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# On the Ascorbic Acid Content of Russian comfrey

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(Tables 1-6)

## INTRODUCTION

Russian comfrey is a perennial feed crop belonging to *Borraginaceae, Symphytum asperrimum*, Sims (Prickly comfrey). About one hundred years ago, it was imported from Eurasia to England and then cultivated in South Africa[1] and Australia.[2] In 1958, again it was imported from Australia to Japan for the first cultivation as a feed crop. The stem, the widely spreading branches and the oblong lanceolate leaves are excessively rough with short and somewhat recurved little prickles. Calyx lobes are short, and the corolla is reddish purple in bud, changing to blue. This sort of changeable color of corolla belongs to the Caucasian group.[3] Though Russian comfrey is a valuable feed crop for its protein content as is shown in the table, it is inferior to lucerne in yield of dry matter, percentage of crude protein and digestibility of protein.[4] It also contains less crude fiber than lucerne. When solar radiation and temperature are optimum, it has a good harvest[5] owing to the strong

Table 1. Chemical composition of Russian comfrey (%)

| | | Dry matter | Moisture | Crude prot. | Crude fat | N free ext. | Crude fiber | Ash |
|---|---|---|---|---|---|---|---|---|
| Dried | Leaf | 83.417 | 16.583 | 26.433 | 2.785 | 28.249 | 11.695 | 14.255 |
| | Stem | 80.225 | 19.775 | 10.202 | 2.100 | 29.278 | 28.605 | 10.040 |
| Fresh | Leaf | 12.013 | 87.987 | 3.806 | 0.401 | 4.069 | 1.069 | 2.053 |
| | Stem | 12.108 | 87.892 | 1.469 | 0.302 | 4.715 | 4.118 | 1.504 |

Table 2. Chemical composition of ash (%)

| | | Moisture | $SiO_2$ | CaO | MgO | $K_2O$ | $P_2O_5$ | MnO |
|---|---|---|---|---|---|---|---|---|
| Dried | Leaf | 16.583 | 0.815 | 2.075 | 0.399 | 8.000 | 0.921 | 0.030 |
| | Stem | 19.773 | 3.405 | 0.633 | 0.142 | 8.600 | 0.653 | trace |
| | Flower | 19.637 | 1.625 | 1.004 | 0.372 | 6.000 | 1.301 | 0.020 |
| | Root | 16.432 | 3.415 | 0.157 | 0.053 | 3.400 | 0.328 | 0.058 |
| Fresh | Leaf | 87.987 | 0.002 | 0.304 | 0.054 | 1.120 | 0.128 | 0.004 |
| | Stem | 87.892 | 0.006 | 0.075 | 0.017 | 1.032 | 0.078 | trace |
| | Flower | 91.714 | 0.005 | 0.170 | 0.063 | 1.020 | 0.221 | 0.003 |
| | Root | 78.657 | 0.017 | 0.037 | 0.013 | 0.850 | 0.082 | 0.014 |

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power of regeneration of its root which contains allantoin.[6] It can also be cut every three or four weeks.

In the south western part of Japan, the feed crops wither in summer due to high temperature and little precipitation. Russian comfrey does not wither because of its deep root, and can be grown for a period of seven or eight months-i.e., from April or May to November or December, making it a very suitable feed crop in the dairy farming region of Japan.

Though the chemical constituents of Russian comfrey have been reported by ELLIOT also,[1] the content of ascorbic acid as the essential nutrient for animals in the leaf of Russian comfrey has never been studied. In this paper, the results determining the ascorbic acid content which is influenced by the fertilization and the trace elements, are reported.

## EXPERIMENTAL METHOD AND RESULT

The root of Russian comfrey (1.5–2.0 cm in diameter, 7–8 cm in length) was cultivated in a depth of 10 cm, early in September 1959, in the center of an earthen pipe (60 cm in diameter, 90 cm in depth) buried in the field. This pipe was filled with alluvial sandy loam developed from the Ashida River which flows through Fukuyama city, Hiroshima Prefecture.

Table 3. Nature and properties of soil

| Moisture of dried soil (%) | Loss on ignition (%) | pH | | Acidity $Y_1$ | Total N (%) |
|---|---|---|---|---|---|
| | | $H_2O$ | KCl | | |
| 1. 554 | 4. 239 | 6. 3 | 6. 6 | 0. 3 | 0. 115 |

| EBC (m. e.) | Ex. CaO | | Ex. MgO | | Saturation degree (%) |
|---|---|---|---|---|---|
| | m. e. | % | m. e. | % | |
| 7. 8 | 3. 7 | 0. 104 | 0. 6 | 0. 013 | 47. 4 |

| Coarse sand (%) | Fine sand (%) | Silt (%) | Clay (%) | Soil class |
|---|---|---|---|---|
| 68. 6 | 6. 8 | 9. 8 | 14. 8 | Sandy loam |

Ammonium sulfate, urea, or calcium cyamide, superphosphate and potassium sulfate were applied 8 kg per 10 ares (100 $m^2$) as N, $P_2O_5$ and $K_2O$ respectively. Late in November the ascorbic acid content in the fresh leaves under these conditions was determined by the indophenol titration method.[7]

A deficiency of nitrogen, phosphoric acid and potassium resulted in a substantial decrease in the concentration of ascorbic acid. Especially potassium and nitro-

Table 4. Ascorbic acid content

| Plot | mg % |
|---|---|
| Without fertilizers | 323.03 |
| 〃 N | 430.28 |
| 〃 $P_2O_5$ | 450.45 |
| 〃 $K_2O$ | 371.12 |
| With fertilizers A (Ammonium sulfate) | 517.68 |
| 〃 B (Urea) | 494.15 |
| 〃 C (Calcium cyamide) | 564.74 |

gen reduced the ascorbic acid content, but phosphoric acid had no obvious effect. The ascorbic acid content is different owing to the kind of nitrogenous fertilizers. A great deal of ascorbic acid in leaves was found in calcium cyamide as compared with ammonium sulfate or urea. Nitrogen, phosphoric acid and potassium are the most important elements for the formation of ascorbic acid.

The ascorbic acid content of crops is not uniform not only by the species of crops[8], the seasons of growth[9)25] or the part of plants,[10)11] but also with the environmental factors such as sunlight[12)13)14], temperature[13)14)15)16], moisture[13] mineral nutrients[13)16] and altitude[17]. The formation of ascorbic acid is shown to require the presence of oxygen and the experiment with organs containing no chlorophyll show that photosynthesis has no necessary association with the formation of ascorbic acid. The only requirement is the presence of carbohydrate fragments[18)19].

Recently DÖRING[20] has discussed that it has been possible to increase the ascorbic acid content of plants by fertilization. There are two results in numerous studies that fertilizations effective or ineffective on the ascorbic acid content. As for the influence of fertilization, it is not found to affect the percentage of ascorbic acid in the harvest crop[21)22)23], and high dosage of mineral fertilizer decreases the ascorbic acid content,[24)25] especially nitrogenous fertilizer alone lowers also the quality of the yield[26)27]. But in many cases, nitrogenous fertilizer increases the ascorbic acid content[28)-33] and the harmful effect of nitrogenous fertilizer can be overcome by the addition of phosphatic fertilizer[26)28] (superphosphate) together with potassic fertilizer[34)35]. The application of superphosphate alone lowered[28)30] or else caused increase[33)36] in the ascorbic acid content of crops or no appreciable effect at all[29]. Potassic fertilizer alone also caused a decrease[33)36] or an increase[29)30)37)38)39].

The accumulation of ascorbic acid in the crops was effected by liming on acid soil[40] and similar effect was noticed when magnesium was introduced together with lime and fertilizers[41)42]. Intensive fertilizing with organic fertilizers decreases the ascorbic acid content[25)43] but the addition of natrium humate[44] which was extracted from peat, made it possible to reduce the amount of phosphoric fertilizer to one tenth and still the yields were higher and the ascorbic acid content also increased.

As before mentioned, although many kinds of experimental results of the influence of fertilizing upon the ascorbic acid content have been reported, unexpectedly potatoes were used often for the test crop among many kinds of vegetables. As the feed crop, red clover, vetch, oats and young corn plants were chosen, but it is obvious that the effect is greatest when the applied fertilizer is also enriched with lime and trace elements[35)41)45)].

Trace elements have obvious effect on the ascorbic acid content of crops. So the influence of trace elecments with fertilizing on the ascorbic acid content was studied. The root of Russian comfrey (1.5–2.0 cm in diameter, 7–8 cm in length) was cultivated in a depth of 10 cm, late in May 1961, in a concrete pipe (100 cm in diameter, 100 cm in depth) buried in the field. The pipe was filled with granite weathered soil. Fertilizers were applied as before mentioned, and trace elements were applied in the following doses, 4 kg of Cu ($CuSO_4$), 2 kg of Zn ($ZnCl_2$), 6 kg of Mn ($MnCl_2$), 2 kg of Co ($CoCl_2$), 6 kg of B ($H_3BO_3$), 2 kg of Mo ($Na_2MoO_4$), and 2 kg of Ni ($NiCl_2$), per hectare. Late in November, the ascorbic acid content in fresh leaves under the same conditions was determined by the same method as has been before mentioned. Trace elements, Co and Mo particularly, were effective in increasing the ascorbic acid content in leaves of many kinds of crops as has been reported.

Table 5. Nature and properties of soil

| Moisture of dried soil % | Loss on ignition % | pH | | Acidity $Y_1$ | Total N % | EBC m. e. | Ex. CaO | |
|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | | | | m. e. | % |
| 3. 136 | 5. 514 | 5. 8 | 4. 9 | 7. 0 | 0. 027 | 5. 9 | 0. 3 | 0. 009 |

| Ex. MgO | | Saturation degree % | Coarse sand % | Fine sand % | Silt % | Clay % | Soil class |
|---|---|---|---|---|---|---|---|
| m. e. | % | | | | | | |
| 1. 3 | 0. 027 | 5. 0 | 70. 8 | 10. 6 | 7. 7 | 10. 7 | Sand |

Table 6. Ascorbic acid content

| Plot | mg % |
|---|---|
| Without trace element | 527. 17 |
| Applied Cu | 673. 07 |
| 〃 Zn | 604. 56 |
| 〃 Mn | 632. 77 |
| 〃 Co | 705. 32 |
| 〃 B | 673. 07 |
| 〃 Mo | 705. 30 |
| 〃 Ni | 589. 43 |

Trace elements except Cu[47)49)] and Co[53)] hasten the maturity of crops and increase the yield[46)] and the ascorbic acid content[52)–67)], and are most valuable for nutritious feed crops[48)]. The combination of trace elements such as Cu + B, Cu +

B + Zn, greatly increase the ascorbic acid content of crops more than a single trace element[63]. But some differences are shown by the kind of crops[64)65] and the environmental conditions such as soil and climate[66)67], and large additions of trace elements[68] tends to hinder, rather than help the increase. Cabbage, tomato, grasses and clover are chosen for the test crop among many kinds of plants. In leaves of Russian comfrey similar to many kinds of plants, the ascorbic acid content is also increased by trace elements in case of such Cu or Co.

Though nature and properties of soils which were filled in earth or concrete pipes were different entirely, the same quantity of fertilizers were applied, and the season of determination of the ascorbic acid content was uniform in different years, the ascorbic acid content in the leaves of Russian comfrey of the "With fertilizers A" plot in Table 4 and of the "Without trace element" plot in Table 6, were almost the same.

## SUMMARY

Deficiency of nitrogen, phosphoric acid and potassium results in a substantial decrease in the concentration of ascorbic acid. Especially potassium and nitrogen reduce, but phosphoric acid has no obvious effect. Fertilizing together with lime increases the ascorbic acid content in leaves of Russian comfrey. Single trace element in the case of Cu increases the ascorbic acid content of Russian comfrey as in many other kinds of plants. The ascorbic acid content of Russian comfrey is uniform under the same conditions in different soils.

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## Russian comfrey のアスコルビン酸含量について

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Russian comfrey はムラサキ科ヒレハリソウ属の永年植物で，蛋白質の含量が高く飼料作物としてその価値は大である．深根性で再生力が強く，西日本の夏季高温の時にも夏枯れをきたすことはない．動物の栄養上必要なアスコルビン酸含量に対し，施肥並に微量要素が如何に影響するかを試験した．

圃場に土管を埋設し，これに沖積土と花崗岩風化土を充塡し，一定の大きさの Russian comfrey の根を植付けた。肥料は10 *a* 当り三要素を 8 *kg*宛施与した．窒素肥料には硫安，尿素，石灰窒素を燐酸肥料には過石を，加里肥料には硫加を用いた．微量要素は ha 当り Cu 4kg, Mn 6kg, Zn 2kg, Co 2kg, B 6kg, Mo 2kg, Ni 2kg を添加した．11月中旬新鮮葉につき Indophenol 滴定法によりアスコルビン酸含量を測定した．

三要素の中その一つを欠いてもアスコルビン酸含量は減少する．特に加里と窒素の影響は大きく燐酸はあまり影響しない．窒素肥料はその種類によってアスコルビン酸含量に差異を示す．微量要素の添加は何れもアスコルビン酸含量を増加する．アスコルビン酸含量に対する土壌の種類の影響はこれを認めることはできなかった．