THE ASSOCIATIVE EFFECT OF LEGUMES ON NON-LEGUMES

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BY

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REFERENCES.

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8. THE RELATION OF CERTAIN NON-LEGUMINOUS PLANTS TO THE NITRATE CONTENT OF SOILS--REPRINT BY LYON & BIZZELL.

9. A DISCUSSION OF CERTAIN METHODS USED IN THE STUDY OF " THE ASSOCIATIVE EFFECT OF LEGUMES ON NON-LEGUMES---REPRINT BY LYON & BIZZELL.

OUTLINE.

I. INTRODUCTION.

2. PROBLEM.

3. FIELD WORK.

4. LABORATORY WORK.

5. CONCLUSION.

Introduction.

That legumes produce a beneficial effect on the soil and the succeeding crops was observed by the ancients, and is still being more fully demonstrated in the work of rebuilding soils which have been depleted by the exhaustive types of farming which were practiced by our forefathers, and are still being practiced by the more ignorant class of farmers. In this work it has been proven, beyond a doubt, that as a green manure crop the legumes improve the soil from a chemical, physical, and bacteriological standpoint and also increase the amount of available plant food in the soil.

Still another benefit, apparently due to the presence of the legume, was noted by the ancients. They observed that when a mixed crop consisting of a legume and a non-legume was grown, the non-legume had a richer, greener appearance and attained a larger growth than when grown alone. However, the reason for this improvement in the appearance and increase in the yield of the non-legume was never satisfactorily settled and is at present, a more or less debatable question.

While it has been the practice among farmers for generations to grow a mixture, consisting of a legume and a non-legume, for hay because the legume would improve the soil and, at the same time, increase the palatability of the hay; if we could prove the theory advanced by many students of the problem, that in their associated growth the legume increases the protein content and the yield of the non-legume materially the planting of these mixtures would receive a great impetus and mixtures heretofore regarded as unprofitable would probably prove to be very profitable.

In an attempt to throw some light on these questions of such great agronomic importance the following problem was outlined

and carried out.

Problem.

The problem is: A study of the effects produced, in the field, when legumes and non-legumes are grown together in the same plat.

The crops grown together were corn and soy beans, and sorghum and cow peas. These crops were grown in the same plat and in different plats and the weights of dry matter grown compared.

To analyze samples from each of these plats for their nitrogen content and study the effect of the legume on the nitrogen content of the non-legume.

Lyon and Bizzell[1] report an increased yield in hay when oats and peas were sown in a mixture over the yield of oats alone. However, in both the mixed plats and plats of oats alone they used the same amount of oat seed and in the mixed plats an additional bushel of peas per acre. In the mixed plats the greatest increase in yield of hay per acre, obtained in their experiment, was one thousand pounds; and if the yield of dry matter in proportion to the seed sown is considered, there is, according to the data given, no proof that the increase of dry matter grown on the mixed plats was due to the associated legume.

These experiments, results and conclusions as stated in the following pages, confirm those obtained by Lipman.

Lipman also conducted a series of experiments in glazed and unglazed pots which tended to show that nitrogen compounds passed out of the roots of legumes and were diffused through the soil and used by the associated non-legume.

Lyon and Bizzell also ran a number of experiments, of which these are practically duplicates, and in every case found

the per cent. of protein of the non-legume to be increased when associated with a legume. They assumed that this increase was due to the legume increasing the supply of available nitrogen in the soil, during the growth of the plant.

In order to prove that the legume did influence the supply of available nitrogen in the soil they ran an experiment to test the rate of nitrification of ammonium sulphate in alfalfa soil and in timothy soil, and found that the rate of nitrification was greater in the alfalfa soil.

Field Work.

The field work consisted of growing the legume and the non-legume in separate plats and in the same plat and determining the weight of dry matter grown on each plat.

For this purpose a piece of land as nearly uniform as could be obtained was well plowed on April 14, 1914, and harrowed and disced intermittently until June 26, 1914, when the plats were laid off and seeded.

The plats were one-fortieth acre in size, with a two foot aisle between each plat, and run in duplicate, using only one-half the original amount of seed of each crop on the mixed plats as was used on the plats not mixed.

The plats were also duplicated and fertilized with the following mixture:

200 # dried blood per acre.

500 # 16% acid phosphate per acre.

100 # muriate of potash per acre.

One half of the plats, both fertilized and unfertilized, were harvested before maturity and the other half was harvested at maturity and average samples of each plat were secured at the time

time of harvesting for a determination of the nitrogen content of the plants grown on each plat.

The soil on which these plats were located had never grown legumes and in order to prevent any discrepancy in the data, due to lack of inoculation, the cow peas and the soy beans were well inoculated, before seeding, with the artificial cultures sent out by the United States Department of Agriculture.

The following table gives the amount of seed used in each plat:

Corn,	1# per plat.
Soy Beans,	2½# " "
Cow Peas,	2½# " "
Sorghum,	1½# " "

The plats which were to be harvested before maturity were mowed on August 31 and after being well cured were weighed.

The corn and bean plats to be harvested at maturity were cut on September 31 and the sorghum and cow peas plats were cut on October 7 and after curing were weighed.

The land on which the plats were located was exceedingly poor in fertility and humus content as the small yields will indicate Then too, the growing season was a very unfavorable one, being almost a continual drought.

The following tables will give the amounts of dry matter grown on each plat:

Table #1

Early cut plats of Beans and Corn. - Unfertilized.

No. Plat.	Crop	Yield in pounds.
1	Corn, (alone)	25
2	Corn & beans	23
3	Beans, (alone)	21
4	Corn, (alone)	27
5	Corn & beans	25
6	Beans, (alone)	15½

Table #2.

Late cut plats of Beans and Corn. - Unfertilized.

No. Plat	Crop.	Yield in Pounds.
1	Corn, (alone)	52
2	Corn & beans	16 (washed)
3	Beans, (alone)	18
4	Corn, (alone)	50
5	Corn & beans	28
6	Beans, (alone)	24

Table #3.

Early cut plats of Beans & Corn. Fertilized.

No. Plat	Crop.	Yield in Pounds.
1	Corn, (alone)	91
2	Corn & beans	56
3	Beans, (alone)	24
4	Corn, (alone)	101
5	Corn & beans	57
6	Beans, (alone)	18 (washed badly)

Table #4.

Late cut plats Beans and Corn. Fertilized.

No. Plat	Crop	Yield in Pounds.
1	Corn, (alone)	130
2	Corn & beans	97
3	Beans, (alone)	54
4	Corn, (alone)	70
5	Corn & beans	62
6	Beans, (alone)	27

Table #5.

Early cut plats Sorghum & Peas. - Unfertilized.

No. Plat	Crop	Yield in Pounds.
1	Sorghum, (alone)	27
2	Sorghum & peas	24
3	Peas, (alone)	19
4	Sorghum, (alone)	13
5	Sorghum & Peas	8
6	Peas, (alone)	6

Table #6.

Early cut plats Sorghum & Peas, Fertilized.

No. Plat	Crop	Yield in Pounds.
1	Sorghum, (alone)	45 (washed)
2	Sorghum & peas	50
3	Peas, (alone)	9
4	Sorghum (alone)	104
5	Sorghum & Peas	62
6	Peas, (alone)	20

Table #7.

Late Cut Plats Sorghum & Peas. - Unfertilized.

No. Plat	Crop	Yield in Pounds.
1	Sorghum, (alone)	33
2	Sorghum & Peas	30
3	Peas, (alone)	12
4	Sorghum, (alone)	15
5	Sorghum & Peas	13
6	Peas, (alone)	9

Table #8.

Late Cut Plats Sorghum & Peas. - Fertilized.

No. Plat	Crop	Yield in Pounds.
1	Sorghum, (alone)	50 (washed)
2	Sorghum & Peas	62
3	Peas, (alone)	25
4	Sorghum, (alone)	65
5	Sorghum & Peas	59
6	Peas, (alone)	32

As was noted in the tables, several of the plats were washed, to some extent, by summer rains thus throwing off the results when compared with the duplicates.

From the preceding tables the following observations were made: (1) in both experiments in the early harvested plats and in the plats harvested at maturity, fertilized and unfertilized, the total yield of dry matter grown on the mixed plats was less than the total yield of dry matter grown on the non-legume plats and greater than the total yield of dry matter grown on the legume plats, except

where the plats were damaged by washing.

(2) In no plat, fertilized or unfertilized, was the yield of dry matter grown on the non-legume plats twice as great as the yield of dry matter grown on the mixed plats.

(3) (continued), of the same set, we find that in 50% of the mixed plats there is a remainder greater than one-half the total weight of dry matter grown in the non-legume plats; and in 50% of the mixed plats there is a remainder less than one-half the total weight of dry matter grown in the non-legume plats.

on the mixed plats, However, the balance is in favor of the fifty per cent. having a remainder less than one-half the total dry matter grown on the non-legume plats. Thus seeming to indicate that on the unfertilized plats the legume associated with the non-legume did not increase the yield of the non-legume.

(4) If the above procedure is repeated on the yields of the fertilized plats there are only two sets of plats which give remainders less than one-half the total weight of dry matter grown on the non-legume plat while six sets of plats give remainders greater than one-half the total dry matter grown on the non-legume plats. The balance being greatly in favor of the remainders greater than one half the dry matter grown on the non-legume plats; thus seeming to indicate that on the fertilized mixed plats the legume associated with the non-legume increased the yield of the non-legume materially However, in almost every case, in the fertilized plats the yield of dry matter grown on the non-legume plat is almost double the yield grown on the mixed plat; and the yield of dry matter grown on the mixed plat is double, or more than double, the yield grown on the legume plat; thus seeming to indicate that the increase in the weight of dry matter grown on the mixed plats is due to the fertilizer and not to the associated legume.

(5) Since, the non-legumes used were naturally much heavier plants than the legumes used, there is a probability that the failure of the mixed plats to produce as much, or more, dry matter as the non-legume plats produced, was due to the fact that only half as many seed of the non-legume were sown in the mixed plat as in the unmixed plat and the legume, being naturally a much lighter plant, could not produce enough dry matter to offset the loss of one half of the non-legume seed.

(6) There is also a probability that in the mixed plat the moisture content was not sufficient to allow both the legume and non-legume to attain their full development and, as a result, one or both failed to attain full growth. Seemingly borne out, by the fact, that in the unmixed plats of legumes and non-legumes the plants grew to a greater height than in the mixed plats.

From the preceding tables and data the conclusion that in this experiment the legumes associated with the non-legumes did not increase the yield of the latter materially is justifiable.

Laboratory Work.

The laboratory work consisted of analyzing the samples obtained from the different plats, at the time of harvesting, for their nitrogen content and calculating the protein content in terms of water-free substance.

For this purpose an average sample from each plat, and in the case of the mixed plats a sample of both the legume and the non-legume, was ground up as fine as possible and the nitrogen content, of two grams of each sample, determined by the Kheldahl method for nitrogen.

The per cent. of moisture in each sample was also determined.

Each sample was run in duplicate and the average protein content of the two duplicates was taken as the protein content of the sample.

The following tables give the per cent. of moisture, the per cent. of protein, and pounds of protein per hundred pounds of water-free substance for each plat.

Table #1.

Sorghum & Cow Peas . - Unfertilized.

Plat No.	Crop.	Harvested.	% Protein.	% Moisture.	#Protein per 100# water-free substance.
1	Sorghum, (alone)	Early	5.17	7.6	5.59
2	" & Peas	"	5.88	4.3	6.04
2	Peas & Sorghum	"	15.00	5.2	15.93
3	Peas (alone)	"	15.18	7.1	16.33
4	Sorghum (alone)	"	4.81	4.6	5.04
5	Sorghum (& peas)	"	3.43	5.9	3.64
5	Peas (& sorghum)	"	15.93	5.7	16.89
6	Peas (alone)	"	11.81	8.4	12.88
1	Sorghum (alone)	Late	6.42	7.8	6.96
2	" (& peas)	"	6.25	4.2	6.55
2	Peas (& sorghum)	"	16.09	5.7	17.06
3	Peas (alone)	"	16.23	7.5	17.54
4	Sorghum (alone)	"	7.03	4.9	7.39
5	Sorghum (& Peas)	"	6.56	6.2	6.99
5	Peas && sorghum)	"	16.27	6.	17.30
6	Peas (alone)	"	18.79	8.8	20.60

Table #2.

Sorghum & Cow Peas - Fertilized.

Plat No.	Crop	Harvested	%Protein.	%Moisture.	#Protein per 100# W-F. sub.
1	Sorghum (alone)	Early	4.72	5.7	5.00
2	" (peas)	"	4.87	5.5	5.15
2	Peas (sorghum)	"	11.09	6.0	11.79
3	Peas (alone)	"	12.19	4.7	12.79
4	Sorghum (alone)	"	4.09	4.1	4.26
5	Sorghum (Peas)	"	5.71	6.0	6.07
5	Peas (sorghum)	"	12.82	5.7	13 59
6	Peas (alone)	"	6.48	7.1	6.97
1	Sorghum (alone)	Late	5.09	5.4	5.38
2	Sorghum (peas)	"	6.58	5.6	6.97
2	Peas (sorghum)	"	13.91	6.4	14.86
3	Peas (alone)	"	11.78	7.4	12.69
4	Sorghum (alone)	"	6.09	5.8	6.45
5	Sorghum (Peas)	"	7.9	7.0	8.49
5	Peas (sorghum)	"	11.59	5.8	12.30
6	Peas (alone)	"	10.81	8.5	11.81

Table #3.

Corn & Soy Beans - Fertilized.

Plat No.	Crop	Harvested.	%Protein.	%Moisture.	# Protein per 100# W-F. Sub.
1	Corn (alone)	Early	6.06	6.0	6.447
2	Corn (Beans)	"	6.05	6.2	6.449
2	Beans (corn)	"	11.67	6.4	12.46
3	Beans (alone)	"	12.69	5.0	13.46
4	Corn (alone)	"	6.19	10.5	6.91
5	Corn (Beans)	"	7.29	6.7	7.81
5	Beans (corn)	"	8.27	5.5	8.85
6	Beans (alone)	"	8.9	6.0	9.46
1	Corn (alone)	Late	5.15	6.6	5.51
2	Corn (Beans)	"	5.16	5.2	5.50
2	Beans (Corn)	"	8.24	5.8	8.74
3	Beans (alone)	"	9.37	6.1	9.97
4	Corn (alone)	"	5.06	7.4	5.46
5	Corn (beans)	"	5.46	5.2	5.82
5	Beans (corn)	"	8.17	5.8	8.67
6	Beans (alone)	"	8.59	5.5	9.08

Table #4.

Corn & Soy Beans - - Unfertilized.

Plat No.	Crop.	Harvested	½ %Protein.	%Moisture.	#Protein per 100# w-f sub.
1	Corn (alone)	Early	5.18	6.0	5.51
2	Corn (beans)	"	5.15	6.2	5.49
2	Beans (corn)	"	10.15	4.9	10.67
3	Beans (alone)	"	9.06	6.9	9.73
4	Corn (alone)	"	8.77	4.5	9.18
5	Corn (beans)	"	10.06	4.5	10.53
5	Beans (corn)	"	10.79	5.8	11.45
6	Beans (alone)	"	11.00	6.7	11.78
&					
1	Corn (alone)	Late	4.53	8.3	4.94
2	Corn (beans)	"	5.53	6.1	5.88
3	Beans (corn)	"	10.96	4.7	11.50
3	Beans (alone)	"	8.53	7.1	9.18
4	Corn (alone)	"	6.09	5.8	6.46
5	Corn (beans)	"	4.66	5.8	4.94
5	Beans (corn)	"	10.53	4.8	11.06
6	Beans (alone)	"	10.45	5.5	11.05

From the preceding tables the following observations were made:

(1) In the plats of sorghum and peas unfertilized, both in those harvested early and in those harvested at maturity combined, there was only one set of plats in which the protein content of the non-legume was increased in the mixed plat; and here it appears to have been increased at the expense of the associated legume.

This increase was hardly beyond the limit of experimental error in nitrogen determination.

(2) In the plats of sorghum and peas fertilized, in both those harvested early and in those harvested at maturity, there was, at least, a small increase in the protein content of the non-legume in the mixed plats, in every case.

In every case, except one, of the plats harvested before maturity, there was also an increase in the protein content of the legume in the mixed plats.

This might be accounted for by the fact that the non-legume appeared to retard the growth of the legume in the mixed plats and when cut the legumes in the mixed plats were not as mature as the legumes in the unmixed plats, and numerous experimental data tend to show that the nitrogen content of a plant decreases as it nears maturity.

(3) In all of the fertilized plats of corn and soy beans there was, in every case, a slight increase in the protein content of the non-legume in the mixed plats, apparently at the expense of the protein content of the legume.

(4) In the unfertilized plats of corn and soy beans one set of the plats harvested before maturity gave an increase in the protein content of the non-legume in the mixed plat and one set gave a decrease. Here again the protein content of the non-legume was

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apparently increased at the expense of the protein content of the legume associated with it.

The above results hold true in the case of the plats harvested at maturity also, with the exception that the protein content of the associated legume was not decreased when the protein content of the non-legume was increased.

(5) In every case, in the unfertilized plats of sorghum and peas, both in those harvested early and in those harvested at maturity there was an increase in the protein content of the legume over the protein content of the legume in the fertilized plats of the same.

The above held true, in almost every case, in the unfertilized plats of corn and beans. Thus seeming to indicate that in the fertilized plats there was a depression in the nitrogen fixing powers of the legume.

(6) Although there was apparently no increase in the per cent. of protein of the non-legume when associated with the legume, if the total protein per hundred pounds of dry matter of the non-legume, both in the mixed and in the unmixed plats, is calculated and the sum total protein of two duplicate mixed plats compared with the sum total protein content of two unmixed plats, of the non-legume, divided by two there is a large remainder in favor of the non-legume in the mixed plats.

This remainder occurs in every set of corn and beans and of sorghum and peas, both in those plats harvested early and in those plats harvested at maturity, whether fertilized or unfertilized. The remainder being largest, in both experiments, in the case of the unfertilized plats.

The division of the sum total protein content of the non-legume grown alone is permissible for as before stated only one half the quantity of non-legume seed was sown in the mixed plats

as in the plats not mixed.

From the preceding tables and data the following conclusions were drawn:

(a) Under some conditions a legume when associated with a non-legume may increase the protein content of the non-legume.

(b) The presence of the non-legume in the mixed seedings need not decrease the total protein content of the legume.

(c) In the fertilized mixed plats the non-legume probably gained an advantage in the competition for moisture, light and plant food, and the growth of the legume was depressed. Therefore, the legume contained, as the tables show, not only less total protein but in most cases less total dry matter.

(d) The presence of the nitrogenous fertilizer probably depressed the nitrogen fixation of the legume.

Conclusion.

The question as to whether a legume when associated with a non-legume increases the yield and protein content of the non-legume has not been definitely settled yet.

Numerous experimental data seem to indicate that the association does increase the yield and protein content of the non-legume, while there is other data to the contrary.

Since, there are practically no data to show that the practice of seeding a mixture of a legume and a non-legume results in any loss, and the data tending to show that it is beneficial preponderates that tending to show that it is not beneficial, this practice can be safely continued by the practical farmer and should be more generally practiced.