THE EFFECT OF VARYING THE TREATMENTS OF NITROGEN, PHOSPHORUS AND POTASSIUM ALONE AND IN COMBINATION ON CERTAIN CHARACTERISTICS OF A DWARF GRAIN SORGHUM.

By

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INTRODUCTION

In general, the genetic composition of any plant species determines its chemical composition and plant characteristics. However, the chemical composition ~~and plant~~ characteristics may be modified to a certain extent by variations in such environmental factors as climate and soil, especially the nutrient supply.

Many investigations have shown the effect of applications of nitrogen, phosphorus and potassium to the soil on plant characteristics such as height of growth, maturity, color and composition. These reveal the fact that variations in application of nitrogen, phosphorus and potassium may affect the plant growth and in some cases cause variation in chemical composition of the grain or fruit. The chemical composition of the leaves and stems of the plant is generally more responsive to variations in nutrients than is the grain. The seed of the plant, representing future generations, is in general relatively constant in mineral composition.

The acreage of dwarf grain sorghum is increasing in Virginia on those farms where there is a shortage of labor. Less labor is required to produce an acre of grain sorghum than an acre of corn in Virginia, because grain sorghum is harvested with a combine. Grain sorghum yields approximately ninety percent of adapted hybrid corn under similar conditions. The replacement of corn by grain sorghum is not expected, but a further increase of grain sorghum on the well mechanized farm with a labor shortage is anticipated.

No literature has been found reporting the effect of varying the rate of application of nitrogen, phosphorus and potassium upon the type of growth and grain composition of a dwarf grain sorghum in the eastern United States. The height, maturity, type of growth, and yield are very important. Shorter or dwarf growth, early maturity, heavy yield and grain with a high nutrient content are desired. Any effect of fertilization of the soil with nitrogen, phosphorus and potassium upon the growth and development of this plant is important.

REVIEW OF LITERATURE

Vandecaveye (19) has presented an excellent review of the effect of soil type and fertilizer treatments on the chemical composition of certain forage and small grain crops. The response of cereal grains to nitrogen was found to vary with the amount applied to the soil and the time of application. In only seven of fifteen studies reviewed did the application of phosphorus increase the phosphorus content of the grain. Potash applications resulted in an increase of potassium in the grain in only a few cases.

Beeson (4) has presented a review and compilation on the mineral composition of crops with particular reference to the soils in which they were grown. This review shows wide variation and conflicting results. The need for basic research on this problem is evident.

Studies by Bayfield (1) (2) (3), Blair (5), Gainey, et al (8), Geddes, et al (7), Guyon (10), Teakle, et al (17) and Tulaikov (18) indicate that additions of nitrogen to the soil resulted in an increased percent of protein in the grain.

Garola (9), Holtz, et al (11), Joret, et al (12) and Vincent, et al (20) report that the effect of nitrogen on the protein content of the grain is variable, depending upon the soil, time and amount of application and also other factors.

Reports of Guyon (10), Lefort (14) and Murphy (15) show definitely that the addition of phosphorus for wheat increased the percent of phosphorus in the grain. Results of studies by Bayfield (1) (2) (3), Geddes, et al (7), Vincent, et al (20) and Weidemann (22) indicate that the phosphorus treatment had little or no effect upon the phosphorus content of the grain.

Results of investigations dealing with the effect of potassium applications on the potassium content of the grain have been inconsistent. Some investigators found that potassium applications increased the potassium content in the grain while others showed that potassium had no effect in increasing the potassium content of the grain.

Cartter (6) states that direct fertilizer applications on a soil of medium to high fertility showed very little effect on the yield or the composition of soybean seed.

Weeks, et al (21) reported from Kentucky that manure, lime and fertilizer treatments affected the amount of phosphorus, calcium, magnesium and potassium and to a lesser extent the nitrogen in the grain of corn.

PURPOSE OF INVESTIGATION

The purpose of this investigation was to determine if varying the rates of nitrogen, phosphorus, and potassium alone and in combination applied to a poor soil would significantly influence (1) the nitrogen, phosphorus and potassium content of the sorghum grain produced on that soil and (2) the height of plant, date of heading and pollination, maturity, moisture percent in the seed at harvest, color of leaves, color of grain, number of suckers, percent germination of seed, weight per 100 grains, prevalence of disease and yield.

PLAN OF EXPERIMENT

Location and Description of Area Selected

The experiment was conducted on a Groseclose silt loam soil. The soils of the Groseclose series have developed from cherty dolomitic limestone in association with the gray-brown podzolic soils of the Appalachian Valley. The Groseclose soils are medium to strongly acid in reaction. The silt loams predominate.

The topography is rolling to hilly. Internal and external drainage are good. The Groseclose soils of the section are practically all cleared and used for all of the more common crops of the area. Groseclose is found primarily in western Virginia and eastern Tennessee.

The A horizon is light to yellowish-gray in color and ranges from 7 to 9 inches thick. The B horizon is light brownish-yellow friable silty clay and is 5 to 7 inches thick. The C horizon is similar to the B horizon but splotched with red, brown and gray. A few shale fragments occur locally. The C horizon is 18 to 36 inches thick.

The experimental area selected was located on a 150 acre pasture field to which no fertilizer had been applied for 35 years. Records of fertilization are not available beyond 35 years. Records show the field had been in pasture since 1900 and older people in the section say that the area had been in pasture continuously for over 74 years. One ton of ground limestone per acre was applied in 1940.

The soil of the entire area was carefully mapped and checked to determine the best location for the experiment. The four acre area selected was nearly flat with enough slope to allow good surface drainage. The area was then checked every four or five feet to determine the depth of the top soil, depth of the sub-soil, type of sub-soil and color of the soil. This was done to locate the most uniform area of 3/4 of an acre needed for the experiment. The area used showed very little variation in depth of top or sub-soil, color of soil and other visible characteristics.

Chemical Properties of the Soil

The area was laid out into plots and from each plot a soil sample was taken. A quick soil test according to Virginia procedure was run on all the samples. The soils showed uniformly low to very low in available phosphorus, uniformly good in available potassium, good in available calcium and magnesium, a pH of 6.0 and an organic matter content of 1.3%.

Available phosphorus was also run on the same soil samples by Truog's method and all gave a low test.

Base exchange properties of the soil were determined by the methods outlined by Peech, et al. (16). The base exchange capacity was 9.38 m.e. per 100 grams of dry soil and the exchangeable Ca, Mg, K and H was 3.59, 1.71, 0.20 and 3.88 m.e. per 100 grams of dry soil respectively.

Fertilizer Treatments and Plot Design

Four treatments of nitrogen, two treatments of phosphoric acid and two treatments of potash were used in a four by two by two factorial design. Three replications were used instead of four due to the lack of sufficient uniform land. The treatments of fertilizer and plot design were as follows:

Treatments per acre

Nitrogen	Phosphoric acid	Potash
0 - 0 lbs.	0 - 0	0 - 0
1 - 60 lbs.	1 - 240 lbs.	1 - 120 lbs.
2 - 120 lbs.		
3 - 180 lbs.		

Plot Design *

Replicate 1.

block a			block b		
N	P_2O_5	K_2O	N	P_2O_5	K_2O
3	0	1	2	1	1
3	1	0	1	0	1
0	0	0	3	0	0
2	1	0	2	0	0
2	0	1	0	0	1
1	1	1	1	1	0
1	0	0	3	1	1
0	1	1	0	1	0

Replicate 2.

block a			block b		
N	P_2O_5	K_2O	N	P_2O_5	K_2O
2	1	0	3	1	0
0	0	0	0	1	0
2	0	1	0	0	1
1	0	1	3	0	1
1	1	0	1	0	0
0	1	1	1	1	1
3	1	1	2	1	1
3	0	0	2	0	0

Replicate 3.

block a

N	P_2O_5	K_2O
3	1	0
0	1	1
1	0	1
1	1	0
2	0	0
2	1	1
3	0	1
0	0	0

block b

N	P_2O_5	K_2O
2	1	0
0	0	1
1	0	0
0	1	0
2	0	1
1	1	1
3	1	1
3	0	0

* Numbers refer to rates per acre indicated under "Treatment per acre".

The 240 lb. rate of P_2O_5 and the 120 lb. rate of K_2O per acre were thought to be ample to prevent any deficiency from occurring. The 180 lb. rate of nitrogen was expected to be ample.

The nitrogen was supplied as 16% nitrate of soda, the phosphorus as 45% triple superphosphate and the potassium as 62% muriate of potash.

Land Preparation and Method of Fertilizer Application

The sod land was plowed March 25 to an average depth of 7 to 8 inches with a tractor plow. The land was double disced April 10 and a second time on May 13. The triple superphosphate and muriate of potash were applied broadcast May 13 immediately before the second discing. Fertilizer for each plot was mixed with soil before applying to prevent drifting or blowing. The fertilizer and soil for each plot was divided into four equal parts and each part or one-fourth was sown over the entire plot to give a more even distribution and assure no skips. On all plots receiving 60, 120 and 180 lbs. of nitrogen per acre, 20 lbs. of the nitrogen was applied at the same time the phosphate and potast were applied. The remainder of the nitrogen or the 40, 100 and 160 lbs. was applied as a side dressing on June 30 when the plants were about 12" high on the better plots and 3" to 4" high on the poorer plots. The nitrogen was applied in a band 12" to 18" wide between the rows.

Planting, Cultivating, and Thinning

The plots were 16.5' wide and 26.5' long with five 40" rows per plot. The three center rows were used for all measurements. The sorghum was planted thick with a seeder to insure a good stand and was thinned to 4 inches between plants in the row on June 23. A measuring stick was used in the thinning to insure equal distance between plants. There were no alleys between plots. The sorghum was cultivated three times, once with a rotary hoe when 2" high and twice with a regular cultivator.

Plainsman, a dwarf grain sorghum variety, was used which is recommended for Virginia as a combine sorghum. The sorghum was planted on May 15 which is the recommended planting date for the area. The soil was in excellent physical condition when the sorghum was planted. Ample moisture was present throughout the growing season.

RESULTS and DISCUSSION

The Effect of Fertilization on the Height of the Plants

The plant height is the average of three replicates with 100 plants measured from two rows of each plot. Therefore, for each treatment a total of 300 plants were measured. The plant height was measured on July 8, August 5 and September 20. The results are shown in Table 1 and Figure 1. The statistical analysis is given in Tables 2 and 3.

Table 1.- The average height of plants in inches.

Treatment * $N - P_2O_5 - K_2O$	July 8	August 5	September 20
0 - 0 - 0	5.77	26.6	28.0
1 - 0 - 0	5.59	23.0	24.0
2 - 0 - 0	5.90	23.9	25.0
3 - 0 - 0	5.90	27.2	25.7
0 - 0 - 1	7.23	26.4	26.5
1 - 0 - 1	6.24	27.0	26.0
2 - 0 - 1	6.44	25.5	25.9
3 - 0 - 1	6.10	24.2	26.0
0 - 1 - 0	11.39	41.4	42.0
1 - 1 - 0	13.24	45.4	45.1
2 - 1 - 0	14.27	44.8	45.0
3 - 1 - 0	15.60	44.5	47.1
0 - 1 - 1	11.94	40.6	41.0
1 - 1 - 1	14.09	44.7	46.3
2 - 1 - 1	13.90	42.9	44.0
3 - 1 - 1	12.74	44.2	43.5

* See page 7 for treatments per acre.

Table 2.- Analysis of variance of the height of the plants in inches on July 8.

Source	D.F.	S.S.	M.S.
Blocks	5	14.67	2.93
N	3	8.36	2.79
P	1	630.75	630.75**(+)
K	1	.19	.19
NP	3	17.62	5.87* (+)
NK	3	9.85	3.28
PK	1	4.08	4.08
NPK	3	2.77	.92
Error	27	36.69	1.36
Total	47	724.98	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 3.- Analysis of variance of the height of the plants ~~in~~ inches on August 5.

Source	D.F.	S.S.	M.S.
Blocks	5	93.50	18.70
N	3	13.50	4.50
P	1	3924.08	3924.08**(+)
K	1	.33	.33
NP	3	54.09	18.03
NK	3	17.17	5.72
PK	1	6.76	6.76
NPK	3	16.81	5.60
Error	27	165.76	6.14
Total	47	4292.00	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Phosphorus had more influence on the height of plants than nitrogen or potassium. Phosphorus was the principal element stimulating early growth. Nitrogen alone, potassium alone and nitrogen-potassium combined had no significant influence on plant height on July 8, but decreased slightly the height on August 5 and September 20 compared to the check. Plants grown on nitrogen-phosphorus, and nitrogen-phosphorus-potassium treated plots showed an increase in height over those grown with phosphorus treatment. Plants produced on $N_1P_1K_1$ fertilized plots were taller than plants from $N_2P_1K_1$ or $N_3P_1K_1$ plots.

Potassium alone and in combination with nitrogen and phosphorus had no significant influence on the height which was probably due to a sufficient supply of potassium in the soil. Potassium decreased the height slightly when combined with N_2P_1 and N_3P_1. A significant interaction between nitrogen and phosphorus occurred. Plants grown on nitrogen-phosphorus treated plots were taller than plants on phosphorus treated plots throughout the growing season. Nitrogen and phosphorus were both needed to give plants height, with phosphorus having the greatest influence.

Of interest is the fact that nitrogen had much less influence on the height than phosphorus.

The Effect of Fertilization on Suckering, Heading, Maturity, Pollination and the Percent Moisture in the Seed at Harvest

The average number of suckers per 15 foot row was determined September 25, five days before harvesting. The numbers are averages for the three replicates and the three center rows of each plot. Heading data were taken from the same plants as the suckering data. These data are presented in Table 4 and Figures 2, 3, 4, and 5. The statistical analysis is presented in Tables 5, 6, 7, and 8.

Table 4.- Suckering and Maturity Rate as Influenced by Fertilization.

Treatment* N -P_2O_5- K_2O	Suckers per 15 ft. row	Percent plants full head August 5	Percent brown heads August 20	Percent suckers pollinating August 20	Percent moisture in seed Sept. 30	Percent moisture in sucker seed Sept. 30
0 - 0 - 0	2.22	6.1	0	.62	40.0	44.5
1 - 0 - 0	6.74	1.8	0		44.6	59.4
2 - 0 - 0	7.91	1.7	0		43.1	60.9
3 - 0 - 0	7.97	3.5	0	.39	39.1	62.0
0 - 0 - 1	5.70	8.6	0	3.8	42.4	49.7
1 - 0 - 1	4.25	4.6	0	.36	38.2	63.3
2 - 0 - 1	6.31	3.4	0		39.6	68.0
3 - 0 - 1	3.42	1.4	0		41.4	38.1
0 - 1 - 0	11.61	69.2	80.0	66.2	29.3	35.9
1 - 1 - 0	16.06	85.0	95.3	84.7	27.5	41.6
2 - 1 - 0	25.10	83.3	98.0	88.9	29.0	33.9
3 - 1 - 0	13.49	84.9	97.0	88.1	23.2	37.7
0 - 1 - 1	10.00	64.2	92.7	50.1	26.0	35.3
1 - 1 - 1	32.45	86.5	95.3	83.2	25.7	34.0
2 - 1 - 1	37.45	85.3	93.7	84.3	24.4	41.5
3 - 1 - 1	24.70	87.0	97.3	91.5	28.7	42.0

* See page 7 for treatments per acre.

Table 5.- Analysis of Variance of the Number of Suckers per Fifteen Feet of Row.

Source	D.F.	S.S.	M.S.
Blocks	5	7.7795	1.5559
N	3	13.3245	4.4415 *(+)
P	1	54.8269	54.8269**(+)
K	1	1.6060	1.6060
NP	3	4.1499	1.3833
NK	3	.2625	.0875
PK	1	4.1419	4.1419
NPK	3	3.6309	1.2103
Error	27	26.9999	1.0000
Total	47	116.7220	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 6.- Analysis of Variance of the Percent Plants in Full Head August 5.

Source	D.F.	S.S.	M.S.
Blocks	5	11.9507	2.3901
N	3	97.3667	32.4556 *(-)
P	1	34267.3313	34267.3313**(+)
K	1	12.5359	12.5359
NP	3	826.4915	275.4972**(+)
NK	3	35.3671	11.7890
PK	1	5.1025	5.1025
NPK	3	38.3138	12.7713
Error	27	260.4227	9.6453
Total	47	35554.8822	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 7.- Analysis of Variance of the Percent of the Suckers Pollinating on August 20.

Source	D.F.	S.S.	M.S.
Blocks	5	373.5402	74.7080
N	3	323.1680	107.7226
P	1	45896.4114	45896.4114**(+)
K	1	3.8307	3.8307
NP	3	1649.3847	549.7949 *(+)
NK	3	25.3762	8.4587
PK	1	60.7951	60.7951
NPK	3	179.5476	59.8492
Error	27	3823.0717	141.5952
Total	47	52155.5780	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 8.- Analysis of Variance of the Percent Moisture in the Seed When Cut September 30.

Source	D.F.	S.S.	M.S.
Blocks	5	13.3648	2.6730
N	3	4.4940	1.4980
P	1	914.7293	914.7293**(-)
K	1	6.1776	6.1776
NP	3	1.0571	.3524
NK	3	49.9242	16.6414 *(+)
PK	1	.0332	.0332
NPK	3	12.6901	4.2300
Error	27	44.2049	1.6372
Total	47	1046.6753	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Suckering: Nitrogen alone and phosphorus alone increased significantly the amount of suckering compared to no treatment. Nitrogen-phosphorus increased the suckering above phosphorus alone and nitrogen-phosphorus-potassium increased suckering above nitrogen-phosphorus.

Plants on plots treated with N_2P_1 or $N_2P_1K_1$ showed an increase in suckering above plants grown on plots to which N_1P_1 or $N_1P_1K_1$ was applied; but plants on plots receiving N_3P_1 and $N_3P_1K_1$ suckered less than plants on plots receiving N_2P_1 or $N_2P_1K_1$.

It is interesting to note that also the yield was lower on N_3P_1 and $N_3P_1K_1$ treated plots than N_2P_1 or $N_2P_1K_1$ fertilized plots. Corn and barley yields in Virginia have shown similar results in certain experiments.

Suckering is increased primarily by phosphorus and nitrogen. There were no significant interactions with NP, NK, PK or NPK.

Heading and Pollinating: The earliness of heading and pollination showed a highly significant increase from the phosphorus treatment. Nitrogen alone decreased significantly the earliness of heading. Nitrogen-phosphorus increased significantly the earliness compared to phosphorus fertilization alone. Potassium had no effect on the date of pollination and heading. Increased rates of nitrogen above 60 pounds per acre had no influence on the dates of heading or pollination. Of interest is the fact that the sorghum on plots fertilized with nitrogen-phosphorus headed and pollinated earlier than plants grown on phosphorus fertilized plots. This fact showed that nitrogen did not delay maturity if properly balanced with phosphorus and potassium. There was a significant interaction between nitrogen and phosphorus.

Maturity and Moisture percent in the Grain: The grain was harvested on September 30 which was five days after the first killing frost. The grain contained too much moisture to thrash with a regular head thrasher. Eight heads from each plot were thrashed by hand and the moisture percent determined. Grain produced on plots treated with nitrogen alone and potassium alone contained approximately the same percent moisture as the grain on no treatment plots. Grain from phosphorus treated plots contained ten percent less moisture than seed from the check plot which was significant. Seed from nitrogen-phosphorus treated plots showed a lower moisture content than seed from the phosphorus treatment alone. There is an indication that potassium with phosphorus or potassium with nitrogen-phosphorus gave grain with a slightly decreased moisture content. Increased rates of nitrogen did not influence significantly the percent moisture in the grain at harvest. Nitrogen-potassium treated plots developed grain with a significantly higher moisture content at harvest than grain from plots fertilized with nitrogen or potassium alone.

Fertilization shows the same effect on maturity as on heading and percent moisture in seed at harvest. Nitrogen hastens maturity when balanced with phosphorus on a soil well supplied with potash. During 1947 and 1948 these results were duplicated with corn on experimental plots in Virginia.

Suckers: The suckers headed, pollinated and matured approximately two weeks later than the regular heads. The influence of fertilization on these characteristics is nearly the same as for the regular heads but is not as consistent.

The Effect of Fertilization on the Average Weight of Head, Weight of Seed Per Head, Weight of Seed Per Sucker Head, Weight of 100 Seed from Regular and Sucker Heads, Percent Germination of Seed After Dry (12% moisture) and the Relation of the Weight of the Head to the Weight of the Seed.

All measurements were made with seed at 12% moisture. The results are given in Table 9 and Figures 6, 7, 8, 9, 10, 11, and 12. Statistical analyses of the measurements are given in Tables 10, 11, 12, and 13.

Table 9.- The Effect of Fertilization on the Heads, Seed and Germination.

Treatment * N -P_2O_5- K_2O	Wt.Per Head Grams	Wt.Seed per Head Grams	Wt.Seed / wt.head percent	Wt.seed per sucker head - Grams	Wt.100 Seed Grams	Wt.100 seed from suckers grams	Germination percent
0 - 0 - 0	48.5	35.8	81.9	11.8	2.40	1.98	87.9
1 - 0 - 0	41.2	24.0	81.9	10.4	2.08	1.79	83.3
2 - 0 - 0	37.1	26.3	81.0	9.1	2.22	1.72	79.6
3 - 0 - 0	41.7	33.1	83.3	16.8	2.16	1.74	88.1
0 - 0 - 1	46.2	39.0	81.9	16.3	2.42	1.94	86.9
1 - 0 - 1	41.2	34.9	82.3	16.8	2.34	1.73	88.0
2 - 0 - 1	44.4	36.2	81.4	15.6	2.30	1.88	87.2
3 - 0 - 1	35.8	27.2	82.2	13.1	2.10	2.01	92.3
0 - 1 - 0	68.9	47.6	83.3	16.3	2.58	2.27	94.0
1 - 1 - 0	64.8	52.5	81.8	23.6	2.69	2.25	94.9
2 - 1 - 0	81.1	62.5	82.0	24.5	2.85	2.57	91.9
3 - 1 - 0	75.2	56.2	80.5	26.7	2.74	2.41	96.3
0 - 1 - 1	61.2	48.5	81.2	23.1	2.62	2.09	95.1
1 - 1 - 1	72.0	48.5	81.2	26.3	2.66	2.41	93.3
2 - 1 - 1	67.0	47.6	82.3	22.2	2.72	2.41	91.8
3 - 1 - 1	73.4	56.2	81.4	21.7	2.80	2.44	91.7

* See page 7 for treatments per acre.

Table 10.- Analysis of Variance of the Weight Per Head at 12% Moisture.

Source	D.F.	S.S.	M.S.
Blocks	5	.0017	.00033
N	3	.0002	.00007
P	1	.0469	.04688**(+)
K	1	.0003	.00028
NP	3	.0028	.00094 *(+)
NK	3	.0006	.00021
PK	1	.0002	.00023
NPK	3	.0014	.00047
Error	27	.0046	.00017
Total	47	.0587	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 11.- Analysis of Variance of the Weight of the Seed Per Head at 12% Moisture.

Source	D.F.	S.S.	M.S.
Blocks	5	.000387	.000077
N	3	.000429	.000143
P	1	.024843	.024843**(+)
K	1	.000004	.000004
NP	3	.002191	.000730 *(+)
NK	3	.000398	.000133
PK	1	.001046	.001046 *(+)
NPK	3	.001529	.000510 *(-)
Error	27	.003617	.000134
Total	47	.034444	

*Significant at 5% point
**Significant at 5% point
(+)increases (-)decreases

Table 12.- Analysis of Variance of the Percent of Head Weight Is Seeds.

Source	D.F.	S.S.	M.S.
Blocks	5	23.60	4.72
N	3	1.52	.51
P	1	.88	.88
K	1	.05	.05
NP	3	6.68	2.23
NK	3	4.31	1.44
PK	1	.07	.07
NPK	3	13.99	4.66
Error	27	95.62	3.55
Total	47	146.75	

*Significant at 5% point
**Significant at 1% point
(+)increases (-) decreases

Table 13.- Analysis of Variance of the Weight of 100 Sorghum Kernels.

Source	D.F.	S.S.	M.S.
Blocks	5	.057231	.011446
N	3	.062115	.020705
P	1	2.485666	2.485666**(+)
K	1	.010414	.010414
NP	3	.333069	.111023 *(+)
NK	3	.035115	.011705
PK	1	.021973	.021973
NPK	3	.055322	.018441
Error	27	.353912	.013108
Total	47	3.414817	—

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 14.- Analysis of Variance of the Percent Germination of the Seed.

Source	D.F.	S.S.	M.S.
Blocks	5	92.7949	1.8559
N	3	116.1318	38.7106
P	1	545.4008	545.4008**(+)
K	1	7.8085	7.8085
NP	3	26.9593	8.9864
NK	3	22.3159	7.4386
PK	1	70.4222	70.4222
NPK	3	37.9469	12.6490
Error	27	533.3847	19.7550
Total	47	1453.1650	

*Significant at 5% point
**Significant at 1% point
(+)increases _ (-) decreases

Weight Per Head: Heads produced on plots treated with nitrogen alone were lighter than those from the unfertilized plot. Heads from nitrogen-potassium treated plots were slightly lighter than heads from plots fertilized with potassium alone or the check. Increased rates of nitrogen alone had no influence. Heads from phosphorus treated plots were significantly heavier than those from no treatment. The nitrogen-phosphorus treated plots produced heads significantly heavier than those grown on plots treated with phosphorus alone. The necessity of having an adequate supply of nitrogen and phosphorus to produce the heaviest head was evident even though phosphorus had the greatest influence on the weight of the head. Phosphorus and nitrogen-phosphorus had a significant influence on the weight per head.

The weight of seed per head, weight of seed per sucker head, weight of 100 seed from regular heads and weight of 100 seed from sucker heads showed nearly the same effect from fertilization as did the weight per head.

Fertilization had no influence on the relation of the weight of heads to the weight of seeds per head.

Germination: The percent germination was determined by germinating the seed in a standard germination.

The effect of various treatments on the germination does not present a trend from which conclusions may be drawn for all treatments. The average percent germination of the seed from all plots fertilized with phosphorus is 93.63% and from all plots without phosphorus fertilization is 86.66%. Seed produced on phosphorus treated plots showed a significant increase in the percent germination compared to seed produced on plots receiving no phosphorus.

Seed from phosphorus treated plots gave a quicker germination than seed from plots receiving no phosphorus fertilization. In Table 18 it is shown that seed from phosphorus treated plots contained significantly more P_2O_5 and in Table 1 it is shown that phosphorus increases the early growth. Thus it is seen that phosphorus plays a vital role from germination to maturity.

The Effect of Fertilization on the Percent of the Leaves Browning and Drying on September 10, Prevalence of Disease and Yield in Bushels Per Acre.

Counts were made of the number of leaves browning on September 10. The total number of leaves browning in two fifteen foot rows of each plot were counted and the percent determined. The number of diseased plants were counted in two fifteen foot rows of each plot and the total number of diseased plants in 30 feet of row was recorded. The yield was determined by harvesting two fifteen foot rows from each plot, drying the heads and seed to 12% moisture and then thrashing and weighing. The yields were calculated in bushels (56 lbs.) per acre. The results of these determinations are presented in Table 15 and Figures 13, 14, and 15. Statistical analysis of the determinations is presented in Tables 16 and 17.

Table 15.- The Effect of Fertilization on the Browning of the Leaves, Amount of Disease and Yield.

Treatment * N -P_2O_5- K_2O	Brown leaves Sept. 10 - percent	Number Diseased Plants - 30' Row Sept. 10	Yield-Bushels Per Acre 12.0% moisture
0 - 0 - 0	16.0	.97	45.2
1 - 0 - 0	13.0	.65	27.2
2 - 0 - 0	10.0	.75	27.2
3 - 0 - 0	6.0	.64	35.8
0 - 0 - 1	10.0	.63	40.3
1 - 0 - 1	10.0	1.11	44.7
2 - 0 - 1	10.0	.67	42.3
3 - 0 - 1	10.0	.78	33.2
0 - 1 - 0	36.0	1.64	55.5
1 - 1 - 0	20.0	2.88	65.4
2 - 1 - 0	10.0	2.41	89.9
3 - 1 - 0	10.0	2.89	80.2
0 - 1 - 1	37.0	2.30	56.2
1 - 1 - 1	16.0	2.60	82.5
2 - 1 - 1	10.0	3.76	72.3
3 - 1 - 1	6.0	2.16	72.5

* See page 7 for treatments per acre.

Table 16.- Analysis of Variance of the Number of Diseased Plants Per 30 Feet of Row.

Source	D.F.	S.S.	M.S.
Blocks	5	9.8380	1.9676
N	3	1.8773	.6258
P	1	39.1324	39.1324**(+)
K	1	.2611	.2611
NP	3	2.1735	.7245
NK	3	1.3239	.4413
PK	1	.1323	.1323
NPK	3	2.0820	.6940
Error	27	16.3476	.6055
Total	47	73.1681	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 17.- Analysis of Variance of the Yield in Bushels Per Acre at 12% Moisture.

Source	D.F.	S.S.	M.S.
Blocks	5	193.39	38.68**
N	3	480.31	160.10**(-)
P	1	14560.33	14560.33**(+)
K	1	58.08	58.08**(-)
NP	3	1988.42	662.81**(+)
NK	3	930.94	310.31**(-)
PK	1	199.27	199.27**(-)
NPK	3	432.10	144.03**(-)
Error	27	188.66	6.73
Total	47	19024.50	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Browning of leaves: Sorghum produced on plots fertilized with nitrogen alone showed less browning than that produced on the check. A decrease of browning generally occurred as the rate of nitrogen was increased. The amount of browning of the leaves was small on plants from all plots except with phosphorus alone and with phosphorus-potassium treatments. The plants on these two plots showed a high percent of browned leaves. The plants on the unfertilized plot showed much less browning than the plants on the phosphorus alone or phosphorus-potassium treated plots. This is to be expected since the check plot received no phosphorus to stimulate growth and encourage the development of nitrogen deficiency. The percent of leaves browning showed that 60 pounds of nitrogen with phosphorus or with phosphorus-potassium was not sufficient to prevent browning but that plants on plots treated with 120 pounds of nitrogen showed no increase in browning compared to leaves from plants produced on plots receiving 180 pounds of nitrogen.

Tissue tests (Purdue method) for nitrogen, phosphorus and potassium were made on plants from all plots on July 24, August 20 and September 20.

Plants on all plots showed high in nitrogen and potassium on July 24. Plants on plots receiving no phosphorus showed very low in phosphorus; but plants on phosphorus fertilized plots showed high.

On August 20 plants on all plots showed high in potassium. Tissue tests for phosphorus gave the same results as on July 24. Plants grown on plots receiving phosphorus and phosphorus-potassium fertilization gave a low test for nitrogen. Plants from all the other plots showed medium to high in nitrogen.

The September 10 tissue tests presented a changed picture for nitrogen. The plants from the plot receiving no fertilizer gave a medium test for nitrogen. Plants from N_1, N_2, and N_3 treatments and also from N_1K_1, N_2K_1 and N_3K_1 treatments showed high to very high in nitrogen. The tissue test showed no nitrogen in the plants from P_1 and P_1K_1 fertilized plots. Plants from the N_1P_1 treatments tested low in nitrogen but plants from N_2P_1 treatments showed high.

Plants from phosphorus treated plots still tested high but plants on plots receiving no phosphorus showed none in the plant. This test indicates that phosphorus was very deficient in this soil; but that the rate of 240 lbs. of P_2O_5 per acre was ample to prevent any deficiency of phosphorus. Plants from plots not receiving phosphorus showed phosphorus deficiency symptoms; but no such symptoms were found on plants produced on phosphorus treated plots.

On September 10, plants from all plots showed high in potassium. The test shows that ample potassium was present in the soil before the 120 lb. application of K_2O was made.

The tissue tests for nitrogen correlate quite closely with the percent brown leaves on September 10.

Disease: Plants were observed at maturity which broke at the ground level and had a dry stalk. The plant pathologist examined these stalks and diagnosed the disease as anthracnose. With the help of the plant pathologist, counts for diseased plants were made on all plots September 10. The results of the counts are difficult to interpret due to their inconsistency, however, significantly more diseased plants were found on plots treated with phosphorus. No reason can be given for this except that sorghum on plots receiving phosphorus was more vigorous and probably more succulent and thus more susceptible to the disease. Work by plant pathologists in Virginia, however, shows that generally the more vigorous plants on well fertilized soil are more resistant to disease rather than more susceptible as shown here.

Yield: The effect of the treatments on the yield is quite interesting. The fact that a 45 bushel yield was secured on the check plot is unusual. Nitrogen alone decreased the yield significantly compared to no fertilizer. Plants on nitrogen alone plots did not develop as good heads as those on the check plots. Apparently, the unbalanced nutrient condition due to the excess nitrogen had a detrimental effect on seed formation. The nitrogen may have stimulated forage growth which used up the available phosphorus resulting in a deficiency of available phosphorus for seed formation.

Plants from plots fertilized with potassium alone and nitrogen-potassium decreased the yield significantly below the yields from the no treatment plots. This is possibly due to an unbalanced nutrient supply with a deficiency of phosphorus.

Plants grown on phosphorus treated plots gave significantly higher yields than those grown on the check, nitrogen, potassium or nitrogen-potassium treatments. This shows two things: (1) the deficiency of phosphorus in this soil and (2) the necessity of phosphorus for seed production. Nitrogen-phosphorus treatments gave significant increases in the yield above phosphorus alone which also demonstrates the importance of nitrogen in seed production when ample phosphorus is present.

Plants produced on the N_3P_1 fertilized plots gave a lower yield than the plants from the N_2P_1 treated plots. However the plants on the N_2P_1 plots gave a higher yield than the plants on the N_1P_1 plots. Of interest is the fact that the highest yield from plots treated with NPK came from the $N_1P_1K_1$ treatment and not from the $N_2P_1K_1$ or $N_3P_1K_1$ treatments.

The reduced yield from plots treated with N_3P_1, $N_2P_1K_1$ and $N_3P_1K_1$ compared to the yield from the N_2P_1 and $N_1P_1K_1$ treatments may be due to a direct or indirect effect of an unbalanced nutrient supply. The decreased yield from plots receiving the high rates of nitrogen was not caused by delayed maturity and frost damage.

Potassium treatments had a depressing effect on the yield.

The Effect of Fertilization on the Nitrogen, Phosphorus and Potassium Content of the Seed.

Nitrogen, phosphorus and potassium determinations were made according to a micro-chemical procedure (13) after ashing the material in an electric furnace. Potassium was determined by the direct reading method using the Perkin-Elmer flame photometer. The analysis was made of a composite sample of seed from each plot. The results of the analysis are given in Table 18 and Figures 16, 17 and 18. Statistical analysis of the results is given in Tables 19, 20 and 21.

Table 18.- The Percent Nitrogen, P_2O_5 and K_2O in the Seed*.

Treatment ** $N - P_2O_5 - K_2O$	Regular Seed Percent N	Regular Seed Percent P_2O_5	Regular Seed Percent K_2O	Sucker Seed Percent N	Sucker Seed Percent P_2O_5	Sucker Seed Percent K_2O
0 - 0 - 0	2.1	.48	.41	2.04	.57	.44
1 - 0 - 0	2.3	.50	.44	2.34	.63	.51
2 - 0 - 0	2.3	.52	.44	2.36	.56	.47
3 - 0 - 0	2.5	.52	.40	2.23	.63	.59
0 - 0 - 1	2.0	.51	.39	1.96	.51	.41
1 - 0 - 1	2.3	.50	.42	2.03	.59	.39
2 - 0 - 1	2.4	.51	.41	2.16	.59	.48
3 - 0 - 1	2.5	.51	.43	2.40	.61	.49
0 - 1 - 0	1.5	.68	.41	2.02	.65	.44
1 - 1 - 0	2.4	.77	.42	2.10	.60	.45
2 - 1 - 0	2.5	.80	.43	2.10	.69	.39
3 - 1 - 0	2.7	.81	.43	2.35	.71	.42
0 - 1 - 1	1.8	.61	.43	1.61	.67	.45
1 - 1 - 1	2.3	.71	.40	1.73	.58	.40
2 - 1 - 1	2.6	.77	.45	2.10	.64	.43
3 - 1 - 1	2.6	.78	.43	2.17	.69	.40

* Oven dry basis.
** See page 7 for treatments per acre.

Table 19.- Analysis of Variance of the Percent Nitrogen in the Seed (Oven Dry Basis)

Source	D.F.	S.S.	M.S.
Blocks	5	1.0708	.2142
N	3	15.1338	5.0446**(+)
P	1	.0001	.0001
K	1	.1398	.1398
NP	3	2.4048	.8016 *(+)
NK	3	.1502	.0501
PK	1	.0275	.0275
NPK	3	.3861	.1287
Error	27	3.4805	.1289
Total	47	22.7936	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 20.- Analysis of Variance of the Percent P_2O_5 in the Seed.

(Oven Dry Basis)

Source	D.F.	S.S.	M.S.
Blocks	5	.3262	.0652
N	3	.6157	.2052 *(+)
P	1	8.9355	8.9355**(+)
K	1	.0540	.0540
NP	3	.3747	.1249 *(+)
NK	3	.0024	.0008
PK	1	.0808	.0808
NPK	3	.0299	.0100
Error	27	1.0530	.0390
Total	47	11.4722	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Table 21.- Analysis of Variance of the Percent K_2O in the Seed.

(Oven Dry Basis)

Source	D.F.	S.S.	M.S.
Blocks	5	.4396	.0879
N	3	.0663	.0221
P	1	.0091	.0091
K	1	.0001	.0001
NP	3	.0600	.0200
NK	3	.0228	.0076
PK	1	.0140	.0140
NPK	3	.0136	.0045
Error	27	.4005	.0148
Total	47	1.0260	

*Significant at 5% point
**Significant at 1% point
(+)increases (-)decreases

Regular Seed

Nitrogen: Seed produced on plots fertilized with nitrogen alone contained significantly more nitrogen than seed from untreated plots. No increase in nitrogen content occurred in the seed from nitrogen-potassium treated plots compared to nitrogen treatments alone.

Potassium treatments alone had no influence on the nitrogen in the seed.

Seed grown on nitrogen-phosphorus treated plots contained significantly more nitrogen than seed from plots treated with nitrogen alone. Therefore, phosphorus caused an increase in the nitrogen content of the seed when ample nitrogen was present.

Of interest is the fact that seed from plots fertilized with phosphorus alone and phosphorus -potassium had a lower nitrogen content than seed produced on any other plot. In this case, the phosphorus stimulated vegetative growth, which probably utilized most of the available nitrogen. As a result, there was insufficient nitrogen for the seed needs.

Phosphorus: Potassium alone and nitrogen-potassium fertilization had no influence on the phosphorus content of the seed compared to seed from plants receiving no fertilizer, all showed practically the same phosphorus content.

The phosphorus fertilized plots produced seed with a phosphorus content significantly higher than seed produced on the other plots not treated with phosphorus. This is probably due to the acute deficiency of phosphorus in this soil. Research done at the Virginia Agricultural Experiment Station has shown that corn grown on soil very deficient in phosphorus, produced grain with a lower phosphorus content than corn grown on soil with an ample supply of phosphorus.

Perhaps the most interesting result is the significant increase in the phosphorus in the grain on plots fertilized with nitrogen alone compared to grain from untreated plots; and the significant increase of phosphorus in the grain from nitrogen-phosphorus treatments compared to phosphorus treatment alone. On these plots, the nitrogen has been responsible for an increase in the phosphorus content of the seed. The nitrogen fertilizer used was sodium nitrate. Sodium is supposed to aid in the translocation of phosphorus, therefore, the addition of sodium may have aided in the translocation of the phosphorus to the seed. Wheeler (23), et al., reported in 1906 that sodium salts applied to Rhode Island soils increased the percentage of phosphorus in the plant. Ample nitrogen and phosphorus is essential to secure the highest phosphorus content in the seed. Here again the necessity of balanced nutrients is evident.

Potassium: There was no significant difference in the potassium content of the seed produced on the various plots. One factor influencing this is the high potassium content in the soil before treatment. Nitrogen or phosphorus alone or in combination had no influence on the potassium in the seed.

Sucker Seed

Nitrogen: The nitrogen content of the seed from the suckers showed in general the same influence from fertilization as the regular seed. The principal exception was the higher nitrogen content of the seed from phosphorus treated plots alone compared to seed from the other plots.

Phosphorus: Phosphorus treatments did not have as marked influence on the sucker seed as the regular seed. Sucker seed from the nitrogen, potassium, phosphorus, nitrogen-potassium and phosphorus-potassium treated plots were as high or higher in phosphorus than regular seed from similar plots. The phosphorus in the sucker seed was lower from plants grown on the nitrogen-phosphorus and nitrogen-phosphorus-potassium plots than seed from the regular heads produced on these plots.

Potassium: The potassium content of the seed showed no effect from any treatment.

The nitrogen, phosphorus and potassium content of the sucker seed show in general the same effects from fertilization as the regular heads but not as consistent. The lack of consistency is probably due to the variation in the maturity of the suckers.

The Effect of Fertilization on the Foliage Color

The color of the foliage was determined by the use of the color standards as given in Robert Ridgeway's book "Color Standards and Color Nomenclature" published in 1912 by the author. The color of the three center leaves was matched with the nearest color plate in the book. The color determinations were made on August 4, 5, and 6 and the three readings averaged. If there was variation in the readings on the three successive days, the readings were made again on August 7, 8, and 9.

After the color of the leaves was matched with the nearest color given in the color standards; the composition of the color was determined from a table given in the book. The composition of the color of the leaves as determined for each treatment is given in Table 21 and shown in Figures 18 and 19. According to the standards used, an increase in the percent of black and a decrease in the percent of yellow gives a darker green and an increase in yellow and decrease in black would mean a lighter green.

Table 22.- The Color of the Plant Foliage on August 5 and September 1.

Treatment *	Color Percent August 5			Color Percent Sept. 1		
N- P_2O_5 -K_2O	Yellow	Green	Black	Yellow	Green	Black
0 - 0 - 0	6	49	45	11	44	45
1 - 0 - 0	6	49	45	6	49	45
2 - 0 - 0	6	49	45	6	49	45
3 - 0 - 0	6	49	45	6	49	45
0 - 0 - 1	6	49	45	11	44	45
1 - 0 - 1	8	47	45	8	47	45
2 - 0 - 1	8	47	45	6	40	54
3 - 0 - 1	6	49	45	6	40	54
0 - 1 - 0	17	53	30	24	76	0
1 - 1 - 0	5	32	63	6	49	45
2 - 1 - 0	4	25	71	3	26	71
3 - 1 - 0	4	25	71	3	26	71
0 - 1 - 1	17	53	30	24	76	
1 - 1 - 1	4	25	71	6	40	54
2 - 1 - 1	3	26	71	3	26	71
3 - 1 - 1	3	26	71	3	26	71

* See page 7 for treatments per acre.

August 5 Readings: Nitrogen alone, potassium alone and nitrogen-potassium fertilization had no effect on the color of the foliage compared to no fertilization. The supply of phosphorus was very low in the soil and therefore the nitrogen was unable to function properly in developing chlorophyll. Phosphorus is not a component of chlorophyll, but is apparently essential for its development.

Plants grown on phosphorus treated plots were lighter in color with more yellow and less black than plants grown with no treatment, which shows a deficiency of nitrogen developed through the increased plant growth.

Plants grown on phosphorus-potassium plots showed the same color as those grown on phosphorus treated soil.

Nitrogen-phosphorus and nitrogen-phosphorus-potassium produced an increase in green color of plants above the check, nitrogen, potassium, nitrogen-potassium and of course much increase over phosphorus and phosphorus-potassium treatments. These results show the necessity of a balanced nutrient supply to develop the greenest color. Plants grown on N_1P_1 and $N_1P_1K_1$ treated plots were a little lighter green than plants on the N_2P_1 and $N_2P_1K_1$ fertilized plots. The plants grown on the N_2P_1 and $N_2P_1K_1$ fertilized plots were as dark green as those plants on the N_3P_1 and $N_3P_1K_1$ fertilized areas. These results show that 120 lbs. of nitrogen per acre was sufficient to produce the darkest green color.

Potassium alone or in combination with nitrogen and phosphorus had no effect on the color of the plants. The potassium supply in the soil was thought to be ample in the beginning, which may be the reason for the potassium applications showing no significant effect on the color of the foliage.

September 1 Readings: There was little change in color of the plants grown on the check, nitrogen, potassium and nitrogen-potassium treated plots from August 5 to September 1. There was a slight decrease in the green color of the plants on the check and the potassium plots, but this is probably not of significance.

Plants on the phosphorus and phosphorus-potassium treated plots showed a marked decrease in green color as the season developed. This is due to a further decrease in the nitrogen supply.

Plants grown on the N_1P_1 and$N_1P_1K_1$ fertilized soils decreased in green color from August 5 to September 1, which shows that 60 lbs. of nitrogen was not sufficient to maintain the green color throughout the season. Plants on the N_2P_1 and $N_2P_1K_1$ treated areas maintained the dark green throughout the growing period, and were as dark green on September 1 as the plants grown on the N_3P_1 and $N_3P_1K_1$ treated plots.

The Effect of Treatment on the Color of the Seed

The color of the seed was determined by the same method as the color of the foliage except that a different color plate was used from Ridgeway's "Color Standards and Nomenclature". Color determinations were made after the seed had become air dried and in a darkened room with a constant light. The seed was not exposed to the sun at any time after harvest. The percentage color of the seed is presented in Table 23.

Table 23.- Color of the Seed.

Treatment *	Color Percent				
N- P_2O_5 -K_2O	Red	Orange	Yellow	Black	White
0 - 0 - 0		32	10	29	29
1 - 0 - 0		27	15	29	29
2 - 0 - 0		36	15	20	29
3 - 0 - 0		36	19	45	
0 - 0 - 1		39	16	45	
1 - 0 - 1		27	15	29	29
2 - 0 - 1		30	16	25	29
3 - 0 - 1		42	13	45	
0 - 1 - 0		33	18	39	10
1 - 1 - 0	11	44		45	
2 - 1 - 0	25	17		29	29
3 - 1 - 0	25	17		29	29
0 - 1 - 1	8	44		34	14
1 - 1 - 1	7	48		45	
2 - 1 - 1	4	51		45	
3 - 1 - 1		55		45	

* See page 7 for treatments per acre.

As shown by the data in Table 23, single elements alone had very little effect on the color of the seed compared to no treatment. Seed produced on nitrogen-phosphorus treated plots were darker in color and brighter than those from the unfertilized areas. Seed produced on plots receiving nitrogen with phosphorus-potassium were brighter but this could not be expressed by color differences.

SUMMARY AND CONCLUSIONS

A uniform area of soil (Groseclose silt loam) very low in available phosphorus, very low in nitrogen and organic matter but showing medium to high in available and exchangeable potassium was selected, to study the effect of varying the rates of nitrogen, phosphorus and potassium alone and in all combinations on certain plant characteristics of a dwarf grain sorghum. This was the poorest soil in available phosphorus and nitrogen that could be located. The available and exchangeable potassium was high which is often found in old unfertilized pastures in this area.

A 4 x 2 x 2 factorial design was used with four treatments of nitrogen (0, 60, 120 and 180 pounds N per acre), two treatments of phosphorus (0 and 240 pounds P_2O_5 per acre) and two treatments of potassium (0 and 120 pounds K_2O per acre).

The effect of the treatments on the plant characteristics is given in condensed form in table 24.

The Effect of Nitrogen

This soil was very low in nitrogen and organic matter as shown by the soil tests. No legumes had grown on this soil for many years. The light color of the sparse vegetation indicated a lack of nitrogen.

Nitrogen alone influenced significantly only five of the plant characteristics studied; increasing the number of suckers, delaying the heading, decreasing the yield and increasing the percent nitrogen and phosphorus in the seed. The nitrogen combined with phosphorus had a more pronounced influence on the characteristics than nitrogen alone as evidenced by the significant increase in the height of plants, earliness of heading of the regular heads and suckers, increase in the weight per head, the weight of seed per head, the weight of one hundred seed, yield per acre and the percent nitrogen and phosphorus in the seed.

The results, in general, show that the addition of nitrogen alone to a phosphorus deficient soil had a minor influence on the characteristics studied but a significant depressing effect on the yield. Whereas nitrogen combined with phosphorus had a positive stimulating effect on many of the characteristics.

The results of this study show conclusively the necessity of nutrient balance.

The Effect of Phosphorus

The fact that the application of 240 pounds per acre of P_2O_5 had a highly significant influence on thirteen of the sixteen plant characteristics statistically analyzed; and had a pronounced influence on those that were not statistically analyzed shows the importance of this element to dwarf grain sorghum on this soil. The general responce to phosphorus substantiates the conclusion that the supply in the soil was inadequate based on the results of the soil test.

The data from this experiment and unpublished data from the Agronomy Department of the Virginia Agricultural Experiment Station show conclusively that phosphorus is a key element and probably the key element to stimulate early growth of dwarf grain sorghum.

The highly significant increase in percent germination of the seed produced on phosphorus treated plots is important and warrants further investigation. The seed not only gave a higher percent germination but germinated more rapidly.

The significant increase of nitrogen in the grain on plots treated with nitrogen-phosphorus shows a significant interaction between nitrogen and phosphorus and the necessity of nutrient balance. Phosphorus alone depressed the nitrogen content in the seed.

Phosphorus had more influence on plant characteristics than either nitrogen or potassium.

Phosphorus is a key element from "germination to germination".

Effect of Potassium

Potassium alone or in combination with nitrogen-phosphorus had little or no influence on most of the plant characteristics studied. Potassium alone and in combination with nitrogen-phosphorus had a depressing effect on the yield. Seed produced on potassium-nitrogen treated plots had a significantly higher percent moisture at harvest but showed a significant decrease in the weight of the seed per head.

The lack of effect of added potassium on more characteristics is probably due to an adequate supply in the soil. The 120 pounds of potassium per acre added may have caused an unbalanced nutrient condition in the soil which resulted in a depression of the yield and the weight of the seed per head. The necessity of knowing the level of nutrients in the soil is brought out many times.

General

The writer feels that the results of this study show also the necessity of determining as accurately as possible the plant nutrient supply in the soil at the beginning of any fertility experiment. By having carefully checked the nutrient balance in this soil, the lack of response to potassium and strong response to phosphorus treatments can be at least partially explained.

Table 24.- The Effect of Treatments on Plant Characteristics.

Plant Characteristics	Treatments						
	N	P	K	NP	NK	PK	NPK
Height of plants July 8	0	**+	0	*+	0	0	0
Height of plants August 5	0	**+	0	+	0	0	0
Number of suckers per 15' row	*+	**+	+	+	0	0	+
Percent of plants in full head August 5.	*-	**+	0	**+	0	0	0
Percent of suckers pollinating August 20.	0	**+	0	*+	0	-	0
Percent moisture in the seed at harvest.	+	**-	+	-	*+	-	0
Weight per head	-	**+	0	*+	0	-	-
Weight of seed per head	-	**+	0	*+	0	*+	*-
Percent of head weight is seed	0	0	0	0	0	0	0
Weight of seed per head from suckers.	0	+	+	+	0	+	0
Weight of one hundred seed	-	**+	0	*+	0	0	0
Weight of one hundred seed from suckers	-	+	0	+	0	0	0
Percent germination	-	**+	0	0	0	0	0
Percent brown leaves Sept. 10.	-	+	0	0	0	0	0
Number of diseased plants	-	**+	-	+	0	+	0
Yield per acre	**-	**+	**-	**+	**-	**-	**-
Percent nitrogen in seed	**+	-	0	*+	0	0	0
Percent P_2O_5 in seed	*+	**+	0	*+	0	-	0
Percent K_2O in seed	0	0	0	0	0	0	0
Foliage color August 5 - green	0	-	0	+	0	0	0
Foliage color Sept. 1 - green	0	-	0	+	0	0	0

*Significant at 5% point — - Decrease — + Increase

**Significant at 1% point — 0 No influence

Fig. 1.- Effect of treatment on the plant height of a dwarf grain sorghum, July 8 and August 5.

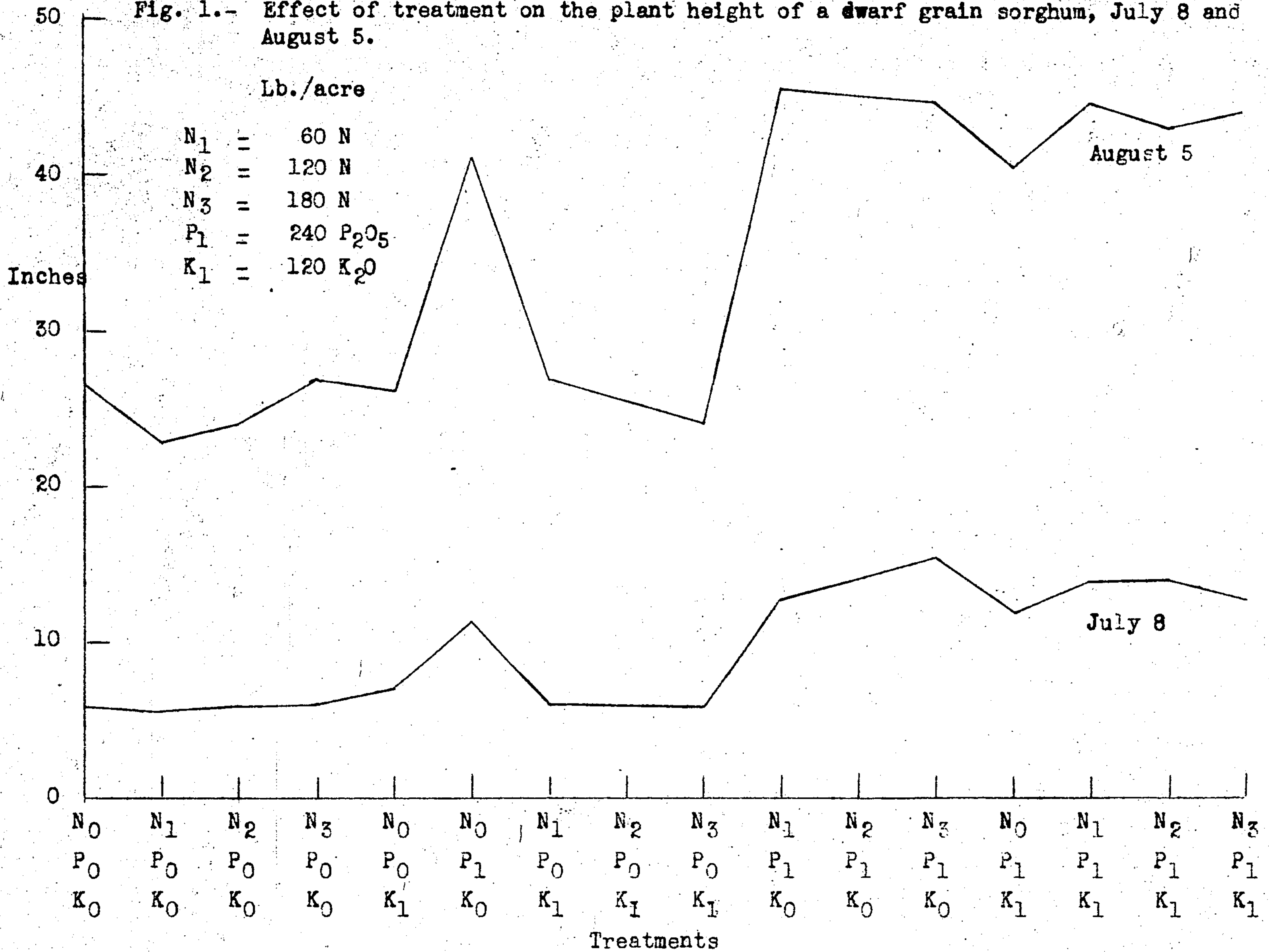


Fig. 2- Effect of treatment on the number of suckers per fifteen feet of row of a dwarf grain sorghum.

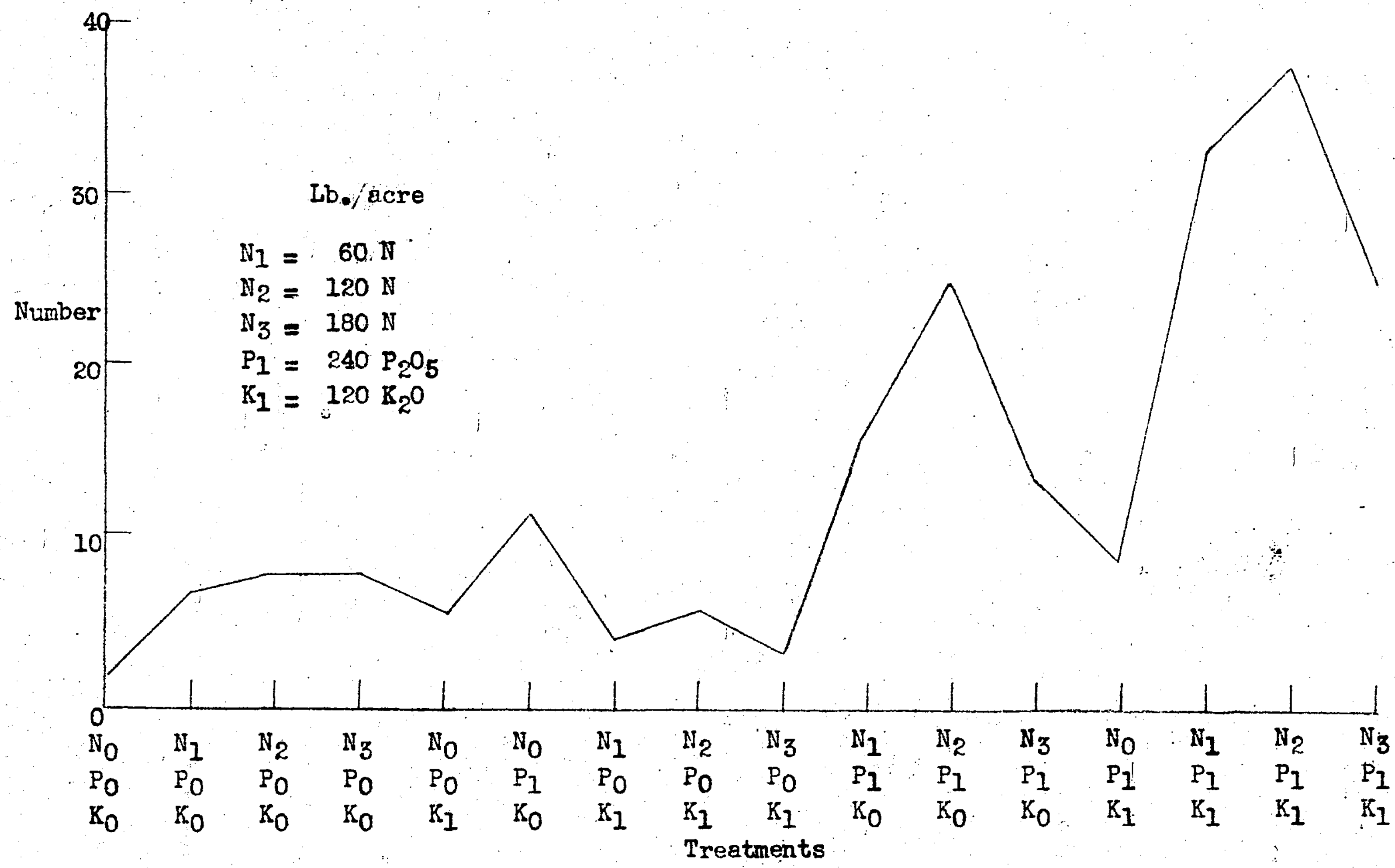


Fig. 3.- Effect of treatment on the percent of plants in full head August 5 of a dwarf grain sorghum.

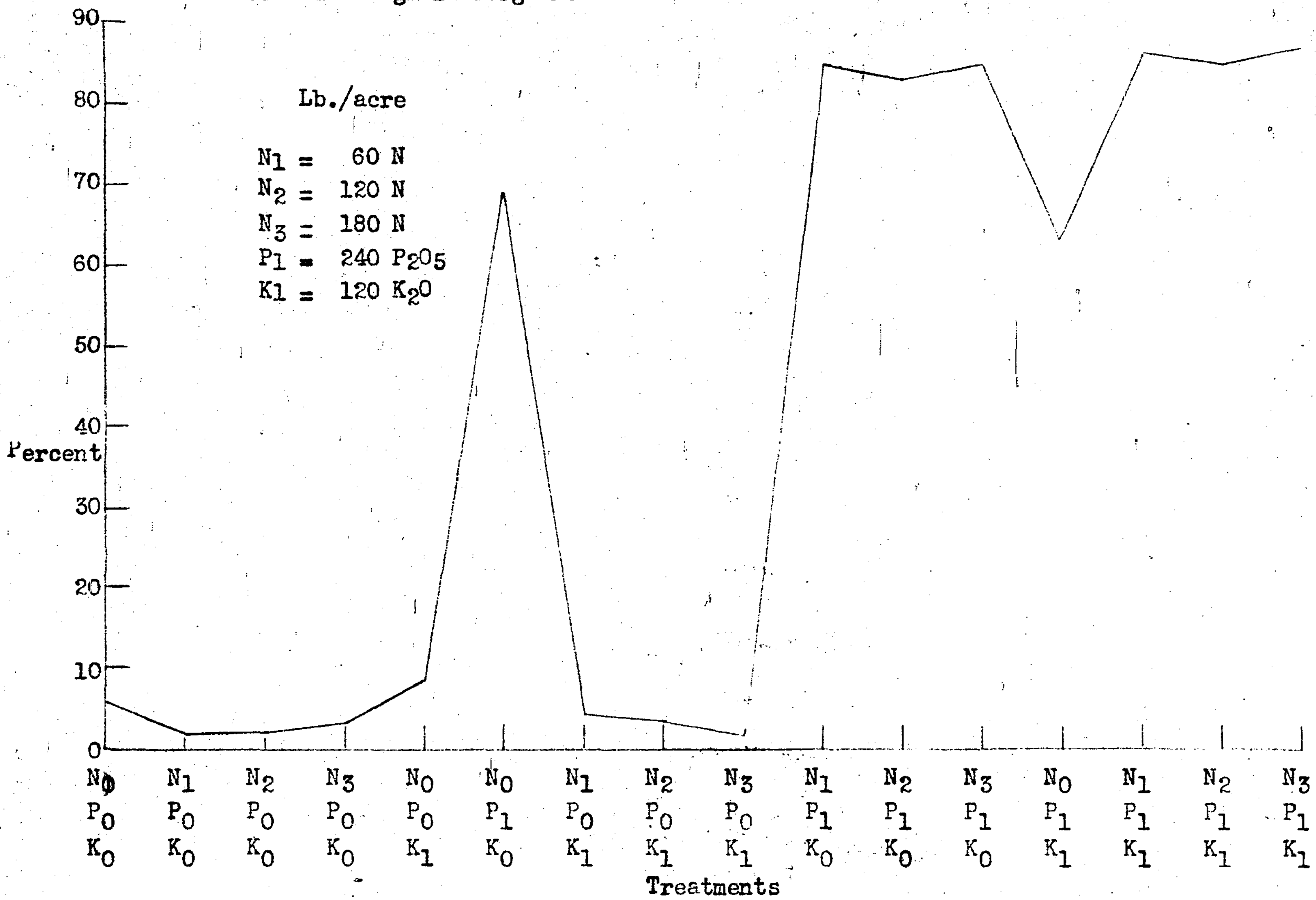


Fig. 4.- Effect of treatment on the percent of the suckers pollinating on August 20 of a dwarf grain sorghum.

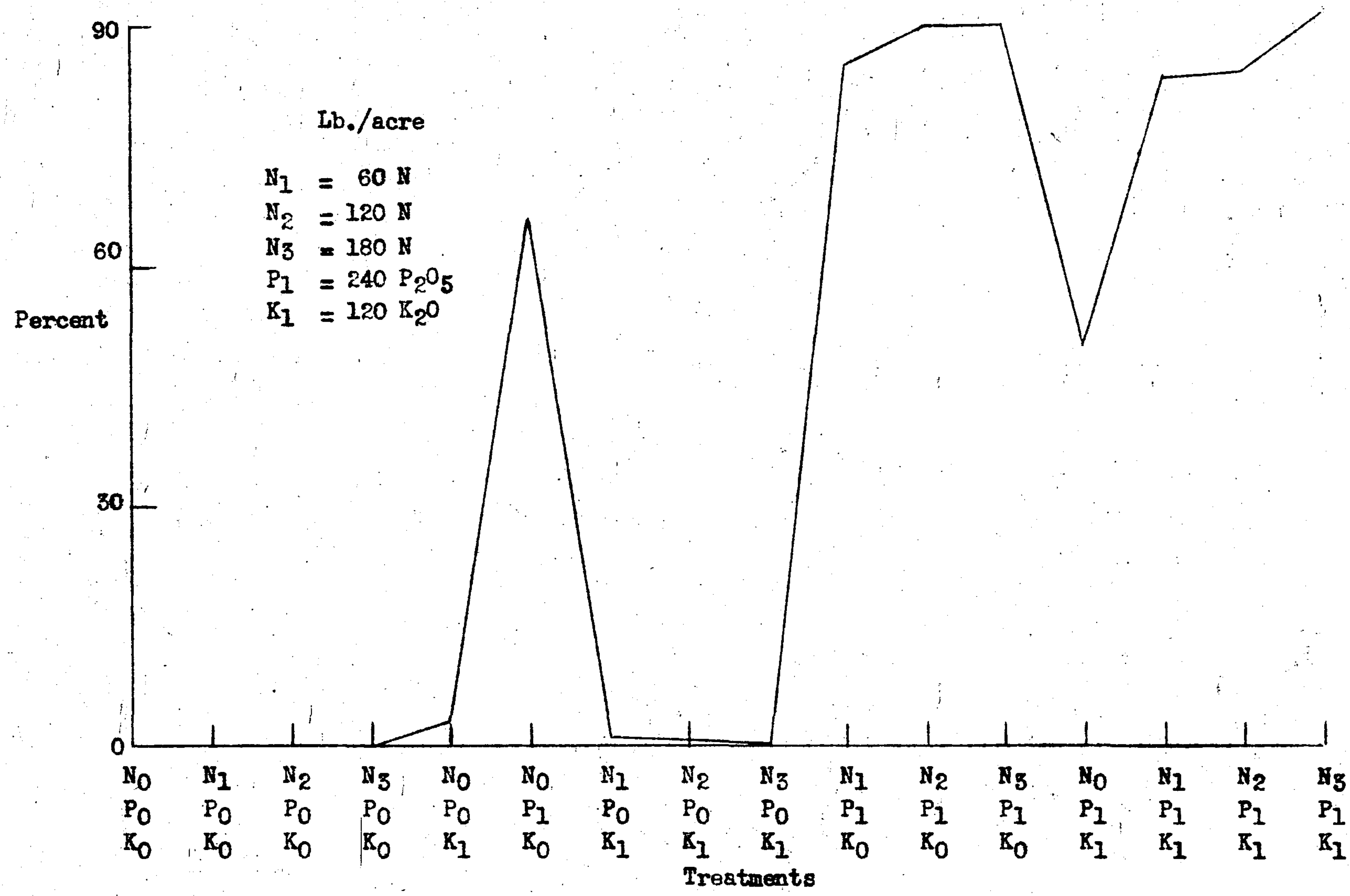


Fig. 5.— Effect of treatment on the moisture percent in the seed at harvest of a dwarf grain sorghum.

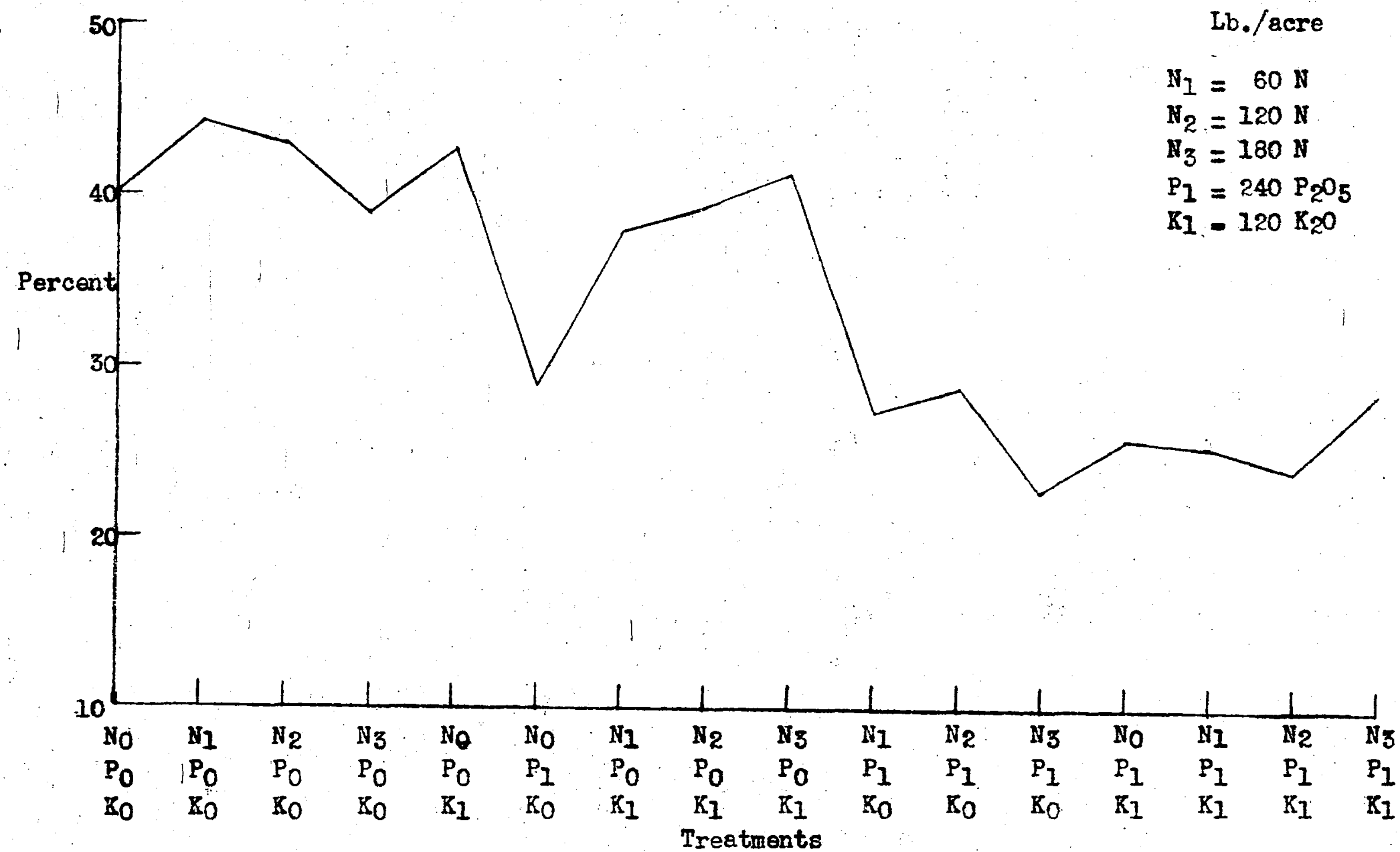


Fig. 6.- Effect of treatment on the weight per head of a dwarf grain sorghum.

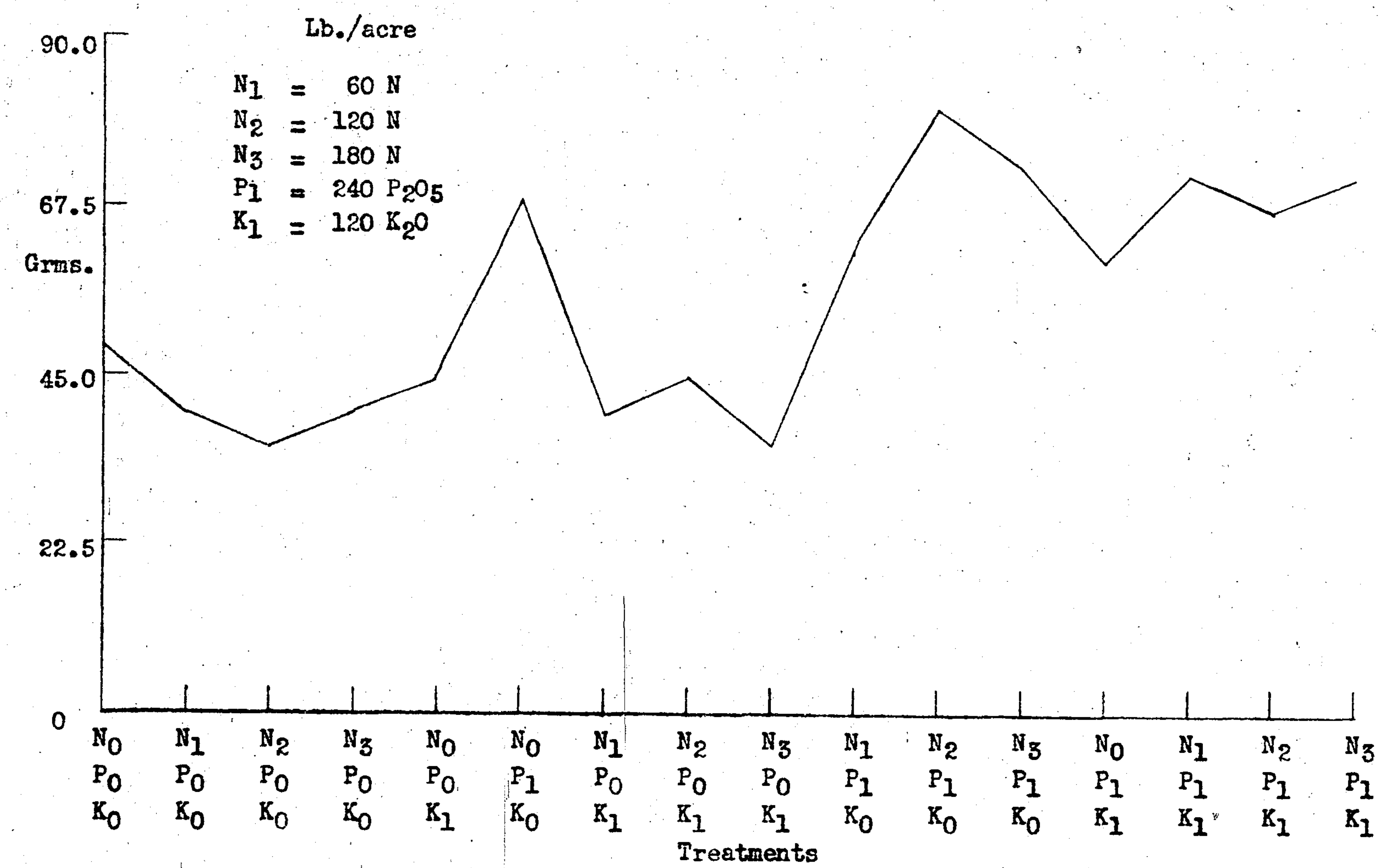


Fig. 7.- Effect of treatment on the weight of the seed per head of a dwarf grain sorghum.

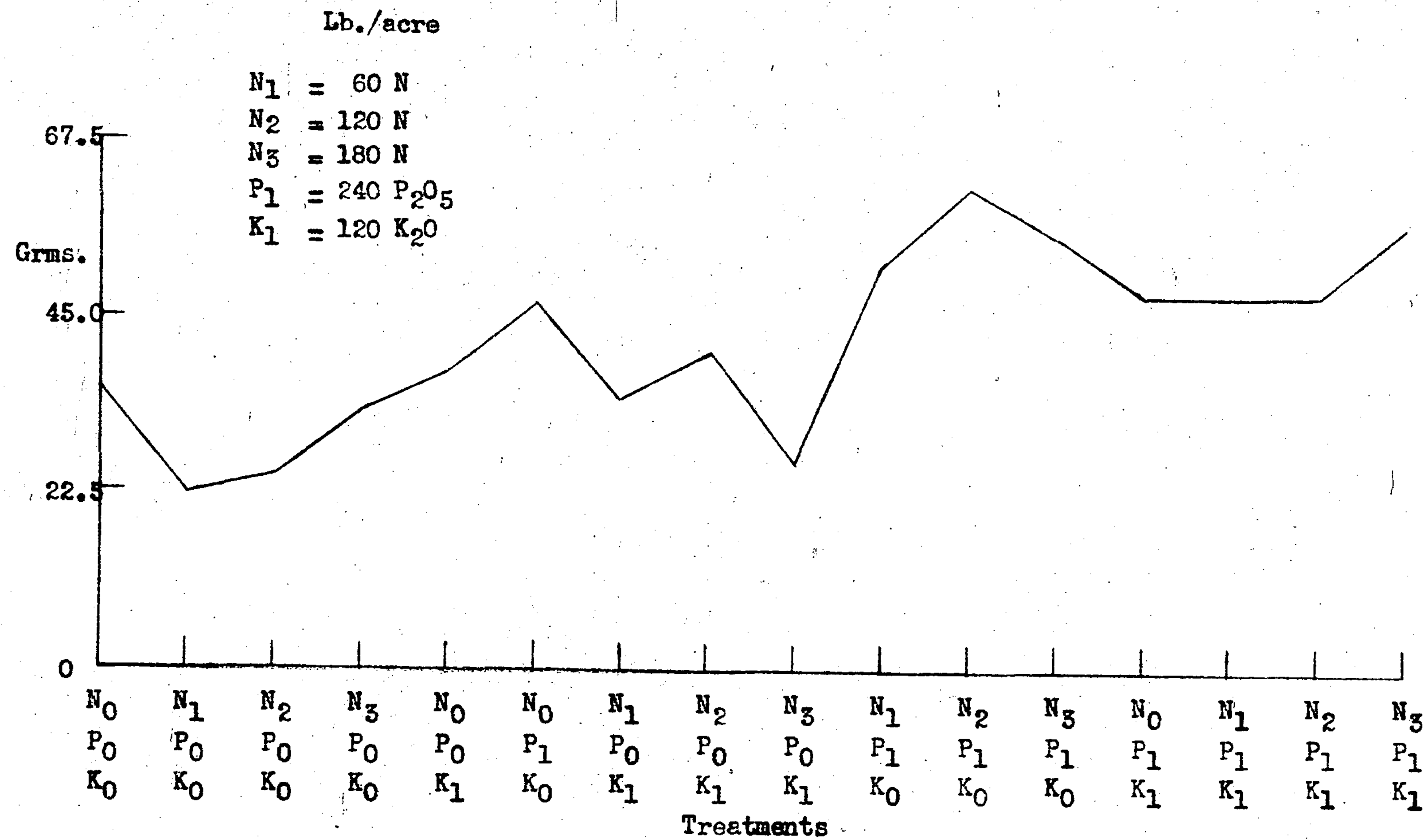


Fig. 8.- Effect of treatment on the percent of head weight is seed of a dwarf grain sorghum.

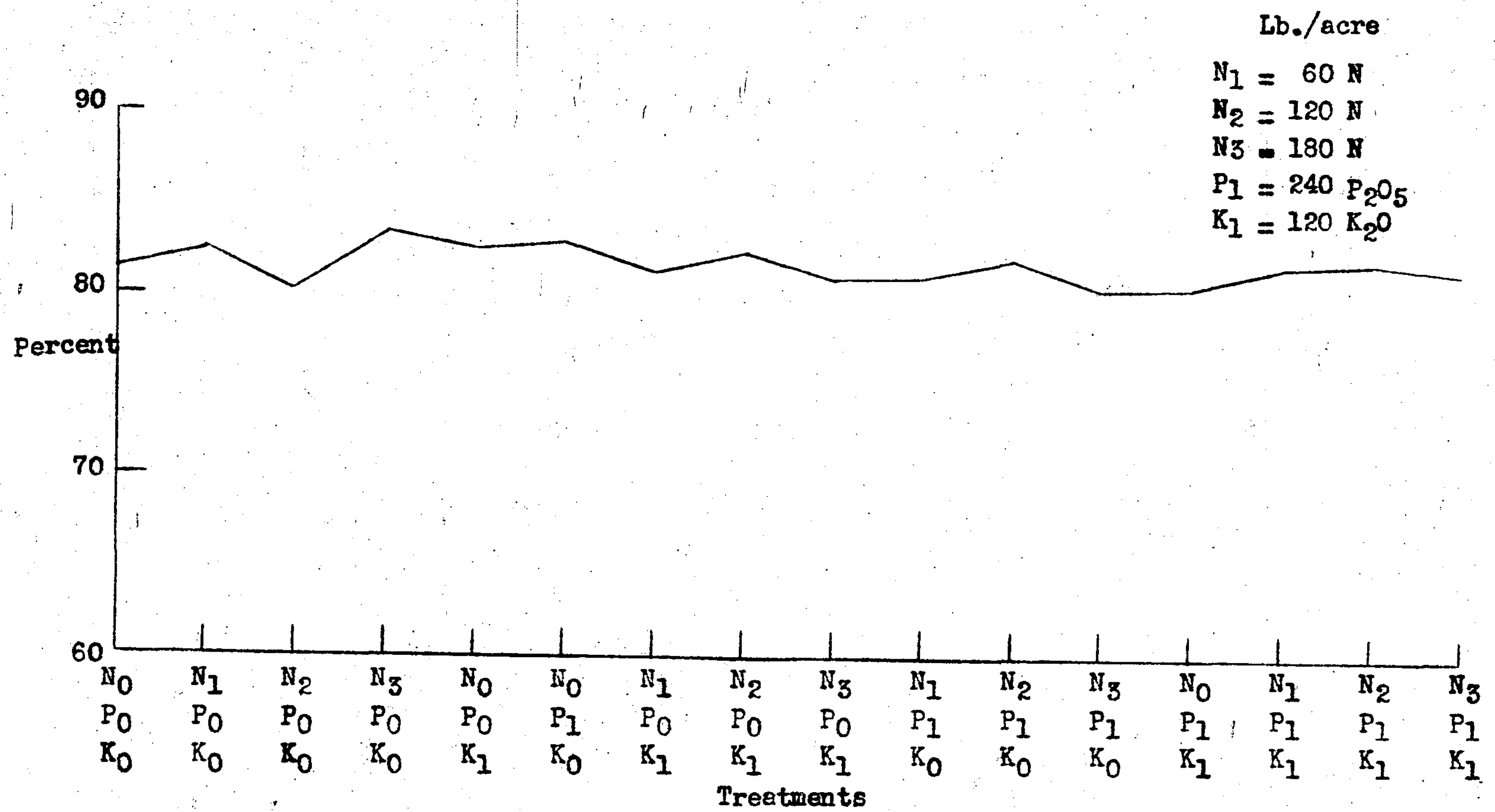


Fig. 9.- Effect of treatment on the weight of the seed per head from suckers of a dwarf grain sorghum.

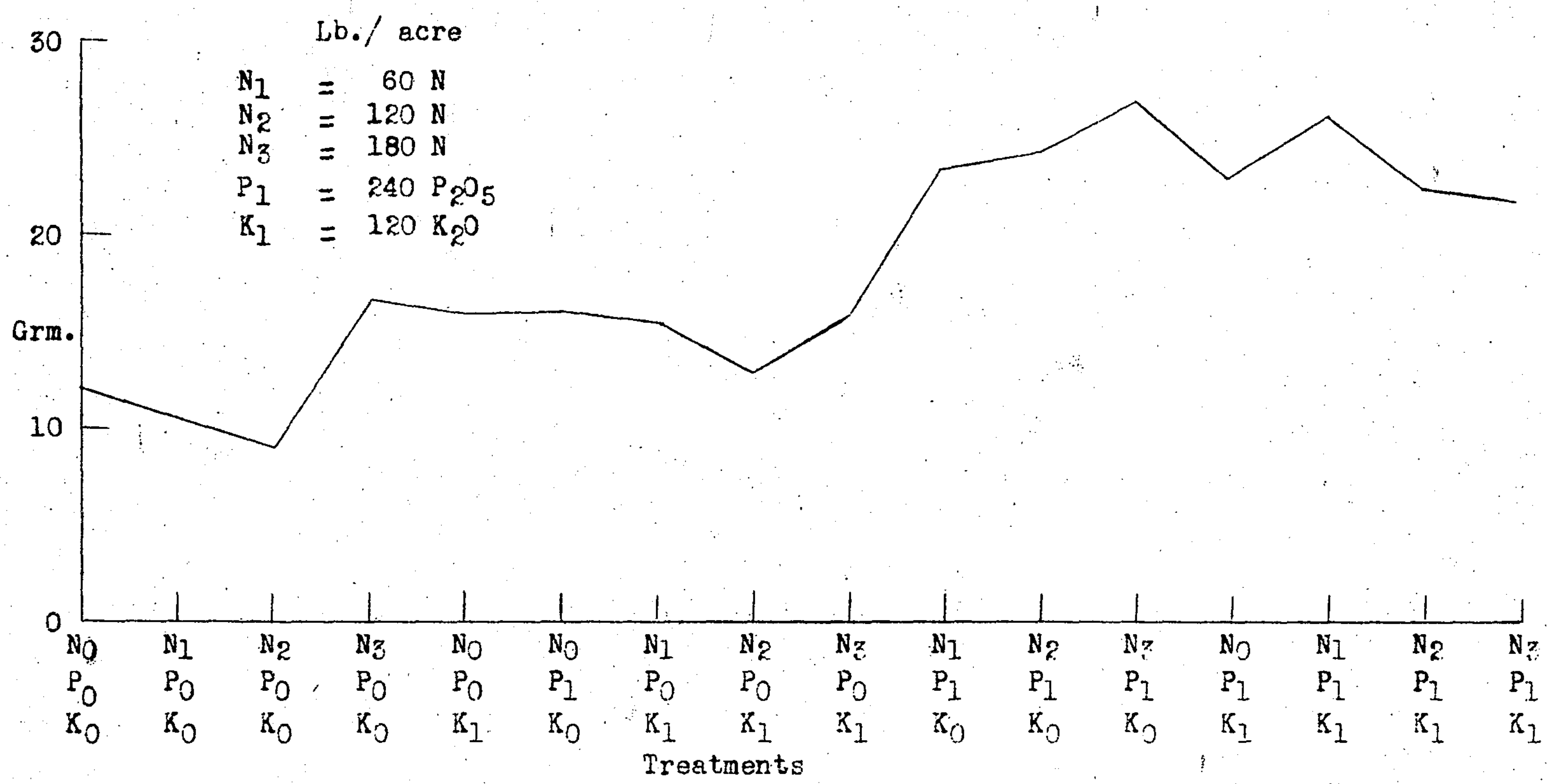


Fig. 10.- Effect of treatment on the weight of 100 seed of a dwarf grain sorghum.

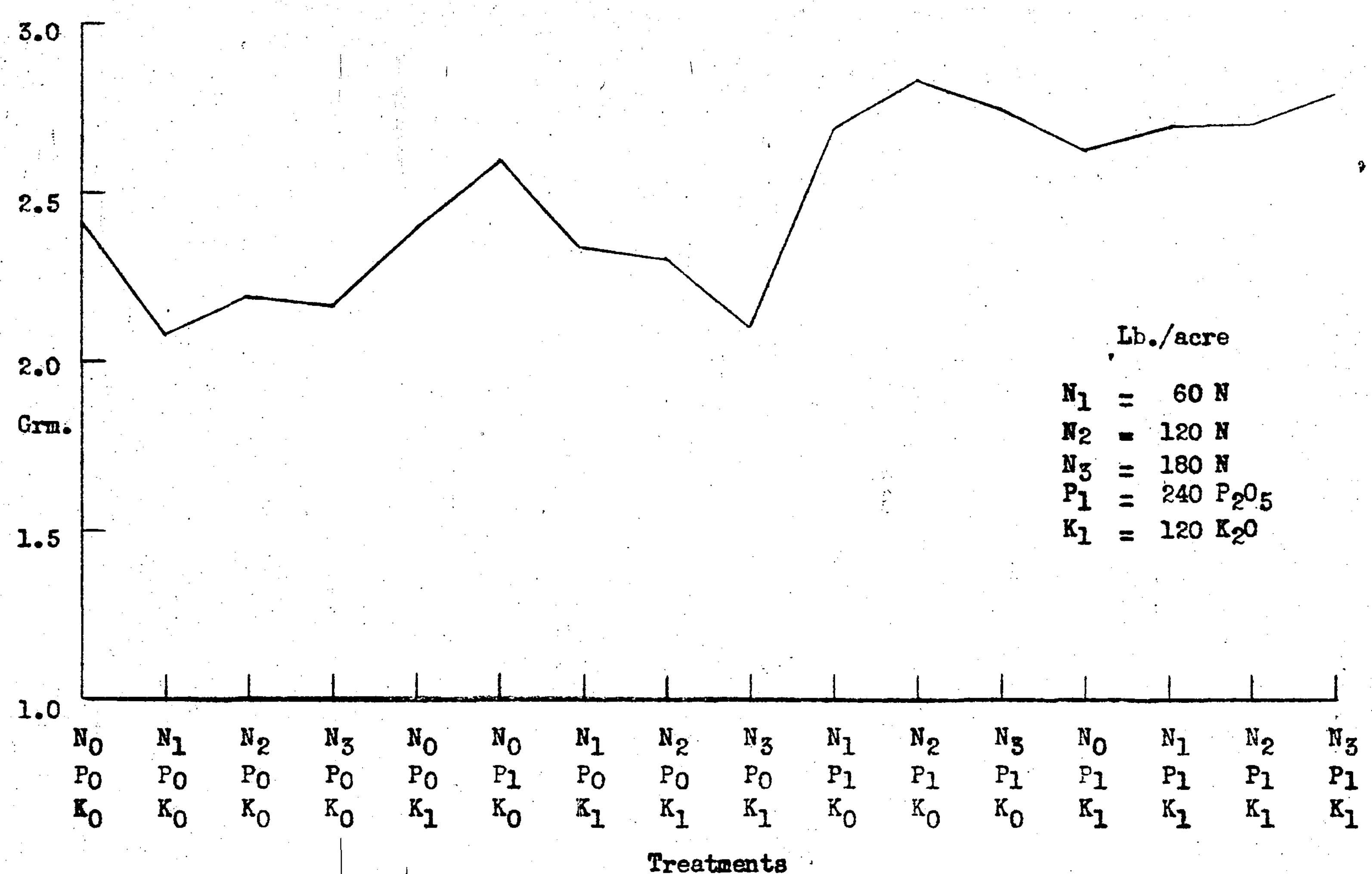


Fig. 11.- Effect of treatment on the weight of 100 seed from the sucker heads of a dwarf grain sorghum.

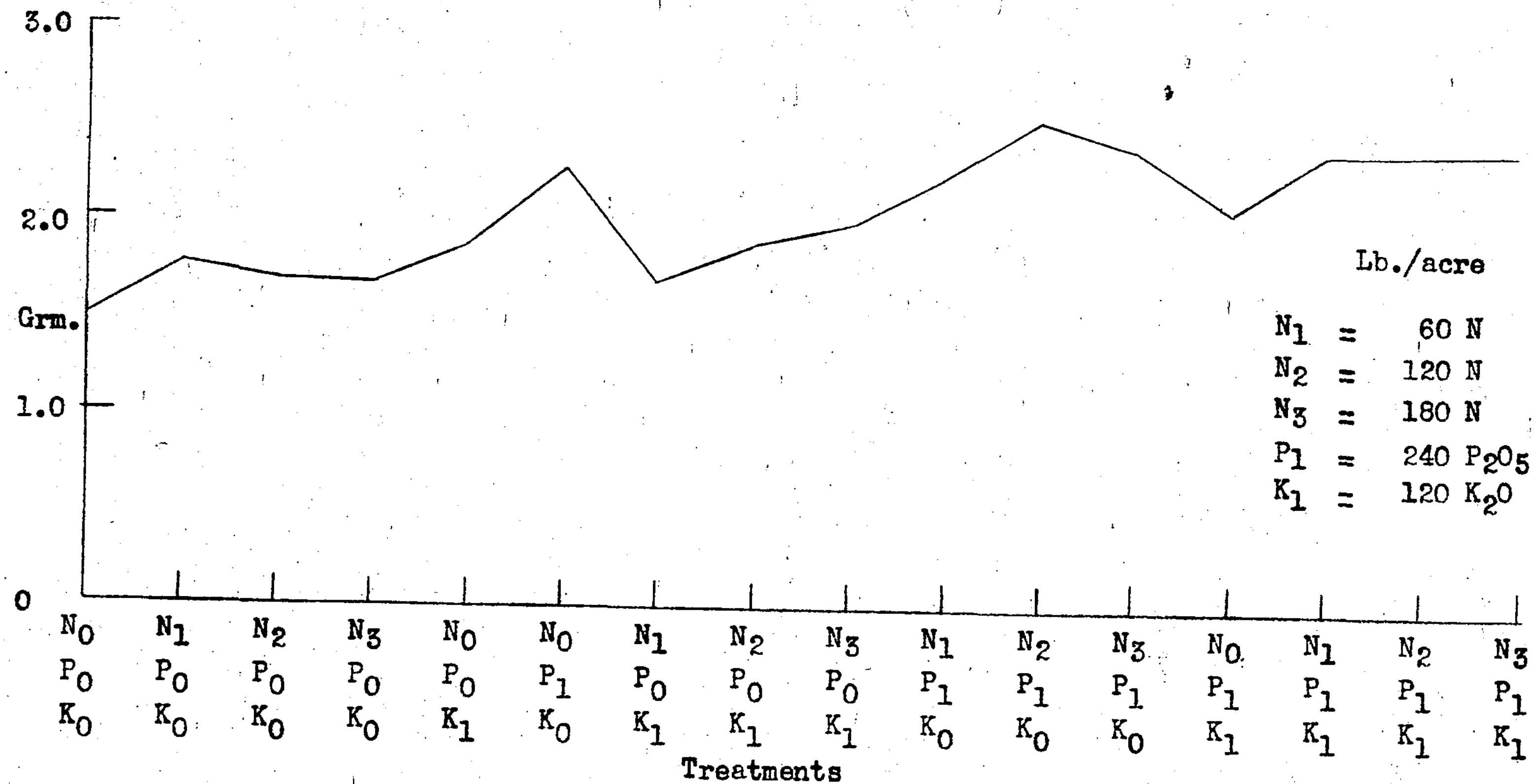


Fig. 12 - Effect of treatment on the percent germination of a dwarf grain sorghum.

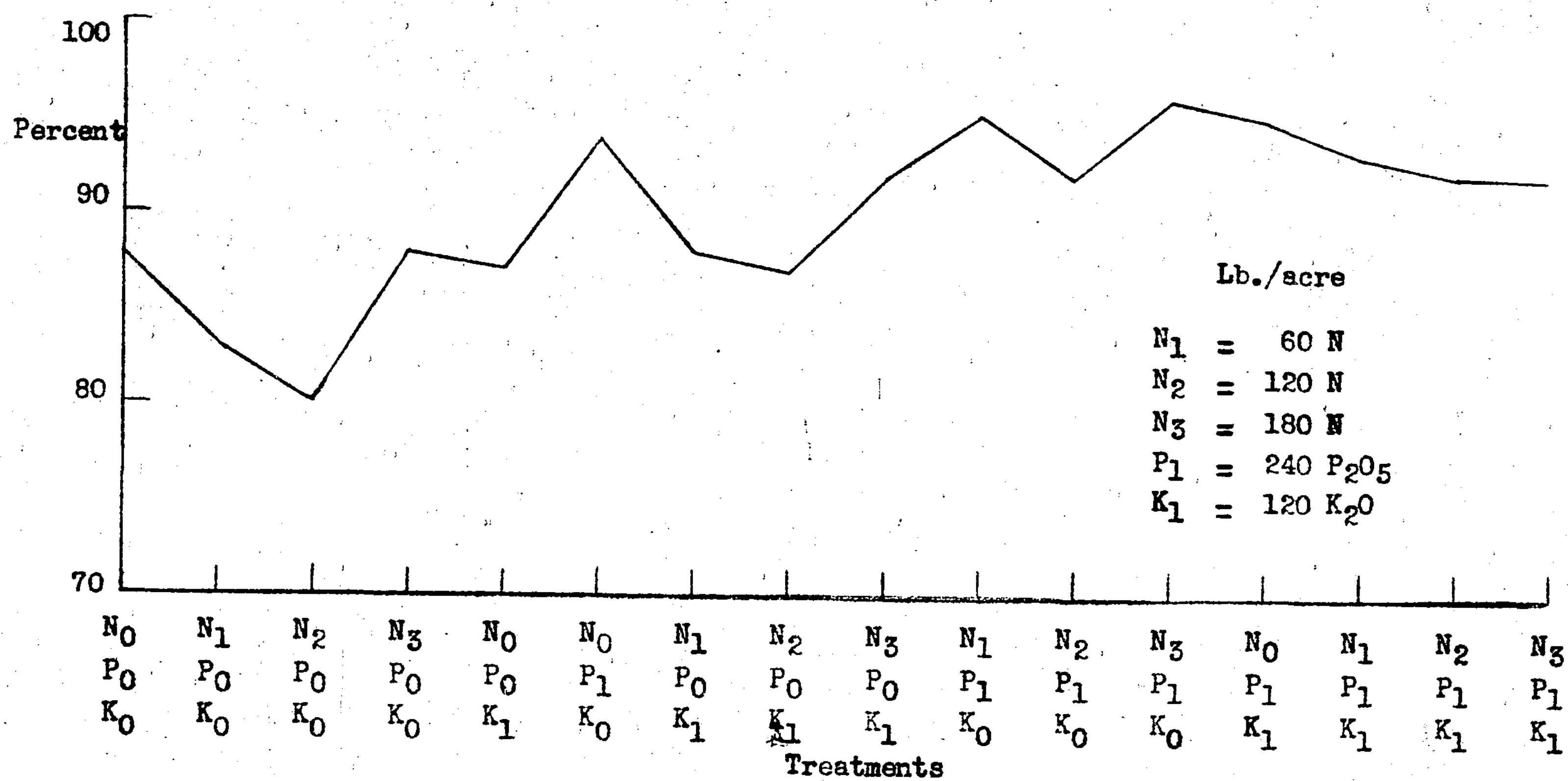


Fig. 13.- Effect of treatment on the percent brown leaves September 10 of a dwarf grain sorghum.

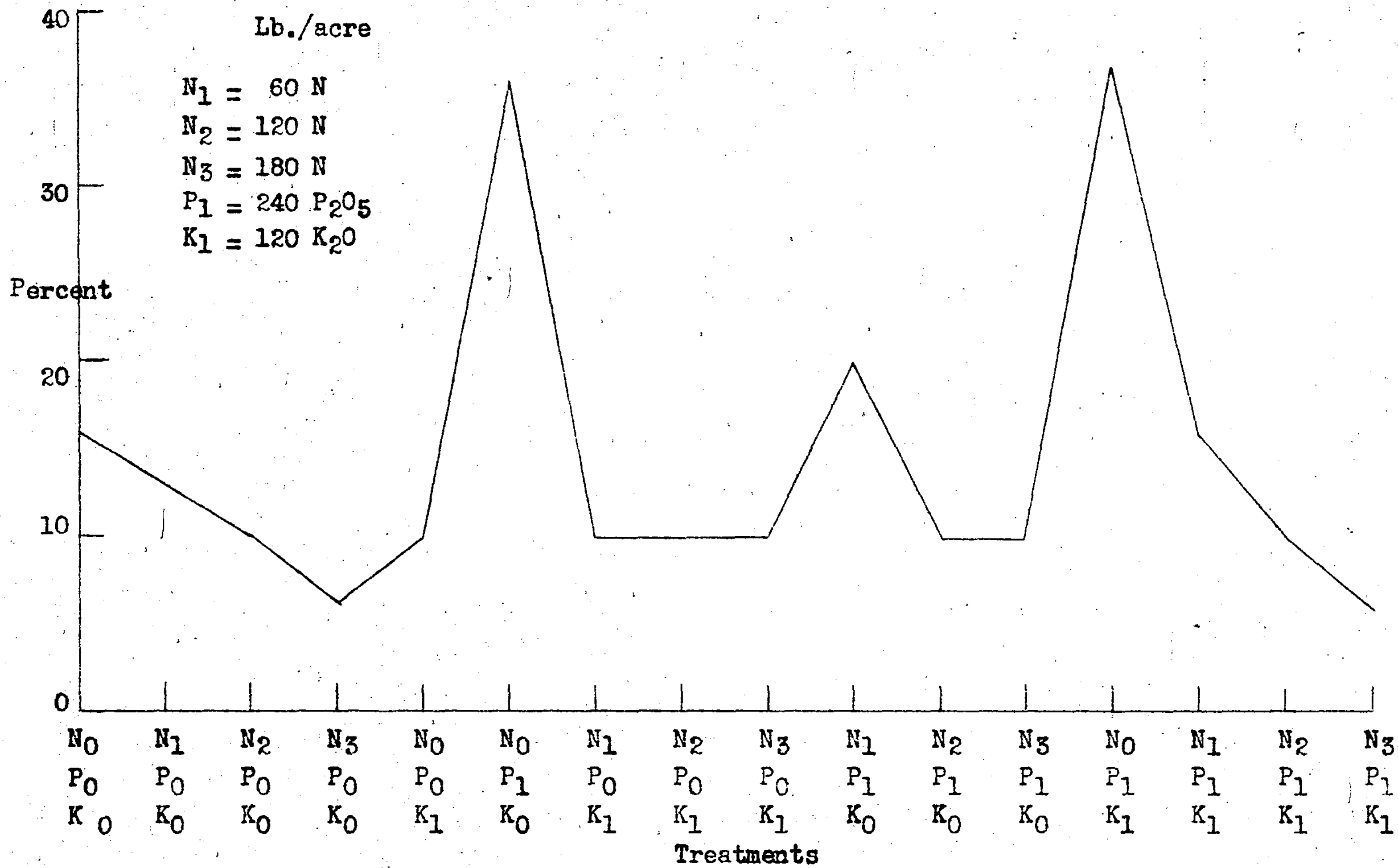


Fig. 14.- Effect of treatment on the number of diseased plants per 30 foot row of a dwarf grain sorghum.

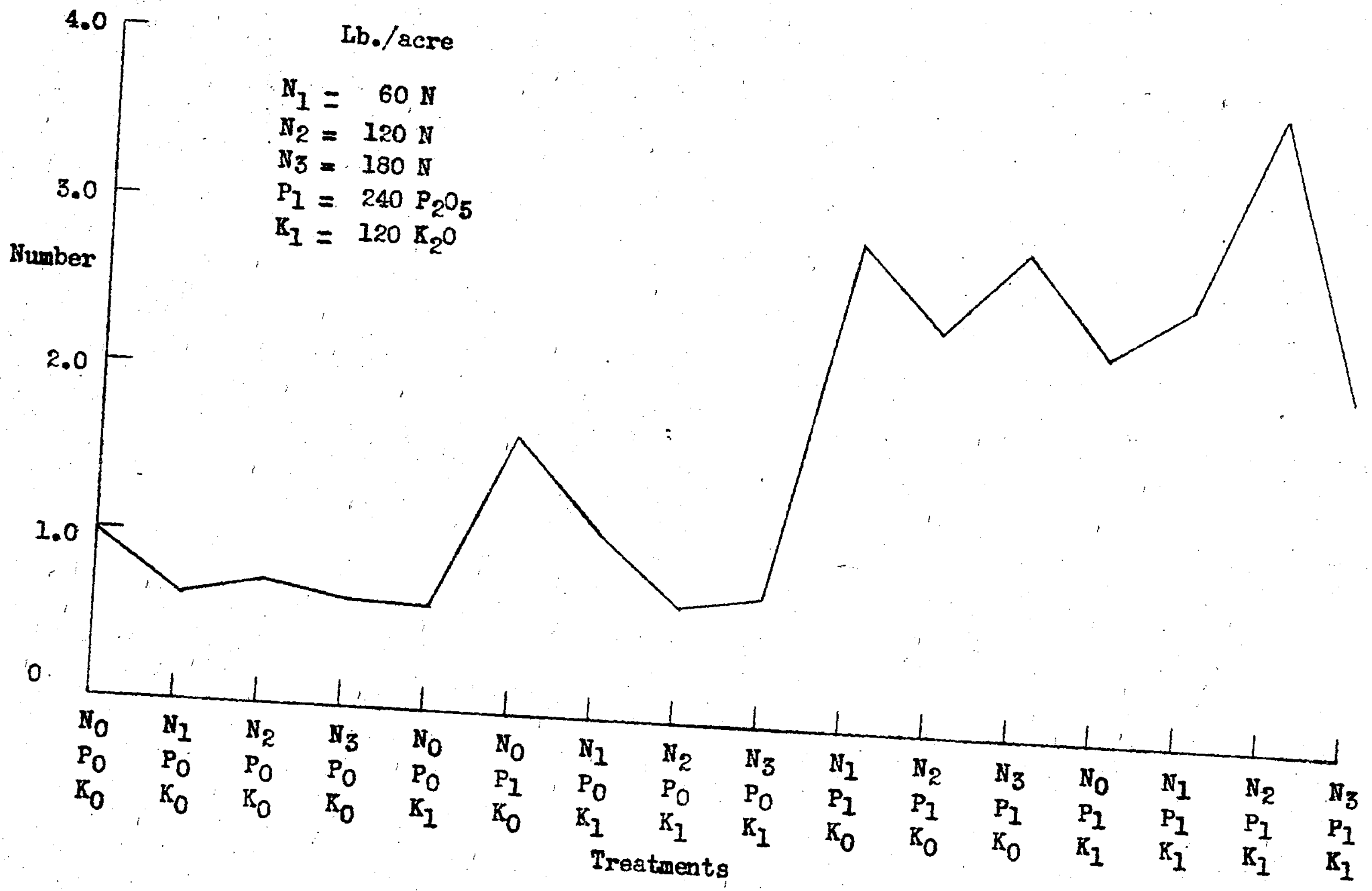


Fig. 15.- Effect of treatment on the yield per acre of a dwarf grain sorghum.

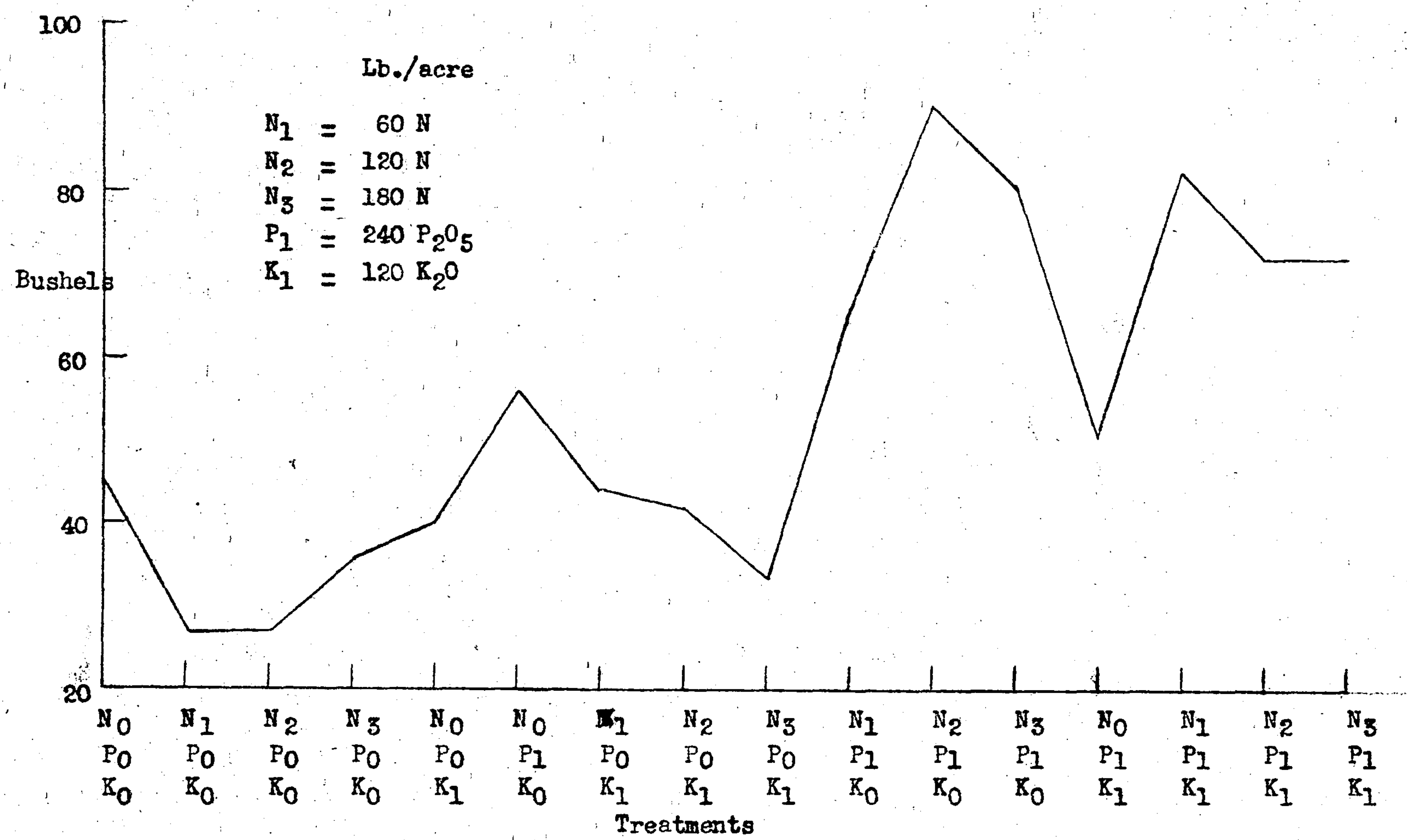


Fig. 16.- Effect of treatment on the percent of nitrogen in the seed of a dwarf grain sorghum.

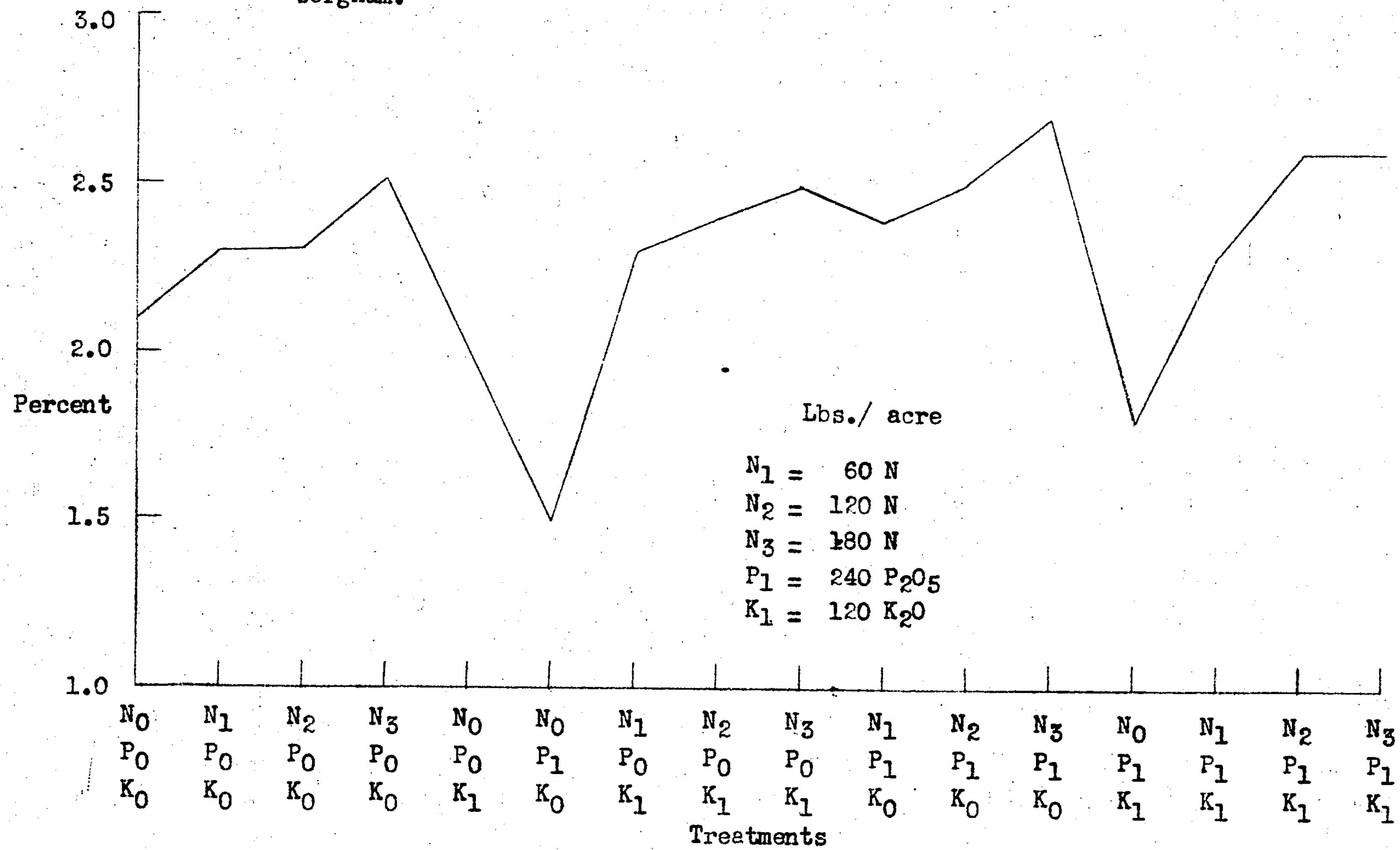


Fig. 17.- Effect of treatment on the percent of P_2O_5 in the seed of a dwarf grain sorghum.

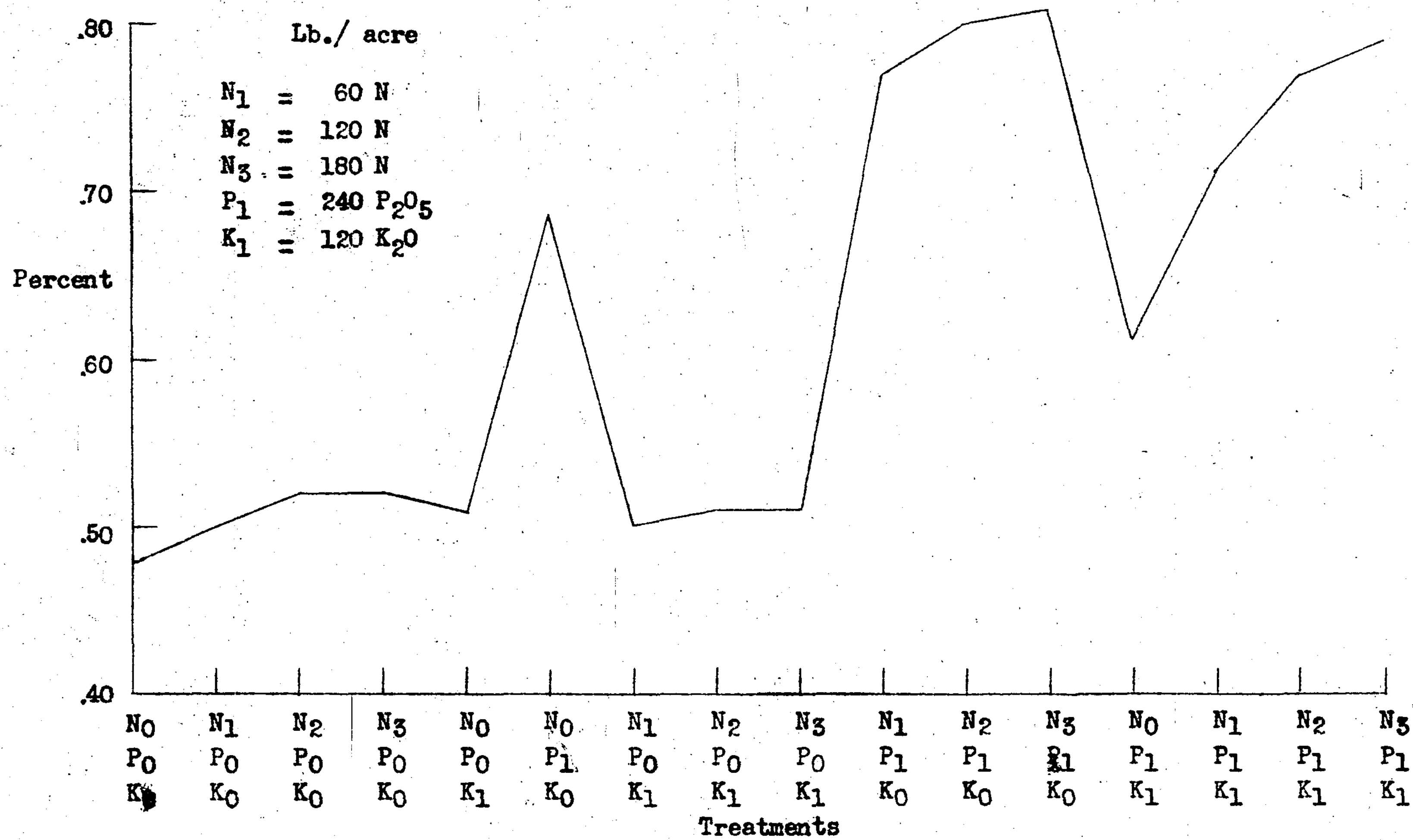


Fig. 18.- Effect of treatment on the percent of K_2O in the seed of a dwarf grain sorghum.

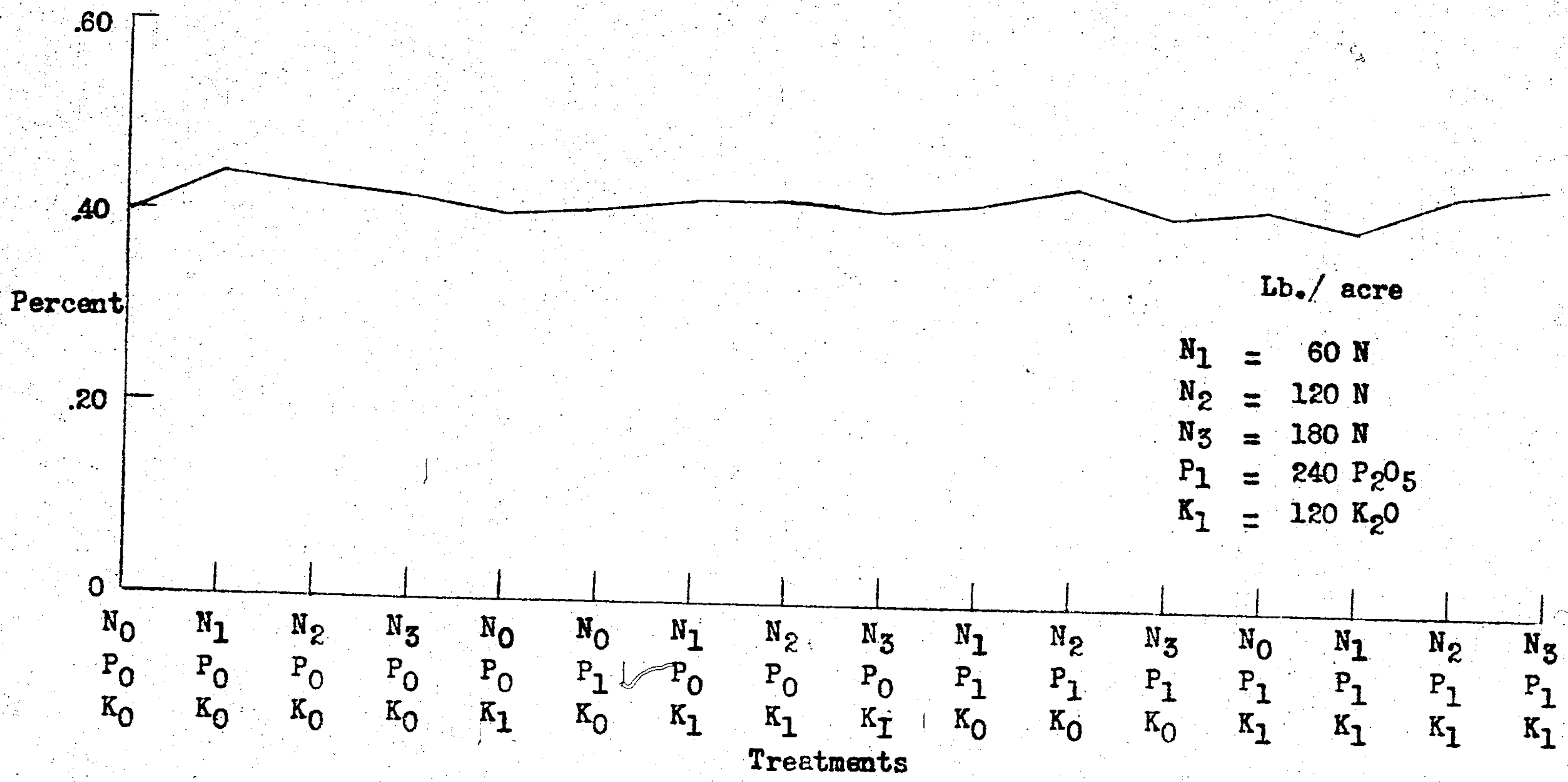


Fig. 19.- Effect of treatment on the amount of black, green, and yellow in the foliage on August 5 of a dwarf grain sorghum.

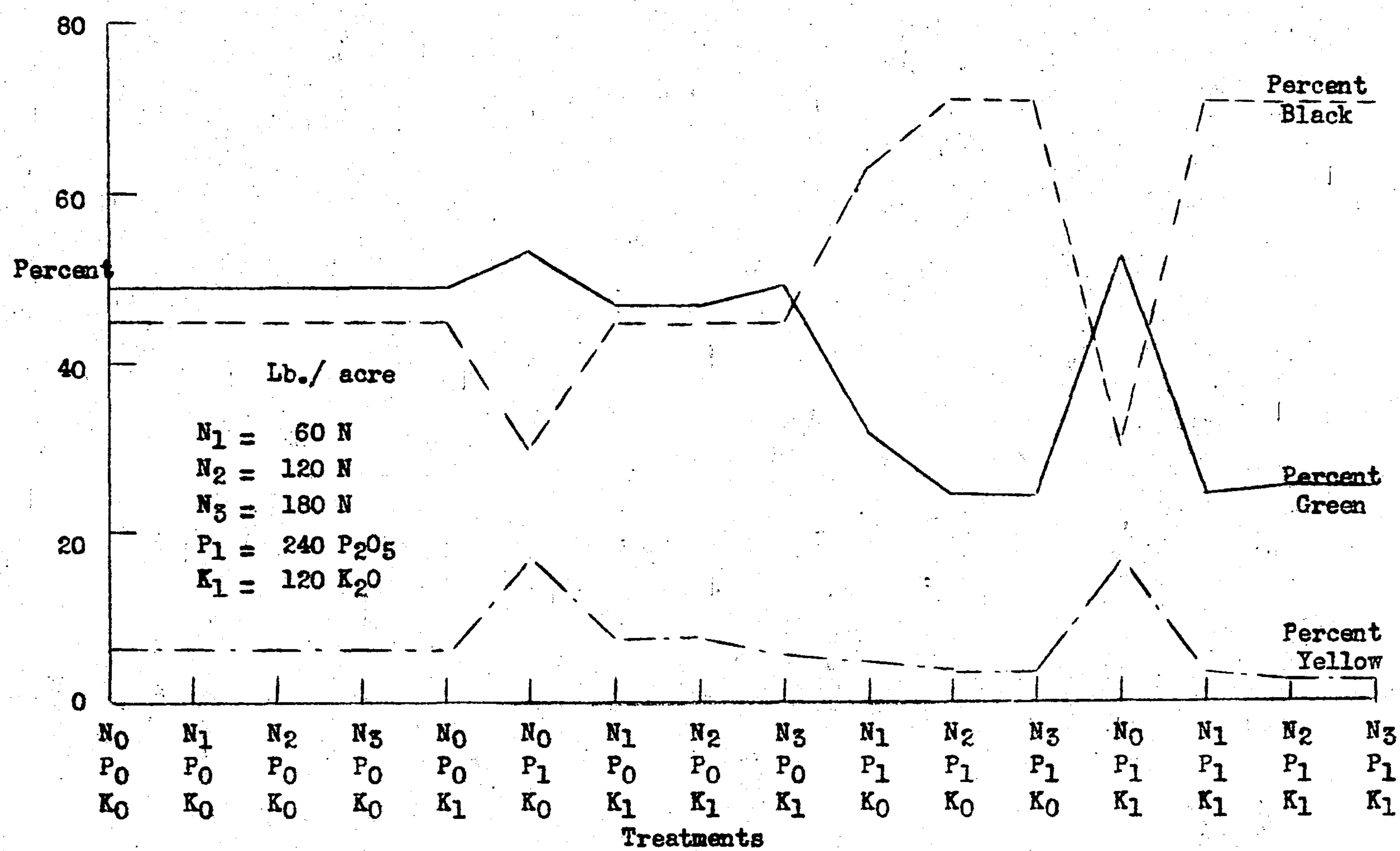
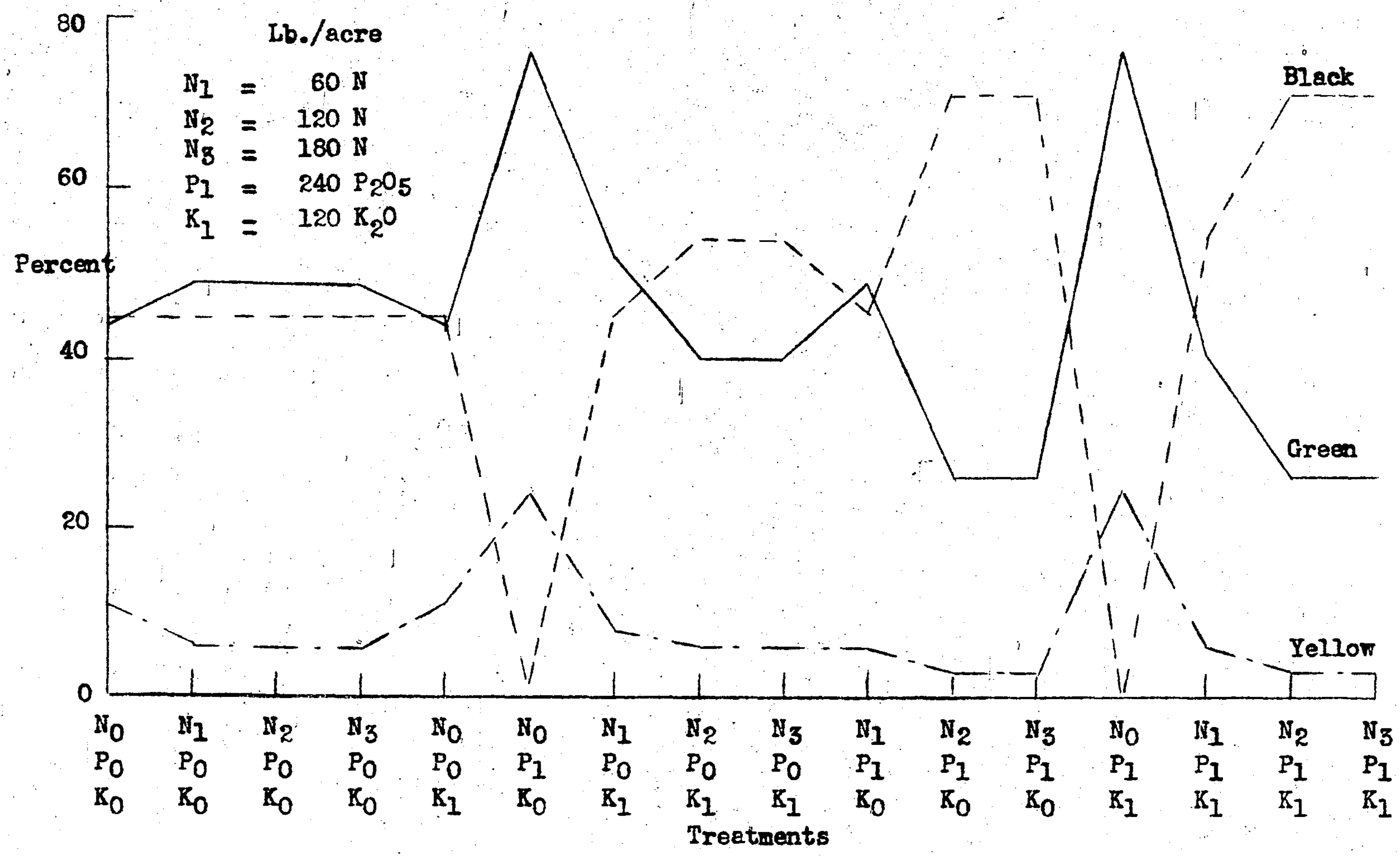


Fig. 20.- Effect of treatment on the amount of black, green, and yellow in the foliage on September 1 of a dwarf grain sorghum.



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