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STUDIES ON THE BITING TASTE OF THE BURLEY TOBACCO LEAVES (NUTRITIONAL PHYSIOLOGY OF JAPANESE TOBACCO)

II EFFECT OF THE SOIL AND FERTILIZATION ON THE FORMATION OF THE BITING TASTE WITH SPECIAL REFERENCE TO PHOSPHATE

By

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Introduction

The authors have reported (5) that the biting taste of burley tobacco leaves are closely concerned with the metabolism of nitrogen and carbohydrate in the plant, that is, the smoking taste of tobacco leaves are severely bitter when the content of soluble carbohydrate is low as compared with that of nitrogenous compound, and on the contrary, the reverse condition produces neutralization of the biting taste. This physiological metabolism concerning nitrogen and carbohydrate has close relationship with the maturity of the plant controled by the date of the transplanting and even though the date of the transplanting was almost the same, the differences of the soil and fertilizer application have remakable effects on the maturity of the plants.

Therefore precise culture experiments were undertaken concerning the difference of soil types and fertilizer practice. The researches on this problem are quite few and the results by Shedd O. M. (1) and Moseley J. M. *et al* (7) upon the effect of nitrogen and mineral constituents on the quality of the tobacco leaves in Kentucky or Richmond, is worthy of attention.

Materials and Methods

Cultivation method

The seedlings of burley tobacco were transplanted on May 28, 1951 and carefully raised in the 1/12500 acre Wagner's pot. Then since July 30, according to its maturity the tobacco plants were harvested. After the harvested plants were killed by heating at 70°C for 30 minutes, they were dried at 40–50°C and pulverized for the investigations.

As to the soils for the cultivation, three kinds of soils having different amounts of available phosphorus were selected. As shown in the previous reports, phosphorus seems to have an excellent effect on the maturity, and the quality of the burley tobacco leaves.

Soils applied for cultivation

(1) Kawatabi soil (abb. Ka-soil)

Volcanic ash soil, a kind of ando-soil, strongly allitic, highly defficient in available phosphorus, pH 5.5, silica alumina ratio 1.6

(2) Mukaiyama soil (abb. Mu-soil)

Tertiary origin, allitic soil, poor in available phosphorus, pH 5.4, silica alumina ratio 2.6

(3) Minamikoizumi soil (abb. Mi-soil)

Alluvial siallitic soil, rich in available phosphorus, pH 6.0, silica alumina ratio 3.4

Fertilizer practice

As the nitrogenous fertilizer, ammonium sulphate, sodium nitrate and urea were chosen. The amount of nitrogen, phosphate and potash supplied to the culture pots was 0.7 g each. 0.3 g of nitrogen was given as the basic application and 0.4 g was supplied as the top dressing, namely each 0.2 g was given at one and two weeks after the transplanting.

Experimental plots

Several kinds of plots were made for the basis of experiments, as follows. The plots without nitrogen but supplied with phosphate and potash (abb. OPK), the plots without phosphate but with three kinds of nitrogen and potash (abb. NOK), and the plots without potash but with nitrogen and phosphate (abb. NPO) were established for Ka, Mu and Mi-soil. For Mi-soil, no fertilizer plots (abb. OOO), the plots with three times of normal nitrogen supply but with normal amounts of phosphate and potash (abb. 3NPK), three times of normal phosphate supply (abb. N3PK) and three times of normal potash supply (abb. NP3K) were made. N_{NH_4}, N_{NO_3} and N_{urea} each indicates ammonnium sulphate, sodium nitrate and urea.

Plant growth

Generaly considered, the plant growth, judged from the standpoint of tested soil, was observed most vigorously in Mi-soil, next in Ka-soil and its growth was most inferior in Mu-soil. The plants matured earliest in Mi-soil and in the Ka-soil the tobacco plants remained still immature at the end of the harvest period.

Nitrate nitrogen was most excellent for the growth of the burley tobacco, next came urea, and ammonia nitrogen was most inferior. Especially (3NPK) of nitrate nitrogen made vigorous growth and brought a heavy harvest but the plants remained rather immature at the time of the harvest owing to the excess of nitrogen as compared with the stored carbohydrate. The heavy application of phosphate enables better growth and early maturity in each of the plots.

The yields are shown in Tables 1 and 2. For Mi-soil the omittion of potash

Table 1. Yield (g per dry plant)
Minamikoizumi (alluvial soil)

	Granulators	Cutters	Red leaf	Tips	Sum
OPK	1.15	2.65	2.13		5.93
$N_{NH_4}OK$	1.08	6.90	4.98	3.35	16.35
$N_{NO_3}OK$	1.57	7.08	6.00	3.38	18.03
$N_{urea}OK$	1.58	5.88	5.35	3.33	16.14
$N_{NH_4}OK$	1.60	5.59	5.34	3.30	15.83
$N_{NO_3}PO$	1.52	6.77	6.00	3.05	17.34
$N_{urea}PO$	0.87	6.15	5.62	2.75	15.39
$N_{NH_4}PK$	1.35	6.88	5.43	3.10	16.76
$N_{NO_3}PK$	1.32	7.88	4.15	3.83	17.18
$N_{urea}PK$	1.30	6.22	5.07	4.00	16.59
OOO	0.65	2.17	1.17	0.75	4.74
$3N_{NH_4}PK$	1.62	6.48	7.30	3.45	18.85
$3N_{NO_3}PK$	2.00	9.49	11.73	3.68	26.90
$3N_{urea}PK$	1.10	7.23	10.95	3.28	22.56
$N_{NH_4}3PK$	1.33	6.85	5.53	2.90	16.61
$N_{NO_3}3PK$	0.98	8.42	4.03	2.83	16.26
$N_{urer}3PK$	1.90	7.23	4.10	3.50	16.73
$N_{NH_4}P3K$	2.00	5.35	5.60	3.95	16.90
$N_{NO_3}P3K$	2.77	7.60	5.10	3.45	18.92
$N_{urea}P3K$	2.15	6.65	6.18	4.03	19.01

Table 2. Yield (g per dry plant)
Mukaiyama (tertiary soil)

	Granulators	Cutters	Red leab	Tips	Sum
OPK	0.45	0.97	0.43		1.85
$N_{NH_4}OK$	0.78	3.95	3.75	4.10	12.58
$N_{NO_3}OK$	1.40	2.95	3.60	2.78	10.73
$N_{urea}OK$	1.53	3.95	4.50	2.90	12.88
$N_{NH_4}PO$	0.89	3.48	2.98	0.85	8.20
$N_{NO_3}PO$	1.44	3.72	2.67	2.55	10.38
$N_{urea}PO$	1.45	3.27	2.10	2.87	9.69
$N_{NH_4}PK$	0.88	4.71	3.47	2.65	11.71
$N_{NO_3}PK$	0.90	7.70	3.05	3.65	15.30
$N_{urea}PK$	0.82	3.33	4.30	3.50	11.95
Kawatabi (volcanic ash soil)					
OPK	0.83	5.00	3.38		9.21
$N_{NH_4}OK$	0.60	6.55	5.65	4.15	16.95
$N_{NO_3}OK$	2.59	6.43	4.65	2.48	16.15
$N_{urea}OK$	1.10	4.53	6.87	2.78	15.28
$N_{NH_4}PO$	1.83	5.40	4.67	2.25	14.15
$N_{NO_3}PO$	2.85	6.20	5.50	2.08	16.63
$N_{urea}PO$	1.40	3.58	5.45	1.87	12.30
$N_{NH_4}PK$	1.67	5.77	6.90	2.40	16.74
$N_{NO_3}PK$	2.47	6.67	5.53	2.15	16.82
$N_{urea}PK$	2.68	4.33	4.53	1.98	13.52

and phosphate bought almost no significant decreases in the yield as expected.

As to Ka-soil, the authors expected a severe decrease by the omittion of phosphate, but the obtained result was not so clear. For the Mu-soil, the phenomenon of potash defficiency was also slightly observed.

Analytical method

The methods were the same as in the previous report (5). Only soluble sugar was estimated by the colorimetry method after the precipitate caused by the addition of neutral lead acetate to the extracted solution from the samples was filtered off. Extra lead was removed by the addition of sodium carbonate and hydrolysed by sulphuric acid.

Results and Discussion

Total nitrogen

As stated in the previous report, the content of total nitrogen has the most important effect on the quality. The content of total nitrogen, as shown in Tables 3 and 4, is highest in the tips and decreases in accord with our previous report as has been verified by Hasegawa (2) and many other investigators.

Comparing the soils, alluvial Mi-soil produced tobacco leaves with the lowest nitrogen content, and leaves from ando Ka-soil and tertiary Mu-soil were high in nitrogen content. This shows that in Mi-soil the yields were high, and in the other two soils the amount of leaves produced were low; also the differences of maturity between these plants had remarkable effect on the content of total nitrogen.

Table 3. Total nitrogen (% on dry basis)
Minamikoizumi (alluvial soil)

	Granulators	Cutters	Red leaf	Tips	Average
OPK					1.83
N_{NH_4}OK	1.42	2.21	2.76	3.74	2.57
N_{NO_3}OK	1.87	2.14	2.17	3.52	2.39
N_{urea}OK	1.60	2.13	2.21	3.12	2.33
N_{NH_4}PO	1.61	2.26	2.44	3.42	2.50
N_{NO_3}PO	1.49	2.06	2.26	3.67	2.38
N_{urea}PO	1.84	2.12	2.29	3.12	2.38
N_{NH_4}PK	1.68	1.87	2.33	2.93	2.21
N_{NO_3}PK	1.56	1.80	2.25	2.89	2.16
N_{urea}PK	1.63	1.83	2.23	2.87	2.18
OOO					1.76
3N_{NH_4}PK	3.37	5.26	5.05	4.51	4.89
3N_{NO_3}PK	2.45	3.48	3.82	4.21	3.67
3N_{urea}PK	3.43	4.85	4.20	4.45	4.42
N_{NH_4}3PK	1.95	1.91	2.56	2.67	2.24
N_{NO_3}3PK	1.65	1.86	2.37	2.76	2.09
N_{urea}3PK	1.86	1.90	2.56	2.73	2.24
N_{NH_4}P3K	1.81	1.95	2.36	2.87	2.22
N_{NO_3}P3K	1.67	1.67	2.32	2.69	2.03
N_{urea}P3K	1.74	1.80	2.30	2.54	2.11

Table 4. Total nitrogen (% on dry basis)

Mukaiyama (tertiary soil)

	Granulators	Cutters	Red leaf	Tips	Average
OPK					2.04
N_{NH_4}OK	1.93	2.32	2.87	3.28	2.77
N_{NO_3}OK	2.61	2.42	2.55	3.01	2.64
N_{urea}OK	1.96	2.12	2.66	3.31	2.56
N_{NH_4}PO	2.28	2.54	2.93	3.40	2.74
N_{NO_3}PO	2.29	2.48	2.96	3.23	3.12
N_{urea}PO	2.28	2.39	2.73	3.36	2.73
N_{NH_4}PK	1.85	2.61	2.58	3.32	2.70
N_{NO_3}PK	1.97	2.33	2.44	2.78	2.44
N_{urea}PK	1.67	2.14	2.62	2.63	2.42
Kawatabi (volcanic ash soil)					
OPK					2.14
N_{NH_4}OK	2.09	2.27	2.33	3.03	2.46
N_{NO_3}OK	1.76	2.43	2.62	3.75	2.57
N_{urea}OK	1.94	2.25	2.63	3.46	2.63
N_{NH_4}PO	1.54	2.34	2.66	3.16	2.47
N_{NO_3}PO	1.92	2.19	2.75	3.49	2.43
N_{urea}PO	1.91	2.62	3.13	3.78	2.94
N_{NH_4}PK	1.91	2.21	2.64	3.10	2.49
N_{NO_3}PK	1.56	2.30	2.79	3.05	2.41
N_{urea}PK	1.64	2.17	2.39	2.80	2.23

Considering the nitrogenous sources, the content of total nitrogen was least in the nitrate plot, next came the urea plot, and was highest in the ammonia plot. These results depend partly upon the yield of each plot. As to the relation between the totol nitrogen content of the leaves and the amount of nitrogen applied, the heavy dressings of nitrogen causes an increase of total nittrogen content in the leaves, and this result is conspicuous especially in the ammonia plot. So it may be concluded that the inferiority in the quality caused by the heavy application of nitrogen is lowest when nitrate was used as the nitrogenous source.

The effect of phosphate application seems to depress the nitrogen content in eveay case, and the results were clear in the tips especially by the heavy application as three times of phosphate. The action of the addition of potash was almost similar. It seems that the heavy application of phosphate and potash brought the stimulation of the leaf development in the early stage of growth, hence the absorption of nitrogen was accelerated and matured earlier than in the other plots. Sommers A. L. (4) has observed a similar phenomenon.

Soluble sugars

As the general tendency, content of soluble sugar is higher in the higher situated leaves, as shown in Tables 5 and 6, which is in agree with the results of Evans H. J. (6). The relation between the soluble sugar content and the forms of nitrogen applied have no distinct tendency, but in Mi-soil the heavier application of ammonia nitrogen causes a increase in the sugar content and on the contrary heavier application of nitrate nitrogen decreased the sugar content. The supply of phosphate always resulted in an increase of the total sugar content, as reported by Komatsu (3).

Table 5. Soluble sugar (% on dry basis)
Minamikoizumi (alluvial soil)

	Granulators	Cutters	Red leaf	Tips	Average
OPK					2.74
$N_{NH_4}OK$	1.78	2.28	2.68	2.91	2.35
$N_{NO_3}OK$	1.88	2.38	2.84	3.24	2.61
$N_{urea}OK$	1.75	2.55	2.70	3.09	2.63
$N_{NH_3}PO$	2.04	2.51	2.80	3.43	2.72
$N_{NO_3}PO$	1.90	2.63	2.68	3.43	2.68
$N_{urea}PO$	2.17	2.54	2.81	2.85	2.67
$N_{NH_4}PK$	2.14	2.43	2.65	3.00	2.58
$N_{NO_3}PK$	2.46	2.56	2.96	3.13	2.77
$N_{urea}PK$	2.38	2.59	2.63	3.20	2.81
OOO					2.85
$3N_{NH_4}PK$	2.42	2.74	3.05	3.56	2.97
$3N_{NO_3}PK$	2.37	2.67	2.89	3.08	2.68
$3N_{urea}PK$	2.48	2.40	3.23	3.56	2.97
$N_{NH_4}3PK$	2.00	2.78	2.77	3.67	2.86
$N_{NO_3}3PK$	2.54	2.70	2.93	3.27	2.80
$N_{urea}3PK$	2.43	2.85	2.83	3.08	2.81
$N_{NH_4}P3K$	2.39	2.83	2.84	3.26	2.90
$N_{NO_3}P3K$	2.44	2.52	2.83	3.65	2.80
$N_{urea}P3K$	2.25	2.65	2.86	3.40	2.83

Table 6. Soluble sugar (% on dry basis)
Mukaiyama (tertiary soil)

	Granulators	Cutters	Red leaf	Tips	Average
OPK					2.25
$N_{NH_4}OK$	2.00	2.12	2.92	3.50	2.81
$N_{NO_3}OK$	1.90	2.13	2.43	3.25	2.49
$N_{urea}OK$	1.05	2.00	2.85	3.23	2.46
$N_{NH_4}PO$	1.77	2.26	2.94	3.43	2.71
$N_{NO_3}PO$	1.77	2.29	2.97	3.20	2.62
$N_{urea}PO$	2.20	2.23	2.95	3.20	2.63
$N_{NH_4}PK$	1.78	2.13	3.03	3.53	2.70
$N_{NO_3}PK$	1.70	2.20	3.07	3.73	2.67
$N_{urea}PK$	1.67	2.30	3.10	3.83	3.00
Kawatabi (volcanic ash soil)					
OPK					2.80
$N_{NH_4}OK$	2.10	2.49	3.08	3.60	2.94
$N_{NO_3}OK$	2.15	2.61	2.90	3.40	2.74
$N_{urea}OK$	2.28	2.66	3.00	3.70	2.98
$N_{NH_4}PO$	2.30	2.63	3.62	3.40	3.04
$N_{NO_3}PO$	2.40	2.75	3.50	4.00	3.08
$N_{urea}PO$	2.51	2.65	3.00	3.42	2.91
$N_{NH_4}PK$	2.51	2.73	3.43	3.93	3.12
$N_{NO_3}PK$	2.63	2.79	3.42	3.72	3.10
$N_{urea}PK$	2.68	2.71	3.59	3.94	3.18

It is very interesting that the heavy application of phosphate has not so significant an increase in the total carbohydrate content of the leaves cultivated in the nitrate or urea plot, but in the ammonium plot a significant increase in the soluble sugars content was observed. This result indicate that the cheaper nitrogenous source as ammonium salts in Japan may be applied economically by the addition of phosphate.

Potash applidation has a similar effect of increasing the sugar content. Heavy application of potash could increase the sugar content even in the ammonia plot, similar as phosphate application.

Ratio of soluble sugars to total nitrogen

In the previous report, the authors proposed that the ratio of soluble sugars to total nitrogen is an excellent scale for indicating the quality of the burley tobacco leaves. In this experiments this ratio was calculated and is shown in Tables 7 and 8.

These ratio in the red leaves are generally wider, indicating the better quality of these leaves. Considering soils, ando soil provided a wide ratio and the tertiary soil produced a narrow ratio. This ratio seems to be highest in the nitrate plot and lowest in the ammonia plot, and heavier application of nitrogen, of course, decreased this ratio. The decrease in the ratio is clearly observed in the ammonia and urea plots as expected.

The application of phosphate promoted this ratio, hence indicated that phosphate application enables the improvement of the quality of the leaves. Also the application of potash has a similar effect, and especially this effect is conspicuous in the heavy application of potash. This desirable effect of application of phosphate and potash is clearly shown in the tips and the red leaves. In Japan the tips are neglected owing to their inferiority, but the

Table 7. Soluble sugar/Total nitrogen

	Granuiators	Cutters	Red leaf	Tips	Average
OPK					1.52
N_{NH_4}OK	1.25	1.03	0.97	0.78	0.91
N_{NO_3}OK	1.00	1.09	1.31	0.92	1.09
N_{urea}OK	1.09	1.21	1.24	0.99	1.13
N_{NH_4}PO	1.22	1.11	1.15	1.00	1.09
N_{NO_3}PO	1.27	1.27	1.19	0.94	1.15
N_{urea}PO	1.18	1.20	1.24	0.92	1.14
N_{NH_4}PK	1.28	1.30	1.13	1.02	1.17
N_{NO_3}PK	1.65	1.42	1.33	1.08	1.28
N_{urea}PK	1.45	1.43	1.17	1.11	1.29
OOO					1.62
3N_{NH_4}PK	0.72	0.52	0.61	0.78	0.61
3N_{NO_3}PK	0.97	0.77	0.76	0.74	0.79
3N_{urea}PK	0.72	0.50	0.77	0.80	0.67
N_{NH_3}3PK	1.05	1.46	1.08	1.37	1.28
N_{NO_3}3PK	1.55	1.45	1.23	1.18	1.34
N_{urea}3PK	1.30	1.50	1.10	1.16	1.26
N_{NH_4}P3K	1.38	1.42	1.20	1.14	1.31
N_{NO_3}P3K	1.46	1.52	1.21	1.35	1.36
N_{urea}P3K	1.29	1.47	1.24	1.34	1.34

Table 8. Soluble sugar/Total nitrogen
Mukaiyama (tertiary soil)

	Granulators	Cutters	Red leaf	Tips	Average
OPK					1.11
N_{NH_4}OK	1.04	0.92	1.02	1.06	1.02
N_{NO_3}OK	1.07	0.87	0.97	1.08	0.94
N_{urea}OK	0.84	0.95	1.07	0.98	0.96
N_{NH_4}PO	0.78	0.89	1.00	1.01	0.99
N_{NO_3}PO	0.78	0.93	1.00	1.00	0.84
N_{urea}PO	0.96	0.94	1.08	0.90	0.96
N_{NH_4}PK	0.96	0.82	1.17	1.06	1.00
N_{NO_6}PK	0.86	0.95	1.26	1.27	1.10
N_{urea}PK	1.00	1.07	1.21	1.43	1.24
Kawatabi (volcanic ash soil)					
OPK					1.31
N_{NH_4}OK	1.00	1.09	1.38	1.18	1.20
N_{NO_3}OK	1.22	1.07	1.12	0.92	1.16
N_{urea}OK	1.17	1.18	1.14	1.08	1.13
N_{NH_4}PO	1.49	1.12	1.17	1.08	1.23
N_{NO_3}PO	1.25	1.25	1.27	1.14	1·25
N_{urea}PO	1.31	1.05	1.00	0.90	0.99
N_{NH_4}PK	1.31	1.24	1.30	1.26	1.25
N_{NO_3}PK	1.68	1.21	1.24	1.22	1.29
N_{urea}PK	1.62	1.25	1.50	1.37	1.42

improvement by the addition of heavy phosphate and potash supply seems to be available for practical tobacco growing. The classes of the quality determined by the smoking test well agreed with this ratio of soluble sugar to total nitrogen and the decrease of this ratio always accompanied the biting taste.

By the soil cultivation tests, the authors could confirm in the northestern part of Japan having cooler climate, that the soil is short in supply of available phosphate and potash. The heavier application of phosphate and potash stimulate the growth of the early stage, and quickens the change from the vegetable growth to the reproductive growth, hence the accumulation of carbohydrate was accelerated as compared with that of nitrogen, which enables a harvest of higher qualities.

Generally speaking in Japan, the leaves are picked away from the granulators to the tips during considerable intervals, so the improving effect is especially clear in the tips. The authors recommend a heavier application of phosphate and potash in the cooler parts of Japan.

Summary

1. In the previous report, the quality of the burley tobacco leaves including the biting taste was reported in relation to their chemical composition. The present paper deals with the quality in relation to the soil and fertilizer practice. Precise pot cultivation methods were carried out and the crops were

fully investigated.

2. As the models of the soils of the burley growing region in the northeastern cooler part of Japan, three representative soils, namely, volcanic ash ando soil, tertiary and alluvial soils were chosen for the culture medium. Nitrogeous sources, as ammonium sulphate, sodium nitrate and urea were supplied in combination with various amount of phosphate and potash.

3. Tobacco leaves raised in the alluvial soil were excellent in their growth, yield and quality, being especially low in biting taste. The tobacco plant cultivated in the ando soil matured late probably owing to the lack of available phosphorus, and the crops produced in the tertiary soil were far inferior in their yield and gave a strong biting taste.

4. As the nitrogenous sources, the nitrate of soda was best, next came urea and sulphate of ammonia was most inferior.

5. The application of phosphate and potash highly improved the growth, the maturity and increased the ratio of the soluble sugar to the total nitrogen which brought a decrease of the biting taste remarkably. Special attentions were directed to the improvement of the tips which were neglected so far.

6. The application of a higher amount of nitrogen gave a heavy yield with inferior quality, or diminished soluble sugar and increased the content of total nitrogen hence the biting taste appeared severely.

7. The heavier supply of nitrogen brought a delay of the maturing, and so retarded the accumulation of sugar and other carbohydrates. The cultivation method to accelarate the changes from the vegetative growth to the reproductive growth should be considered, to obtain burley tobacco leaves with higher quality.

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