EFFECTS OF SOME CHEMICALS ON BREAKING THE DORMANCY OF POTATO TUBERS

by

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Potato (Solanam tuberosum L.) is one of the important crops in the world, its tubers contain high starch and rich vitamin C. So that it can be surved as our daily vegetables, forage crops and the raw materials of starch and alcohol industries. Even the small area of subtropical Taiwan was also needed amount to 400 tons of seed potato in 1959. Potato is propagated by division of the tubers, which are short thickened undergroud stems with numerous eyes or buds. It has long been known that the buds of potatoes are dormant for some months after their period of active growth. However, the dormancy of potato tubers is different due to the various varieties and the productive areas. In order to settle the cultivative season of potato production, the dormant problem of the potato tubers will be solved first of all in Taiwrn. Because if we can overcome the dormancy of potato tubers and accelerate the growth of sprouting formally by some chemical treatment easily, we are able to adjust the cultivative season to produce two crops one year in the subtropical Taiwan, in which the absence of adequate cold weather. Thus in Taiwan, the spring crop can be grown immediately upon the harvest of the fall crop, and Taiwan would be supplied the seed potato by itself too. This experiment was carried out for the purpose of detecting the effects of the chemicals and comparing the cost and facilities among these treatments.

MATERIALS AND METHOD

A. Materials of Experiment

(1) The trial chemicals:

1. Calcium cyanamide, $CaCN_2$, product of Taiwan Fertilizer Co. Taiwan.
2. Ammonium thiocyanate, NH_4SCN, product of Wakuo Chemical Co. Japan.
3. Gibberellin, $C_{19}H_{24}O_6$ & $C_{19}H_{22}O_6$, product of CHAS. PFIZER & Co. U. S. A.
4. Atonic, $CH_3O \cdot C_6H_4O \cdot NO_2$, product of Asai Chemical Co. Japan.
5. Urea, $(NH_4)_2CO$, product of Taiwan Fertilizer Co. Taiwan.

The above chemicals were tested for their capacity to shorten the rest periods of potatoes.

(2) The trial potatoes:

Irish Cobbler, the most popular variety in Taiwan, was selected as main material, which came from Japan in 1958. Two crops had been planted with Tuber Index Method to make virus free after introduction. The second crop was harvested on December 28'59 and these tubers were also disinfected with Granosan solution. The chemical

treatment of this experiment was carried out on Feb. 8. 1960.

Another varieties for testing and observing were Kennebec, Katahdin, Merrimack, Pontiac, Plymouth, Red Lasoda, Saco, Sebago, Teton, Triumph, Tawa, X927-3, B595-76, Boone, Cherokee, Delus, Early Gem, Huron and Nolin No. 1.

B. Methods of Treatment

The chemical treatments and designes are shown in Table 1. using calcium cyanamide, ammonium thiocyanate, gibberellin, atonic and urea solution by soak method which is more convenient than dip or vapor method to growers in Taiwan due to their small cultivative area and the want of suitable equipment.

Table 1. Experimental Treatments and Designs

Treatments	Chemicals	Contents	Concentration	Tubers	Hour of soaking (hr)	Total wt. of tubers (g)	No. of tubers (No.)
A	Calcium cyanamide	$CaCN_2$	10%	Half	1	607	20 Halves
B	Calcium cyanamide	$CaCN_2$	10%	Whole	1	608	10 Wholes
C	Calcium cyanamide	$CaCN_2$	10%	Whole	2	576	10 Wholes
D	Ammonium thiocyanate	NH_4SCN	0.8%	Half	1	580	20 Halves
E	Ammonium thiocyanate	NH_4SCN	0.8%	Whole	2	592	10 Wholes
F	Gibberellin	$C_{19}H_{24}O_6$ $C_{19}H_{22}O_6$	5 ppm	Whole	1	592	10 Wholes
G	Gibberellin	$C_{19}H_{24}O_6$ $C_{19}H_{22}O_6$	1 ppm	Half	2	608	20 Halves
H	Atonic	$CH_3O \cdot C_6H_4O \cdot NO_2$	200 ppm	Half & Whole	20	582	10 Halves & 5 Wholes
I	Urea	$(NH_4)_2CO$	5%	Half & Whole	1	598	10 Halves & 5 Wholes
J	Water	H_2O	—	Half & Whole	1	578	10 Halves & 5 Wholes

After treatments, these tubers were placed in the sand beds under greenhouse, and covered over with one inch-thick sands, and watering daily to keep suitable moisture.

C. Date of Investigation

In order to detect and observe the effects of chemicals on sprouting and rooting, five investigation are designed in Table 2.

Table 2. Date of Investigation

Time	Date	Days after treatment
1st	Feburary 15	1 week after treating
2nd	Feburary 18	10 days after treating
3rd	March 3	24 days after treating
4th	March 9	30 days after treating
5th	April 13	65 days after treating

D. Meteorographic Data

The growth of sprouting and rooting may be related to temperature. The meteorographic curves of this experimental duration are shown in Figure 1.

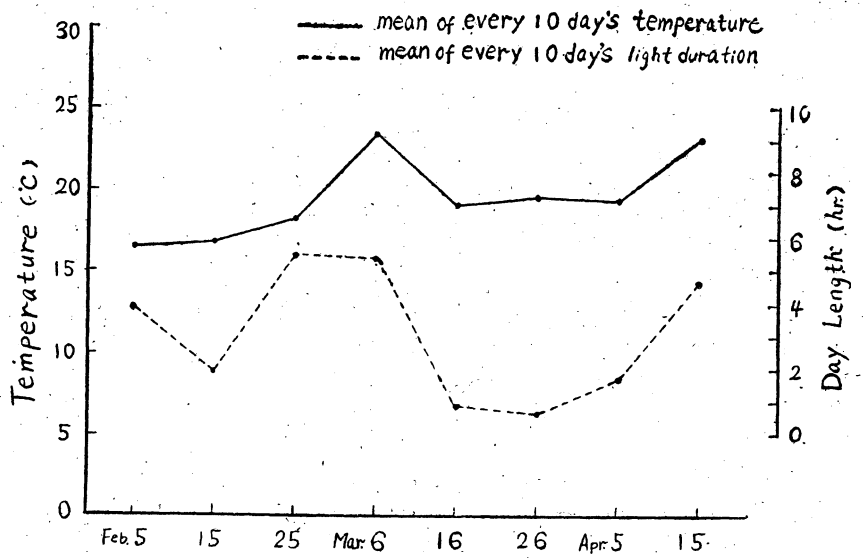

Fig. 1. The meteorographic curves of experimental duration

RESULTS

In consequence of detecting the effects of chemical treatments on potato dormancy and bud formation, the five investigations in Table 2. are recorded as follows:

On Feburary 15, one week after treatments, there were no sprouts yet in any treatments. On Feburary 18, 10 days after treatments, Treatment G, F, and D were shown some white point sprouts. On March 3, 24 days after treatments, Treatment G, F, and D were shown green bud formation, while Treatment C, H and E were shown some white point sprouts. On March 9, 30 days after treatments, some descriptions are shown in Table 3, and Fig. 2. (See Table 3 and Fig. 2.).

On April 13, 65 days after treatments, the average hight of bud stems which were transplanted on the field on March 10, and withont fertilizer application, were measured in belows:

Treatment: A 28.84 cm, D 26.98 cm, G 27.66 cm, H 15.89 cm, I 17.32 cm, J 17.10 cm. above treatments were planted with half tubers.

Treatment: B 11.68 cm, C 5.83 cm, E 5.34 cm, F 10.67 cm, H′ 2.06 cm, I′ 4.54 cm, J′ 2.70 cm.

These treatments were planted with whole tubers.

Table 3. Comparative Effects of Chemical Treatments on Potato Tubers

Treatment	No. of tubers observed	Bud number		Bud stems		Roots		Percentage of decayed	Percentage of weight changed
		Total (No.)	Apical (No.)	Max. length (cm)	Max. diameter (cm)	Number (No.)	M. x. length (cm)	(%)	(%)
A	20H	2.75 (5.50)	1.17 (2.34)	3.17	0.44	5.91	5.66	40	+ 4.99
B	10W	1.80	0.40	0.34	0.28	0	0	0	+ 1.65
C	10W	4.00	1.00	0.58	0.56	0	0	30	+ 1.20
D	20H	3.65 (7.30)	1.25 (2.50)	4.15	0.47	9.10	8.76	0	+ 16.89
E	10W	2.60	0.70	0.64	0.53	0	0	0	+ 0.69
F	10W	1.70	0.50	0.79	0.21	0.60	1.59	0	+ 1.35
G	20H	3.75 (7.50)	1.55 (3.10)	6.85	0.36	11.10	10.24	0	+ 16.61
H	10H	2.20 (4.40)	1.30 (2.60)	1.22	0.51	0.40	0.67	0	+ 5.16
H′	5W	2.00	0.20	0.18	0.15	0	0	0	
I	10H	3.10 (6.20)	0.90 (1.80)	1.06	0.57	0.20	0.43	0	+ 6.86
I′	5W	3.38	0.67	0.86	0.55	0.33	1.03	40	
J	10H	2.10 (4.20)	1.00 (2.00)	1.01	0.67	0	0	0	+ 5.89
J′	5W	1.80	0.20	0.26	0.24	0	0	0	

Note: 1. above data are arithmetical means except the decays.
2. figure in parentheses are assumptive number based on double half cut tubers for comparing with whole tubers clearly.
3. "H" represented half cut tubers while "W" represented whole tubers.
4. the percentage of weight changed measured on March 9, the thirty day atter treatments.

DISCUSSION

From the results presented above, very striking formations of buds and roots occured in A, D and G treatment respectively, while there were no significant effects among B, C, E, F, H, I and J treatments. In other words, we find the rest period of potatoes can be successfully broken or shortened by treatment of the tubers with chemicals such as calcium cyanamide, ammonium thiocyanate and gibberellin.

Effects of Calcium cyanamide Treatments—The 10 per cent solution of calcium cyanamide, the upper part of suspension, which had been agitated for an hour, had an effect of overcoming tuber dormancy and made tuber sprouts come up simultaneously and evidently. However, the half cut tubers were more sensitive than the whole ones. Moreover, we can make the whole tubers more effectual if increasing the soaking hour for 2 hours, but some decayed tubers would be found also. It may be the injuries of dense cyanamide particles. Therefore, if we make the dense particles more fine with a hairy towel to filtrate, it could decrease the percentage of decay.

Effect of Gibberellin Treatments—Gibberellin solution had a striking effect to overcome potato tuber dormaney. Sprouts would be found within 10 days after

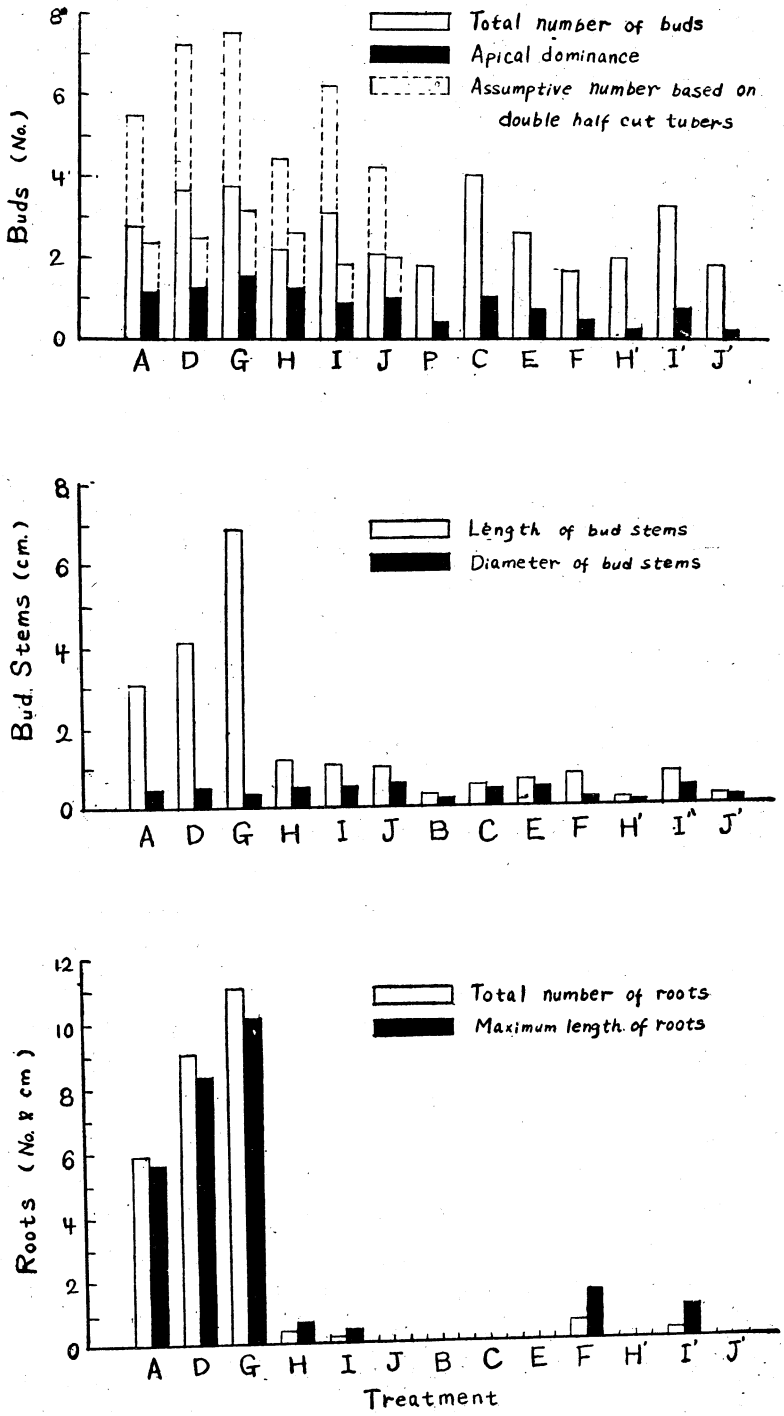

Fig. 2. Comparative effects of chemical treatment on sprouting and rooting of potato tubers

treatments, which were earlier than other treatments such as ammonium thiocyanate and calcium cyanamide. Gibberellin not only had an evident effect on dormant period but also made sprouts grow quickly. Average height of bud stems would be arrived at 6.85 cm 30 days later. And the half cut tubers were more sensitive and significant than the whole ones. The former were very effective with 1 ppm concentration only, while the latter were no significant even with 5 ppm concentration. However, the tuber sprouts treated with gibberellin were inclined to elongate and somewhat slender and flexible, but the developments of roots were quite well.

Effect of Ammonium thiocyanate Treatment—The 0.8 per cent solution of ammonium thiocyanate had a striking effect to break the rest period of potato tubers and more effective than the 10 per cent solution of calcium cyanamide both sprouting and rooting but need higher cost. It could come up stout strong sprouts and well-developed roots after treatment of half cut tubers with ammonium thiocyanate by soak method. But the whole tubers treated could hardly get the same eflect as the half cut tubers or seed pieces. Ammonium thiocyanate would be hopeful to breaking the potato tuber dormancy owing to its stout bud, no injury and simultaneity.

Effect of Atonic Treatment—The five thousand fold solution of Atonic for 20 hours' soaking had no significant effect on sprouting of dormant potato tubers. However, the half cut tubers treated were a little better than the whole ones. It seems possible to increase effect, if the concentration of Atonic solution is increased. Further study of the concentration would be valuable.

Effect of Urea Treatment—A 5 per cent solution of urea soaking for one hour also had no significant effect on sprouting of resting tubers but a little better than the above Atonic solution.

Effect of Water Treatment—A few white point sprouts occured on the resting tubers too, but with tardiness. Because the trial tubers had been stocked at the cool room (20°C) for a while, and also had been elapsed for a long resting period. The resting tubers were not so difficult to sprout if soaking in water for an hour and giving the good condition of suitable moisture. But it was still tardy than other chemical treatments especially calcium cyanamide, ammonium thiocyanate and gibberellin, see Figure 2 & 3.

Weight Changes of Tubers—The weights of tubers after treatment, measured on 30 days later, had increased than before treatment on Feburary 8. This inclination would be evident, if suitable moisture given, especially in G and D treatments. In other words, it could be certified also some striking bud formation had occured in G and D treatments.

Difference of Effect on Tuber Kind—According to the experimental results, there were significant differences of effects between half cut tubers and whole ones. Generally speaking, the former had an evident effect of bud formation, while the latter was no significant. see Figure 2. Why the whole tubers, without cut, can hardly be promoted the growth of bud stems, while the white point sprouts had been come up on

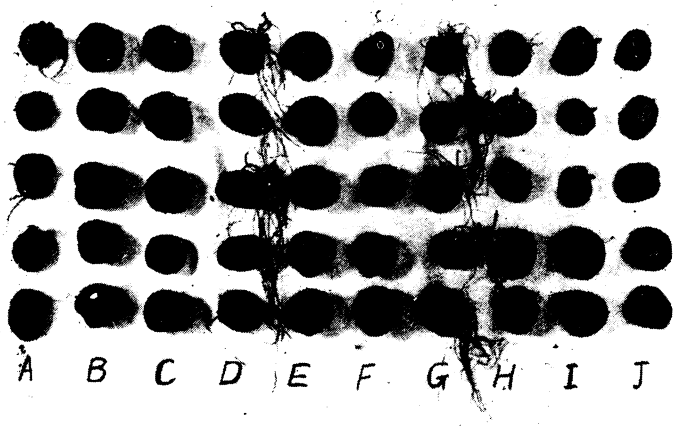

Fig. 3. Effects of chemical treatments on sprouting and rooting of potato tubers
A, treated with calcium cyanamide, 10%, 1 hr., soak method.
D, treated with ammonium thiocyanate, 0.8%, 1 hr., soak method.
G, treated with gibberellin, 1 ppm, 2 hrs., soak method.

the tuber skins? It seems that the function of nutrient absorption is somewhat unconvenient owing to its corky skins. However, the foundation seeds and certified seeds should have been planted by the Tuber Index Method, so that treatment of the whole tubers will be neccessary at that ocasion. We could get the same effective as the half cut tubers or seed piecies by improving the treatment such as knoching or cutting without separation. Profound studies of this work would be valuable.

Varieties and Different Dormancy—According to the observation of experiment, there are different effects occured in dormancy owing to the various varieties. Two group will be separated among the above varieties mentioned in the Materials of Experiment.

A. The varieties of sensitive to chemicals (NH_4SCN) or short dormancy are Sebago, Noulin #1, Saco, Katahdin, Sequaia, Teton, Tawa, Kennebec, Plymouth, Huron, Cherokee.
B. The varieties of unsensitive to chemicals (NH_4SCN) or long dormancy are Triumph, Irish Cobbler, Early Gem, Boone, Red Lasoda, X923-3, Delus, B595-76, Pontiac, Merrimack.

The varieties of unsensitive to chemicals or long dormancy may be treated with higher concentration or soaking hour to shorten the resting period, while the varieties of sensitive to chemicals or short dormandy may be treated with lower concentration. Generally speaking, the deep eyed varieties should have long dormancy and the thick-skinned varieties should have short dormancy. Irish Cobbler, the popular variety in Taiwan, treated with NH_4SCN or NaCNS by soak method are more effective than that

treated with Ethylene Chlorohydrin by dip or vapor method.

Effect and Cost of Chemicals—According to the above results and observation, we found that the sprouting of dormant potato tubers can be hastened and that the percentage of germinating within a limited period can be increased by soaking cut seed piecies in a solution of ammonium thiocyanate, gibberellin and calcium cyanamide. However, there are differences among the price of chemicals. According to the cost (unit price × concentration), the ratio of chemical cost is A, B, C:D, E:F:G:H:I= 2:12:25:5:2:3 Although ammonium thiocyanate more or less needs high cost, it will be still stand in the first due to its stout and uninjured bud.

The Mechanism of Bud Formation—Buds can be induced to break dormancy simultaneously by chemicals in this experiment. But the mechanism and process of sprouting or bud formation are unknown completely. The evidence relating toxic action of chemicals with respiratory metabolism is still rather scattered and fragmentary, but some interesting possibilities are apparent. It seems possible that the increase in respiration caused by chemical stimulation may be essential part of its action in sprout and growth. However, the effect on sprouting may be ascribed to CN^-, CNS^-, $CS^=$, $C_2H_2^{++}$, $C_2H_5^{++}$, CH_2, H_2S, which are somewhat toxic in chemical properties. The mechanism and process of sprouting may be explained as follows:

The toxic chemicals contained such as CN^-, CNS^-, will act as stimulus and will cause a variety of toxic effect in tissues. Hence, the respiratory metabolism may be accelerated, and periderm may be formed and thickened. Here in addittion to the activities of enzymes such as amylase, the fats will be decomposed and the starch will be saccharified. Therefore, the osmostic pressure of cells will increase due to the increment of sucrose aud make bud come up.

In conclusion, we are likely to make more progress toward understanding the mechanism of chemical action when we have more complete knowlege of the respiratory machinery of the tissues in which the action of chemicals is studied, or possibly when we are able to study their action in tissues whose mechanism are already better known. If we are to understand how chemicals control metabolism and ultimately sprouting, it is important that we have further studies on the stimulation in relation to sprout and growth.

SUMMARY

1. It has been known that the buds of potatoes are dormant for some months after their period of active growth, and the dormancy is different owing to the variety and productive area. But the buds can be induced to break dormancy by chemicals.

2. The potato growers in subtropical Taiwan are faced with certain dormant problems that chemical treatments may solve. Potatoes in the mild climates often remain dormant because of insufficient cold weather, thus making desirable treatments that hasten the sprouting of potatoes. Hence, the potato growers would have a growing season long enough for two crops one year, i. e. where the spring crop can be

grown immediately upon the harvest of the fall crop and Taiwan would be supplied the seed potatoes by itself too.

3. This experiment was carried out for the purpose of detecting the effects of the chemicals and comparing the cost and facilities among treatments.

4. The chemicals such as Calcium cyanamide, Ammonium thiocyanate, Gibberellin, Atonic and Urea were tested for their capacity to shorten the rest period.

5. The resting period of potato can be successfully broken or shorten by treatment of tubers with chemicals such as Ammonium thiocyanate, calcium cyanamide and Gibberellin.

6. The effective concentration of these chemical treatments are 10% solution of Calcium cyanamide, 0.8% solution of Ammonium thiocyanate and 1 ppm solution of Gibberellin. The first two need soaking cut seed piecies for an hour and the last one, soaking cut seed piecies for two hours.

7. According to the experimental results, there are evident difference of effect between the half cut tubers and the whole ones by soaking method.

8. According to the computation of chemical cost (i. e. unit price × concentration), the ratio of treatments is A, B, C:D, E:F:G:H:I=2:12:25:5:2:3.

9. The procedure of recommended treatment is to cut freshly harvested tubers into seed pieces, soaking for 1 hour in 0.8 per cent water solution of ammonium thiocyanate, covered with sands and watering for a week to promote sprouts and then plant.

10. The effect on sprouting or bud formation is ascribed to the CNS^-, CN^-, $CS^=$, $C_2H_4^{++}$, $C_2H_5^{++}$, H_2S, CH_2 etc, which are somewhat toxic in chemical properties.

11. The mechanism of sprouting is unknown completely yet, the further studies of this field would be necessary and valuable.

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藥劑對於馬鈴薯休眠打破效果之研究

林　昭　雄

中文摘要

一、馬鈴薯之生育期完成後即進入一段休眠期，其長短因品種，栽培地區與時期而略異，惟此休眠期今可用化學藥品處理隨時打破促進其發芽。

二、在亞熱帶之臺灣，馬鈴薯栽培者即面臨此休眠問題，然而此難題，今可因化學藥劑處理打破休眠，促進其發芽，而解決了栽培季節之配合問題。如此一年可種植兩季馬鈴薯，即秋季播種，冬季收成之種薯可供春季種植，而其初夏收成者，可再供秋季種植，並同時能解決種薯自給問題。

三、本試驗之目的在於探研各種藥劑對馬鈴薯休眠打破之影響情形，並比較其效果與成本，以利於本省馬鈴薯種薯自給供應。

四、本試驗之供試藥劑有氰氮化鈣、奇伯靈、硫氰氨、亞特尼克、尿素等，根據試驗結果，以奇伯靈、氰氮化鈣、硫氰氨最有效，而亞特尼克、尿素未能獲得顯著之效果。

五、各藥劑之有效濃度爲奇伯靈百萬分之一，氰氮化鈣十分之一，硫氰氨千分之八，此等濃度不僅能打破休眠且能促進其發根。

六、各種處理中，馬鈴薯以切開者效果較顯著，而未切開者效果較低，則恐因前者切開面比後者已木栓化之表皮較易吸收養分或易受刺激，而促進其生理作用以致易早萌芽。因此供塊莖單位栽培者，如改善處理方法，將種薯作不完全之切開或適當之切刻，則可增加功效。

七、根據各種藥劑成本（單位價格乘濃度）計算，各處理間之成本比例如下：氰氮化鈣百分之十溶液，硫氰氨千分之八溶液，奇伯靈百萬分之五，奇伯靈百萬分之一溶液，亞特尼克五千分之一溶液，與尿素百分之五溶液之比例爲二、十二、二十五、五、二、三之比。

八、最有效而可推廣之處理方式爲將新鮮收穫之種薯切開成小種塊，浸漬於硫氰氨千分之八溶液一小時後取出陰乾使切開面癒合，再埋於砂中一星期，俟其萌芽即可種植，如此可獲得强壯而整齊之發芽種薯。。

九、藥劑影響馬鈴薯萌芽之主因可能由於藥劑中含有如 CNS^-, CN^-, $CS^=$, $C_2H_4^{++}$, $C_2H_5^{++}$, H_2S, CH_2 等多少有毒之化學藥品，刺激所致。

十、至於馬鈴薯萌芽過程與機構，至今尙未完全明瞭，此機構實有進一步研究之必要。