Effects of Chlorine on Growth and Quality of Tobacco

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A common sense in growing tobacco is to avoid the use of chlorine-containing fertilizers as far as possible, because of their adverse effects on tobacco quality However, tobacco growing with a premise of uptake of some amount of chlorine has to be considered in recent years, due to the application of composts, farmyard manures[1,2,3,4], various kinds of chemical fertilizers[5,6], soil disinfectants[5,7], and residue of fertilizers applied to preceeding crops[8]. A so-called mulch-cultivation, in which soil surface is covered by polyethylene films, has come to be used widely in Japan, and it is not neglected that the method causes environmental changes which tend to prevent the leaching of chlorine in soils. In view of these facts, the problem of effects of chlorine on growth and quality has been re-examined. Results of the recent studies will be presented in this paper together with the past research results.

Growth of tobacco and chlorine

It is since the study of Broyer et al.[11] that chlorine has come to be regarded generally as an essential micro-nutrient element for tobacco. Since then, physiological functions of chlorine in (1) the process of oxygen evolution from water in photosynthesis, (2) activating amylase, and (3) regulating pH of cell sap have been proposed.

Moss reported that the absorption of small amount of chlorine was favorable to tobacco plants, giving an yield increase by the application at the rate of 2.2–2.8 kg of Cl/10a. Many studies carried out later also made clear that small amount of chlorine is effective in increasing tobacco yields.

However, it has been reported at the same time that the excessive application of chlorine causes some definite damages. In our pot soil culture experiment in greenhouse, the application of ferrous chloride at the rate of 7.6 g of Cl/plant caused chlorine content of lower leaves reaching 15% at the maximum. In this case the early growth was retarded, lower leaves were light green in color, and leaf margin curled upwards, a typical symptom of damage by excessive chlorine (chlorine toxicity). That the iron supplied in the form of ferrous chloride was not absorbed at all indicates that tobacco plants absorb selectively chlorine alone when their roots are healthy. With a solution-culture experiment in greenhouse, Honda et al.[5] showed that chlorine toxicity occurred at 3.6–5.6% of chlorine content of plants. Takahashi et al.[5,16,17] recognized that the occurrence of chlorine toxicity is not only related to chlorine concentration but also influenced by the form of nitrogen; no occurrence when only NO_3-N is applied, whereas apt to occur at the presence of NH_4-N.

As to the distribution in plant of absorbed chlorine, more distribution is found in stems when absorbed in small quantity; but with the increase of absorbed chlorine, distribution in leaves increases. Distribution to roots is always less than that of stems and leaves. Chlorine application at an early stage of growth results in high chlorine content of lower leaves, while the application at the later stage gives high content of upper leaves. This

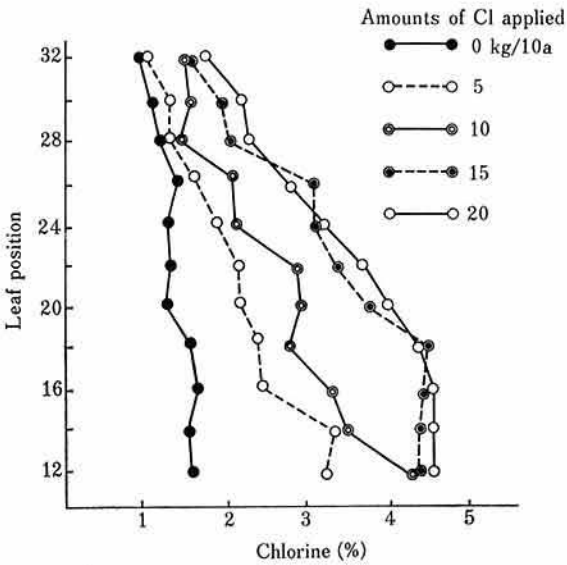

Fig. 1. Chlorine contents by leaf position

is the result of solution-culture experiments in greenhouse, but the result obtained in fields with varying rates of application of chlorine is shown in Fig. 1 and Table 2. The variety used was Shiro-enshu, a representative domestic variety in Japan, and was grown on humic volcanic ash soil in the Utsunomiya Tobacco Experiment Station with fertilizers (12 kg N, 24 kg P_2O_5 and 28 kg K_2O/10a). Chlorine was applied in the form of NaCl as basal dressing.

Table 1 shows amounts of chlorine absorbed per plant and per 10a. Even without chlorine application, 6 kg of chlorine were absorbed by plants per 10a. Of which, about 0.5 kg came from compost, 4 kg from fertilizers and about 2 kg from chlorine existed in the soil. With the increase of chlorine application, amount absorbed increases, but the rate of utilization decreases. When absorbed in small quantity, chlorine is distributed to stems, but with the increase of absorption it accumulates in leaves, giving high chlorine content of leaves.

Fig. 1 shows that chlorine content of leaves increases at all leaf position, particularly in lower leaves, with the increased chlorine application, and that more chlorine was absorbed in an early stage of growth. On the other hand, a field survey made recently in tobacco producing areas indicated many cases showing high chlorine content in upper leaves. This may be caused by an extended period for chlorine absorption due to the use of manures which contain chlorine, an extended ripening season of tobacco, and the concentration effect due to the less number of leaves, etc.

In this experiment (Fig. 1), chlorine content of nearly 5% was observed in some leaves, but no toxicity symptom was recognized during the growing season. Although no toxicity symptom was recognized during the growth period or at immediately after leaf-curing, as in this case, changes of outer appearance of cured tobacco leaves are known to occur sometimes during the bulking. What is called Wet dog in the United States of America, occurring after re-drying and packing of hogshead is regarded to be caused by chlorine[18]. The symptom which appears during the bulking is remarkable with flue-cured varieties with bright yellow color of cured leaf: with 4–5% of chlorine content the leaf color changes greyish yellow, and at 7–8% of chlorine content it becomes blackish grey. In case of Japanese domestic varieties (air

Table 1. Amount of chlorine absorbed by tabacco plant

Amount of Cl applied	Amount of Cl absorbed per plant (g/plant)			Amount of Cl absorbed	Absorption ratio
(kg/10a)	Leaf	Stem	Total	(kg/10a)	(%)
0	0.96	1.03	1.99	6.04	—
5	2.11	1.41	3.52	10.65	92.2
10	2.16	1.56	3.72	11.29	52.4
15	2.56	1.92	4.48	13.57	50.1
20	2.84	1.98	4.82	14.59	42.7

cured varieties), the color of dry leaf is brown, sugars and ether-extracts are less, and hygroscopicity is also low, so that no remarkable change in appearance is expressed even when the chlorine content is at about 5% level.

Relation to chemical constituents

It was reported that total nitrogen content decreases in general with the increase of chlorine content[19], but it is not necessarily so with dry leaf of tobacco produced in upland farms of Japan[20,21]. However, it will be added here that chlorine effects nitrogen metabolism causing an increased ratio of soluble-N and aminoacids[22] or decreased ratio of protein-N[23] to the total nitrogen. Most of reports[14,20,24] suggest that total alkaloid content is hardly effected by chlorine.

Positive correlations between chlorine content and sugar content[24,25] or starch content[26] were observed. Honda et al.[27] examined the effect of chlorine on inorganic ions. Among anions, sulfate content was apparently decreased by the increased chlorine supply, whereas phosphate was not effected. Among cations, which increase with the increased chlorine supply, calcium was remarkably increased, but no clear relation was recognized with potassium and magnesium contents. Results of chemical analysis of dry leaf obtained in the above-mentioned our experiment are shown in Table 2. Leaves at the middle position (20–21st leaves) were used. The table indicates that the contents of total carbohydrates, cations, sodium, and phsphate were increased with the increased content of chlorine.

In comparison of lamina to midribs, it was found that midribs contained more chlorine, potassium, and sodium than lamina, while total-N, total alkaloids, phosphate and calcium were contained more in the lamina. In the midribs, an increase of potassium with the increase of chlorine was apparently observed. With flue-cured varieties too[28], chlorine and potassium are accumulated in midribs. It is presumed that chlorine is moved into midribs in the form of potassium chloride during the curing period.

Effects on physical quality of leaves

High content of chlorine causes the lowering of burning quality and the ash shows black color. The adverse effect of chlorine on the burning quality has been recognized since 19th century, but its mechanism is not well known yet. An increase of hygroscopicity[33] due to increased chlorine content was regarded as one of the factors effecting the burning quality. In addition, it is presumed that chlorine reduces the content of potassium salts of organic acids which are useful for burning. According to recent studies, decreases in contents of malic acid, citric acid, and oxalic acid, as well as of inorganic acid and unknown anions are observed in the chlorine-rich leaves. To make clear these points is the future task.

The burning quality of leaves with different

Table 2. Chemical constituents (%) of leaves with different chlorine contents

Amounts of Cl applied (kg/10a)	Leaf organ	Cl	N	P_2O_5	K_2O	CaO	MgO	NaO	Protein-N	Water soluble N	Total sugars	Total carbohydrates	Total alkaloides
0	Lamina	0.83	3.82	0.48	4.82	5.04	1.79	0.75	1.43	2.39	2.01	7.80	1.59
	Midrib	3.79	2.27	0.28	8.76	3.64	2.11	1.05	—	—	—	—	—
10	Lamina	2.27	3.78	0.52	4.11	6.16	2.21	0.83	1.40	2.38	1.76	8.40	1.12
	Midrib	5.88	2.35	0.29	10.28	3.74	1.94	1.05	—	—	—	—	0.14
20	Lamina	2.91	3.95	0.52	4.77	5.60	1.94	1.05	1.43	2.52	1.87	10.00	1.39
	Midrib	6.57	2.32	0.28	11.32	3.74	1.77	1.32	—	—	—	—	0.12

Table 3. Physical properties of leaves as affected by chlorine content and leaf position

position Leaf	Cl (%)	K_2O (%)	Leaf moisture at 20°C, 60% RH	Filling capacity (mg/cigarette)	Time of burning (min/4 cm)	Dying out rate of lighted cigarettes
14-15	1.56	6.63	10.1	577	5.7	0
	3.33	5.28	11.0	513	6.7	0
	4.54	7.23	13.0	527	6.5	0
20-21	1.14	5.06	10.4	663	8.3	0
	2.77	4.16	11.0	545	9.6	0
	3.72	4.76	10.9	524	8.7	0
26-27	1.09	3.49	9.9	522	11.4	0
	1.96	3.10	10.7	551	—	100
	2.73	3.25	11.1	505	—	100

chlorine contents obtained by the above-mentioned experiment is shown in Table 3. The table shows that with the increase of chlorine both hygroscopicity and burning quality decrease, but apparently the burning quality is also largely influenced by the potassium content and leaf position.

Therefore, to clarify this point, a field experiment with varying rates of supply of chlorine and potassium was carried out using a flue-cured variety, MC. Leaves obtained in the experiment, each differing in content of chlorine and potassium, were used to produce unblended cut tobacco, and tested for the burning quality. As shown in Fig. 2, it was made clear that the territory of dying out of lighted cigarette under natural burning is determined by the chlorine and potassium content, and also by the leaf position. Namely, chlorine is related to the aggravation and potassium to the improvement of burning quality, i.e., they are antagonistic. Such an antagonistic relation is kept unchanged for any leaf position, but the higher the leaf position, the lower is the chlorine content which causes dying out of lighted cigarette.

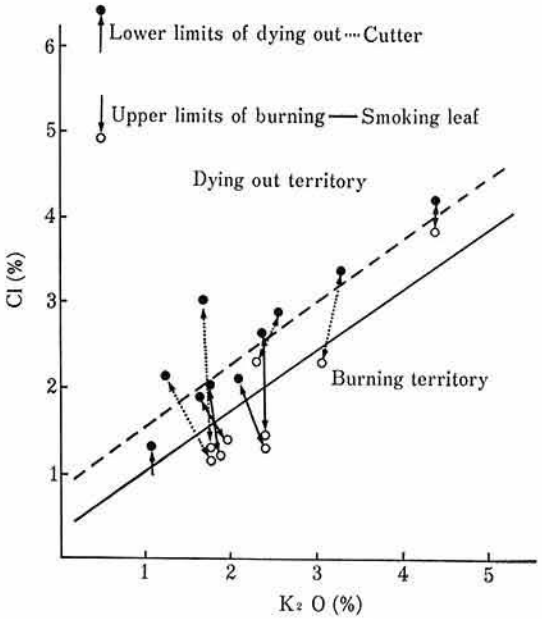

Fig. 2. Effect of Cl and K_2O contents on burning territory

Masuo[34] reported that chlorine in tobacco leaves exists mostly as potassium chloride, and its involvement to burning quality may be related to an reaction of carbonized substance produced to oxygen.

Effects on aroma and taste of tobacco

Aroma and taste of tobacco are aggravated when chlorine content increases: a green grass oder and raw oder are developed while the aroma and taste specific to each varieties disappear. The difference becomes more clear as the chlorine content increases. Allowable limitation of chlorine content from the view point of aroma and taste was reported[35] to be

Table 4 Chlorine contents of leaves of tabacco plants grown on different soils

Amount of Cl applied (kg/10a)	Cl content (%)			
	Hatano soil	Utsunomiya soil	Okayama soil	Kagoshima soil
0	0.62	0.73	0.26	0.20
1	0.86	0.68	0.17	0.19
2	0.97	1.03	0.18	0.17
4	1.12	1.66	0.19	0.16

in the range of 2–3%, although it may vary to some extent with varieties and leaf positions.

Quantity of chlorine supply in tobacco growing

According to various experiments in the United States of America, it seems to be desirable that the total amount of chlorine contained in all the fertilizers applied does not exceed 2.2–3.4 kg/10a. In Japan, more leaching of chlorine is considered to occur due to more rains during the growing period of tobacco, but it is regarded that if chlorine in the form of potassium chloride is applied at the rate more than 3.5 kg Cl to volcanic ash soil some adverse effects may occur. As chlorine is one of the elements most easily leached away in soils, the critical rate of application varys greatly depending on soils and precipitations. An example is given in Table 4, in which a flue-cured variety, BY, was grown on different soils of different stations. When the same amount of chlorine was applied, leaf chlorine content increased in parallel to the increased amount of application in volcanic ash soils at Hatano and Utsunomiya, whereas leaf chlorine content was not effected by chlorine application in granite soil of Okayama and in shirasu soil of Kagoshima because applied chlorine was mostly leached away. However, as the mulch-cultivation is widely practiced, about 4 kg Cl/10a is regarded as a limit at present.

To prevent the excessive uptake of chlorine by tobacco crop, an appeal to avoid the use of manures and fertilizers containing chlorine is being made. Volcanic ash soils with high water-holding capacity are not to be supplied with manures and fertilizers containing chlorine. Particularly in the use of manures with the purpose of maintaining soil fertility, it is recommended to practice field piling and frequent turning of the manures, as well as the autumn application to facilitate the leaching of chlorine. When the chlorine content in soil is high, chloirne is removed by irrigation, or by growing maize or wheat as preceeding crops, which absorb chlorine.

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