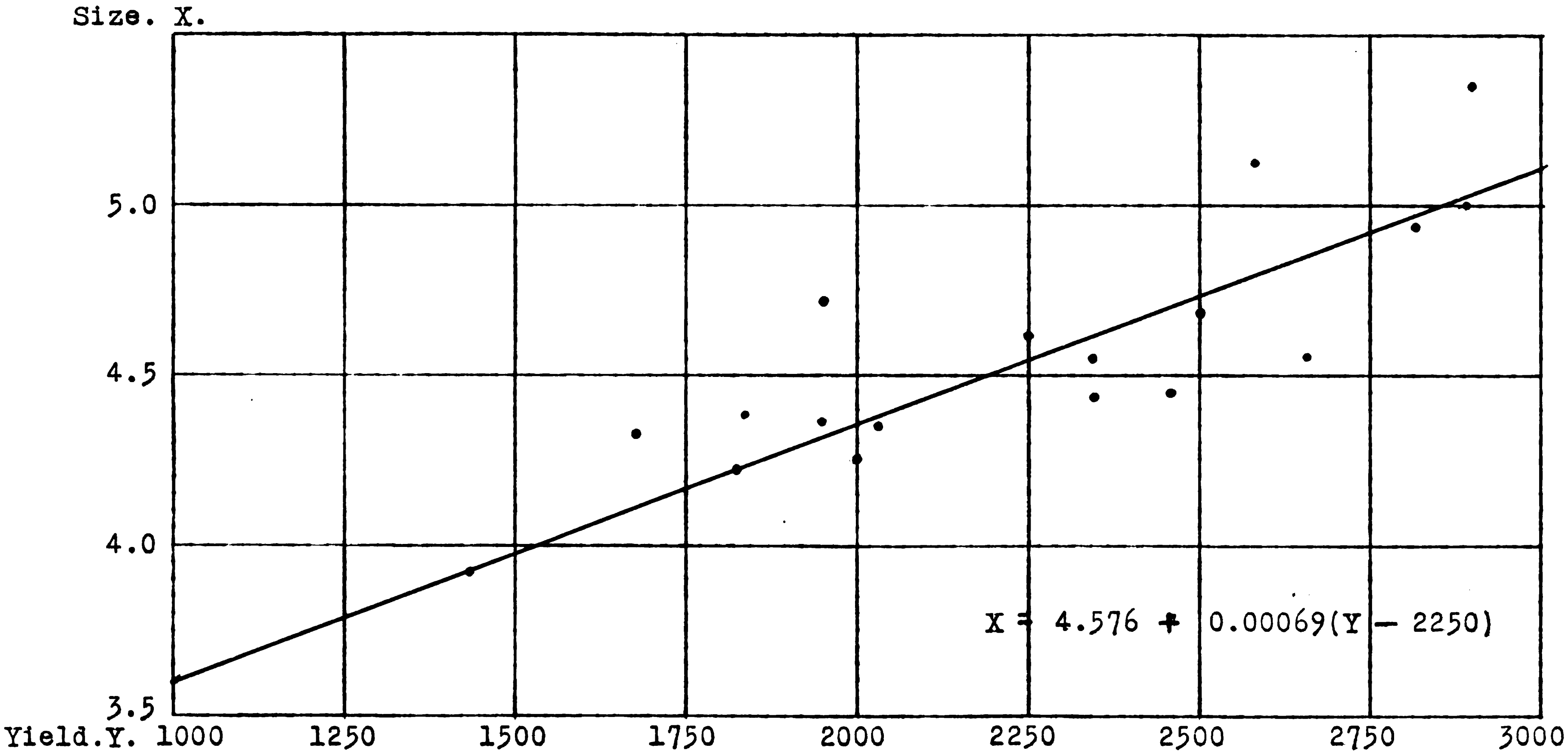

Figure 5.--Correlation between the average yield per acre, 1933-38, and average "size" of edible spears of asparagus from eighteen treatments.

Net Loss or Gain over Basal (acre basis).--The average price received for asparagus during the past six years was 9.75 cents per pound delivered at the canning factory. It was thought, however, that an average price of 10 cents per pound would be more representative, as this was the price selected by a recently appointed Marketing Board. The monetary loss or gain on the basis of 75 per cent marketable is shown in column 5 of table 12, and the net loss or gain over the basal treatment after the expense or saving in fertilizer or manure was considered is shown in column 8. This figure "net loss or gain over basal treatment" is used in comparing the performance of each treatment in the presentation of the results.

Table 12.--The relation between yield of edible spears and cost of fertilizers in 18 treatments as compared with a basal treatment

Plot letter	Exp. symbol	Total yield	Diff. from basal treatment	Loss or gain in yield @10¢ & 75% marketable	Total cost of fertilizer	Exp. or saving in fertilizer	Net loss or gain over basal
		lb.	lb.	$	$	$	$
O	2N10M(Sp.)	17376	2401**	180.08	208.00	-42.88	137.20
N	20M	17474	2499**	187.43	240.00	-74.88	112.55
P	2N10M(Su.)	16925	1950**	146.25	208.00	-42.88	103.37
M	10M	15499	524**	39.30	120.00	45.12	84.42
L	2N2P2K5M	16011	1036**	77.70	225.12	-60.00	17.70
E	2N1P2K	14815	-160	-12.00	147.36	17.76	5.76
C	2N2P2K	14975			165.12		
K	1N1P1K5M	14054	-921**	-69.08	142.56	22.56	-46.52
G	2N2P1K	14016	-959**	-71.93	144.32	20.80	-51.13
D	2N2K	13493	-1482**	-111.15	129.60	35.52	-75.63
I	1N1P1K	11715	-3260**	-244.50	82.56	82.56	-161.94
J	5M	11029	-3946**	-295.95	60.00	105.12	-190.83
F	2N2P	11710	-3265**	-244.88	123.52	41.60	-203.28
R	2N2P2K(Ext)	11977	-2998**	-224.85	165.12	--	-224.85
Q	2.7N2P2K	12212	-2763**	-207.23	185.91	-20.79	-228.02
B	1N2P2K	10930	-4045**	-303.38	121.12	44.00	-259.38
A	2P2K	10124	-4851**	-363.83	77.12	88.00	-275.83
H	0	8628	-6347**	-476.03	--	165.12	-310.91

Necessary difference for significance in total yield to the 1% point = 223 pounds

The greatest net loss as compared with a standard treatment, in this case the basal treatment, was where no fertilizer was applied and this loss amounted to $310.91.

The best returns were obtained from treatments which received ten tons of manure and nitrogen in the spring, or 20 tons of manure alone. The application of ten tons of manure alone was more economical than the basal treatment, the difference in profit amounting to $84.42.

EFFECT OF FERTILIZERS

A more detailed analysis of the influence of nitrogen, phosphorus, potash, and manure in varying amounts, in different combinations and at two times of application, is presented here. Each series (table 3) was designed to investigate the value of seven methods of fertilizing asparagus, so that all the available experimental information on each treatment is included in this presentation.

Nitrogen

Four levels of nitrogen, varying from no nitrogen, 30 pounds, 60 pounds, and 80 pounds of nitrogen applied in the form of nitrate of soda, together with 64 pounds of phosphoric acid and 96 pounds of potassium oxide, are available for comparison in the nitrogen series. The high nitrogen treatment (2.7N2P2K) was begun in 1933 by converting into a fertilizer treatment a short harvesting plot which up to that time had received the basal treatment. In table 13 the performance of each of the levels of nitrogen is shown. The first application of nitrogen at the rate of 30 pounds brought about a very significant increase in yield amounting to 806 pounds (see also figure 4), a slight but not significant decrease in "size" of spear, and a gain of $16.45 over no nitrogen which was en extremely poor plot.

Table 13.--The effect of nitrogen in the fertilizer treatment on the yield, weight, and returns from edible spears, 1933-38

Quantity N per acre	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
lb.		lb.		$		
0	2P2K	10124	-4851	-275.83	4.332	-0.349
30	1N2P2K	10930	-4045	-259.38	4.225	-0.456
60	2N2P2K	14975	basal treatment		4.681	
80	2.7N2P2K	12212	-2763	-228.02	4.336	-0.345

Total yield - necess. diff. for significance 1% = 223 lb.

"Size" - necess. diff. for significance 1% = 0.118 lb.

The basal treatment (2N2P2K) outyielded the high nitrogen treatment to the extent of 2,763 pounds, and produced spears which were also significantly larger than spears produced by other nitrogen treatments. Under the conditions of this experiment the increases brought about by nitrogen were greater than those attributable to the addition of phosphorus or potash. A net gain of $275.83 and $259.38 were obtained by the basal application over no nitrogen and 30 pounds of nitrogen, respectively.

The high nitrogen treatment (2.7N2P2K) in 1933 was outyielded by the basal treatment to the extent of 340 pounds (table 10) because at this time it was a short harvesting treatment. The trend, however, as shown in figure 6 indicates that the difference between the two levels of nitrogen became progressively greater until 1936 when it was reduced to 55 pounds, only to become greater in 1937 and 1938. The season of 1936 was very dry, and the extra nitrogen was apparently beneficial.

These results seem to indicate that a 6 per cent level of nitrogen, in the form of nitrate of soda, when combined with 6 per cent phosphoric acid and 10 per cent potassium oxide and applied at the rate of 1,000 pounds per acre, will outyield levels of 8 per cent and 3 per cent nitrogen significantly.

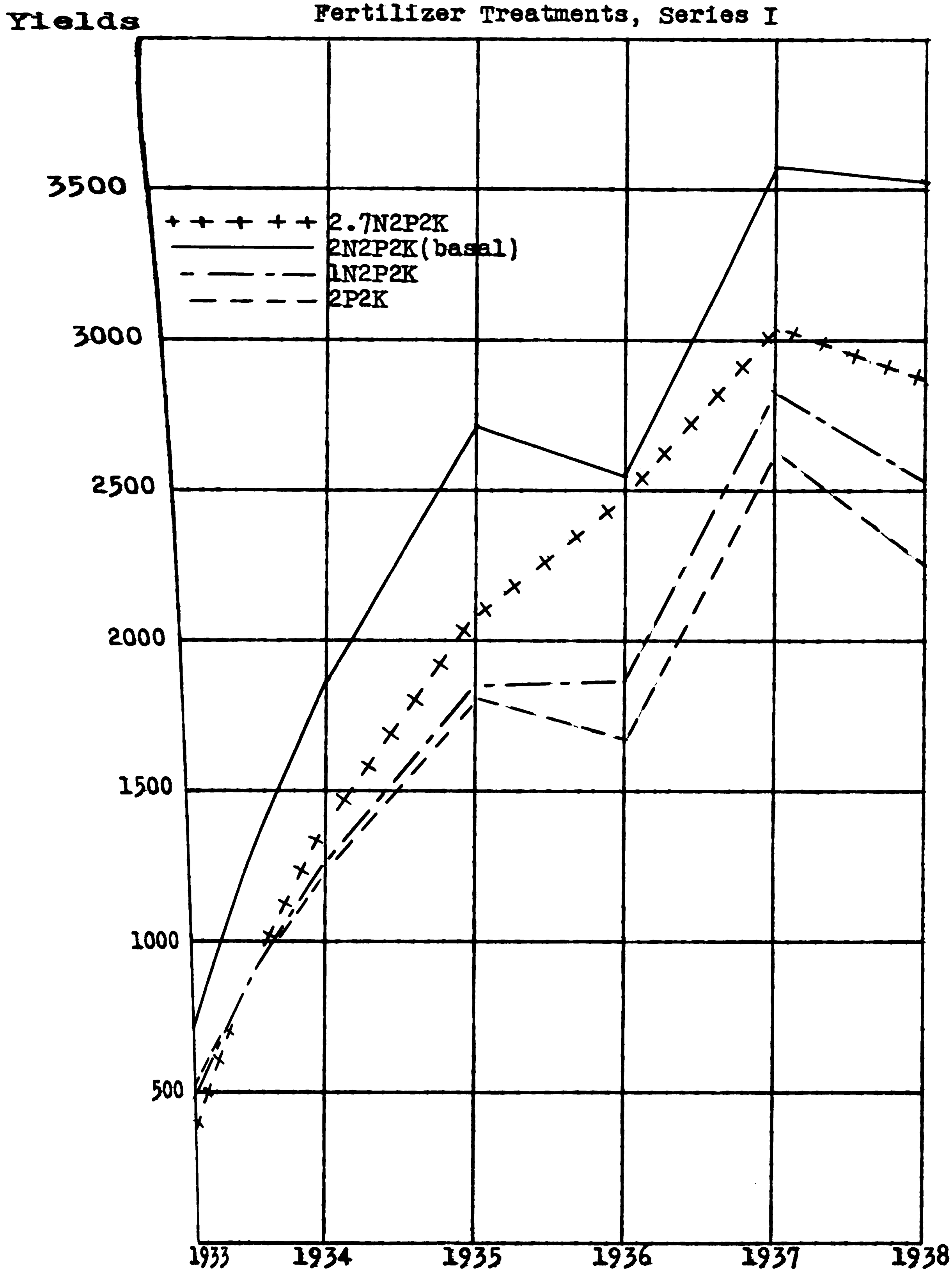

Fig. 6.--Yields of asparagus, in pounds per acre, in the Nitrogen Series (no nitrogen, 30 pounds, 60 pounds, and 80 pounds nitrogen per acre).

Phosphorus

Phosphorus was applied in the form of 16 per cent superphosphate at the rate of none, 32 pounds, and 64 pounds of phosphoric acid per acre, together with 60 pounds of nitrogen and 96 pounds of potash. A significant increase in yield was obtained by the addition of 32 pounds of phosphorus, but no additional response was procured by increasing this application up to 64 pounds (table 14).

Table 14.--The effect of phosphorus in the fertilizer treatment on the yield, weight, and returns from edible spears, 1933-38

Quantity P per acre	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
lb.		lb.		$		
0	2N2K	13493	-1482	-75.63	4.618	-0.063
32	2N1P2K	14815	-160	5.76	4.440	-0.241
64	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

An examination of figure 7 shows that the lower level of phosphorus (1P) outyielded the basal treatment in 1934, 1936, and 1937. The "size" of spear obtained from the treatment receiving 1P was quite significantly smaller than that obtained from the basal treatment, and smaller than that harvested from the treatment which did not receive phosphorus. The increase in yield of the basal treatment over 2N1P2K (table 14) was not large enough to justify the extra cost of the additional superphosphate.

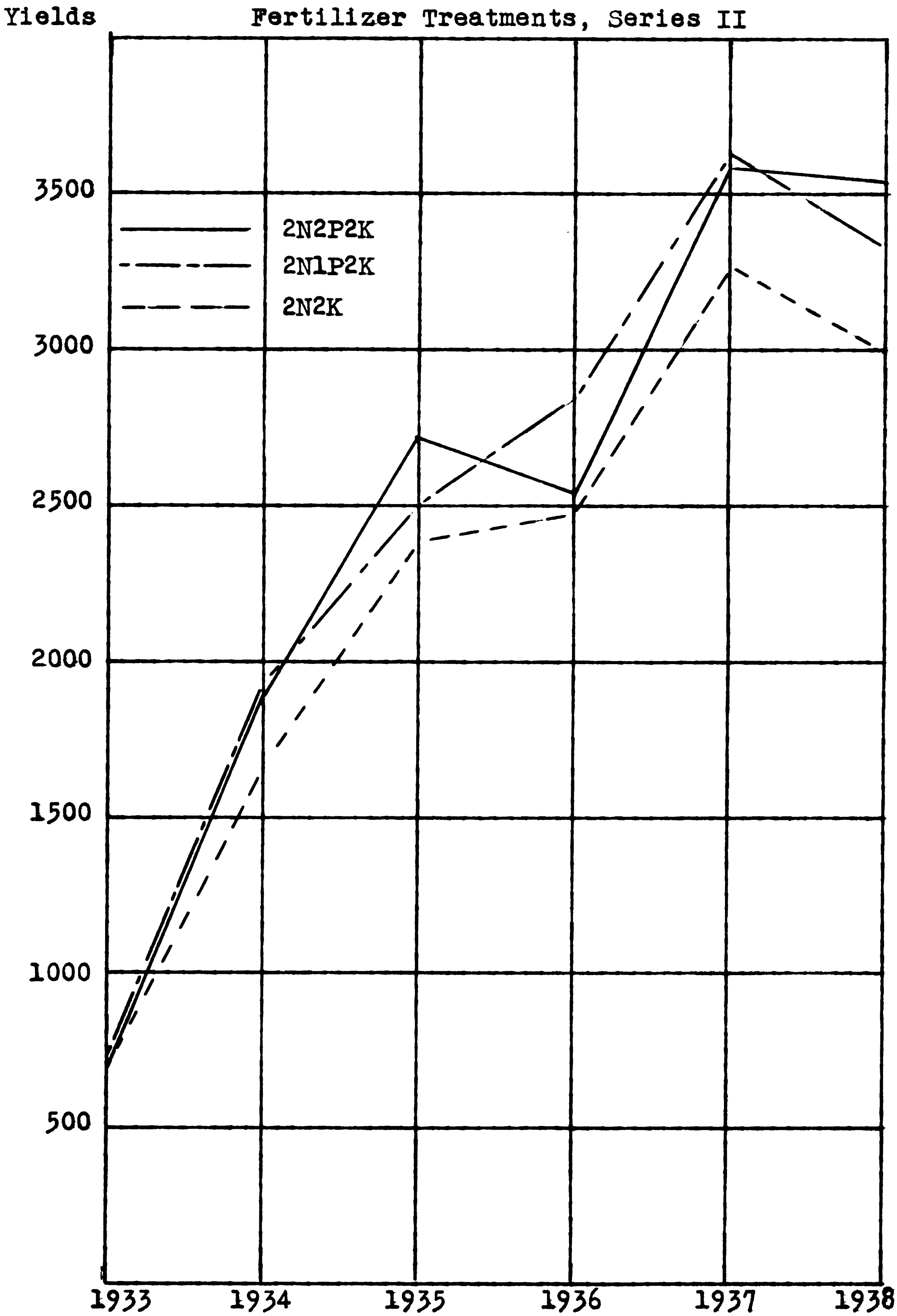

Fig. 7.--Yields of asparagus, in pounds per acre, in the Phosphorus Series (no phosphorus, 32 pounds, and 64 pounds of phosphorus per acre).

These results show that at Harrow a three to four per cent level of phosphoric acid was sufficiently high when combined with a six per cent level of nitrogen and a ten per cent level of potash.

Potash

The plots used in the study of the effect of potash on the growth of asparagus received annually no potash, 48 pounds, and 96 pounds of potassium oxide in the form of muriate of potash, together with 60 pounds of nitrogen and 64 pounds of phosphoric acid per acre. The plot receiving only 2N2P (table 15) averaged 544 pounds of asparagus per year and 3,265 pounds over the entire period less than the basal treatment (2N2P2K), and the difference between 2N2P2K and 2N2P1K amounted to a total of 959 pounds in favour of the higher application of potash. These differences are highly significant. The addition of 48 pounds of potassium oxide increased the size of spear 0.158 pounds per 100 spears over the plots receiving no potash. The application of 96 pounds of potassium oxide, as in the basal treatment, increased the "size" 0.147 pounds per 100 spears. These increases in size of spear are also highly significant. From the standpoint of cost, the net loss as compared with the basal treatment amounted to $203.28 and $51.13, respectively, which emphasizes the need of potash in the fertilizer.

Table 15.--The effect of potash in the fertilizer treatment on the yield, weight, and returns from edible spears, 1933-38

Quantity K per acre	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
lb.		lb.		$		
0	2N2P	11710	-3265	-203.28	4.376	-0.305
48	2N2P1K	14016	-959	-51.13	4.534	-0.147
96	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

Figure 8 shows the performance of each level from year to year, and demonstrates clearly the need of potash. The difference between 1K and 2K, whilst significant over the period, was extremely small in 1936--a year in which the basal treatment did not perform very well.

These results indicate that asparagus can utilize to advantage 96 pounds of potassium oxide when applied at the rate of 1,000 pounds per acre in a 6-6-10 ratio of fertilizer.

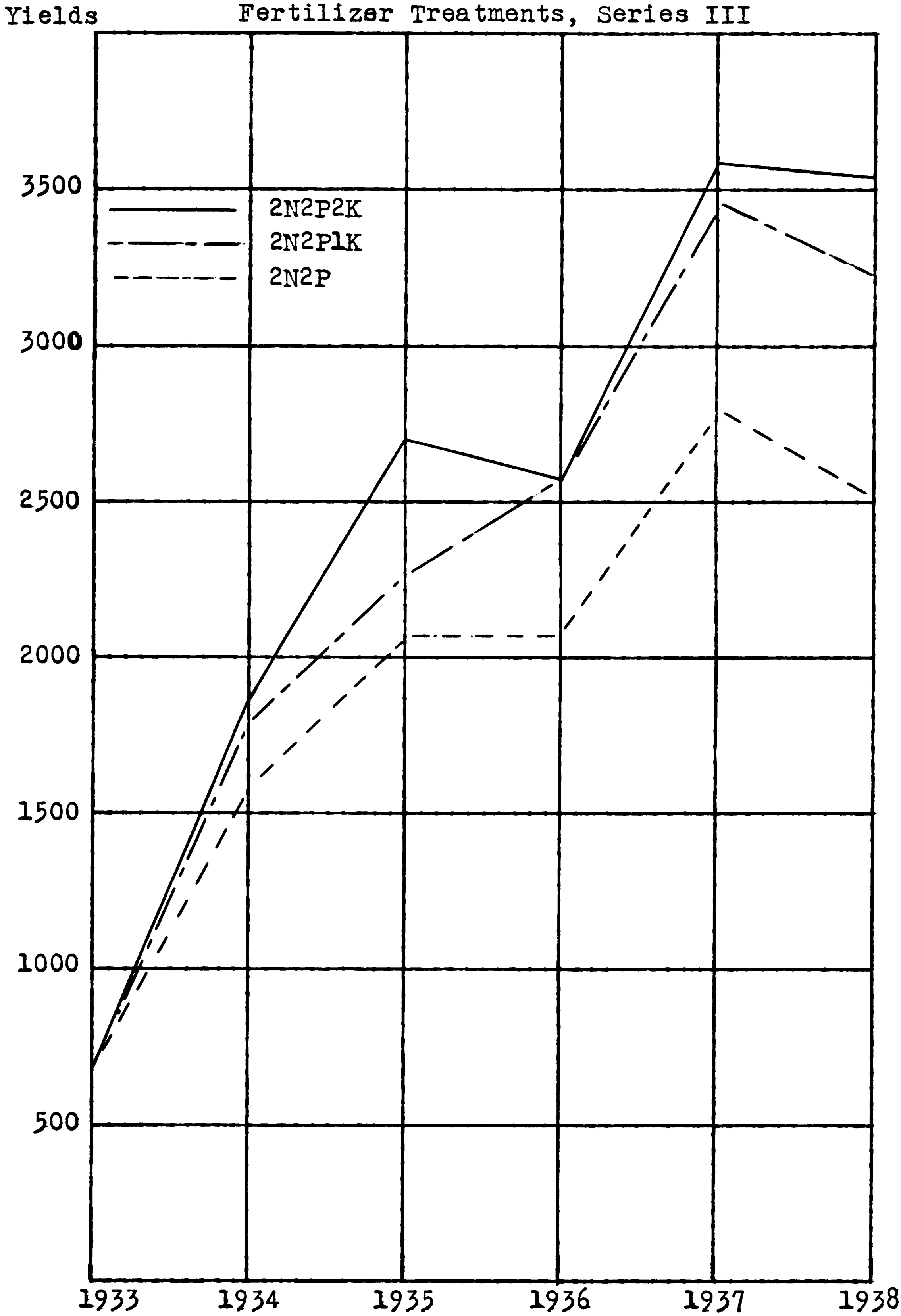

Fig. 8.--Yields of asparagus, in pounds per acre, in the Potash Series (no potash, 48 pounds, and 96 pounds of potash per acre).

Amount of Fertilizer

The heaviest application of fertilizer made in the experiment consisted of 1,000 pounds of a 6-6-10 ratio fertilizer (2N2P2K) known as the basal treatment, with which is compared a 500-pound application of the same ratio (1N1P1K).

In table 16 the effect of these two rates of application of fertilizer as compared with the plots that received no fertilizer on the yield, "size" of spear, and returns are shown. The addition of fertilizer brought about a steady increase in total yield. The 500-pound application brought about an increase of 3,087 pounds which was increased by an additional 3,260 pounds where the application was 1,000 pounds. These results seem to indicate that asparagus would have responded favourably to even heavier applications of this analysis of fertilizer. The use of fertilizer increased the "size" of spears very significantly, but no difference was observed between the amounts of fertilizer, despite the high correlation between the yield and "size" of spears shown to exist. (figure 5).

Table 16.--The effect of the amount of basal fertilizer on the yield, weight, and returns from edible spears, 1933-38

Quantity 6-6-10 per ac.	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
lb.		lb.		$		
0	-0-	8628	-6347	-310.91	3.937	-0.744
500	1N1P1K	11715	-3260	-161.94	4.723	0.042
1000	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

The performance of the three treatments is shown graphically in figure 9, and indicates the uniform response of the treatments in each season regardless of the amount of fertilizer used. There is a gradual tendency for the differences in yield per year to become wider over the period of the experiment, but the fluctuations in 1936 and 1938 are similar. The performance of the check seems to indicate, however, that this treatment has probably already reached its period of maximum production as the response to the favourable weather conditions of 1937 was very slight as compared with the better-yielding treatments.

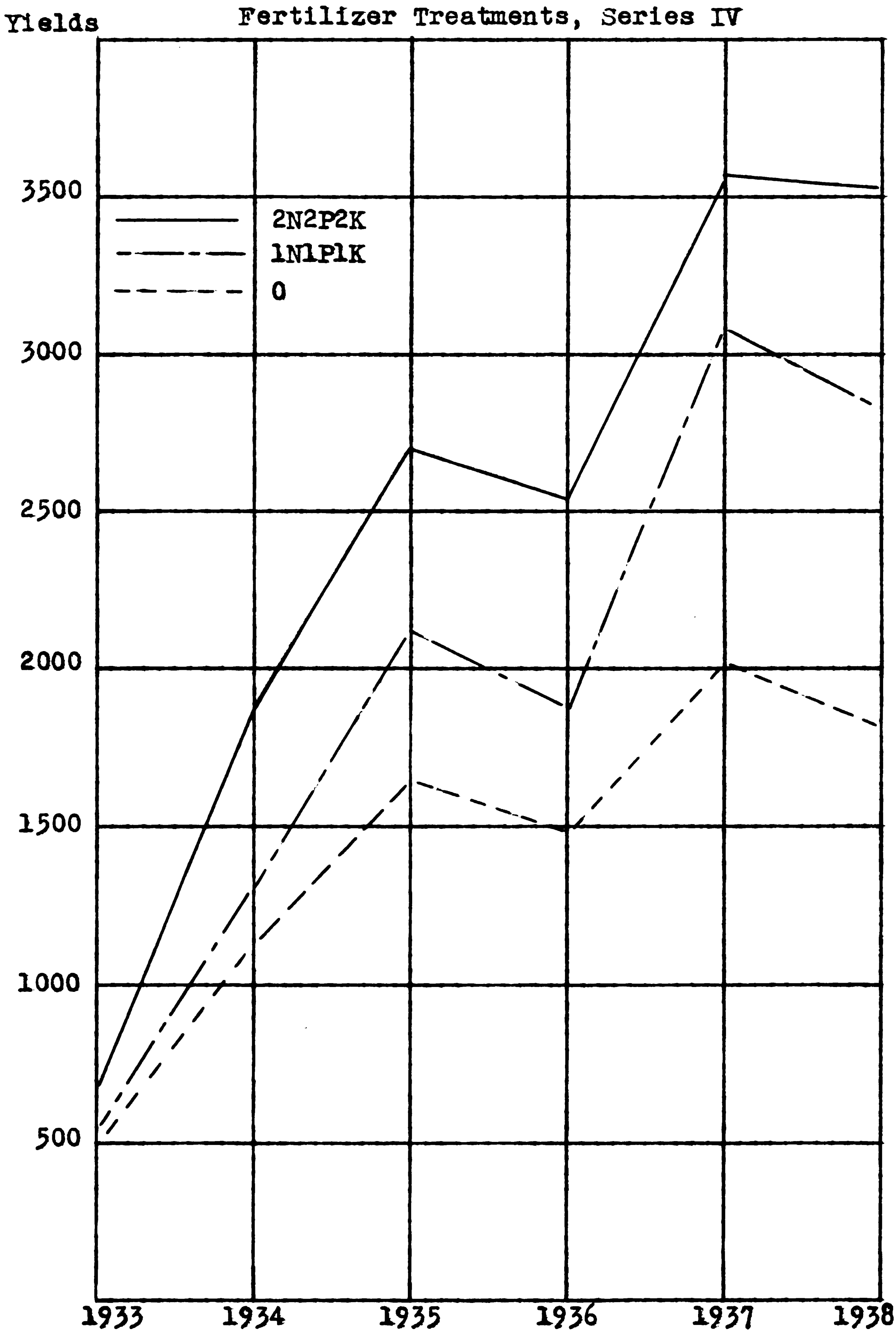

Fig. 9.--Yields of asparagus, in pounds per acre, in the Quantity of Basal Fertilizer Series (no fertilizer, 3-3-5, and 6-6-10 at the rate of 1000 pounds per acre).

Chemical Fertilizer and Manure

The experimental plots were arranged in such a manner that the relative values of manure and commercial fertilizer when applied separately and together could be compared. In table 17 the yield data are given for the plots receiving no manure or fertilizer, five tons of manure, five tons of manure plus 500 pounds and 1,000 pounds of 6-6-10 fertilizer, and 500 and 1,000-pound applications of 6-6-10.

Table 17.--The effect of the amount of basal fertilizer added to five tons of manure, compared with the basal treatment on the yield, weight, and returns from edible spears, 1933-38

Quantity 6-6-10 per ac.	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
lb.		lb.		$		
0	5M	11029	-3946	-190.83	4.399	-0.282
1000	2N2P2K	14975	basal treatment		4.681	
500	1N1P1K5M	14054	-921	-46.52	4.477	-0.204
1000	2N2P2K5M	16011	1036	17.70	4.561	-0.120
0	0	8628	-6347	-310.91	3.937	-0.744
500	1N1P1K	11715	-3260	-161.94	4.723	0.042

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

A glance at this table shows that the addition of 500 pounds of a 6-6-10 fertilizer (1N1P1K) was superior in yield, "size", and net returns to the application of five tons of manure. Five tons of manure, however, when added to 500 pounds of 6-6-10 fertilizer (1N1P1K5M) and 1,000 pounds of

6-6-10 fertilizer (2N2P2K5M) increased the total yield by 2,339 and 1,036 pounds, respectively, but decreased the "size" of spear significantly in both cases. All these treatments, however, were sufficiently profitable to absorb the increased cost of fertilizer.

The manure and fertilizer treatments are shown graphically in figure 10, in which the behaviour of chemicals and manure can be compared over the six seasons. In the early years of the experiment, in contrast to the performance of 2N2P2K5M and 2N2P2K, the addition of five tons of manure to 500 pounds of 6-6-10 fertilizer did not lower the yield. In direct comparison with chemical fertilizers at low and high rates of application, it can be seen that the addition of manure produced a normal increase in yield, whereas the chemical fertilizer treatments suffered a decrease in yield in 1936 as compared with 1935. This beneficial effect continued on into 1937 in the case of the 1N1P1K5M treatment which even outyielded the basal treatment in that year.

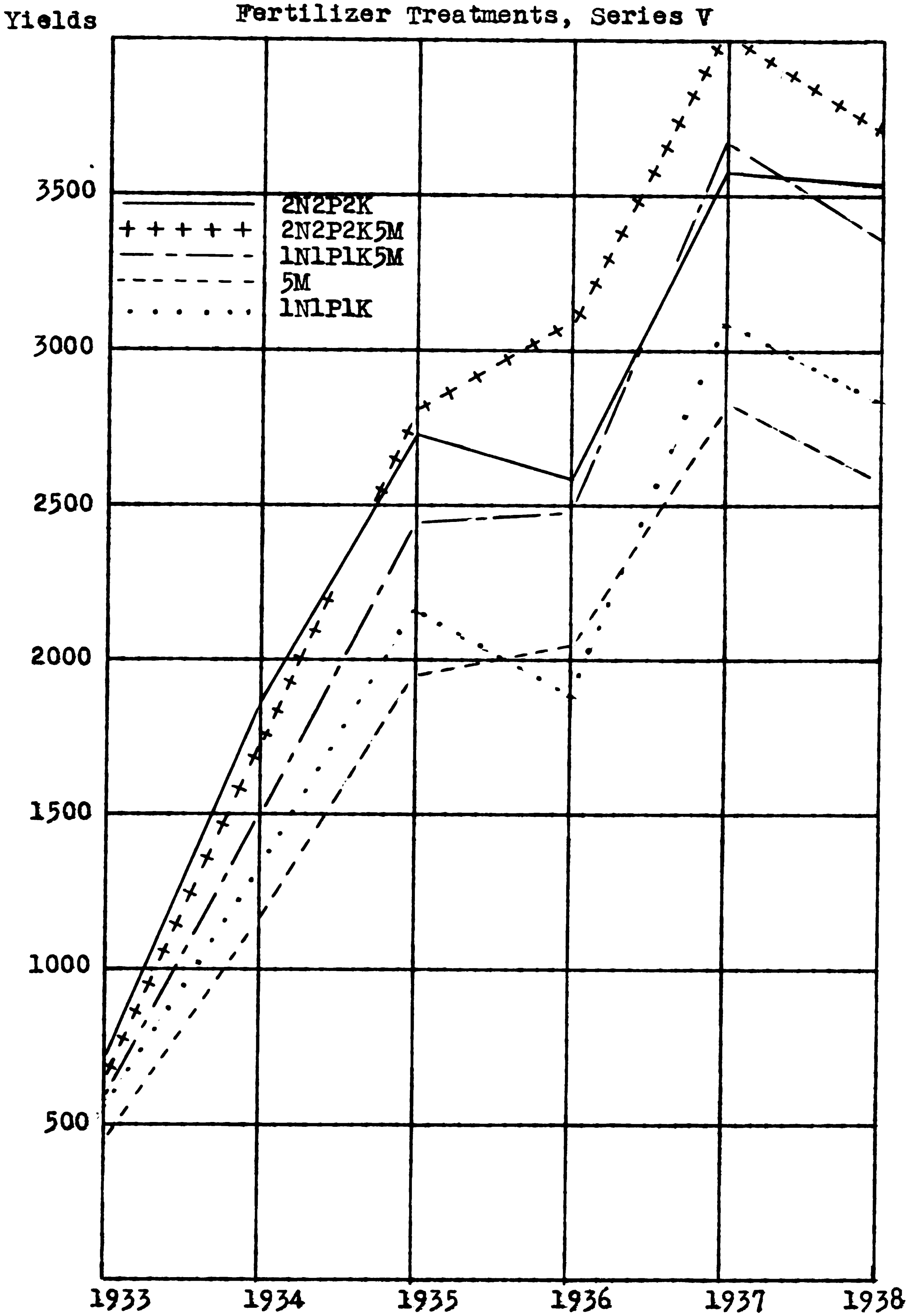

Fig.10.--Yields of asparagus, in pounds per acre, in the Manure and Complete Fertilizer Series (5 tons of manure alone and in combination with 1000 pounds of 3-3-5 and 6-6-10 fertilizer compared with the basal treatment).

Amount of Manure

Barnyard manure, as obtained from the horse stables and the cow barns, was applied in the fresh condition in the spring at 5, 10, and 20-ton rates per acre. The first application was made in 1932 at the beginning of the second year of growth, bringing the total number of applications per plot up to seven during the experiment.

Table 18 shows the effect on the yield, "size" and returns of these three levels of manure as compared with no fertilizer and the basal treatment (2N2P2K). The additional increments of manure caused a consistent increase in yield and "size," the greatest differences per ton applied occurring between the five and ten-ton rates of application. At $1.50 per ton, the 10 and 20-ton rates were also more profitable than an application of 1,000 pounds of a 6-6-10 fertilizer.

Table 18.--The effect of the amount of manure compared with the basal treatment on the yield, weight, and returns from edible spears, 1933-38

Quantity manure per ac.	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
ton		lb.		$		
0	-0-	8628	-6347	-310.91	3.937	-0.744
5	5M	11029	-3946	-190.83	4.399	-0.282
10	10M	15499	524	84.42	5.136	0.455
20	20M	17474	2499	112.55	5.321	0.640
0	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

Figure 11 shows graphically the trend of the five treatments. The chemical fertilizer treatment (2N2P2K) outyielded 20 tons of manure in 1933, and even no fertilizer produced a larger yield than five tons of manure. In 1934, however, the trend changed so that in 1936, a very dry year, the differences were highly in favour of the manurial treatments, and seemed to point to the beneficial effect of the accumulation of organic matter. All treatments suffered a severe set-back in 1938 which seemed to be proportionally greater on the higher-yielding treatments.

These results indicate where asparagus is planted on a porous lake sand low in organic matter that ten tons of manure will outyield 1,000 pounds of a 6-6-10 ratio fertilizer, and that further additions of manure up to 20 tons will still bring about profitable increases in yield.

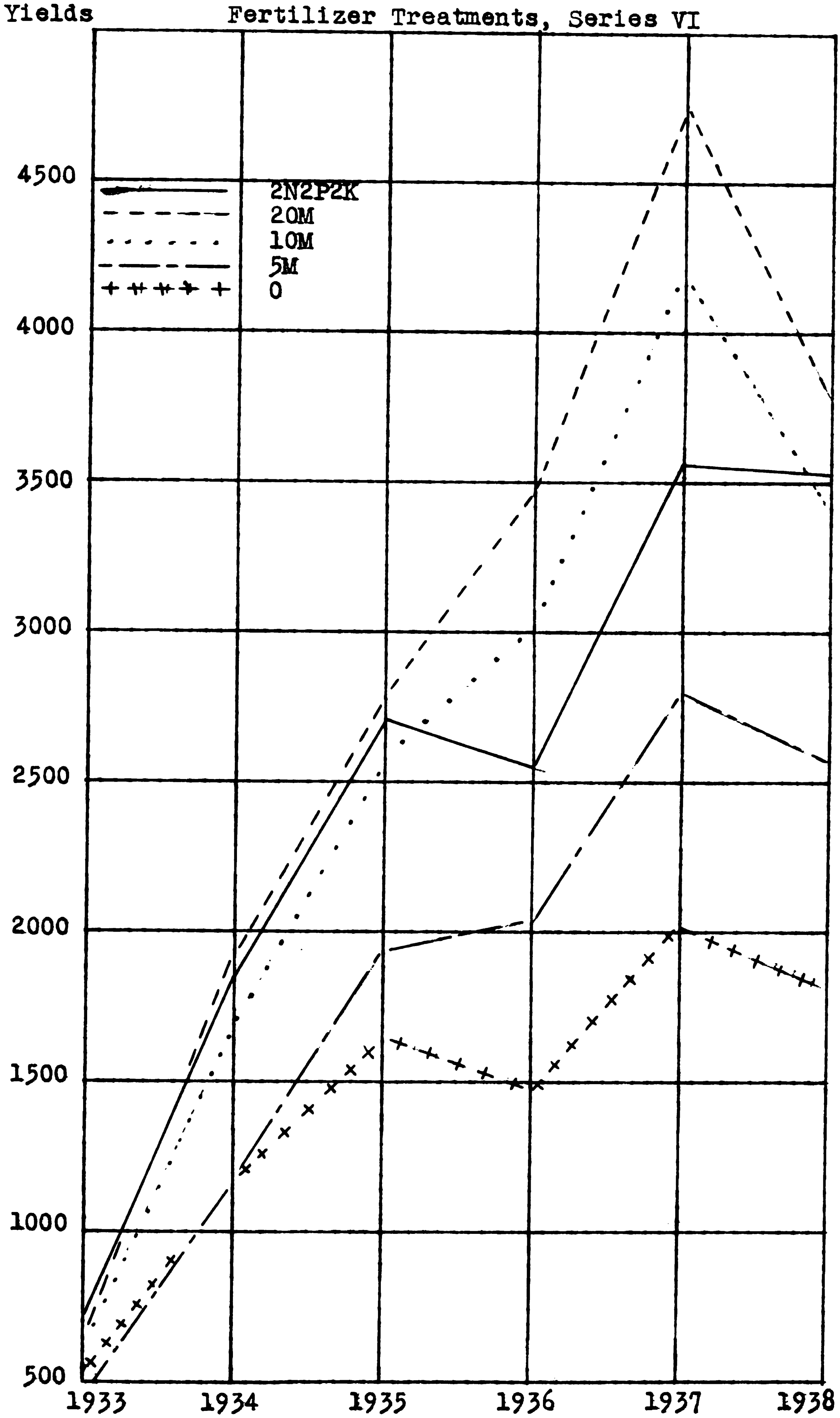

Fig. 11.--Yields of asparagus, in pounds per acre, in the Manure Alone Series (no manure, 5 tons, 10 tons, and 20 tons of manure compared with the basal treatment).

Time of Application of Nitrogen, and Manure

Nitrogen, as nitrate of soda, at the rate of 400 pounds per acre (2N), added either in the spring or in the summer to a spring application of ten tons of barnyard manure is compared in table 19 with the performance of the basal treatment which was always applied in the summer. A decided increase in total yield, "size," and net returns was obtained over basal from both the nitrogen-manure treatments. In comparing these two latter treatments a significant increase in yield of 451 pounds was procured in favour of the spring application, and this was reflected in a greater "size" of spear and in the largest net returns over basal obtained in the experiment (figure 4).

Figure 12 shows graphically the trend of these treatments under discussion. In the early years of the experiment, despite the extra application of nitrogen to take care of the decomposition of the manure, the purely chemical fertilizer (2N2P2K) was slightly better. In 1935, however, the spring application of N (2N10M) gained the lead and, in common with all the organic treatments in the experiment, continued to increase in yield despite the drought season of 1936. The summer application of nitrogen followed very closely the performance of the spring application, and likewise suffered a severe reduction in yield in 1938.

In a consideration of the time of application of nitrogen these results seem to show that where ten tons of manure are applied in the spring the nitrogen can be added with benefit at the same time as the manure.

Table 19.--The effect of time of application of nitrogen, added to ten tons of manure, on the yield, weight, and returns from edible spears, 1933-38

Time of application	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
		lb.		$		
Spring	2N10M(Sp)	17376	2401	137.20	5.060	0.379
Summer	2N10M(Su)	16925	1950	103.37	4.962	0.281
Summer	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

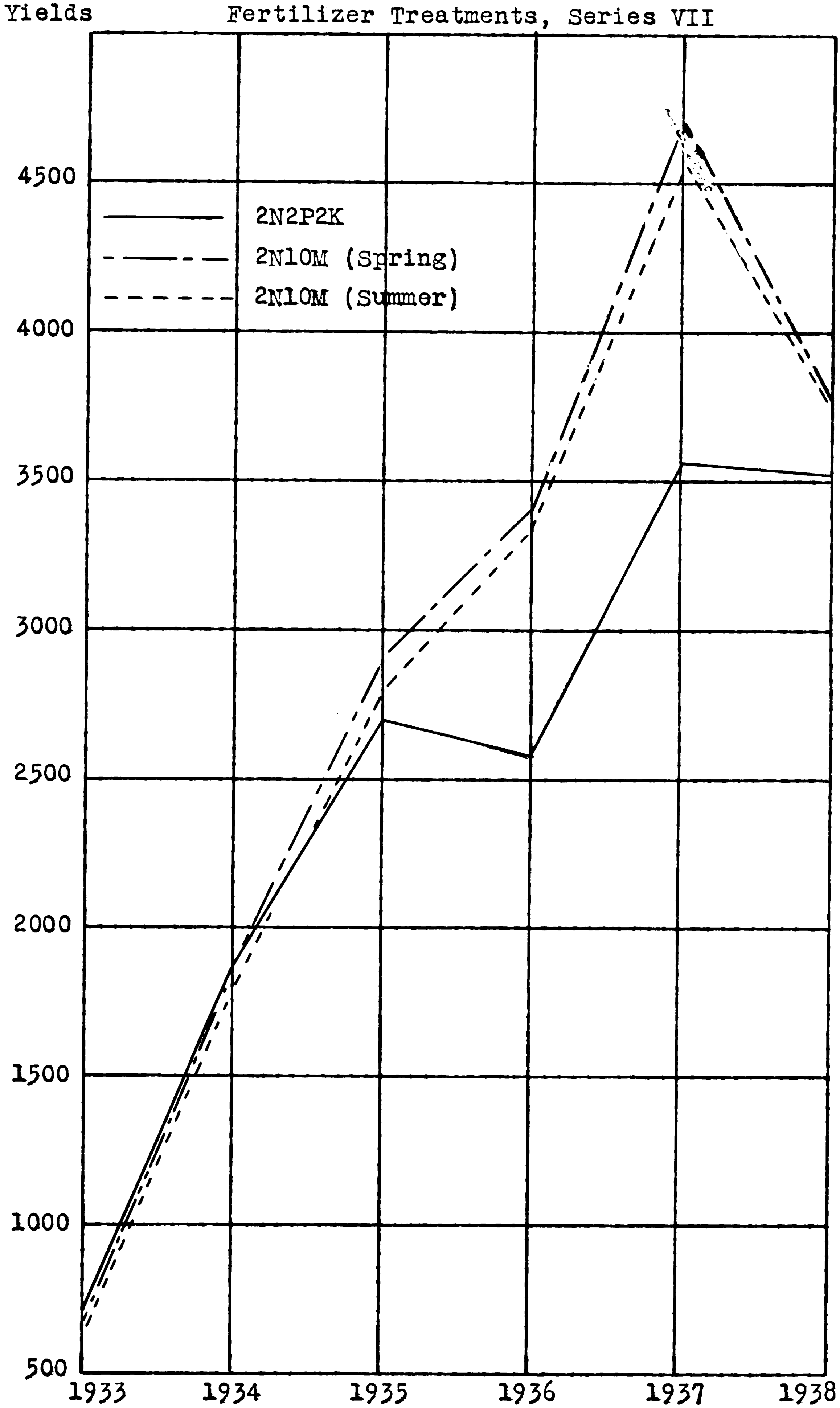

Fig. 12.--Yields of asparagus, in pounds per acre, in the Time of Application of Nitrogen plus Manure Series (spring vs. summer applications of 60 lbs.N plus 10 tons M, compared with

EFFECT OF HARVESTING

Extended Harvesting

The extended harvesting treatment, begun in the same year as the normal harvesting treatment, was designed to show the danger of cutting the spears over too long a period. A difference of from four to nine days in the length of the harvesting period was maintained (table 5). An application of 1,000 pounds of a 6-6-10 fertilizer was made annually to the treatment, similar to that made on the basal treatment.

A difference of almost 3,000 pounds total yield of asparagus (table 20) was obtained in favour of normal harvesting as conducted on the basal treatment. A glance at table 10 and figure 13 shows the consistent behaviour of normal harvesting. Despite the longer period of harvesting given to the extended harvesting treatment in 1933, the normal treatment outyielded it; but the general trend in the years following, however, would indicate that the more drastic cutting was responsible for the difference, which over the period of the experiment was very significant.

The net financial gain in favour of the normal harvesting treatment amounted to $224.85, even though no allowance has been made for the extra cost of extended harvesting. It would seem justifiable on the basis of these results to conclude that three weeks of cutting in the third year of growth, six weeks in the fourth year, and eight weeks in the fifth or sixth year, as applied to the bulk of the experiment, was a reasonable treatment.

Table 20.--The effect of extended cutting as compared with normal (basal treatment) on the yield, weight, and returns from edible spears, 1933-38

Harvesting	Exp. symbol	Total yield	Diff. from basal treatment	Net loss or gain over basal	Avg. wt. per 100 spears "size"	Diff. from basal treatment
		lb.		$		
Extended	2N2P2K(Ext)	11977	-2998	-224.85	4.250	-0.431
Normal	2N2P2K	14975	basal treatment		4.681	

Total yield - Necess. diff. for significance 1% = 223 lbs.

"Size" - Necess. diff. for significance 1% = 0.118 lbs.

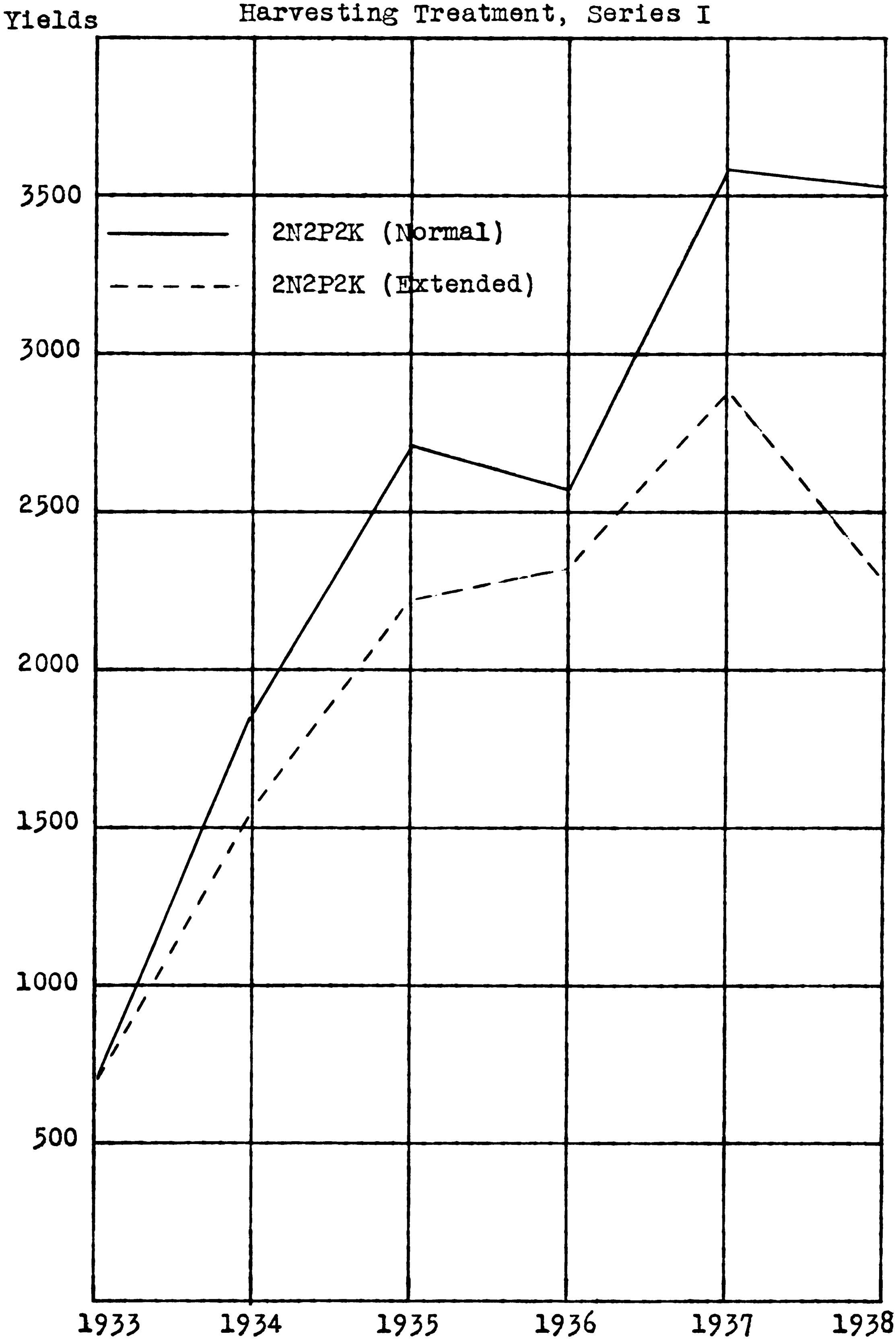

Fig. 13.--Yields of asparagus, in pounds per acre. Extended cutting as compared with normal cutting (1000 pounds of 6-6-10 fertilizer per acre annually).

EFFECT OF SEASON AND AGE

The curves (figures 6-13), showing the trend of growth from 1933-38 of the 18 treatments, are not smooth nor are they similar in form, which points to a differential response to other factors of growth. The only measurable factors which varied from season to season were those of cutting (table 5) and weather. In order to assist in discussing the effect of seasonal differences in weather, a brief synopsis of Seasonal Notes at Harrow (25) is included.

The Seasons at Harrow

Temperature and precipitation records have been taken at Harrow since 1917. The sunshine records were begun a year later, and these observations were augmented in 1935 by records on soil temperature, relative humidity, and evaporation. Seasonal Notes also have been prepared each year on the general character of the season as it influenced the growth of crops (25). A graph (figure 14) based on these records has been prepared over the period of the experiment, 1931-38, incorporating the mean temperature during the growing season, the total annual precipitation, and the average number of hours sunshine per month during June, July, August, September, and October. The "normal" or average of these records obtained since 1917 or 1918 has been added also, and appears as parallel lines on the graph. As a background the average annual treatment yield per acre has been charted in order to demonstrate the general response, if any, of the asparagus plant to these environmental conditions.

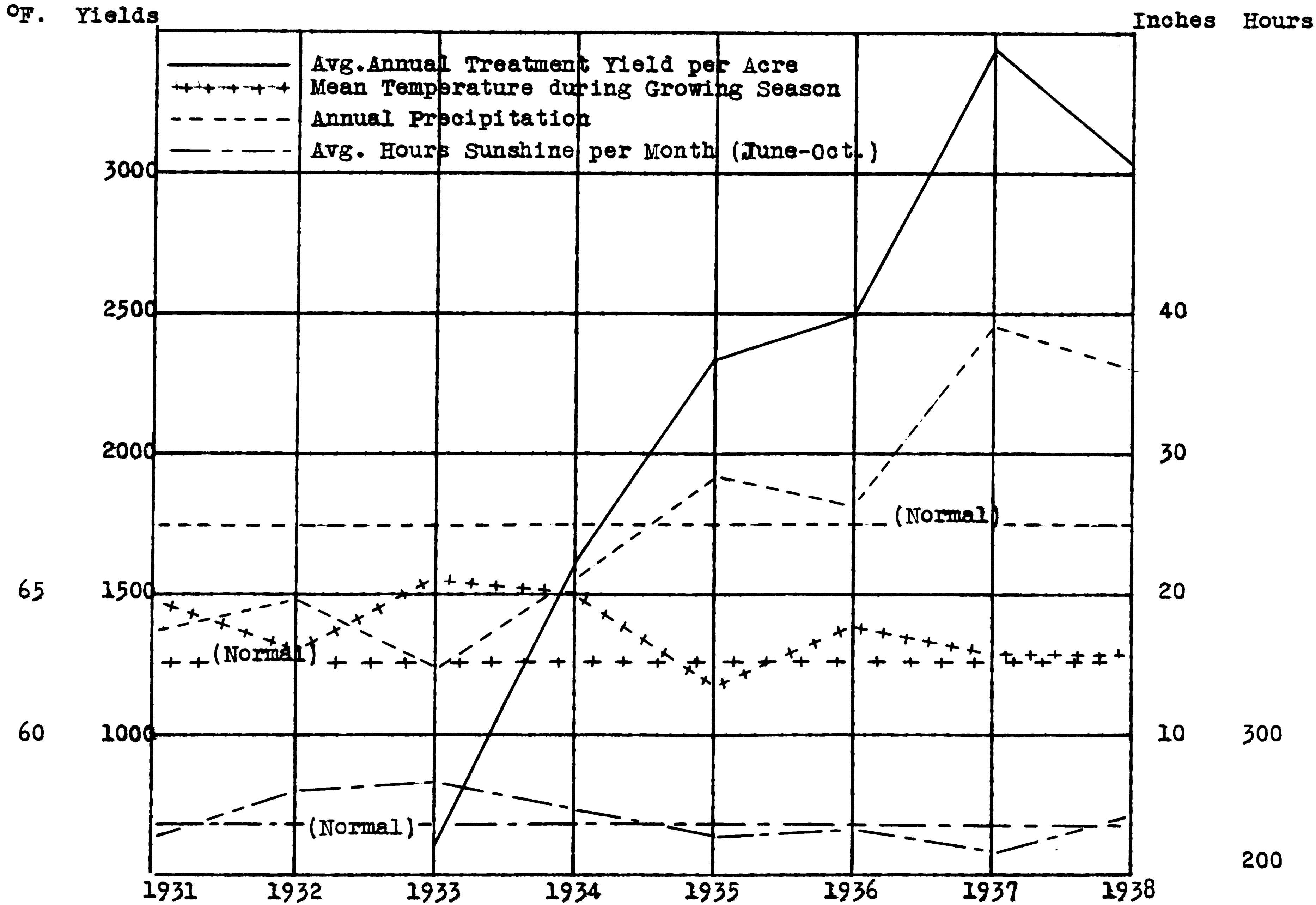

Fig. 14.--The relation between the average annual treatment yield per acre and some meteorological data at Harrow, 1931-38.

According to the Seasonal Notes (25), the season of 1931 was earlier, warmer, and drier than usual but precipitation was well-distributed. Exceptionally good crops of sweet corn, field corn, and tobacco were obtained in the district. The experiment was planted in the spring of 1931 and made excellent growth.

The spring of 1932 was dry but was followed by very heavy precipitation in May. The mean temperature was almost normal but precipitation, whilst greater than that of 1931, was very poorly distributed throughout the growing season. An excellent crop of flue-cured tobacco was harvested despite the difficulties of the season. The asparagus bed was not cut at all during the second season of its growth and is reported to have developed very well.

The year 1933 was the driest year ever recorded at Harrow month by month since 1917. June was extremely hot and all early crops suffered because of lack of moisture. It was necessary to delay the planting of tobacco, corn, and tomatoes. The continuation of drought in July and August lowered both the quality and yield of these crops. The asparagus plots were cut over a period of 19 days in 1933, and an average yield of 589 pounds per acre was obtained. Weather data obtained at Chatham, 60 miles away in a north-easterly direction, did not show such extreme drought conditions as were experienced at Harrow. The average number of hours sunshine during the period when the asparagus plant carries on photosynthesis was the highest recorded during the period of the experiment.

Seasonal Notes (25) for 1934 reported another very dry season in which the precipitation for May achieved a new minimum. The rainfall throughout the season was poorly distributed and all crops yielded less than in previous years. The mean temperature during the growing season was almost as high as that for 1933 and the second highest recorded during the period of the experiment. The average number of hours sunshine, however, showed a decided drop as compared with the previous season. The experimental plots were harvested over a period of 39 days, and an average yield of 1,584 pounds per acre was obtained.

The season of 1935 was described as almost ideal for the growth of crops in Southwestern Ontario. Rainfall was well-distributed throughout the season and reached a maximum figure in August double that of the normal figure for this month. The sunshine records showed a decided drop as would be expected. The experimental plots were harvested over a period of 42 days, and an average yield of 2,335 pounds was obtained. In contrast to the ideal season of 1935, it was reported (25) that the season of 1936 was inclement. "It was characterized by a cool wet spring, a very hot dry midsummer, and a late fall with ample moisture. The drought covered a period from July 4 until the middle of August, during which time only one-half inch of rainfall was recorded." The lack of moisture was accentuated by seven days of the hottest weather on record, and a record absolute temperature of 105.1 degrees F. was reached. Heavy rainfall, however, in August and September followed by a long fall promoted the growth of late crops such as corn, tobacco, and asparagus tops. The sunshine records in 1936 remained normal despite the hot, dry weather. The asparagus plots were harvested for 44 days and an average treatment yield of 2,500 pounds per acre was obtained, which was not as large considering the age of the plantation as the yields of 1933 and 1934 promised.

The season of 1937 was different in character from that of 1933, 1934, and 1936 in that, at no time, did any serious deficiency of moisture occur. In fact, the total precipitation of 39.08 inches was the highest recorded at the Station. The mean temperature was lower than that of 1936, and the average number of hours sunshine was the lowest recorded during the experiment. The plots were harvested over a period of 55 days, and an average yield of 3,452 pounds was obtained, which was more in keeping with the rate of increase established in 1933 and 1934.

The year 1938 was similar in many respects to the season of 1937, except that it was characterized by an unusually early spring followed by a severe frost. The supply of moisture was constant throughout the summer, and the mean temperature and number of hours of sunshine were normal and similar to those in 1937. The plots were harvested over a period of 64 days, nine days longer than in 1937, and a yield of 3,043 pounds per acre was obtained. This yield was considerably lower than that of 1937 and may have been caused by a late discing which followed the early development of shoots, and by a severe frost on May 9 which curtailed cutting for eight days.

During the period of the experiment the average number of hours of sunshine during the months of June, July, August, September, and October, and the mean temperature during the growing season decreased gradually, and this was accompanied by a rapid increase in the total annual precipitation. These data when averaged over the eight years closely approximate a normal season at Harrow. Almost every type of extreme which has been recorded occurred during the period of the experiment, so that it can be assumed that the weather conditions were normal.

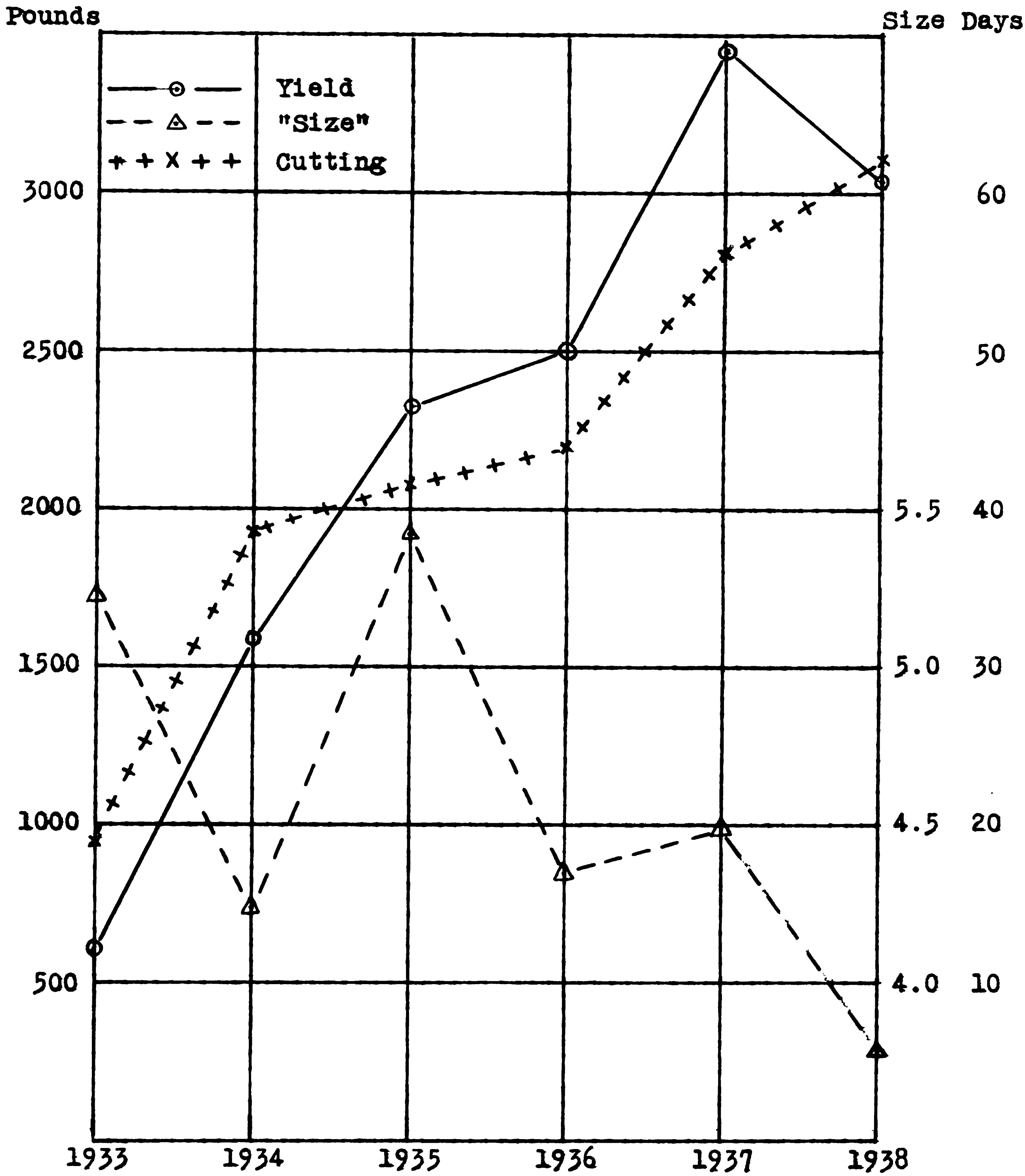

Figure 15.--The average yield per acre and "size" of spears from eighteen treatments from the third to the eighth year of growth, together with the length of cutting season in days.

Age

It is the natural tendency for the asparagus plant to increase its root system gradually until the increase is curtailed by competition from adjacent plants. It has been estimated that it takes five or six years to reach this stage of maximum root development (Morse, 22), although the period of time has been found to vary directly as the area allotted to each plant is increased (Hanna, 10). Asparagus growers, recognizing this principle, permit the plant to carry on photosynthesis throughout the entire season until the third year of growth when a light cutting is given, which is increased each year until the sixth year of growth. At Harrow the average yield of all treatments increased proportionally as the length of cutting was extended (figure 15). The "size" of spear, however, fluctuated in the first three years only to decrease rapidly in 1936, 1937, and 1938 (table 11, figure 15). A very significant positive correlation between yield and "size" was found in individual treatments (figure 5), but this is not true of the gross yield between years of growth. The difference between the largest and smallest "size" and yield per treatment in each year became wider as the fertilizer requirements of the poorer plots became more acute (figure 16, table 21), but this difference was influenced to some extent by the seasonal response of the treatments.

Table 21.--The yield and "size" of the high, basal, and low treatments, and average of all treatments in each year, 1933-38

Treatment	1933 Yield	1933 "Size"	1934 Yield	1934 "Size"	1935 Yield	1935 "Size"	1936 Yield	1936 "Size"	1937 Yield	1937 "Size"	1938 Yield	1938 "Size"
High	702	5.760	1947	5.027	2926	6.130	3482	5.337	4813	5.320	3813	4.637
Basal	695	5.393	1887	4.407	2706	5.787	2552	4.257	3586	4.377	3548	3.867
Low	447	4.350	1157	3.740	1645	4.907	1480	3.643	2024	3.680	1819	2.860
Average	589	5.222	1584	4.240	2335	5.437	2500	4.342	3452	4.449	3043	3.764

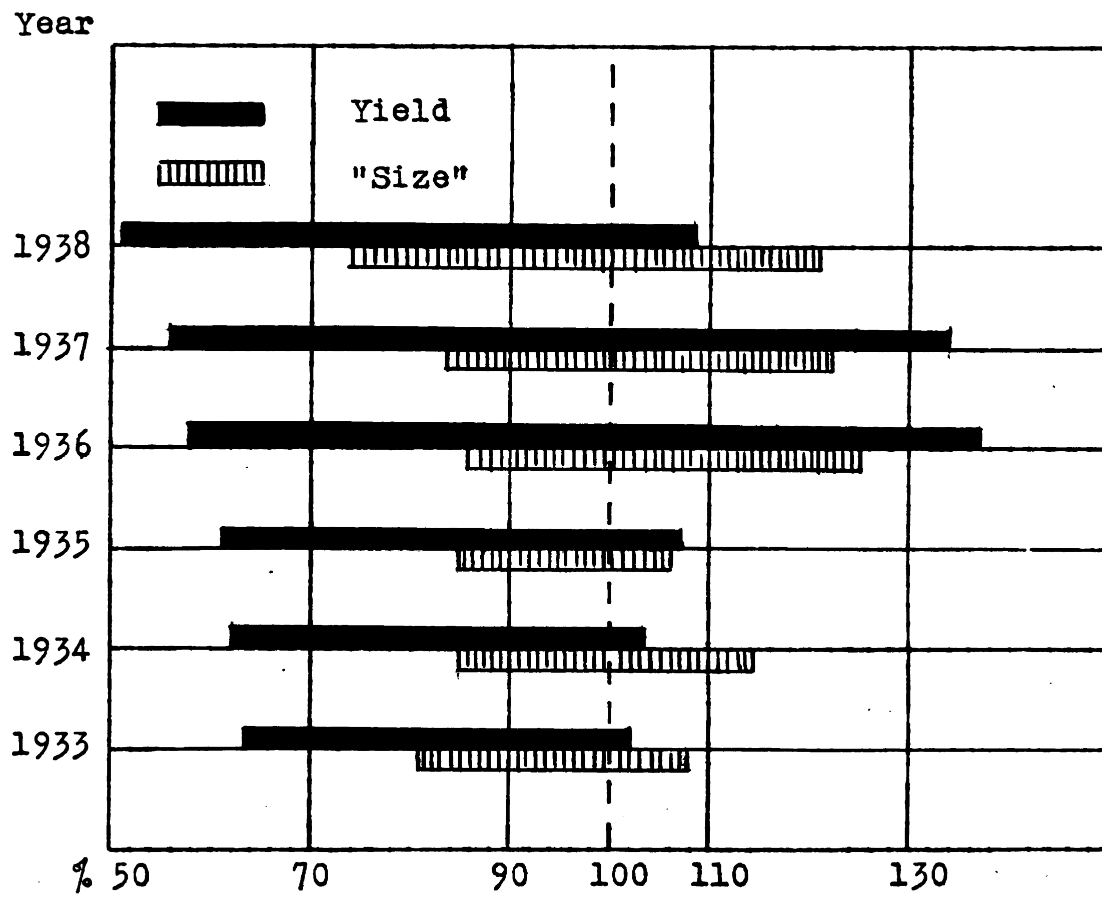

Figure 16.--The range between high and low yield and "size" treatments expressed as a percentage of basal treatment (100%).

Age and Seasons

From 1933 the average annual treatment yield increased rapidly until 1935 which was an excellent season as reflected in the "size" of spear and the average yield (figure 15). This rate of increase in yield, however, was reduced quite perceptibly in 1936, and was accompanied by a marked reduction in the "size" of spear, which the weight of evidence available would indicate was caused by the dry, hot cutting season of this year. The yield obtained in 1937 was more in keeping with the rate of increase established in 1933 and 1934, which may be accounted for by the smaller yield harvested and the excellent conditions for photosynthesis and growth in the latter part of 1936, which permitted a long cutting season. The fall in yield in 1938 has been attributed to damage which was done by early discing and later by a mid-season frost, but these reasons will not account for the small average "size" of spears harvested in 1938. It should be recalled that the cutting season of 1938 was cold and wet, which may explain this reduction in size.

DISCUSSION OF RESULTS

An examination of the results of this experiment shows that the growth of asparagus, as exemplified by the yield and "size" of spears, was influenced by chemical and organic fertilizer, the amount and the time of application of fertilizer, the harvesting method, the season, and the age of the plantation. The results of comparable experiments with asparagus are compared in this discussion with those obtained at Harrow; and an attempt will be made to explain why similar or contradictory results were reported elsewhere.

The effects on the annual yield per acre and the average "size" of spears of asparagus, obtained by varying quantitatively the three elements N, P, and K in the basal treatment are shown in figure 17.

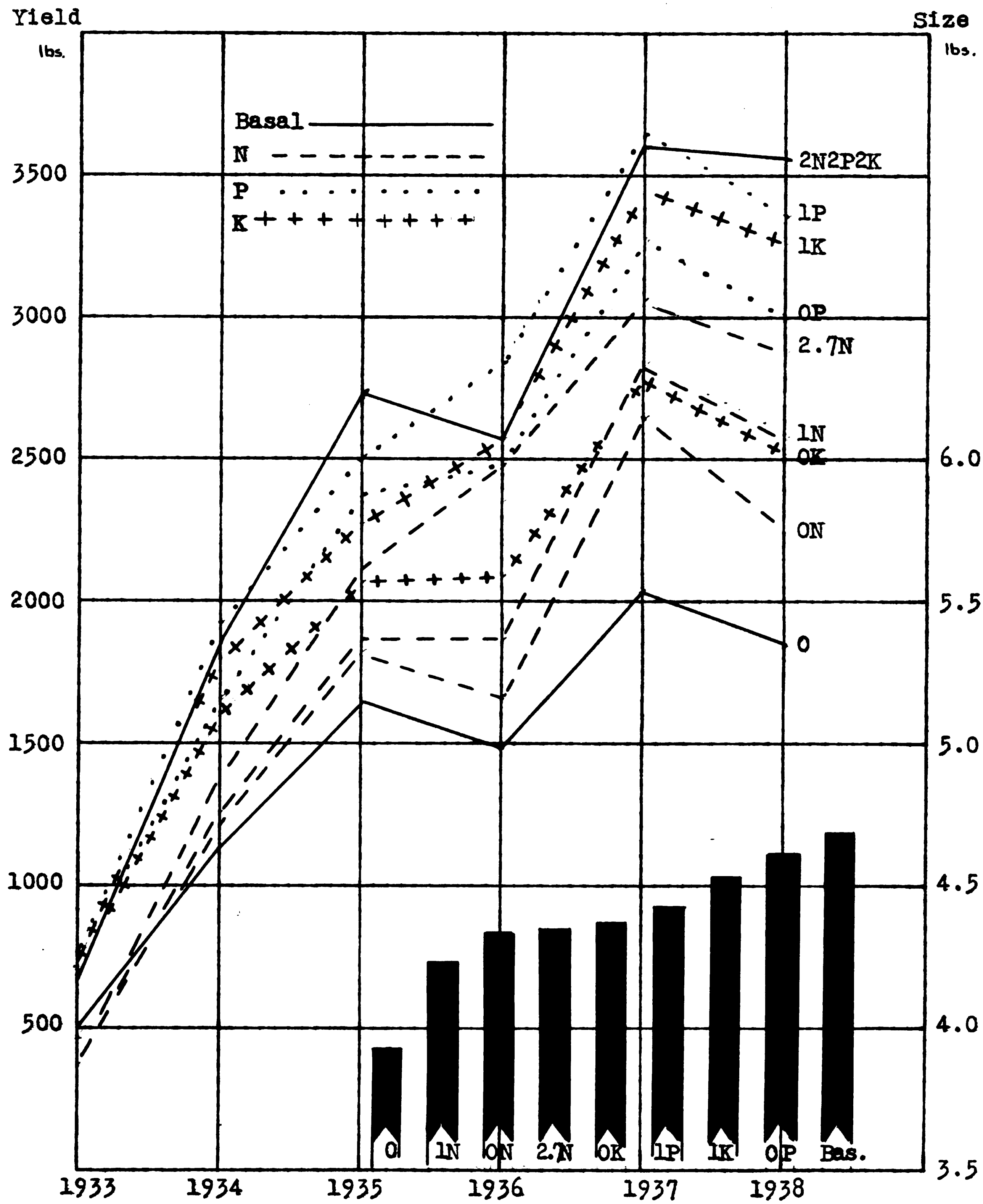

Figure 17.--Annual yields per acre of asparagus and average "size" 1933-38 of four levels of N, and three levels of P and K

At Harrow, nitrogen appeared to be the most limiting factor of growth as demonstrated by the performance of 1N which was inferior in yield and "size" to OP and OK, but when applied at the basal level showed a marked improvement in yield and "size." A greater application of nitrogen, as at the 2.7N level, resulted in a decreased yield and smaller spears. These results agree closely with those obtained by other investigators. Warren (Jones, 15) found a three per cent level of nitrogen at 2,000 pounds per acre sufficiently high in Maryland. Wessels and Thompson (42) on Long Island also found that five per cent level was superior to the ten per cent level of nitrogen as obtained from nitrate of soda and ammonium sulphate, although the reduction in yield was attributed to the "acid effect" of ammonium sulphate. These workers found that larger yields were obtained where no fertilizer was applied than on the treatment lacking nitrogen but supplied with phosphorus and potash. Brooks and Morse (2) in Massachusetts obtained the highest yields from an application of nitrogen similar to that used in the basal treatment at Harrow. Similarly, Watson (40) obtained no benefit by applying more than 1,000 pounds of a 7-5-7 fertilizer, although Bryan (3) was more successful where he used 2,000 pounds of a 5-7-5 fertilizer.

Phosphoric acid, regardless of the amount applied, had the least noticeable effect on the yield and "size" of spears as can be seen by the narrow range within which the three levels of phosphorus lie. Spears smaller than those produced on the no phosphorus treatment and the basal treatment were harvested from an application of 30 pounds of phosphorus. This effect was duplicated by the application of 30 pounds of nitrogen as compared with the no nitrogen treatment where the reduction in "size" of spear was almost significantly different (figure 17), but both these treatments were excelled by the basal treatment. There does not seem to be any satisfactory explanation for this peculiar effect of phosphorus. It seems safe, however, to conclude from the results obtained at Harrow that a fertilizer containing a four per cent level of phosphoric acid when combined with a six per cent level of nitrogen and a ten per cent level of potash is well-balanced for the production of asparagus. Brooks and Morse (2) obtained similar results in Massachusetts where a four per cent level of phosphorus was found to be most effective. Seaton (33) in Michigan applied 1,200 pounds of a 4-6-10 fertilizer and obtained excellent results. Bryan (3), however, found that 2,000 pounds of a fertilizer containing a seven per cent level of phosphorus produced maximum yields. Similarly, Wessels and Thompson (42) were forced to apply 13 per cent phosphoric acid at the rate of 1,000 pounds per acre in order to obtain any significant increases in yield, and attributed this behaviour to the absorptive effect of the soil colloids for phosphorus. No workers reported any significant increase in "size" of spear which could be linked with the increase or decrease in the amount of phosphorus applied.

Potash was intermediate between nitrogen and phosphorus in its effect on the yield and "size" of asparagus spears. Figure 17 shows clearly how the absence of potash in the ratio compared with the absence of nitrogen. The relative proximity of the five per cent level of potash to the basal treatment seems to suggest that at Harrow an eight per cent level of potassium oxide, when combined with six per cent nitrogen and four per cent phosphorus, would constitute a fertilizer well-balanced for the growth of asparagus. These results are in agreement with those obtained by Bryan (3), Brooks and Morse (2), and Wessels and Thompson (42) who also concluded that potassium chloride, the form used at Harrow, was the most satisfactory source of potash. Young, however, in Massachusetts (45) stated that significant increases have been obtained from the application of 1,000 pounds of fertilizer containing an 18 per cent level of potash. Bryan (3) and Young (45), contrary to the results obtained at Harrow, found that potash influenced the "size" of spear more significantly than nitrogen or phosphorus.

In comparing the amounts of 6-6-10 ratio fertilizer which could be applied to asparagus (table 16), the results seemed to indicate that a heavier application than 1,000 pounds could be made with the assurance of greater yields. In support of this Bryan (3), in South Carolina, reported that 2,000 pounds of 5-7-5 ratio fertilizer could be applied economically to asparagus. Young (45) in Massachusetts also recommended 2,000 pounds of fertilizer but increased the ratio to an 8-10-12 fertilizer.

Seaton (33), however, found that 1,250 pounds of a 4-8-6 ratio fertilizer were more economical than 1,800 pounds of a similar ratio in Michigan. Brooks and Morse (2) in 1911 emphasized the unnecessary expense entailed in applying more than 1,000 pounds of a 7-6-13 fertilizer to asparagus in Massachusetts, but Young's (45) more recent suggestions do not agree with this statement, although the latter worker did not mention whether there was any economic advantage in applying more than 1,000 pounds of the 8-10-12 ratio stated in his recommendations. At Harrow, the addition of 1,000 pounds of 6-6-10 fertilizer brought about an increase over 500 pounds of the same ratio, similar to that produced by the latter application over no fertilizer, which might justify raising the application to 1,500 or 2,000 pounds of a properly-balanced ratio. A consideration of the effect of varying the levels of N, P, and K suggests that a 6-4-8 ratio of fertilizer is well-balanced, which is not markedly different from that used in the basal treatment (6-6-10). The slight reduction in annual yield which occurred in the dry year of 1936 in the case of the basal treatment is compared with varying levels of N, P, and K in figure 17. Where the nitrogen was increased to 8 per cent (2.7N), no reduction in yield occurred, which was also true of the 5 per cent level of potash (1K) and the 3 per cent level of phosphorus (1P). This reduction in yield appears to be peculiar to plots lacking sufficient nitrogen, or receiving an over-balanced amount of phosphorus and potash. It is interesting to notice, however, that where barnyard manure was added to the full application and half application of basal fertilizer (figure 10) no reduction in yield occurred, which may be explained as being due to the added nitrogen and the improved water-holding capacity by reason of added organic matter, since the practice of removing and burning the "brush" was followed. Jones and Robbins (15) state that French and German growers, forced to reduce the amount of manure used, combine chemical fertilizer and manure with excellent results. Seaton (33), however, in Michigan obtained good yields by using chemical fertilizers alone and returning the "brush" to the soil, thereby maintaining a supply of organic matter. Brooks and Morse (2) came to the same conclusion in Massachusetts since they believed that, in addition to the return of the "brush" annually, the general decay of the older roots tended to maintain a satisfactory supply of humus.

Where manure alone was used (table 18) at Harrow, without the addition of chemical fertilizer, it was found that ten tons of manure outyielded 1,000 pounds of a 6-6-10 fertilizer and produced spears of greater size. Wessels and Thompson (42), in support of these results, found that during the latter part of eight years' observations ten tons of manure outyielded a fertilizer application of 1,000 pounds of a 10-13-16 fertilizer. White and Boswell (43) in Maryland on a soil that was initially high in organic matter, obtained better results from an application of 1,250 pounds of a 7-3-5 fertilizer than from ten tons of manure, but obtained opposite results in sand culture work. The highest yield obtained at Harrow was harvested from the plots receiving 20 tons of manure, and the spears were also of corresponding "size." Similar results were obtained by Close (5) in Maryland, and more recently by Wessels and Thompson (42), although both these workers conclude that the high cost of manure renders it impracticable.

Realizing this objection to the use of manure might one day apply to the Essex Peninsula, ten tons of manure were augmented by an application of 400 pounds of nitrate of soda, which can be applied at a cost slightly less than that of 20 tons of manure. The nitrogen was applied in two separate treatments, either in the spring or in the summer. The yield obtained from the spring application (2N10MSp.) was statistically as good as that obtained from the addition of 20 tons of manure, and significantly greater than the yield obtained from the summer application of nitrogen (2N10MSu.). The following workers--Seaton (33), Schermerhorn (32), and Young (45)--seem to agree that it is advisable to apply all the fertilizer in the spring. Watson (40), in an asparagus forcing experiment, obtained excellent responses by applying nitrogen before cutting. Nightingale (27) and Working (44), under laboratory conditions concluded that the asparagus plant could utilize nitrates without the aid of photosynthesis. Bryan (3) and White and Boswell (43) were unable to detect any difference in yield over a period of years which could be attributed to the time of application of fertilizer, provided the roots were in a good state of vigour. Brooks and Morse (2) failed to obtain any beneficial effect by combining nitrogen and manure, since either when applied alone yielded as well.

In comparing a slight extension of the harvesting season, beginning in the third year of growth, with the "normal" treatment given to the bulk of the experiment, the results show that permanent damage occurred, as reflected in significantly lower yields (figure 13, table 20). The "normal" treatment consisted of three weeks' cutting in the third year of growth, five weeks in the fourth year, and eight in the sixth year (table 5).

Experimentally similar results were recently reported by Haber (9) in Iowa, and by Lewis, Lloyd and McCollum (19,20) in Illinois, who found that cutting should be delayed until the third year of growth and increased gradually up to a maximum cutting period of eight weeks in the fifth year of growth.

In California, however, Jones and Robbins (14,15,16) state that it is possible to cut for a short time in the second year of growth, and when the plantation is fully established, to extend the cutting season up to ten weeks. Similar recommendations were made by Schermerhorn (32) in New Jersey.

It would appear, from a perusal of these results, that in sections characterized by a long, temperate cutting season which might exist along a sea-board harvesting can begin earlier in the life of the plantation and extend longer than is possible in areas of short and warm growing seasons, such as are typical of Illinois, Iowa, Michigan, and Ontario.

A rough study of the relationship between age, season, and the length of cutting season,. based on the average yield and "size" of the whole experiment and the best and worst treatments, permits the following conclusions: The average increase in yield up to the sixth year of cutting appears to vary directly as the period of harvesting, and indirectly as the "size" of spears (figure 15). The difference between treatments of smallest and largest yield and spears appears to increase, but may be influenced by seasonal conditions. Dry, hot weather as experienced in 1936 had an adverse effect on the yield and "size" of spears, but was more severe in those treatments lacking in organic matter. The experiment has passed its sixth year of cutting, during which a maximum yield of 4,813 pounds of spears was harvested in 1937 from the treatment receiving 20 tons of manure. It is not possible, however, to determine whether the plantation has reached its period of maximum production as yet, but certain treatments have already begun to decline in yield.

Results somewhat similar to those obtained at Harrow are reported elsewhere. Brooks and Morse (2) stated that maximum production was reached in the sixth year in Massachusetts, whilst Jones and Robbins (15) and Schermerhorn (32) extend this point to the seventh or eighth year, after which a period of steady production follows until the twelfth year. Wessels and Thompson (42) found also that there was a marked decrease in the percentage of marketable spears as the plantation became older. Most workers (15,22,32,44) have advocated the use of irrigation in the culture of asparagus when an emergency occurs as in very dry years. The maximum yield of 4,813 pounds as harvested at Harrow compares favourably with those harvested under experimental conditions elsewhere. Wessels and Thompson (42) obtained 4,459 pounds of spears in the sixth year of cutting in New York State where 20 tons of manure were applied. White and Boswell (43) bettered this in the twelfth year of cutting by an application of ten tons of manure. Seaton (33), however, in Michigan harvested 5,243 pounds of spears in the fourth year of cutting from the best-yielding treatment which had received chemical fertilizers entirely. These comparisons should strengthen the contention that asparagus, with proper care as to fertilization and harvesting, can be grown with success in Southwestern Ontario.

SUMMARY OF RESULTS

Any conclusions which may be drawn from an eight-year-old asparagus experiment can only be regarded as preliminary. It is felt, however, that some conclusions are sufficiently clear-cut to deserve mention so that prospective growers may utilize the information where similar conditions of growth occur. It is worthwhile to reiterate that the experiment was planted on a Berrien sand, low in organic matter, nitrogen, and potash, medium in phosphorus, and of a pH 5.4.

1. A high positive correlation was found between the average yield and the average weight per 100 spears within treatments, but the latter tended to decrease as the plantation became older.

2. In varying the amounts of either N, P, or K in a 6-6-10 ratio fertilizer at 1,000 pounds per acre, when keeping the remaining elements constant, it was found that nitrogen up to a six per cent level brought about increases in yield and "size" of spears.

3. Potash was also instrumental in causing an increase in yield and "size" of spears, but a lack of this element in the ratio was not as severe as insufficient nitrogen.

4. Phosphorus had the least significant effect on the yield and "size" of spears. No difference in "size" occurred where this element was omitted or applied at the six per cent level, but a reduction in "size" was obtained

at the three per cent level for which there does not appear to be any explanation.

5. The necessity of a proper balance between nitrogen, phosphorus, and potash was shown very early in the experiment. A ratio approximating a 6-4-8 relationship is suggested by the results, which may be applied in amounts exceeding 1,000 pounds per acre.

6. Manure and chemical fertilizer were combined to advantage, since the soil used was low in initial organic matter. The addition of five tons of manure to 1,000 pounds of a 6-6-10 fertilizer increased the yield and "size" of spear, particularly in the dry season of 1936.

7. The highest yield and largest "size" of spear were obtained from an application of 20 tons of manure, which was followed closely by ten tons of manure and 400 pounds of nitrate of soda. The yields obtained are comparable with yields reported in other asparagus producing areas in North America.

8. A slight extension of the harvesting period in the early years of development was shown to cause permanent damage, as indicated by the reduction in yield.

9. Those treatments receiving organic matter were not adversely affected by the dry season of 1936, contrary to the results obtained on the plots not receiving organic matter. It is questionable whether the practice of removing the "tops" in the fall and burning them is justified on soils low in organic matter.

10. There is no reason to believe that the better yielding treatments have passed their period of maximum production, which appears to be true, however, of those receiving no nitrogen.

BIBLIOGRAPHY

(1) Barnes, J. and Robinson, W. Asparagus culture. Orange Judd and Company, New York.

(2) Brooks, W. P. and Morse, F. W. A fertilizer experiment with asparagus. Mass. Agr. Exp. Sta. Bull. 194. 1919.

(3) Bryan, A. B. Fertilizing asparagus in South Carolina. Better Crops with Plant Food, XXII:10, Dec. 1938.

(4) Churchill, Capt. Gardener's Chronicle, London, England. pp. 187, March 19, 1842.

(5) Close, C. P., White, T. H., and Ballard, W. R. Fertilizers on asparagus. Maryland Agr. Expt. Sta. Bull. 151. 1911.

(6) Dominion Outlook and Agricultural Situation, for the years 1934-1938. Dept. of Agr., Ottawa.

(7) Fruit and Vegetable Preparations Industry Report in Canada,1936. Dept. of Trade and Commerce, Ottawa. 1938.

(8) Haber, E. S. Effect of harvesting. Proceed. Amer. Soc. Hort. Sci. 28: 309. 1931.

(9) __________. Effect of harvesting, spacing and age of plants on yields of asparagus. Iowa (Ames) Agr. Expt. Sta. Bull. 339. 1935.

(10) Hanna, G. C. Spacing studies with asparagus. Proceed. Amer. Soc. Hort. Sci. 33: 1935.

(11) __________. The effect of the duration of the cutting season on asparagus that has been flooded. Proceed. Amer. Soc. Hort. Sci. 29: 466. 1932.

(12) Hexamer, F. M. Asparagus, its culture for home use and for market, 1901. Orange Judd and Company, New York.

(13) Hoare, A. H. The manuring of vegetable crops. Ministry of Agriculture and Fisheries Bull. 71. H. M. Stat. Office, London, England. 1934.

(14) Jones, H. A. Effect of extending the cutting season on the yield of asparagus. Calif. Agr. Expt. Sta. Bull. 535. 1932.

(15) ___________ and Robbins, W. W. The asparagus industry in California. Calif. Agr. Expt. Sta. Bull. 446. 1928.

(16) ______________________________. Influence of cutting asparagus the first year after planting on production in later years. Proceed. Amer. Soc. Hort. Sci. 23: 23-25. 1926.

(17) Jones, T. H. Vegetable gardening. Ont. Dept. of Agr. Bull. 369. 1932.

(18) Johnson, G. W. History of English gardening. p. 13. Baldwin, Craddock and Longman, London. 1829.

(19) Lewis, E. P. Asparagus yields as affected by severity of cutting. Illinois Agr. Expt. Sta. Bull. 401, 1934.

(20) Lloyd, J. W. and McCollum, J. P. Yields of asparagus as affected by severe cutting of young plantation. Illinois Agr. Expt. Sta. Bull. 448. 1938.

(21) Loudon, J. C. Loudon's Horticulturist, p. 665. H. G. Bohn, London, England. 1860.

(22) Morse, F. W. A chemical study of the asparagus plant. Mass. Agr. Expt. Sta. Bull. 171. 1916.

(23) Morwick, E. F. and Chapman, L. J. General soil climatic map of Southwestern Ontario. Ont. Agr. Exp. Union, Guelph, Ont. 1938.

(24) Murwin, H. F. and Hoegstedt, B. S. Hort. project H.604, 1931, Asparagus, fertilizer experiment. Dom. Exptl. Station, Harrow, Ont.

(25) ______________________________. Annual Reports, Harrow, 1931-38. Dom. Exptl. Station, Harrow, Ont.

(26) Myers, C. E. Root selection in asparagus culture. Annual Report, Penn. State College, pp. 563-576. 1915-16.

(27) Nightingale, G. T. and Schermerhorn, L. G. Nitrate assimilation in the absence of light. New Jersey Agr. Expt. Sta. Bull. 476. 1928.

(28) Ontario Agricultural Outlook Report 1936, 1937. Ont. Dept. of Agr., Toronto, Ont.

(29) Paterson, D. D. Experimentation and applied statistics for the practical agriculturist. Govt. Printing Office, Port-of-Spain, Trinidad. 1933.

(30) Ponton, H. H. Private communication, Oct., 1938. Dom. Marketing Service, Hamilton, Ont.

(31) Robb, O. J. Asparagus in Ontario. Better Crops with Plant Food, Reprint Y-7. 1937.

(32) Schermerhorn, L. G., et al. Questions and answers relative to asparagus production. New Jersey Agr. Expt. Sta. Bull. 650. 1938.

(33) Seaton, H. L. Asparagus fertilizer tests. Mich. Agr. Expt. Sta. Quarterly Bull. 15: 2. pp.110-115. 1932.

(34) Snedecor, G. W. Calculation and interpretation of analysis of variance and covariance. Collegiate Press Inc., Ames, Iowa. 1934.

(35) Symons, S. H. H. Monthly Crop Report. Ont. Dept. Agr., Statistics Branch, Toronto, Ont., June, 1938.

(36) Thompson, H. C. Vegetable crops. McGraw-Hill Book Company. 1931.

(37) Thompson, R. C. Asparagus culture. U. S. Dept. Agr. Farmers' Bull. 1646. 1937.

(38) Vegetables. Area in 1931 and area, production and value in 1930. Dom. Bureau of Statistics, Dept. of Trade and Commerce, Ottawa.

(39) Waltham Station Staff. Asparagus and its culture. Waltham Sta. (Mass.) Ext. Leaflet 49. 1932.

(40) Watson, L. P. The relationship of the amount of fertilizer and the time of application to the total yield of asparagus. Thesis of the Degree M. S. Mich. State College, East Lansing, Mich. 1930.

(41) Wellman, H. R. and Braun, E. W. Asparagus--series on California crops and prices. Calif. Agr. Expt. Sta. Bull. 487. 1930.

(42) Wessels, P. H. and Thompson, H. C. Asparagus fertilizer experiment on Long Island. Agr. Expt. Sta. (Cornell) Bull. 678. 1937.

(43) White, T. and Boswell, V. R. Field and sand culture experiments on fertilizing asparagus. Maryland Agr. Expt. Sta. Bull. 314. 1929.

(44) Working, E. B. Physical and chemical factors in the growth of asparagus. Arizona (Tucson) Tech. Bull. 5. 1924.

(45) Young, R. E. Fertilizers for better asparagus. Better Crops with Plant Food, Reprint U-7. 1937.

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