EFFECT OF FERTILIZERS, SOIL TYPE, AND CERTAIN CLIMATIC FACTORS ON THE YIELD AND COMPOSITION OF OATS AND VETCH [1]

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INTRODUCTION

Climatic conditions as well as soil type and fertilizers may be expected to influence the yield and composition of crops. Although much work has been done to determine the effect of fertilizers and soil types on the yield and composition of crops, very little information is available on the influence of climatic factors when the same soil or culture solution is used under different climatic conditions the same year. The conclusions of Dickson (*6*) [3] that oats grown at Madison, Wis., contained a higher percentage of calcium and phosphorus than oats grown at Pullman, Wash., under the same cultural conditions were not based on work done the same year but in different years. Variations in climatic conditions in the same locality from year to year may also be expected to result in differences in composition of crops. Likewise the report of Delwiche and Tottingham (*5*) to the effect that the nitrogen content of corn, barley, and clover was only slightly influenced by climatic conditions is open to question as these crops were grown on two different soil types, which by their very nature may cause differences in the composition of crops. It is apparent, therefore, that while the effect of fertilizers on crop yield is generally conceded, any differences in composition that may result from applications of fertilizers, differences in soil type, and variations in climate can be determined with certainty only when the same soils receiving identical treatments are subjected to different climatic environments the same year.

In an attempt to obtain some light on this subject a series of pail experiments with three widely different soil types was started in 1931. The experiments conducted at Pullman were duplicated in southwestern Washington in the area from which these three soils were obtained. In this manner the same soil receiving identical cultural treatments was subjected to two different climatic environments, the humid climate of southwestern Washington and the semiarid climate of eastern Washington.

The climate of southwestern Washington is of the marine type, having a narrow annual temperature range, an annual mean temperature higher than the average for the latitude, and heavy precipitation with a maximum in the winter months. Associated with the high rainfall is a high relative humidity and a large percentage of cloudy or partly cloudy days which may be expected to result in a

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[3] Reference is made by number (italic) to Literature Cited, p. 974.

low-light intensity. The elevation of this area is relatively low; that of the city of Centralia, which is centrally located in the experimental area, is only 182 feet above sea level. The climate of eastern Washington is essentially continental in character, having a wide annual temperature range. The precipitation is light and occurs largely in the winter period. The relative humidity is low, the number of clear days large, and the light intensity high. The elevation of this area ranges from 1,000 to 2,700 feet, that of the city of Pullman being 2,550 feet.

EXPERIMENTAL PROCEDURE

The three soil types selected for this experiment were (1) Felida silt loam from Clarke County, a soil derived from ancient alluvial or marine sediments; (2) Olympic loam from Cowlitz County, a soil derived from residual material; and (3) Chehalis clay loam from Lewis County, a soil derived from alluvial material. The normal annual precipitation in these three areas is approximately 37, 63, and 45 inches, respectively.

The samples of soil were obtained from near the check plots of experimental fields previously established by the Washington Agricultural Experiment Station. Soil taken from the upper 8 inches was thoroughly mixed, half of the amount sent to Pullman, and the other half retained by the cooperators in southwestern Washington. Each sample was sufficient to fill, in each of the two locations, 12 galvanized pails of 12-quart capacity to a depth of 8 inches. The pails were painted with asphaltum paint and provided with drains. Six pails were planted to oats (*Avena sativa* L.) and six to vetch (*Vicia sativa* L.). Each of the two sets of experiments received the following treatments: Check, N, NP, NPCa, NPKCa, and NCa.

Since the primary interest was in the mineral content of the crops, nitrogen was added to all pails except the check so as to eliminate the possibility of its being a limiting factor in plant growth. Chemically pure chemicals were used to avoid so far as possible the complicating effect of certain elements that might otherwise have been introduced. The diameter of the pails, 4 inches from the bottom, served as a means of calculating the area on which to base the rate of fertilizer application. The chemicals applied and their equivalents in fertilizers calculated on the acre basis are given in table 1.

TABLE 1.—*Chemicals applied to pails of soil and their equivalents in fertilizers calculated on the acre basis*

Treatment	Materials added	Fertilizer equivalent [1]	Approximate rate per acre
Check:			*Pounds*
N	$NaNO_3$	Sodium nitrate	300
NP	$NaNO_3$	do	300
	$NaH_2PO_4.4H_2O$	Superphosphate	600
NPCa	$Ca(NO_3)_2.4H_2O$	Sodium nitrate	300
	$CaH_4(PO_4)_2.H_2O$	Superphosphate	1,200
	$CaCO_3$	Lime	4,000
NPKCa	$NaNO_3$	Sodium nitrate	300
	KNO_3	Muriate of potash	270
	$CaH_4(PO_4)_2.H_2O$	Superphosphate	1,200
	$CaCO_3$	Lime	4,000
NCa	$Ca(NO_3)_2.4H_2O$	Sodium nitrate	300
	$CaCO_3$	Lime	4,000

[1] Sodium nitrate, 15.5 percent N; superphosphate, 17 percent P_2O_5; muriate of potash, 48 percent K_2O; lime, 100 percent $CaCO_3$.

The chemicals were thoroughly mixed with the soil and sufficient water was added to bring the moisture content to normal field capacity as expressed by Shaw (*14*). The pails were covered and allowed to stand 3 or 4 days before seeding. Following the harvest, the soils were allowed to dry and were stored under cover during the winter. The second year chemicals were again mixed with the soil as in the previous year, water was added, and the moist soils were allowed to stand a week before seeding.

The three soils studied in southwest Washington, referred to as "the coast", were located at Chehalis in 1931, as were the Chehalis and the Felida soils in 1932. The Olympic soil was located at Woodland in 1932. The work in these localities was done by two cooperators and was conducted in the same manner as at Pullman insofar as it was possible to do this under cooperative arrangement.

Swedish Select oats and common vetch, grown on the college farm at Pullman, were used as seed. The vetch seed was inoculated with a culture of the proper legume bacteria. In both localities the oats and vetch were planted the same day at the rate of 20 seeds per pail. After the seedlings were well established they were thinned to 10 plants.

Each pail was weighed at the outset and the plants were watered frequently (every day during the latter part of the growing season). The pails were made up to weight once a week if necessary by the addition of water. Condensed steam served as a source of water at Pullman. Since neither condensed steam nor distilled water was available at Chehalis and Woodland, the regular city water was used. Although the water in these areas is known to have an extremely low mineral content, a chemical analysis revealed that it contained 7.5 parts per million of calcium, the chief element in water that might influence the results.

Both oats and vetch were harvested simultaneously, for any one soil, at a time when most of the oat plants were in the soft dough stage. The crops on the coast matured a week to 10 days later than at Pullman. After harvest, the crop samples were oven-dried at 65° C., weighed, and ground for chemical analysis.

Nitrogen was determined by the official Kjeldahl method (*2*).

For the determination of the mineral elements the oven-dried plant material was ashed in a muffle furnace at a dull red heat. The ash was taken up with 1:4 hydrochloric acid, diluted with hot water, and filtered into volumetric flasks. Phosphorus was determined by the official method (*2*) with slight modifications, calcium by Chapman's method (*4*), and potassium by the sodium cobaltinitrite method of Volk and Truog (*15*). In all cases the composition is reported in terms of percentages based on oven-dry weight of the plant material.

CLIMATIC CONDITIONS

The available weather data for the coast area are not as complete as those for Pullman, but the United States Weather Bureau data for Centralia, which is 4 miles distant from Chehalis and located in the same river valley, are considered fairly representative and are the best that are available for this purpose. The weather data for the growing seasons of 1931 and 1932 for both localities are given in table 2.

It is noted that the mean minimum temperature for the months of May, June, July, and August in both 1931 and 1932 was lower at Centralia than at Pullman. The mean maximum temperature at Centralia was higher during May and June and lower during July and August than at Pullman. Thus it is evident that the daily temperature differences were greater on the coast, especially during May and June.

In 1932 Pullman experienced a much greater number of clear days than Centralia and less than one-third as many cloudy days. In 1931 the difference in the character of the day for the two localities, although appreciable, was not as great.

Pullman received only 1.81 and 1.84 inches of precipitation during the growing seasons of 1931 and 1932 respectively, as compared to 5.13 and 3.35 inches for Centralia. Since the plants were watered regularly, they were not dependent on the rain for their moisture; but in all probability the difference in the precipitation and number of clear days had a direct effect on plant transpiration and the relative humidity of the air.

TABLE 2.—*Climatic data for Pullman and Centralia, Wash., from May 10 to August 10, 1931 and 1932*

PULLMAN

Year and month	Mean temperature		Character of day			Days when precipitation was—		Precipitation
	Maximum	Minimum	Clear	Partly cloudy	Cloudy	Less than 0.2 inch [1]	Over 0.2 inch	
	°F.	°F.	Number	Number	Number	Number	Number	Inches
1931:								
May	69.4	46.5	10	8	3	1	1	0.44
June	70.2	50.5	12	8	10	5	3	1.37
July	83.4	54.6	20	9	2	0	0	.00
August	82.0	54.4	10	0	0	0	0	.00
1932:								
May	63.9	43.9	12	5	4	5	2	1.29
June	74.8	51.3	20	6	4	0	1	.24
July	78.8	53.4	21	9	1	3	1	.31
August	83.7	59.1	8	2	0	1	0	.00

CENTRALIA

Year and month	Maximum	Minimum	Clear	Partly cloudy	Cloudy	Less than 0.2 inch [1]	Over 0.2 inch	Precipitation
1931:								
May	74.3	43.2	10	6	5	4	2	0.86
June	71.6	47.8	7	8	15	11	9	4.18
July	81.1	51.3	24	5	2	2	0	.08
August	81.3	50.4	7	3	0	1	0	.01
1932:								
May	66.6	42.5	8	5	8	9	1	.58
June	76.0	47.5	18	6	6	5	1	.37
July	72.6	49.7	12	5	14	8	3	2.16
August	79.6	52.1	7	0	3	4	0	.24

[1] Includes days designated as trace.

Because of the heavy rainfall at Centralia in June of 1931, the total exceeding 4 inches, water stood in the pails for a day or two after heavy rains and temporary waterlogging resulted. This may have had a slight effect upon the development of the crops.

CROP YIELDS

EFFECT OF FERTILIZER TREATMENT AND SOIL TYPE

It is often observed that the application of the same fertilizers will not always give the same crop response under apparently similar conditions, perhaps because environmental factors other than fertilizers exert some influence.

The individual crop yields as a result of different fertilizer treatments, soil type, and climatic conditions showed extreme variation. Those of oats ranged from 10.0 to 77.5 g and those of vetch from 1.5 to 46.4 g per pail. Considering the average yields of the 2 years for each of the 2 crops as influenced by fertilizer additions alone, and disregarding soil type and climate, as shown in figure 1, it is evident that the 2 crops responded very differently to fertilizer treatments. The addition of nitrogen alone resulted in a marked increase in yield of oats but depressed the yield of vetch. When phosphate was added in addition to nitrogen, both crops responded about equally in yield, as compared to the nitrogen treatment. There is no clear-cut evidence that the doubling of the amount of phosphate fertilizer contributed materially to crop yields since the apparent increase in yield of vetch resulting from the NPCa treatment, which contained twice as much phosphate as the NP treatment, may have been caused by the addition of lime.

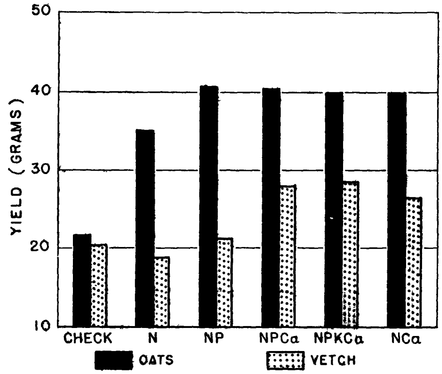

FIGURE 1.—Effect of fertilizers on yields of oats and vetch (average of all experiments).

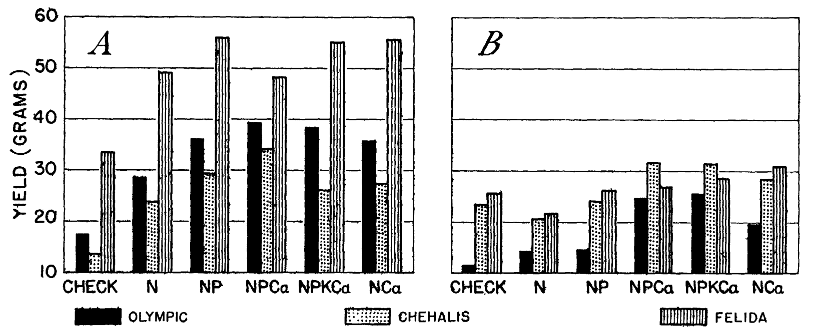

FIGURE 2.—Effect of soil type on yields of oats (*A*) and vetch (*B*) (average of 2 years and both locations).

When lime was used in combination with other fertilizer elements, the oat yields were not materially affected, but the vetch yields were materially increased.

Potassium fertilizer in combination with the other fertilizers had very little effect on yield.

When soil types alone are compared, as in figure 2, it is evident that the same general effects are indicated but with greater or less variation. Of the three soils studied, Felida demonstrated the greatest natural productivity and also produced the greatest yields as a result of fertilizer additions, except that the NPCa and the NPKCa treatments when used for vetch gave slightly better results on the Chehalis soil.

The Olympic soil produced the lowest average yield of vetch. Vetch grown on this soil at Pullman the second year gave exceedingly low yields in the absence of lime—an average of 3.5 g—and high yields in the presence of lime—an average of 38.3 g. Since this condition was observed only at Pullman, it was decided to repeat the experiment with vetch on this soil the third year. The same relative results were obtained. This observed difference in response between the two locations may be partially due to the small amount of calcium present in the water used on the coast.

EFFECT OF CLIMATE

Although certain tendencies in the yield of oats and vetch appear to be characteristic effects of fertilizer treatments and soil types, climatic variations may also be expected to modify these results.

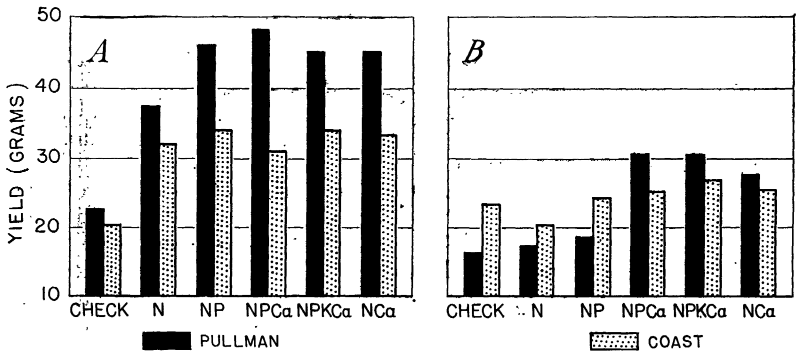

FIGURE 3.—Effect of local climate on yields of oats (*A*) and vetch (*B*) (average for all soils for 2 years)

The average yield for all soils for 2 years for each crop in each location is shown in figure 3. It is observed that oats yielded more at Pullman than on the coast, especially in the soils treated with P, K, and Ca in various combinations. Vetch in the presence of lime also yielded more at Pullman than on the coast. However, in the absence of lime higher yields of vetch were obtained on the coast.

The climatic effect is not necessarily limited to different localities but may exert its influence in the same locality in different years, as has been pointed out by Caldwell (*3*) and as can be seen from an analysis of the data presented by Delwiche and Tottingham (*5*), Dickson (*6*), and Frankena (*10*). Similar results are indicated in figure 4, where the average yields of oats and vetch for the three soil types are illustrated for 1931 and 1932.

The yield of oats was greater at Pullman than on the coast in 1931 but the reverse was true the following year except for the NPCa treatment. The difference in the yield of vetch between the two localities was not as great as for oats the first year, although in general the better yields were obtained at Pullman. In 1932, vetch in the absence of lime gave considerably greater yields on the coast but when lime was present, as already explained, the yields at Pullman were greater. This difference in response the second year was probably due to an actual shortage of calcium as a nutrient, and as a result of a greater total removal of calcium at Pullman this deficiency appeared there first.

The effectiveness of any particular fertilizer, as indicated by yields, may vary with the different seasons, as is shown in figure 4. In 1931 in both locations the addition of nitrogen to vetch increased the yield, whereas in 1932 the yield was reduced when nitrogen was added. This lack of response the second year may have been due to better inoculation.

When phosphate was supplied in addition to nitrogen, the yield of vetch grown on the coast was reduced in 1931 and increased in 1932, while at Pullman the reverse was true.

At Pullman the addition of lime reduced the oat yields in 1931 and increased them in 1932; it was only slightly beneficial for vetch in 1931 but greatly increased the yield in 1932. On the coast the addition of lime had very little influence on the yield of either oats or

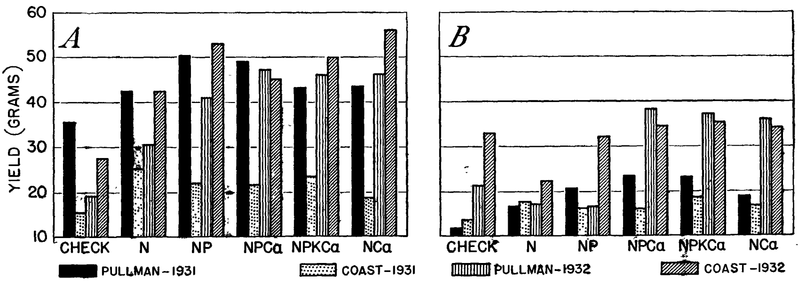

FIGURE 4.—Effect of local climate in different years on the yield of oats (*A*) and vetch (*B*) (average for all soils), 1931 and 1932.

vetch in 1931 or 1932. The small amount of lime supplied by the water used may partially account for the lack of response.

A careful analysis of the data on yields reveals certain outstanding facts. The results clearly indicate that in evaluating the effect of fertilizers on crop yields, the kind of crop, the soil type, and the climatic environment must be considered as well as the kind and amount of fertilizers applied. Although suitable quantities of the proper combination of fertilizers resulted in a generous crop response in all cases, the average increase in yield for the 2 seasons on the 3 soils irrespective of location was approximately 87 percent for oats and only about 42 percent for vetch. As for the influence brought about by soil type disregarding climatic environment, the extremes in the average increase in yield for oats for the 2 seasons varied from 155 percent for the Chehalis soil to 67 percent for the Felida soil, and for vetch from 126 percent for the Olympic soil to 21 percent for the Felida soil.

It is a common experience in field experiments to find that repeated applications of the same fertilizers to the same soil do not give the same results from year to year. Variations in available moisture and especially a deficiency of moisture are generally accepted as the major responsible factors. Since these factors were entirely eliminated in these experiments by providing an adequate supply of available moisture for the crops at all times, other climatic factors undoubtedly had an important bearing on the crop growth. Arthur (*1*) pointed out that light intensity and light quality as well as other climatic factors and soil conditions affect plant growth. When the yields of the 3 soils for the 2 seasons are averaged, the results show that the most favorable fertilizer treatment resulted in a 111 percent increase in the yield of oats at Pullman and only an 89 percent increase on the coast. The yield of vetch, when calculated on the same basis, returned a 67 percent increase at Pullman and only a 13 percent increase on the coast.

CHEMICAL COMPOSITION

EFFECT OF FERTILIZER TREATMENT AND SOIL TYPE

The effect of fertilizers on the composition of crops is somewhat of a controversial matter, perhaps because environmental factors other than fertilizers exert their influence. Gericke (*11*) suggests that some of the unexplained discrepancies that commonly are encountered in comparative studies on plant salt requirements and the application of fertilizer to agricultural soils may be related to climatic influences.

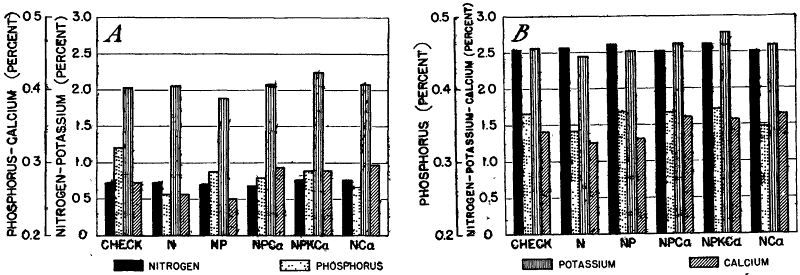

FIGURE 5.—Effect of fertilizers on the chemical composition of oats (*A*) and vetch (*B*) (average for all soils for 2 years and both locations).

Considering the effect of fertilizers from the standpoint of crops alone, and disregarding soil type and climate as is indicated in figure 5, the average composition of oats and vetch grown during two different seasons was most affected by the additions of phosphate fertilizers and lime. When a phosphate fertilizer was added to the soil, the percentage of phosphorus in both oats and vetch was increased above that in oats and vetch which received fertilizer other than phosphate but not above that in the unfertilized plants. The addition of lime to the soils caused an increased percentage of calcium in both oats and vetch above that of plants grown on soils which received no lime. The presence of lime also slightly increased the potassium content of both oats and vetch. The addition of nitrogen alone definitely reduced the percentage of phosphorus and calcium in both oats and vetch. This tendency seemed to be apparent in regard to the phosphorus content of oats even when nitrogen was used in combination with the other fertilizers. This may be partially accounted for by increased yields resulting from the nitrogen fertilizer, since the oats were considerably more affected in this respect than the vetch.

When soil types alone are considered, however, it is evident that although the same general effect is indicated the different soils show considerable variation, especially in the phosphorus and calcium content of both crops. This is shown in figure 6. Oats and vetch grown on Olympic soil, in general had a lower phosphorus and calcium content than those grown on the other soils. The application of phosphate to the Olympic soil did not generally increase the phosphorus content of these crops, but when applied to the Felida and

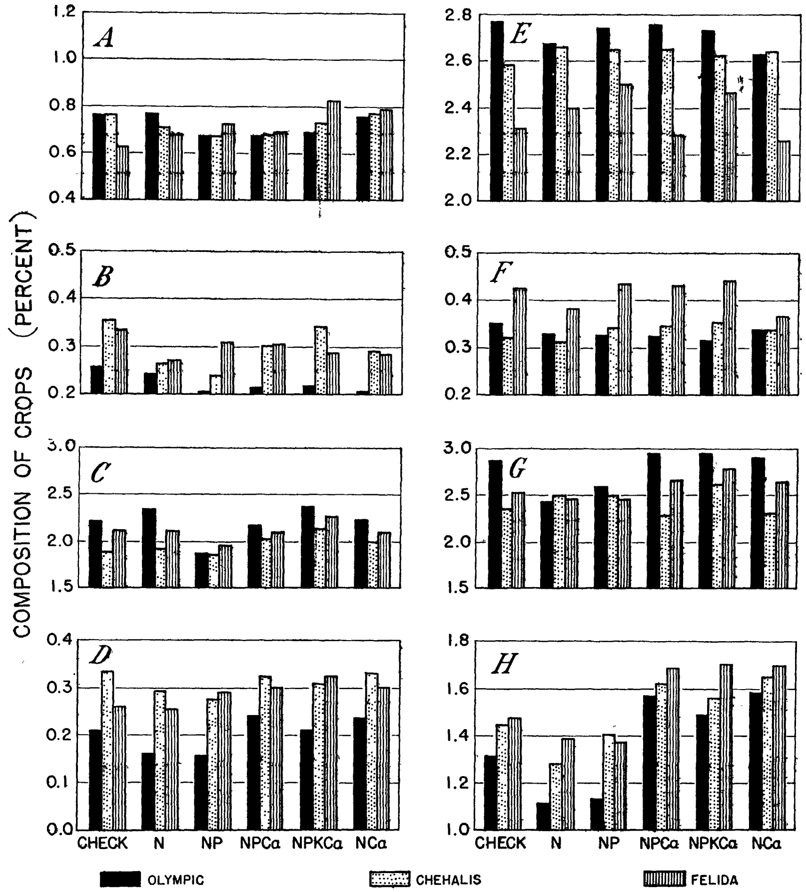

FIGURE 6.—Effect of soil type on the chemical composition of oats and vetch (average for 2 years and both locations): *A* to *D*, Oats; *E* to *H*, vetch; *A* and *E*, nitrogen content of crop; *B* and *F*, phosphorus content of crop; *C* and *G*, potassium content of crop; *D* and *H*, calcium content of crop.

Chehalis soils, it resulted in a uniform rise of the phosphorus content of the vetch but not of the oats. The addition of lime markedly increased the calcium content of oats on the Olympic soil and only slightly on the other soils. The influence of soil type was less apparent in regard to the calcium content of vetch when lime was used, but again the greatest effect was obtained on the Olympic soil. Fonder (*7*, *8*, *9*) also found a considerable variation in the magnesium as well as in the calcium content of alfalfa, beans, and peas when grown on different soil types under the same general climatic conditions in the same locality the same year. The general depressing effect of nitrogen fertilizer on the phosphorus content of the crops, although greater on the Olympic soil, was never completely overcome on either the Chehalis or the Felida soil by any of the fertilizer combinations regardless of the relatively large amounts of phosphate fertilizers used in some of the treatments.

The nitrogen and potassium content of the crops was much less affected by soil type. The results for nitrogen are in accord with those obtained by Delwiche and Tottingham (*5*) and Le Clerc (*12*), who found that the percentage of nitrogen in the crops they studied was influenced only slightly by soil type even though great variation in types existed.

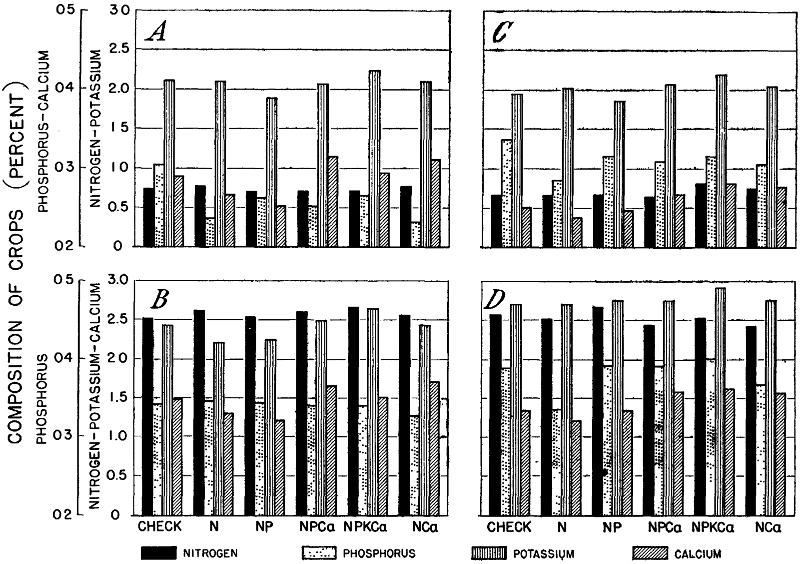

FIGURE 7.—Effect of local climate at Pullman (*A*, *B*) or on the coast (*C*, *D*) on the chemical composition of oats (*A*, *C*) and vetch (*B*, *D*) (average for all the soils for 2 years).

The percentage of a specific element in a plant may be somewhat dependent on the interaction of the soil with the specific element added as a fertilizer. For example, when phosphate in combination with nitrogen was added to the Olympic soil, it resulted in a decrease in the phosphorus percentage of both oats and vetch below that of nitrogen alone but when added to Felida an increase in phosphorus content was observed.

EFFECT OF LOCAL CLIMATE

Although certain definite tendencies in the composition of oats and vetch appear to be characteristic effects of fertilizer treatments and soil types, these are undoubtedly modified by climatic influences. This was very strikingly shown when the average composition of the two crops was considered, as indicated in figure 7. It was found that the percentage of phosphorus was higher and the percentage of calcium was lower on the coast than at Pullman. This phosphorus-calcium-climate relationship has been observed also in unpublished work done in this laboratory when the composition of alfalfa grown on the coast was compared with that of alfalfa grown in the irrigated valleys of the central part of the State. This cannot be entirely attributed to annual climatic changes, as the same general comparison was observed in 1931 and in 1932.

The data in table 2 show that the total number of clear days was greater and the precipitation lower at Pullman than on the coast for both years. This fact, which corresponds with the results of MacMillian's work (*13*) in which he concluded that localities with higher elevation and lower relative humidities receive a greater total amount of ultraviolet rays, indicates that the amount of ultraviolet light received at Pullman should be greater than that received on the coast for both years. Since Wynd and Fuller (*16*) found that tomato and cucumber plants subjected to ultraviolet radiation contained a higher percentage of calcium and a lower percentage of phosphorus than unradiated plants, it seems that the amount of ultraviolet radiation may be one of the important factors that determined the observed phosphorus-calcium relation between the two different localities.

Applications of lime were more effective in increasing the calcium content of both oats and vetch at Pullman than on the coast. The calcium content of the water used on the coast did not have any appreciable effect on the observed results if the chemical composition of the oats and vetch grown is used as a criterion, for in all cases except the NP and NPKCa treatments of the latter crop the calcium content was lower on the coast.

There was very little difference in the nitrogen and potassium content of the oats grown in the two localities, while for vetch the potassium content was higher on the coast and the nitrogen content higher at Pullman.

The climatic effect was not limited to different locations but showed its influence in the same localities in different years. This was also shown in the work of Caldwell (*3*), Frankena (*10*), and Dickson (*6*). The results are illustrated in figure 8 in which the composition of the same crop grown in the same locality is graphed separately for each year.

The percentage of nitrogen in vetch was higher in 1932 than in 1931 for both localities, while in oats the nitrogen content was higher at Pullman in 1931 than in 1932 and on the coast no consistent results were observed. The phosphorus and potassium content of both oats and vetch, on the coast and at Pullman alike, was more or less greater in 1931 than in 1932, but the calcium content was not uniformly affected by seasonal climatic variations in either locality.

The existing differences in the mean daily temperature, in condition of the day, and in precipitation in the same locality in different years did not seem to exert any appreciable effect on composition. It is possible that other climatic factors may be the dominant ones as far as climate is concerned when composition changes are produced, or the cause may be a balance between all climatic factors.

In recent years considerable significance has been attached to the phosphorus and calcium content of feeds for livestock. It has been found that livestock fed on pasturage and hay containing these elements in amounts below a certain critical figure suffer from nutritional diseases. The many controversial data presented in the literature on the effect of fertilizers on the composition of crops cast doubt upon the practicability of improving the mineral content of forage crops by means of fertilizer applications to the soil. However, in the large majority of these cases no consideration has been given to the influence of soil type and climatic factors, both of which have clearly demonstrated their influence in the work here reported. Moreover, in many of the instances reported in the literature the phosphorus and calcium content of the crops grown without fertilizers

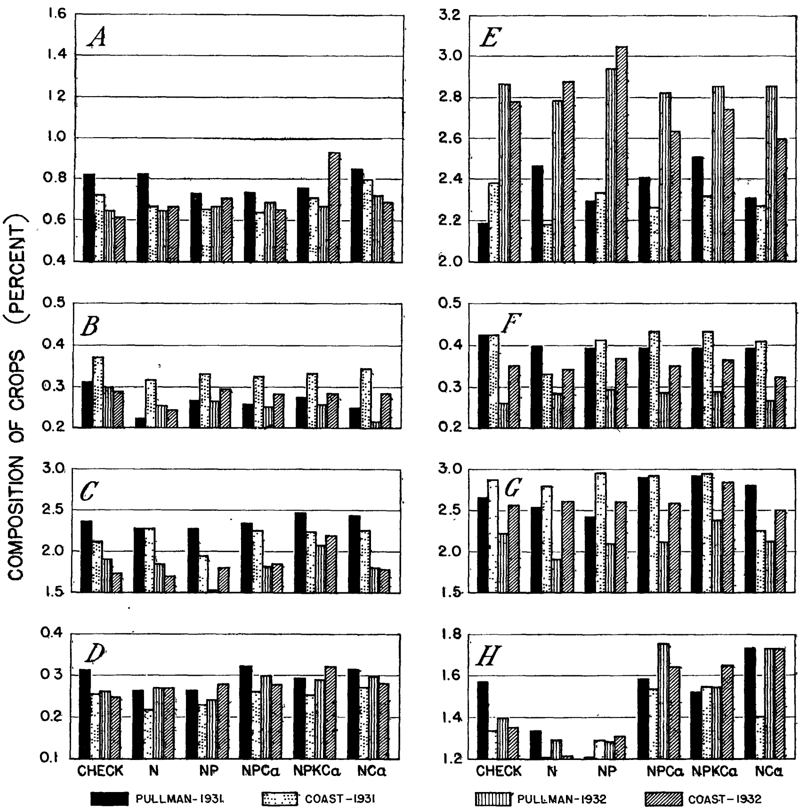

FIGURE 8.—Effect of the climate of different years on the chemical composition of oats and vetch (average of all soils), 1931 and 1932: *A* to *D*, Oats; *E* to *H*, vetch; *A* and *E*, nitrogen content of crop; *B* and *F*, phosphorus content of crop; *C* and *G*, potassium content of crop; *D* and *H*, calcium content of crop.

was not at the critical point, and consequently there was no urgent need for improvement of quality. The oats and vetch grown on the three soils employed here are typical examples. Nevertheless, applications of phosphates and lime to these soils counteracted the depressing effect of nitrogen on the phosphorus and calcium content of the crops, and although this beneficial influence was modified in varying degrees by soil type and climatic factors, it was general in all cases. If corresponding results can be obtained on soils that are so deficient in available phosphorus and calcium as to result in crops with an abnormally low content of these elements, it seems that it should be possible to secure improved quality of crops as well as profitable returns when proper amounts of suitable fertilizers are applied to the soil.

SUMMARY AND CONCLUSIONS

Three of the more important soil types of southwestern Washington were selected for a series of pail experiments to study the effect of fertilizers, soil type, and local climate on the yield and chemical composition of oats and vetch. Duplicate sets of the same soil were used, one in the coastal climate of southwestern Washington in the ocality from which the soil was originally obtained and the other in the semiarid climate at Pullman. The results indicate that fertilizers, soil type, and local climate may have an important effect upon the yield and chemical composition of crops.

Fertilizer additions materially changed the yield of oats and vetch, the two crops responding differently to applications of nitrogen and lime and similarly to applications of phosphate and potassium. The chemical composition of the crops was likewise influenced by the use of fertilizers. Additions of nitrogen depressed the phosphorus and calcium content of both crops while additions of phosphate and lime increased the phosphorus and calcium content of the plants above that of the plants which received nitrogen fertilizers alone but not above that of the unfertilized plants.

The inherent soil characteristics, reflected in soil type, had a marked influence on the yield and chemical composition of the two crops. The same plant species showed a different relative response to the same fertilizers when grown on different types of soil. The percentage of calcium and phosphorus in the crops was especially affected by soil type, while the percentage of nitrogen and potassium was only slightly affected.

Climatic differences, excluding moisture, between the two localities also influenced the yield and chemical composition of oats and vetch. In general, the higher yields were obtained at Pullman. The same crops grown on the same soil under the same cultural conditions contained, on an average, a higher percentage of phosphorus and a lower percentage of calcium when grown in the coastal climate of southwestern Washington than they did when grown in the semiarid climate of Pullman. The effect of the addition of lime on the calcium content of both crops was more pronounced at Pullman than in southwestern Washington. The difference in the character of the light in the two localities probably resulted in a difference in the amount of ultra violet rays received by the plants, and this seemed to be related to the observed results in composition. It is evident that the dominant climatic factors involved are those other than temperature and precipitation.

The yield and chemical composition of the same crop on the same soil under the same cultural conditions may vary from year to year as a result of local climatic variations.

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