# BASIC REQUIREMENTS FOR TPS (TRUE POTATO SEED) PRODUCTION

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## ABSTRACT

The author who originally aimed at the development of True Potato Seed technology in 1975, initiated the project "Flower bud differentiation and development in potato" at CIP in 1984 to analyse the basic requirements for TPS production.

First, the nature of flower bud differentiation was clarified. Then, the adverse effect of sudden changes of the air temperature and light intensity on flower development of the plant at the critical stage was analysed. The plant was likely to become very susceptible to stress two weeks after emergence. In extreme cases, the primordia of the inflorescence could not develop at all.

After various experiments on the effect of plant irradiation were carried out, it was observed that 3 h night break exerted a positive effect on flower development especially in the varieties in which the induction of flowering had been difficult by irradiation immediately after dusk or just before dawn.

The factors controlling the effect of the 3 h night break include variety, air temperature, basic photoperiod, light intensity and timing of 3 h night break and initiation and duration of the break treatment. The effects of these factors were examined and technology is proposed for TPS production under shorter photoperiod than 11.5 h at cooler air temperature.

## Introduction

Recently, the importance of TPS technology has been widely recognized and it is attracting the interest of researchers in the developing countries. According to the report by CIP in 1987, TPS research is being promoted in 40 countries. In several countries TPS technology has already been applied in farmers' fields. The author who originally aimed at the development of True Potato Seed Technology in 1975, had the opportunity to be assigned to CIP from April 1984 to May 1988.

The objective of the series of experiments carried out at CIP was to establish a technology which would facilitate TPS production in the developing countries where potatoes are grown during the cooler season with short days, which impairs the development of the flower bud and TPS production.

## Materials and methods

The varieties mainly employed were ATZIMBA, DTO-28 and DTO-33. Flowering of DTO-28 and 33 had been found to be difficult in Lima. The growing period was approximately three months. The monthly mean temperature ranged between 15°C to 24°C in a year. The seed tuber was planted in two rows 50 cm apart, on a 10 cm raised bed, 110 cm in width.

The space between the plants was about 28 cm. Fertilizers were applied to the bed

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to reach a level of 30, 30 and 30 mg of N, $P_2O_5$ and $K_2O$/100g of soil. Each hill had two stems and each stem was trained to a single one and was supported by a 1 m high stake. The frames were posted over the bed to form a tunnel on which a piece of light proof plastic film was placed to control the basic photoperiod by its folding up and covering down. A piece of transparent plastic film or cheese cloth was placed on the tunnel to control the tomperature or light intensity under the tunnel. The former could maintain the temperature at about 28°C during the daytime and the latter reduce the light intensity by 65%. The 120 cm TOSHIBA FL-40-SW tubes were located lengthwise 20 cm apart just beneath the frames whose height was 1 m. The illuminance at about 10 cm above the bed was 600 lx. Hand pollination on the blooming flowers was performed without emasculation. Pollen varieties included R 128.6, C-83119 and ATZIMBA. A split plot design was employed with two replications. Generally, 5 to 7 seed tubers of a variety were planted in a plot.

## Results and discussion

### 1 Examination of flower bud differentiation and analysis of the factors which affect the differentiation (June 1984-June 1985)

A non-dormant tuber sprout starts growing under moderate temperature and moisture conditions. The apex changes from the vegetative to the reproductive stage. When the growing sprout emerges from the soil, it is light, grows and the leaves expand rapidly. The apex grows from stage I (fat shape), to stage II (dome shape) and to stage III (arch shape). When the diameter of the sprout ranges from 0.5 to 0.6 cm, the growing apex at stage III reaches the two flower primordium stage a few days after emergence and

Fig. 1 Growing apex at two flower primordium stage

progresses further (Fig. 1) though slight varietal differences in the days until differentiation were observed. These observations suggest that the lack of flowering of potatoes often reported is not caused by the absence of flower bud, but by the absence of factors which promote the normal growth of flower primordia once differentiated. The importance of normal growth of a sprout for the normal differentiation of the flower bud was stressed.

## 2 Effect of temperature and light intensity on the development of the flower bud (March 1985-July 1986)

The relevant findings included the adverse effect of high temperature (28°C), the positive effect of moderate light intensity (25 klx), the presence of optimal environmental conditions for flower development of the respective varieties and the difficulty in improving flower development merely by manipulation of the temperature or the light intensity. The developing inflorescence of the potato became very susceptible to sudden changes of the temperature and light intensity between 14-42 days after emergence, when the first cluster appeared and flowered (Fig. 2). Thus, it is assumed that the optimum conditions for promoting the normal growth of the plant are also the minimum and essential conditions for the normal development of the flower organs of the mother plant for TPS production. Drastic changes of the environmental conditions during the critical period of flower development should be avoided.

## 3 Effect of photoperiodic treatment on flower development (September 1985-December 1986)

First, the positive effect of long day and the negative effect of short day were confirmed. As for the effect of the light intensity, the lower the light intensity of the treatment, the less pronounced the effect on plant growth, flowering and fruiting. The potato plant can adapt to the intensity of the light (Fig. 3). The critical light intensity varied with the varieties. Different spectral responses were observed between irradiations with the fluorescent and incandescent light. Effective light intensity of fluorescent light for use, was 1000-600 lx, which was almost equivalent to 300-150 lx of incandescent light.

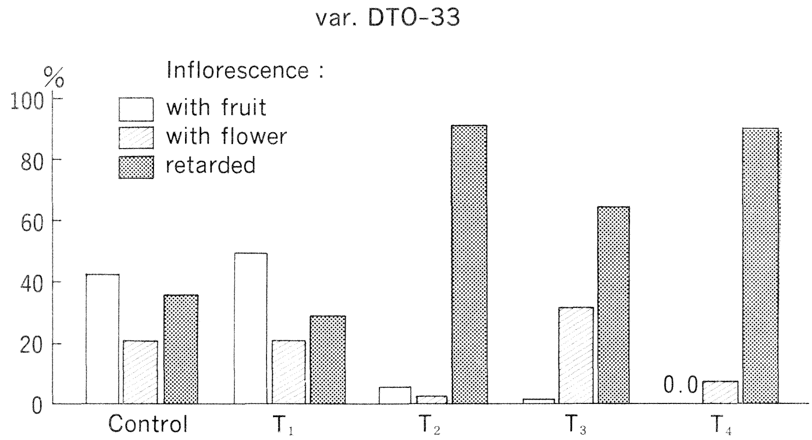


Fig. 2 **Effect of temperature on flower development at different growth stages**

Note : In $T_1$, $T_2$, $T_3$ treatments, plants were respectively exposed to 28°C for lst, 2nd and 3rd two weeks after emergence during daytime. In $T_4$, plants were exposed to 28°C for 42 days. Mean temperature for control plot was 22°C.

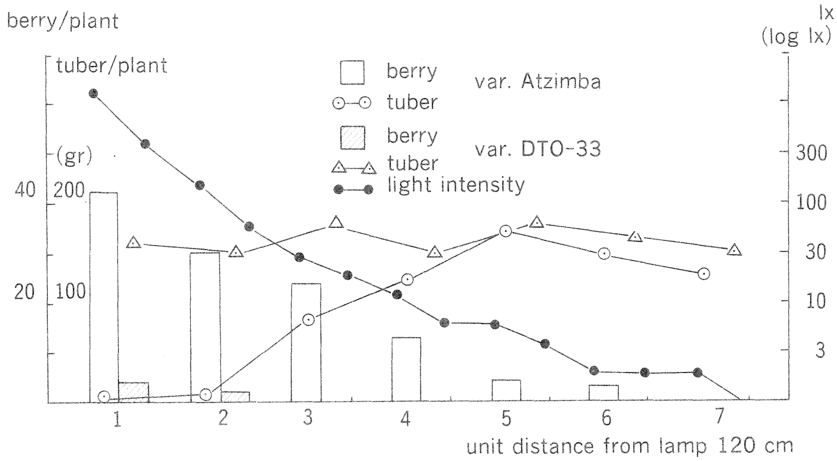


**Fig. 3 Effect of intensity of light irradiation on fruiting and tuber growth**
Note : Growing period, July 7-October 10 1986.
Irradiation was applied following dusk for 6h with fluorescent light under 9h photoperiod. Only the spot 1 was located at a 40 cm distance from the lamp

It was observed that the longer the duration of the light period (4.5, 5.5 and 6.5 h) following dusk under a basic photoperiod of 9 h, the larger the number of fruits in ATZIMBA, whereas in DTO-28, the number of berries on the plant under a 5.5 and 6.5 h light period did not change significantly. The longer light period did not always improve the flowering and fruiting, suggesting the presence of a program built in the plant and ready to respond to a timely stimulus of light in potatoes.

The effect of a 1, 2 and 3 h night break set up at midnight was compared with that of a 6 h irradiation following dusk. The 3 h night break was most effective in the induction of flowering and fruiting in DTO-28 and 33, while the effect of longer night break was not appreciable. Besides, since the 3 h night breaks set up at various times exerted different effects on flowering and fruiting, further examinations were deemed necessary.

## 4 Effect of 3 h night break on flower development and fruiting (August 1987-November 1988)

When the plant was subjected to the 3 h night break immediately after emergence, the longer the duration of the treatment, the more significant the effect on flowering and fruiting. The optimum duration of the 3 h night break treatment was 45 days. As for the initiation, the longer the delay of the initiation of the treatment, the less appreciable the effect (Fig. 4). When the night break was not applied, the plant appeared to develop a physiological system for the partitioning of the photosynthates to the stolon and became insensitive to the night break.

The effect of the time when the 3 h night break was applied on flowering and fruiting was first investigated from August to November in 1987. The 3 h night breaks were applied at 10 different times between 5 pm to 8 am. The growth of the haulm was significantly promoted by the night break along with the increase of the number of flowers and berries. The curves of the response of the number of flowers and berries in DTO-28 and 33 to a series of 3 h night breaks, assumed a Λ shape, while that of the tuber weight and tuber/top ratio assumed a U shape (Fig. 5). The correlations among haulm

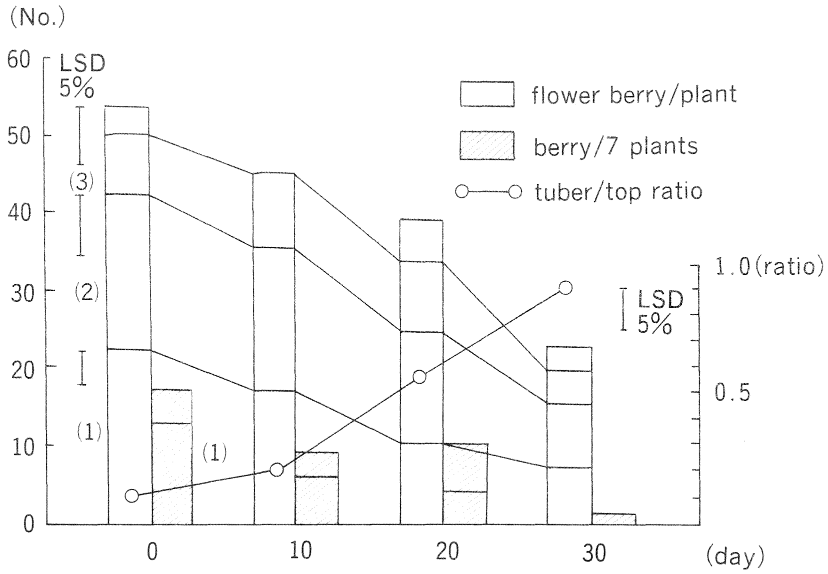


**Fig. 4 Effect of initiation of 6h night break on flowering, fruiting and tuber/top ratio in DTO-33 grown under 9h photoperiod**
Note : Growing period, November 16-February 7 1988. Night break was set up at 7 pm-1 am. (1), (2) and (3) stand for 1st, 2nd and 3rd cluster.

weight, number of flowers and number of berries were positive but the correlation between one of these parameters and the tuber weight or tuber/top ratio was negative. The 3 h night break at 0-3 am, compared with other times for set up, resulted in the production of the largest number of berries in ATZIMBA and DTO-28 followed by DTO-33. Generally the largest number of berries was associated with the maximum weight of haulm, largest number of flowers, minimum weight of tuber and lowest tuber/top ratio. These observations suggest that the 3 h night break may affect the physiological mechanism of partition of the photosynthates in potatoes.

The responses of 13 varieties to a series of 3 h night breaks were examined under a 11.5 h photoperiod. Eight varieties bore the largest number of berries per plant when subjected to the 0-3 am night break, followed by 3 varieties (Table 1). The average number of berries in 13 varieties subjected to the 0-3 am night break was 23.0 followed by 21.6 for the 1-4 am night break. The 23.0 figure corresponded to 156% of that obtained upon exposure to 6-9 pm irradiation after dusk. In the responses of the varieties, generally the lowest value for the tuber/top+root ratio and the largest one for the air-dried top and root weight were associated with the largest number of flowers and berries. Moreover 8 varieties showed similar curves for the response of the number of flowers and fruits and tuber/top+root ratio to the treatment (Fig. 6). Hence the night break set up at 0-3 am was considered to exert a favorable effect on the berry production of most varieties when they were grown under similar conditions in this experiment. However the number of berries of the respective varieties varied widely ranging from 1.7 for SANTO AMOR to 48 for LT-7. The factors responsible for the smaller number of berries in the respective varieties included relatively small air-dried top and root weight and high tuber/top+root ratios*. The lower temperature during this period may have promoted the bulking of the

* Tuber stands for fresh tuber weight and top+root stands for air-dried top and root weight.

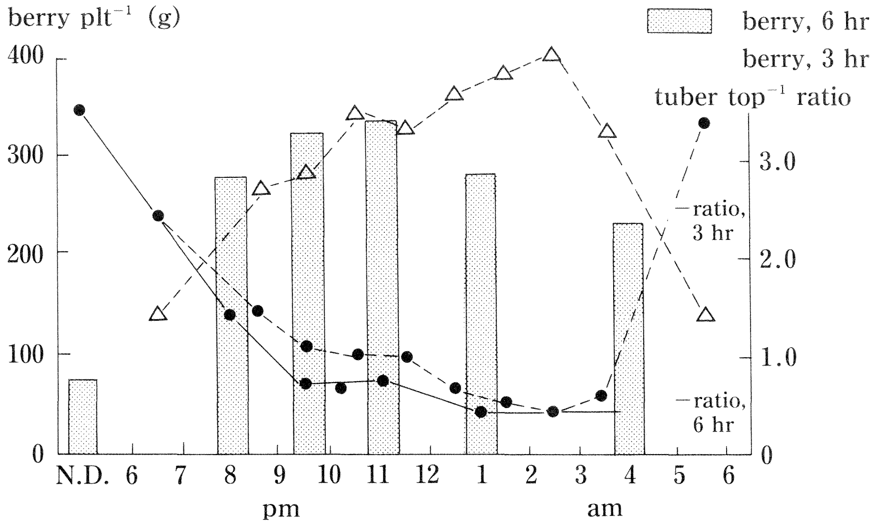


**Fig. 5 Effect of irradiation timing of 3 hr and 6 hr night breakes on fruiting and plant growth (var. DTO-33 Aug. 12-Nov. 19, 1987)**

Note : Basic photoperiod, 9 hr (8 am-5 pm). N. D. stands for natural daylength as control.

**Table 1 Effect of series of 3h night breaks on fruiting of ten varieties**

| Variety | Time of 3h night break | | | | | |
|---|---|---|---|---|---|---|
| | After dusk 6-9 pm (Berry no/plant) | 9pm-12 | 12-3am | 1-4am | 2-5am | Before dawn 3.5-6.5 am |
| ATZIMBA | 39 | − 4 | − 2 | −10 | − 4 | − 1 |
| LT-1 | 33 | −17 | + 5 | + 4 | 0 | − 2 |
| LT-7 | 26 | + 5 | +22 | +23 | +17 | +19 |
| LT-5 | 16 | − 7 | + 8 | + 4 | + 2 | + 1 |
| SERRANA | 11 | − 2 | + 3 | +12 | − 5 | − 5 |
| CFK 69-1 | 11 | − 2 | + 6 | + 5 | + 1 | + 6 |
| KATAHDIN | 9 | − 3 | +24 | +23 | + 5 | 0 |
| DTO-28 | 0.6 | + 5.7 | + 7.6 | + 3.3 | + 1 | + 0.9 |
| DTO-33 | 0.9 | + 7.1 | + 8.8 | + 4.1 | + 2.6 | + 6.5 |
| SANTO AMOR | 0 | +0.4 | + 1.7 | + 0 | + 0 | + 0.2 |
| Average | 14.7 | + 1.7 | + 8.4 | + 6.8 | + 2 | + 2.6 |

Note : Figures in each column except (6-9 pm) indicate the difference between the number of berries at 6-9 pm and that at respective night breaks. Growing period, June 29-October 24 1988. Photoperiod, 11.5 h.

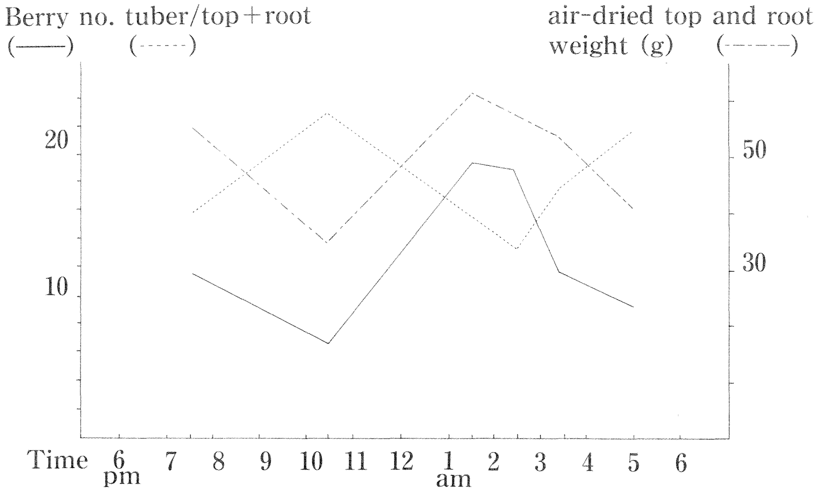


**Fig. 6 Curves of number of berries, air-dried top and root weight and tuber/top+root ratio in response to a series of 3h night breaks**

Note : Figure is an average of 8 varieties (LT-1, 2 and 5, 7-XY-1, Katahdin, Atlantic, Santo amor and Serrana)
Growing period : June 29-October 24 1988.
Photoperiod : 11.5h (6.5 am-6pm)

tuber even in the case of the 3 h night break.

The role of the temperature in the effect of the 3 h night break was investigated. Under a high temperature of about 24°C, the photosynthesis was depressed and the bulking of the tuber became extremely limited upon the exposure to the night break. Although the top growth was not as depressed as that of the tuber, the insufficient amount of photosynthates may have impaired the development of the bud for flowering and fruiting in most varieties except ATZIMBA, LT-7 and ATLANTIC. The optimum set up of the night break under this condition was 8-11 pm, 2-5 am or 3.5-6.5 am. At low temperatures ranging from 14 to 15°C, photosynthesis was markedly promoted. The night break set up at 0-3 am was very effective in most varieties to maintain a suitable tuber/top+root ratio for flowering and fruiting. However the bulking in some varieties was too pronounced to be depressed by the night break and resulted in poor flowering and fruiting as in the case of SANTO AMOR, LT-2, DTO-28 and 33. The optimum temperature of 16-18°C was considered to depress the bulking of tuber moderately and promote the top growth resulting in satisfactory flowering and fruiting, as observed in DTO-28 and 33 at 17-18°C. The optimum temperature for effective night break should be investigated (Table 2).

The positive effect of the 3 h night break so far mentioned was obtained under a 9 h photoperiod. Studies were carried out from June to October 1988 to determine whether this effect took place under a 10.5 and 11.5 h photoperiod. The dome-shaped curve of the air-dried top and root weight under a 9 h photoperiod, became more depressed with the increase of the duration of the basic photoperiods. The narrow U-shaped curve of the tuber/top+root ratio under a 9 h photoperiod became wider at the top and shorter in height with the increase of the basic photoperiods. However under a 10.5 to 11.5 h photoperiod the lowest tuber/top+root ratio and largest top and root weight were observed at a 0-3 am night break, resulting in the largest number of flowers and berries in DTO-28 and 33 as well as in ATZIMBA (Table 3). These results suggest that at a relatively low temperature, the 0-3 am night break leads to optimum flowering and

**Table 2 Effect op seasonal temperature of growing period on performance of a series of 3h night breaks in five varieties**

| Variety | Growing season | Air-dried top and root weight (g) | Tuber fresh weight (g) | Tuber/top+root ratio | No. of flowers and buds | Flower no. | Berry no. |
|---|---|---|---|---|---|---|---|
| LT-7 | Warm | 38 | 10 | 0.3 | 100 | 47 | 14 |
| | Cool | 64 | 784 | 12.2 | 109 | 62 | 40 |
| LT-1 | Warm | 41 | 44 | 1.1 | 78 | 7 | 1.1 |
| | Cool | 77 | 696 | 9.0 | 105 | 57 | 31 |
| LT-5 | Warm | 45 | 23 | 0.5 | 36 | 21 | 1.9 |
| | Cool | 62 | 989 | 16.1 | 86 | 27 | 17 |
| SERRANA | Warm | 47 | 41 | 0.8 | 97 | 7 | 1.8 |
| | Cool | 61 | 698 | 11.4 | 145 | 20 | 12 |
| LT-2 | Warm | 26 | 28 | 1.1 | 65 | 10 | 2.6 |
| | Cool | 35 | 780 | 22.5 | 68 | 3 | 1.3 |

Note : Warm season, growing period from February 8 to May 15 1988. Temperature ranged from 24°C to 20°C. Cool season, growing period from June 26 to October 24 1988. Temperature ranged from 14°C to 18°C. Figure (per plant) is an average of six values obtained for exposure to six kinds of 3h night breaks.

**Table 3 Effect of series of 3h night breaks on number of berries, air-dried top and root weight and tuber/top+root ratio under short day condition**

| Parameter (per plant) | Variety | Time of 3h night break: After dusk | 9 pm-12 | 12-3 am | 1-4 am | 2-5 am | Before dawn |
|---|---|---|---|---|---|---|---|
| Berry number | ATZIMBA | 42.7 | 41.3 | 44.7 | 38.4 | 38.7 | 34.3 |
| | DTO-28 | 0.8 | 4.3 | 8.4 | 4.8 | 2.5 | 0.6 |
| | DTO-33 | 0.7 | 4.0 | 8.1 | 4.6 | 3.8 | 3.1 |
| Air-dried top and root weight (g) | ATZIMBA | 86 | 85 | 87 | 80 | 81 | 65 |
| | DTO-28 | 33 | 50 | 55 | 55 | 32 | 32 |
| | DTO-33 | 40 | 55 | 63 | 53 | 57 | 43 |
| Tuber/top+root ration | ATZIMBA | 3.2 | 1.7 | 1.0 | 0.6 | 0.6 | 5.5 |
| | DTO-28 | 18.5 | 13.6 | 10.1 | 11.8 | 14.0 | 19.3 |
| | DTO-33 | 16.4 | 13.3 | 7.8 | 9.7 | 10.2 | 14.8 |

Note : Figure is an average of those obtained under basic photoperiods of 9, 10.5 and 11.5 h. Growing period : June 13-September 28 1988.

fruiting under a 9 h-11.5 h photoperiod, though the optimum basic photoperiod may vary with the varieties.

## 5 Mechanism of 3 h night break (January 1988-November 1988)

The flowering, fruiting and tuberization of the grafted plant resembled those of the scion. Some part of the top of the plant appeared to be responsible for the monitoring and control of the mechanism of the response of the plant to the light stimulus.

The physiological condition of the plant around dusk and dawn may partly determine the mode of response of the plant to the series of 3 h night breaks as a reaction to the light stimulus.

The night break set up at 0-3 am or 1-4 am generally brought about the lowest tuber/top/root ratio, larger air-dried top and root weight and largest number of flowers and fruits regardless of the other photoperiodic conditions at moderate to low temperatures. This fact suggests the presence of a stable program built in potatoes.

Also, the potato plant appears to have a mechanism enabling it to measure the time because even under short day conditions, the tuber/top+root ratio generally increased towards dusk and dawn upon the response to a series of 3 h night breaks. Sometimes a similar pattern of the response of the plant to a series of the 3 h night breaks occurred with a time lag when two treatments of the basic photoperiod of the same length were differently set up.

## Conclusion

On the basis of the results obtained, the proposed mechanism of the effect of the 3 h night break is as follows : between 10 to 20 days after emergence, tuberization starts. Varietal rhythm and range of growth of haulm and tuber are largely modified by the temperature and photoperiod. The 3 h night break may affect the physiological activity of the potato, resulting in a change in the partitioning of the photosynthates. The 3 h night break set up timely, usually depresses the intensity of tuber bulking and promotes haulm growth. The plant monitors the light of the night break at the top and develops a larger amount of foliage and clusters under the treatment. However under warmer conditions, photosynthesis becomes depressed, abnormal flowers develop and wither and eventually, seed production decreases. Under cool or optimum conditions, photosynthesis is promoted. Normal flowers develop and larger amount of seed is produced. Under cooler or cold conditions where the tuberization is markedly promoted even in the case of the night break, the treatment becomes occasionally less effective and seed production decreases.

The method of TPS production by the application of the 3 h night break under a photoperiod shorter than 11.5 h is as follows :

1) Determine the growing period and identify the site which can secure as low a temperature as 16-18°C especially during the 40 day period after emergence, although the optimum temperature for the 3 h night break varies with the varieties.
2) Irradiate the plant with fluorescent light (1000-600 lx) or with incandescent light (300- 150 lx) at the top of the plant.
3) The shorter the duration of the 3 h night break treatment, the lower the occurrence of flowering and the lower the light intensity of the 3 h night break, the lower the occurrence of flowering. The duration and the light intensity of the irradiation should be determined on the basis of changes in the air temperature during the growing period of the plant and the economy of TPS production, respectively. But the initiation of the irradiation of the plant soon afer the emergence is definitely recommended.
4) The 3 h night break should be set up between 0-4 am. When the mean air temperature is approximately 20°C under a photoperiod of 10.5-11.5 h, it is preferable to change the irradiation time to 1-4 am, but when the temperature is approximately 15°C, irradiation should be applied at 0-3 am. When the conditions favor the tuberization, set up the time of the night break at 0-3 am. When the conditions do not favor the tuberization, set it up at 1-4 am.
5) The cultural practices used for table potato growing at the site, should be applied to the mother plant growing for TPS.
6) Two axillary shoots around the first or the second inflorescence can be left without pruning, if the plant and the conditions allow them to grow satisfactorily. Other axillary shoots from the lower nodes of the main vine should be removed.

Since the night break method affects the physiology of the potato plant so as to promote adequate flowering and fruiting, this method can be applied for TPS production in the countries where potatoes are grown during the cool season under short day. However, it is important to analyse the interaction between the temperature and 3 h night break effect in more detail and to examine the 3 h night break effect under longer day condition than 11.5 h. Also it is important to analyse the mechanism of the 3 h night break effect in many varieties.

It is hoped that this method will be utilized for the progress of the following areas of potato science.

Ⅰ Hybridization breeding
Ⅱ Evaluation of varieties for ecological traits and yielding capacity.
Ⅲ Studies on photosynthesis.
Ⅳ Studies on partition and translocation of photosynthates.

## Acknowledgment

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## Discussion

**Saxena, M. C.** (ICARDA) : Could you indicate whether the onset of flowering or the development of berries from flowers is more sensitive to the 3 hr night break ?

**Answer :** The effect of the 3 hr night break is certainly more pronounced on the development of the flower bud which determines the subsequent development of fruits and seeds.