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Analyses of Growth and Developmental Patterns and Subsequent Grain Yield of Selected Winter and Spring Wheat Cultivars *Triticum aestivum* L. em Thell

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春・秋播性 小麥品種들의 生育 및 收量性分析

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ABSTRACT

Five winter and five spring wheat cultivars of diverse genetic backgrounds were evaluated to examine different developmental responses in terms of stages of the life cycle and grain yield when grown under the different planting dates. Greatest difference in growth and developmental patterns of the winter and spring wheat cultivars occurred in stem elongation, booting, inflorescence emergence and anthesis. The growth stage of stem elongation was found to exhibit larger difference both among planting dates and cultivars. Winter wheat cultivars responded more than spring wheat cultivars to the different planting dates. Winter wheat 'Cho Kwang' and spring wheat 'Jugoku 81' were earlier and exhibited faster growth and development, while winter wheats 'Yamhill' and 'Hyslop' were later in growth and development, but exhibited faster grain filling and higher rate of grain filling, resulting in higher grain yields. Crosses between winter and spring wheat gene pools would result in earlier maturity and higher productivity for both winter and spring wheat cultivars. For developing early maturing wheat cultivars for multiple cropping sequences while maintaining productivity, selection for earliness trait should be started at the stem elongation stage. Furthermore, the breeding materials should be planted at several times for selection of shorter life cycle genotypes adaptable to the cropping sequences. This is due to the genotype x planting date interactions.

INTRODUCTION

Breeding for a shorter life cycle while maintaining stabilized productivity of the wheat plant is a major concern of plant breeders, especially in multiple cropping systems. Using multiple cropping, limited arable land can produce more food per unit area per year through the intensification of cropping both in time and space.

The growth cycle of the wheat plants is controlled by genetic, physiological and environmental factors. Time of heading and flowering, and length of the grain filling period from heading and/or flowering to physiological maturity appears to be important in determining duration of the life cycle and subsequent grain yield. If floral initiation begins too soon, late spring frost may cause sterility, immature and shrivelled or concaved grains. If initiated too late, the grain filling period may be

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cut short by high temperature and water stress resulting in low yield, or the harvesting time may coincide with monsoon rain in some regions.

In Korea, with increasing demands for food, wheat-rice and wheat-soybeans double cropping systems would be desirable. However, being approximately two weeks earlier in maturity, barley rather than wheat is now used in the cropping sequence.

If breeders are to develop wheat cultivars better adapted to various environmental conditions which restrict the length of the growing season, more knowledge is needed regarding genetic and environmental control of the growing cycle and especially the maturation period. Such factors as the interrelationships between time of heading, flowering, physiological maturity, and duration of grain filling period, as they influence the components of yield and grain yield, must be better understood.

The objective of the study was to examine developmental responses of genetically diverse wheat cultivars as influenced by different dates of planting with reference to the length of the maturation period and subsequently the yield components and grain yield.

MATERIALS AND METHODS

This experiment examined different developmental responses in terms of stages of the life cycle, yield components and grain yield for five winter and five spring wheat cultivars when planted at different dates.

The five winter cultivars included Yamhill, Hyslop, Young Kwang, Chang Kwang, and Cho Kwang, while Jugoku 81, Spring Luke, Twin, Pitic 62, and Lerma Rojo represented the five spring type cultivars.

All ten cultivars were planted at five dates. These included November 6, December 6, January 5, February 5 and April 1 in 1976-77. The ten cultivars planted on April 1 were vernalized in a dark room (1-4°C) from February 3 to April 1, 1977 to assure floral initiation. For comparison a second set of the same cultivars were planted at the same time, but were not artificially vernalized.

The experimental design was a split plot design with three replications. Each treatment composed of a single row. Rows were spaced 30 cm apart and were 4 m in length. Plants were sown 10 cm apart within the row. The fertilizer application was 100 kg/ha of N as 16-20-10 of the formulation N-P_2O_5-K_2O respectively during seedbed preparation. This was followed by broadcasting 46 kg/ha of N as urea at jointing stage in the spring. The experimental site was located at the Hyslop Farm of Oregon State University, Corvallis, Oregon, U.S.A.. The soil type is a woodburn silt loam. A summary of climatic data collected during the period of this experiment is presented in Table 1.

From March 29, weekly measurements were taken regarding the growth stages for each treatment until physiological maturity was reached. Measurements were recorded using the Decimal Growth Stage Code of Zadoks (1974). Replicated measurements for each treatment were averaged and rounded to the nearest whole number. Observations were based on an individual plant and included the following traits.

1. Heading date was recorded when the first spike of the plant completely emerged from the flag leaf sheath.

2. Plant height was measured in cm just before harvest from the ground surface to the tip of the tallest spike of the plant, excluding awns if present.

3. Number of tillers per plant was counted and

Table 1. Meteorological data for the 1976-77 crop years for the Hyslop Farm, Corvallis, Oregon.

Month	Precipitation mm	Average temperature, °C			Possible duration of sunshine, hours
		Max.	Min.	Mean	
October	31.8	19.1	5.1	12.1	11.0
November	36.1	13.1	3.4	8.3	9.8
December	37.3	6.4	-0.4	3.1	9.1
January	24.4	7.1	-2.3	2.4	9.5
February	75.4	12.5	1.4	7.0	10.6
March	129.3	11.4	1.4	6.4	11.9
April	25.9	17.1	3.1	10.2	13.3
May	87.1	16.5	5.3	10.9	14.5
June	28.7	23.6	8.7	16.2	15.1
July	3.1	26.0	9.5	17.8	14.8
Total	479.1				

Note: The data for Hyslop Farm were obtained from the Office of Plant Clinic, Botany and Plant Pathology Department, OSU.

included only the productive tillers bearing fertile spikes.

4. Grain yield was the total weight in grams of cleaned seeds from each plant.

5. Grain weight per spike was calculated in grams from the following formula:

$$\frac{\text{Grain Yield per Plant}}{\text{Number of Spikes per Plant}}$$

6. Date of heading was recorded as the number of days from January 1, and cultivar differences of growth and development response to date of planting were evaluated as related to life cycle and grain yield.

RESULTS AND DISCUSSION

A. Analysis of Growth and Development

Figures 1 and 2 illustrate the variations of growth and development patterns found for each of the five winter and five spring types due to the different planting dates. For all winter and spring cultivars, earlier planting resulted in earlier growth, development and earlier maturity. For example, stem elongation of winter type Yamhill was observed on May 7 when planted on November 6, 1976, but stem elongation was delayed until June 7 when planted on February 5. A similar observation was made for all cultivars with Yamhill being the most pronounced. For the spring type Jugoku 81's stem elongation was recorded on March 29 when planted on November 6, 1976, but was delayed until May 7 when planted on February 5, 1977. In both examples cited three-month delay in planting date resulted in a one month delay of stem elongation.

When planted on April 1 without artificial vernalization (VI), all winter type cultivars failed to exhibit stem elongation or spike differentiation as shown in Figure 1.

Greatest variation in growth and development patterns of the winter and spring wheat cultivars occurred in four stages, stem elongation, booting, inflorescence emergence, and anthesis as shown in Figure 3. In this figure a more detailed presentation of growth pattern of each of the cultivars is illustrated for each planting date. Prior to these stages, the cultivars in a given planting date remained equal or similar with respect to growth and development. For example, all the winter type cultivars remained equal or similar in germination, seedling growth and tillering for all dates of planting. Data collected on April 19 suggested cultivar differences in stem elongation for material planted on November 6, 1976. All the spring type cultivars exhibited a similar pattern of development with very little difference for the three early stages of growth, but differences can be observed starting with stem elongation and subsequent stages when

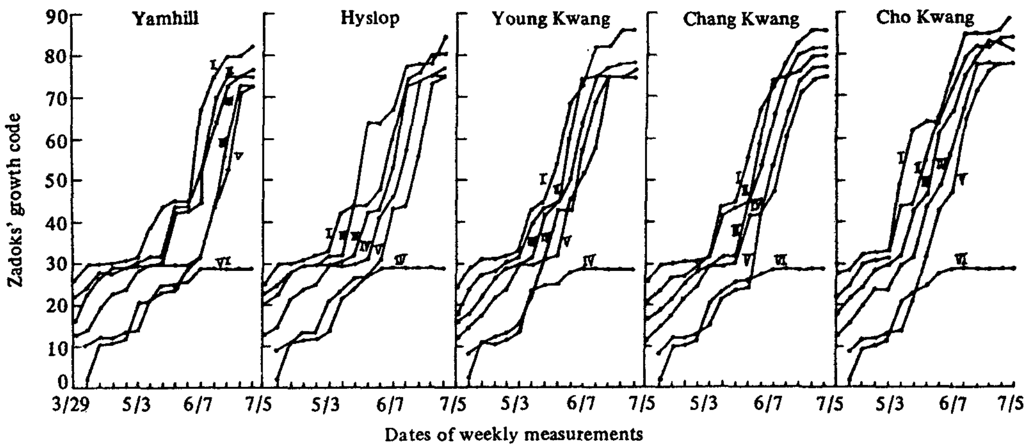

Fig. 1. Growth and developmental patterns for five winter wheat cultivars due to five different planting dates ((Nov. 6(I), Dec. 6(II), Jan. 5(III), Feb. 5(IV), April 1(V), April 1(VI, not vernalized)). Hyslop Farm, Corvallis, Oregon, 1976-77.

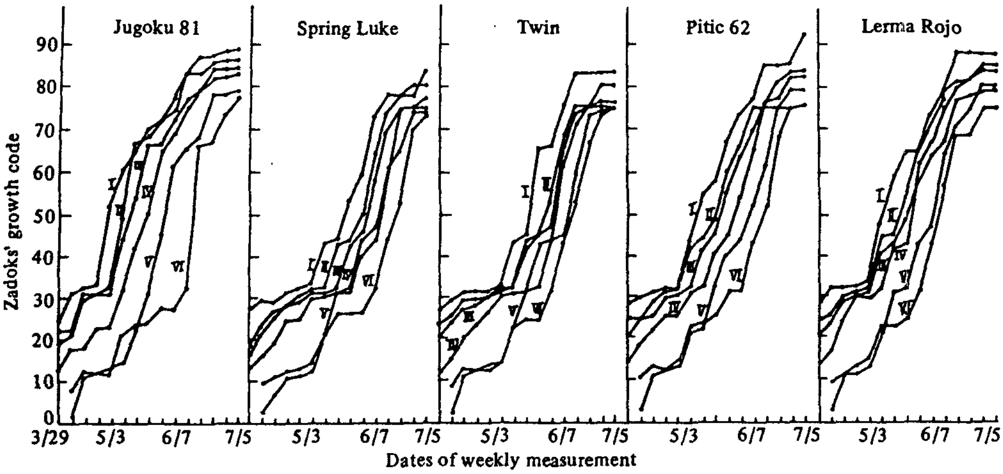

Fig. 2. Growth and developmental patterns for five spring wheat cultivars due to five different planting dates ((Nov. 6(I), Dec. 6(II), Jan. 5(III), Feb. 5(IV), April 1(V), April 1(VI, not vernalized)). Hyslop Farm, Corvallis, Oregon, 1976-77.

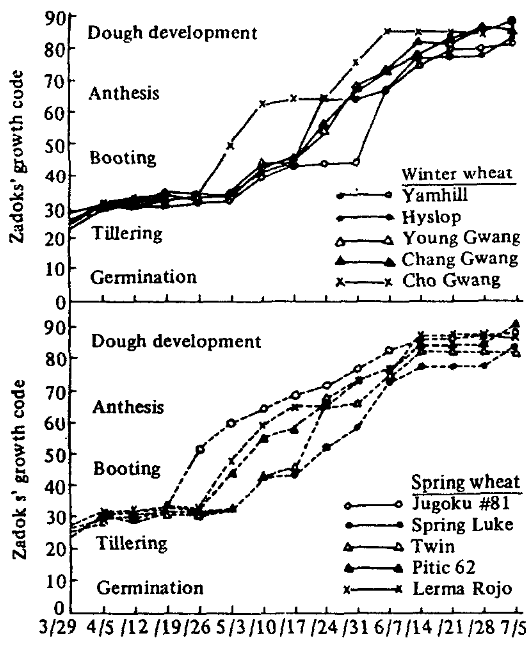

Fig. 3. Growth and development responses of winter and spring wheats planted on November 6 at the Hyslop Farm, Corvallis, Oregon, 1976-77.

measurea on the 19th of April for the same date of planting (Figure 3).

Cho Kwang, a winter type, was consistently earlier and exhibited faster growth and development when compared with other winter cultivars. While for the spring types Jugoku 81 was the earliest and grew faster when compared to the other spring type cultivars. These same two cultivars continue to be earlier under the naturally vernalized environmental conditions when planted on November 6, 1976 through February 5, 1977. At the April 1 planting date, however, Lerma Rojo was earlier and had a faster growth and developmental pattern than Jugoku 81 under the naturally vernalized conditions (Figure 4). However, under artificially vernalized environmental conditions at the same data Lerma Rojo exhibited earlier growth at the tillering stage as well.

In Table 2 the averages of length of time until stem elongation, booting, inflorescence emergence and anthesis from January 1 for five winter and five spring type wheat cultivars are presented for the five different planting dates. All growth stages were gradually later due to later planting. The largest difference in stem elongation (CDPD) was 37 days later when planted on April 1 as compared to November 6. Differences of 21, 24 and 23 days in booting, inflorescence emergence and anthesis respectively can be also noted for the same comparison in planting date. When planted on April 1, the difference in delayed growth between vernalized

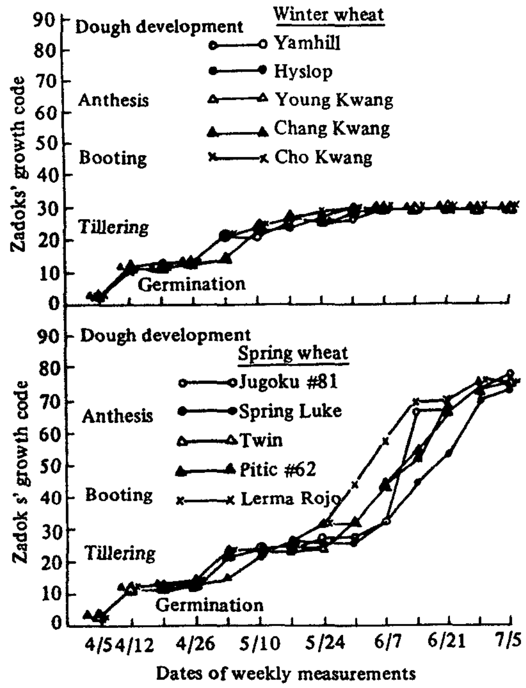

Fig. 4. Growth and developmental responses of winter and spring wheats planted on April 1 (not vernalized) at the Hyslop Farm, Corvallis, Oregon, 1977.

and unvernalized spring wheat cultivars was 14 days in stem elongation, 11 days in booting, 8 days in inflorescence emergence, and 7 days in anthesis. Therefore, stem elongation period shows the largest difference in growth and development for both winter and spring wheat plants.

Also, the later the planting date, the shorter was the stem elongation period. The average length of time from stem elongation to booting (DSEB), from booting to inflorescence emergence (DBIE), and from inflorescence emergence to anthesis (DIEA) are also summarized in Table 2. Duration from stem elongation to booting was the largest as 21 days when planted on November 6, and then was shortened gradually in accordance with later planting to 5 days when planted on April 1. Differences in durations from booting to inflorescence emergence (7 to 15 days) and from inflorescence emergence to anthesis (4 to 6 days) were relatively less with a decreased effect due to the later planting dates. Date of planting did not, therefore, have much effect on the duration from booting to anthesis.

Table 2. Average length of time to reach four stages of growth and the duration between stages for five winter and five spring type wheat cultivars as influenced by five planting dates. Hyslop Farm, Corvallis, Oregon, 1976-77. Data base on days from January 1.

Planting dates	Days to stem elongation	CDPD[1/]	Days to booting	CDPD	Days to inflorescence emergence	CDPD	Days to anthesis	CDPD	DSEB[2/]	DBIE[3/]	DIEA[4/]
November 6	103	0	124	0	134	0	140	0	21	10	6
December 6	112	9	128	4	143	9	148	8	16	15	5
January 5	120	17	138	14	147	13	151	11	18	9	4
February 5	133	30	141	17	152	18	158	18	8	11	6
April 1[5/]	140	37	145	21	158	24	163	23	5	13	5
April 1[6/] Vernalized	136	0	145	0	155	0	160	0	0	10	5
April 1[6/] Not vernalized	150	14	156	11	163	8	167	7	6	7	4

1/ CDPD = Cumulative difference among planting dates, 3/ DBIE = Duration from booting to inflorescence emergence,
2/ DSEB = Duration from stem elongation to booting, 4/ DIEA = Duration from inflorescence emergence to anthesis.
5/ All the winter and spring wheat cultivars were included and artificially vernalized.
6/ Only all the spring wheat cultivars were included.

B. Genotype x Environment Interactions

The heading date of the cultivars in each planting date appears in Figure 5. When considered as the number of days from January 1 for the winter wheats, there were large variations both among the planting dates and within cultivars. Cho Kwang was consistently earlier in heading than the other

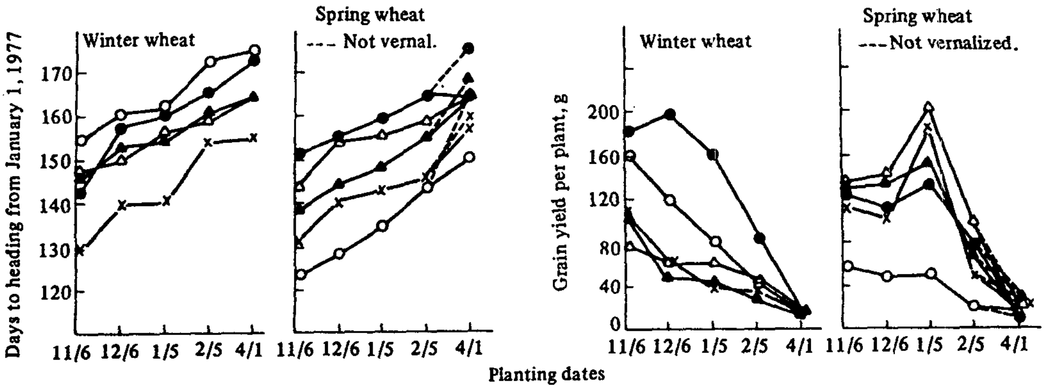

Fig. 5. Response of days to heading and grain yield of five winter and five spring type wheat cultivars to five different planting dates. Hyslop Farm, Corvallis, Oregon, 1976-77.

Winter wheat : Yamhill ○ Hyslop ● Young Kwang △ Chang Kwang ▲ Cho Kwang x

Spring wheat : Jugoku #81 ○ Spring Luke ● Twin △ Pitic #62 ▲ Lerma Rojo x

cultivars with Yamhill being the last to head. In spring wheats, Jugoku 81 was consistently earlier in heading than the other cultivars under the vernalized conditions, but Lerma Rojo was the earlier headed under the nonvernalized condition when planted on April 1 suggesting a different genotype response as the result of the cold treatment. The material ranges from the earliest heading date of 123 days for Jugoku 81 to 175 days for Spring Luke and Yamhill, or 52 days difference due to the different planting dates between cultivars.

Grain yields for the winter cultivars were highest in the first planting date with the exception of Hyslop which had maximum yields in the second date of planting (Figure 5). Grain yields decreased with later planting dates except for a slight variation occurring in Young Kwang when the January 5 planting date is compared with December 6. The spring wheat cultivars achieved their highest yields in the third planting date, and second highest yields were achieved in the first planting date. An exception to this was Jugoku 81 which yielded more from the first planting date (November 6).

Mean values, standard deviations and coefficients of variation for the ten cultivars due to the different planting dates are shown in Table 3. The smallest variation for both winter and spring cultivars was noted for days to heading. The greatest variation for all cultivars was noted for grain yield and grain weight per spike. Tiller number per plant and plant height were intermediate.

In summary the results of this study suggest that

Table 3. Mean values, standard deviations and coefficients of variation for five characters involving five winter and five spring wheat cultivars planted at five dates. Hyslop Farm, Corvallis, Oregon, 1976-77.

Planting dates	Heading date						Grain yield, g/plant					
	Winter type			Spring type			Winter type			Spring type		
	Mean	S	CV	Mean	S	CV	Mean	S	CV	Mean	S	CV
11/06	144.0	9.49	6.59	137.2	10.78	7.86	126.0	44.01	34.93	110.8	30.94	27.92
12/06	152.4	8.14	5.34	144.2	11.10	7.70	96.8	63.09	65.18	105.0	35.87	34.16
01/05	155.0	8.40	5.42	147.8	9.89	6.69	77.2	49.25	63.79	144.0	58.54	40.65
02/05	162.6	7.24	4.45	153.0	8.86	5.79	45.8	20.90	45.63	62.0	29.81	40.08
04/01 1/	166.2	8.04	4.84	159.8	6.26	3.92	15.6	1.52	9.72	17.2	3.13	18.18
04/01	–	–	–	166.8	5.84	3.50	–	–	–	21.6	8.26	38.26

1/ Vernalized in the dark room (1-4°C) from February 3 to planting date April 1, 1977.

for developing early maturing wheat cultivars for multiple cropping sequences while maintaining productivity, selection for earliness trait should be started at the stem elongation stage. It was at this stage that the greatest variability occurred for both the winter and spring wheat cultivars when measured across planting dates. Furthermore, the breeding materials should be planted at several times for selection of shorter life cycle genotypes adaptable to the cropping sequences. This is due to the genotype x planting date interactions.

SUMMARY AND CONCLUSIONS

The objective of this study was to examine different developmental responses in terms of stages of the life cycle, yield components and grain yield for winter and spring wheat cultivars when grown under the different planting dates.

The results and conclusions from this investigation are summarized as follows:

1. Greatest difference in growth and development patterns of the winter and spring wheat cultivars occurred in stem elongation, booting, inflorescence emergence and anthesis.

2. The growth stage of stem elongation was found to exhibit larger difference both among planting dates and cultivars.

3. Winter wheat cultivars responded more than spring wheat cultivars to the different planting dates. Variations between cultivars and between different planting dates were less for heading date, and greatest for grain yield and grain weight per spike, while being intermediate for tillers per plant and plant height.

4. Winter wheat Cho Kwang and spring wheat Jugoku 81 were earlier and exhibited faster growth and development, while winter cultivars Yamhill and Hyslop were later in growth and development, but exhibited faster grain filling and higher rate of grain filling, resulting in higher grain yields.

5. Combination of a new cultivar and optimum planting date would result in earlier maturity and higher productivity for both winter and spring wheat cultivars.

6. Crosses between winter and spring type gene pools would result in earlier maturity and higher productivity for both winter and spring wheat cultivars. When selecting for early maturity types with acceptable productivity, it would be desirable to plant segregating population at several different times, and to select superior individual plants adaptable to a given breeding site from stem elongation period.

摘　　要

벼－밀, 밀－콩 또는 밀－참깨 작부체계에 알맞는 밀품종 육성을 위한 육종 전략수립에 기초정보를 제공하기 위하여 육성배경, 유전 및 생태적 특성이 상이한 추•춘파성 소맥 10품종을 1개월 간격으로 5회 파종하였다.

Zadoks 등(1974)의 Growth Siage Code를 이용하여 이 품종들의 생장단계별 기간 및 수량성에 대하여 비교 분석하였다. 본 시험은 미국 오레곤주 주립대학교에서 실시되었으며 그 결과의 개요는 다음과 같다.

1. 추파성품종 조광과 춘파성 품종 중국81호는 간신장기에서 출수기까지의 기간이 짧았으나 등숙기간이 길었다. 추파성품종 Yamhill과 Hyslop은 간신장기에서 출수기까지의 기간이 긴 반면 등숙기간이 짧고 종실수량이 높았다.

2. 추파성품종이 춘파성품종에 비하여 환경변이에 대한 반응이 컸고 품종×환경 상호작용이 있어 파종기에 대한 추•춘파성 품종들의 반응도 크게 달랐다.

3. 간신장기에서 시작하여 성숙기까지 춘•추파성 품종간에 큰 차이가 있었다. 특히 간신장기는 파종기 및 품종간에 가장 큰 차이를 나타냈다.

4. 따라서 추•춘파성 품종간 교배에 의하여 조숙다수성 품종 육성이 가능하고 이모작재배에 알맞는 우량개체 및 계통 선발을 위하여 분리집단을 2～3회 파종하고 개체 선발을 간신장기부터 시작하는 것이 선발효율을 높일 수 있을 뿐만 아니라 육성지역의 작부시기에 알맞는 개체 및 계통을 선발할 수 있을 것이다.

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