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# COMPARATIVE STUDIES ON THE DEVELOPMENT OF SPIKE PRIMORDIA BETWEEN CULTIVARS OF COMMON WHEAT AND BARLEY

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A new wheat variety with a little earlier maturity has long been desired by the farmers in western and central Japan. The main reasons are to escape damage by rain through early harvest of wheat prior to the rainy season which usually sets in early to mid-June in these districts, and also to cope with the recent trend of earlier planting of rice which is generally practical soon after the winter cereal crops.

Since there are no domestic wheat varieties so early as to be comparable to the earliest barley varieties, considerable efforts have been devoted to obtain wheat varieties with a useful earliness gene in Japan and the foreign countries, but the efforts have not been rewarded as yet. In these circumstances, information concerning the heading behavior of wheat plant in comparison with that of barley plant might be useful for the breeding of earlier wheat varieties, because in general barley ripens much earlier than wheat. Thus, a comparative study was made on the growth and development of shoot apex and ear primordia of wheat and barley in relation to spring and winter habit, under more or less controlled environmental conditions. The results obtained will be presented in this paper.

## MATERIALS AND METHODS

Four experiments were performed using two groups of wheat and barley varieties. Table 1A shows the first group, used in the first three experiments, consisting of six wheat and six barley varieties differing in the grades of spring and winter habit or in requirement of cold treatment for vernalization. The grades were: I (highly spring), II (moderately spring), III (moderately winter) . . . and VI (pure winter). The second group of materials consisting of six wheat and six barley varieties, all with a highly spring habit, were used in Experiment 4 (Table 1B).

These materials were grown under various conditions, such as in the greenhouse, open field or under these two conditions in combination. The air temperature in the greenhouse was maintained at 15°C or somewhat

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TABLE 1. Materials

A. Materials used for Experiments 1, 2 and 3

| Grade of* growth habit | Common wheat | | Barley | |
|---|---|---|---|---|
| | Name | Earliness | Name | Earliness |
| I | Konosu 25 | Very early | Indo Omugi (OUJ 694)** | Very early |
| II | Shinchunaga | Early | Marumi 16 (OUJ 007) | Mid-season |
| III | Norin 25 | Early | Kamaore 1 (OUJ 092) | Mid-season |
| IV | Tokorozawa | Late | Hayakiso 2 (OUJ 064) | Early |
| V | Nishimura | Late | Nagaoka (OUJ 025) | Late |
| VI | Yokozawa | Very late | Iwate Omugi 1 (OUJ 608) | Very late |

* I: highly spring, VI: pure winter.

B. Materials used for Experiment 4 (Spring type cultivars)

| Common wheat | | Barley | |
|---|---|---|---|
| Name | Earliness | Name | Earliness |
| Konosu 25 | Very early | Kinai 5 (OUJ 493)** | Very early |
| Saitama 27 | Very early | Indo Omugi (OUJ 694) | Very early |
| Go 2 | Mid-season | Shokubimugi (OUK 420) | Very early |
| Hayame-haikara | Mid-season | Natsudaikon Mugi (OUK 735) | Mid-season |
| Italy 64 | Very late | Sachsender (OUU 333) | Mid-season |
| Russian 25 | Very late | Mensury C (OUJ 732) | Very late |

** Identification code and registration number of Barley Germplasm Center, Okayama University.

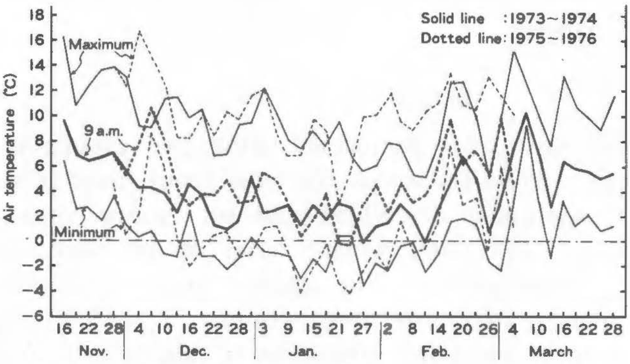


FIG. 1. Changes in average 3-day temperature in an open field during two growing seasons of wheat and barley.

higher during the experimental period. Fig. 1 shows the air temperature during the growing period at two different seasons. Details of the experimental methods employed will be given in each section.

Table 2 shows the criterion for the stages of differentiation or development of the shoot apex in wheat and barley. This was principally

TABLE 2. Criteria for determining and describing stages of differentiation or development of shoot apex in common wheat and barley*

| Stage | States of shoot apex |
|---|---|
| 1 | Differentiation of leaf primordia |
| 2 | Beginning of spike primordia differentiation |
| 3 | Early stage of bract differentiation |
| 4 | Middle stage of bract differentiation |
| 5 | Late stage of bract differentiation |
| 6 | Early stage of spikelet differentiation |
| 7 | Middle stage of spikelet differentiation or double ridge stage |
| 8 | Late stage of spikelet differentiation |
| 9 | Early stage of floret development |
| 10 | Late stage of floret development |

* After Suetsugu (1949a) and Inamura *et al.* (1955).

based on Inamura's standard (1955) which was a modification of the criterion proposed by Wada (1936) and Suetsugu (1949a). It should be noted that stage 7 in this report corresponds to stage 3 described by Nerson *et al.* (1980).

## RESULTS

### 1. *Development of Shoot-Apex in Relation to the Grade of Spring and Winter Habit* (*Experiment* 1)

The first experiment was performed to elucidate the relationship between the spring and winter habits and the development of the shoot apex of the wheat and barley varieties when they were grown without cold pretreatment under long-day and high-temperature condition.

The twelve wheat and barley cultivars shown in Table 1A were used in this experiment. Seeds were sown in a metal box 37 cm long, 55 cm wide and 12 cm high, filled with garden soil, at a density of 50 seeds per box. They were grown under 24-h photoperiod in the greenhouse. Ten samples of each cultivar were taken once a week after sowing, and they were dissected to determine the developmental stage of the shoot apex and the length of the stem internodes.

Fig. 2 shows the weekly change in the developmental stage of the shoot apices of six cultivars each of wheat and barley. It is apparent from this figure (left) that the two barley cultivars (A and B), both with the highest spring habit (grade 1), reached the double-ridge or 7th stage within two weeks after sowing. In the cultivars with a grade of II or lower spring habit, the shoot apices also developed uniformly

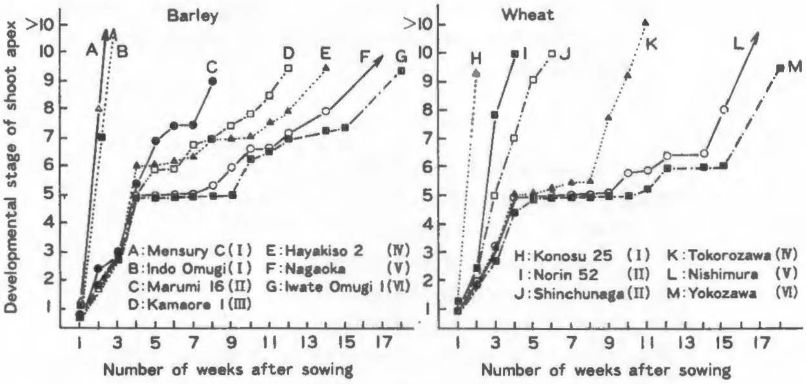


FIG. 2. Weekly changes in developmental stage of shoot apex in wheat and barley cultivars grown under 24-h photoperiod at a high temperature. Roman numerals in parenthesis represent the grades of spring and winter habit.

up to the 5th stage (later stage of bract differentiation), but the development was retarded thereafter, the developmental rate being lower the lower the grade of the winter habit of the variety.

In the wheat cultivars with a grade I or II habit, the shoot apices developed almost similarly to those of barley varieties with the same spring habit, and the shoot apices of the cultivers with a grade IV or lower reached the 5th stage about one or two weeks later than those of the cultivars with a higher spring habit. However, the shoot apices of the latter varieties stopped further development, and those of the cultivars with a grade of IV, V and VI resumed development 9, 15 and 16 weeks after sowing, respectively. This behavior is characteristic to wheat cultivars, and much different from that of barley cultivars.

Next, the relationship between stem elongation and the development of spike primordia was examined, in which measurment of the stem length was made about the same plants as those investigated for the shoot apex development. The results are shown in Fig. 3.

Both wheat and barley varieties with a highly spring habit (grade I) began stem internode elongation one week after sowing, and their stem lengths increased rapidly thereafter. In winter varieties with a grade of III or lower habit, on the other hand, stem internodes began to elongate 4~11 weeks after sowing, a great difference in the time of elongation being observed between wheat and barley. The rate of stem elongation of the barley varieties was very low until about 10 weeks after sowing, after which it increased rapidly except for Iwate Omugi 1 which elongated only slightly even 17 weeks after sowing. On the other hand, the elongation rates of the wheat varieties increased rapidly soon

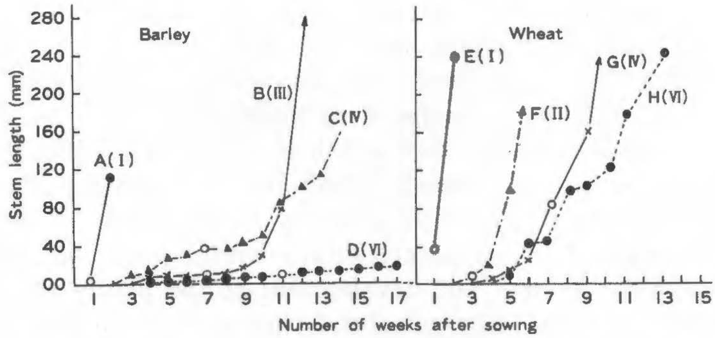


FIG. 3. Weekly changes in stem length of wheat and barley cultivars. White circles represent the 7th stage (spikelet initiation). Roman numerals in parenthesis represent the grades of spring and winter habit.

A: Indo Omugi, B: Kamaore 1, C: Hayakiso 2, D: Iwate Omugi 1, E: Konosu 25, F: Shinchunaga, G: Tokorozawa, H: Yokozawa.

after their stems began to elongate. The elongation of stem internode began at 5th to 6th stage of shoot apex development in barley varieties and at the 5th stage in wheat varieties. At the double ridge stage (7th stage), that is, at the initial stage of spike initiation, the stems of the wheat varieties were 10 cm or longer. A variety, Yokozawa, having a highly winter habit had stems as long as 30 cm before its shoot apex reached the 7th stage.

From the results of this experiment, it is concluded that under such conditions as long days at a high temperature without cold pretreatment, spike development of wheat and barley does not necessarily occur at the time when the stem elongates; under this growing condition, the stem internodes elongated before spike initiation, the tendency of which was more evident in wheat than in barley.

## 2. *Critical Date of the Completion of Vernalization in Wheat and Barley Sown Outdoors in Fall (Experiment* 2)

Experiment 2 was designed to determine the critical date when vernalization was completed under natural conditions at Kurashiki in varieties of wheat and barley with different grades of winter habit. The varieties and methods of growing the plants were the same as described for Experiment 1. The seeds were sown in boxes on November 15 which was the standard or conventional sowing date at Kurashiki, and all the boxes were placed in the open field. The boxes were then moved one by one to the greenhouse every 10 days and subjected to continuous illumination until flag-leaf emergence on the main stem. As already shown in Fig. 1, the air temperature in the field at 9 a. m. after mid-November was below 10°C, and from December to mid-February about 4°C, the daily minimum temperature being below 2°C in December. Needless to say, the natural day length is very short during this season. It is therefore natural to consider that the low temperature as such, accompanied by short days in this season at Kurashiki, is sufficient to vernalize wheat and barley plants with a winter habit, but at the same time it delays the growth and development of the plants with a spring habit and that of these fully vernalized plants. Accordingly, the critical date of complete vernalization was determined by comparing the number of leaves to flag on the main stems of the plants moved from the open field into the greenhouse on different days and exposed to long days. That is, the earliest date when the transfer on the day of which caused the develoment of the minimum number of leaves to flag was regarded as the date of completion of vernalization.

As some examples, Fig. 4 shows the changes in leaf-number on the main stem of four varieties of wheat and barley with a highly spring or a highly winter habit, when 10 plants of each variety were brought

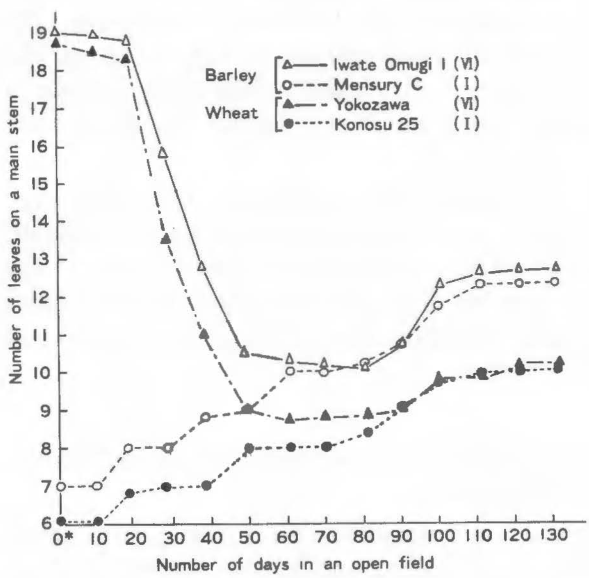


FIG. 4. Number of days from sowing in an open field to transfer into a greenhouse (growing period under low temperature), and number of leaves on the main stem at the time of flag leaf emergence in a greenhouse. Roman numerals in parenthesis represent the grades of spring and winter habit.

*: Grown only in a greenhouse.

into the greenhouse every 10 days. Clearly, both of the wheat and barley varieties with a highly spring habit developed minimal number of leaves when transferred into the greenhouse immediately or 10 days after sowing. These varieties developed on additional number of leaves the longer they were left in the open field. On the other hand, the varieties of both wheat and barley with a highly winter habit had fewer leaves the longer they were kept in the open field up to 60~80 days. The number of leaves increased gradually when the plants were kept in the open field for more than 90 days. The date on which vernalization was completed in all the wheat and barley varieties tested was shown in Table 3.

TABLE 3. The date on which vernalization of wheat and barley cultivars sown outdoors on November 15 was completed

| Name | Common wheat | | | Name | Barley | | |
|---|---|---|---|---|---|---|---|
| | Grade of growth habit | Completion of vernal. | No. of leaves | | Grade of growth habit | Completion of vernal. | No. of leaves |
| Konosu 25 | I | | 6.0 | Indo Omugi | I | | 7.0 |
| Shinchunaga | II | Dec. 5 | 7.0 | Mensury C | II | | 7.0 |
| Norin 52 | III | Dec. 15 | 7.0 | Kamaore 1 | III | Dec. 15 | 7.0 |
| Tokorozawa | IV | Jan. 5 | 8.0 | Hayakiso 2 | IV | Jan. 5 | 7.8 |
| Nishimura | V | Jan. 5 | 8.0 | Nagaoka | V | Jan. 16 | 9.0 |
| Yokozawa | VI | Jan. 25 | 8.8 | Iwate Omugi 1 | VI | Feb. 5 | 10.0 |

When sown on November 15 at Kurashiki, wheat and barley varieties with a grade III of growth habit were fully vernalized on around December 15, and those with a grade IV were fully vernalized on around January 5. As to the varieties with a grade V or VI, the critical date of complete vernalization was somewhat later in barley than in wheat. This may have been caused by the long interval between one transfer and the next transfer, i. e. 10 days.

### 3. *Development of Shoot Apices of Wheat and Barley Varieties Sown in Fall (Experiment* 3)

In Experiment 3, the developmental courses of shoot apices or ear primordia of wheat and barley varieties with various grades of spring and winter habit were investigated after they were sown in fall at Kurashiki (Table 1A). The materials and methods of sowing were the same as those used in Experiment 2. The seeds were sown on November 15 and grown in an open field. Six plants from each variety were sampled every 10 days on the same day as the plants in Experiment 2 were moved from the open field into the greenhouse.

In barley, as shown in Fig. 5, the elongation of the shoot apex began in mid-December, followed by rapid differentiation, and most of the varieties tested attained to the early stage of spikelet development (6th stage) in mid-January, though Indo Omugi with a highly spring habit was already at the middle stage of spikelet development (7th stage). After this, however, the development of the shoot apex was retarded or interrupted for about one month, and after which it continued vigorously (late-February~early-March).

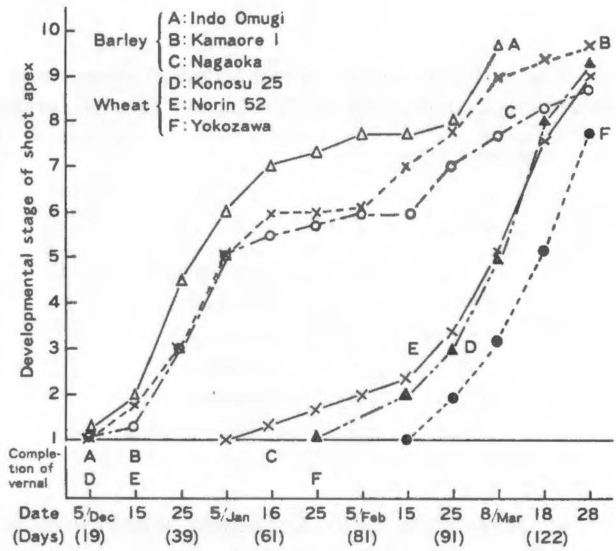


FIG. 5. Development of shoot apex in wheat and barley cultivars when sown outdoors in fall at Kurashiki, and the date vernalization was completed.

In wheat plants, regardless of the variety, the shoot apex started to elongate between late-January and mid-February, which was later than the time when elongation started in barley plants. However, the shoot apices of the wheat plants differentiated successively, and they were at the middle stage of spikelet development (7th stage) in mid- to late-March. In both wheat and barley, no relation has been found between the progress of shoot apex differentiation and the critical time of completion of vernalization. It can be safely said, therefore, that in Kurashiki, spike primordia differentiation of wheat and barley plants sown in fall is not affected by the grades of their growth habits.

## 4. *Effects of Short-Day and Low-Temperature on the Development of the Shoot Apex (Experiment* 4)

Experiment 3 (foregoing experiment) could not clearly demonstrate whether the differences in shoot apex development between wheat and barley plants are attributable to the effect of either short-day or low-temperature prevailing in the winter months. Therefore, the fourth experiment was designed to elucidate this point. The materials used are listed in Table 1B. The methods by which these materials were sown and sampled were the same as those in Experiment 1.

Fig. 6 shows the weekly changes in shoot apex development of three each of wheat and barley varieties which were grown under 12-h photoperiod in the greenhouse (17~23°C). The change in the shoot apex development of the barley variety, Kinai 5, was quite similar to that of the wheat variety, Konosu 25, that of Shokubimugi barley was to that

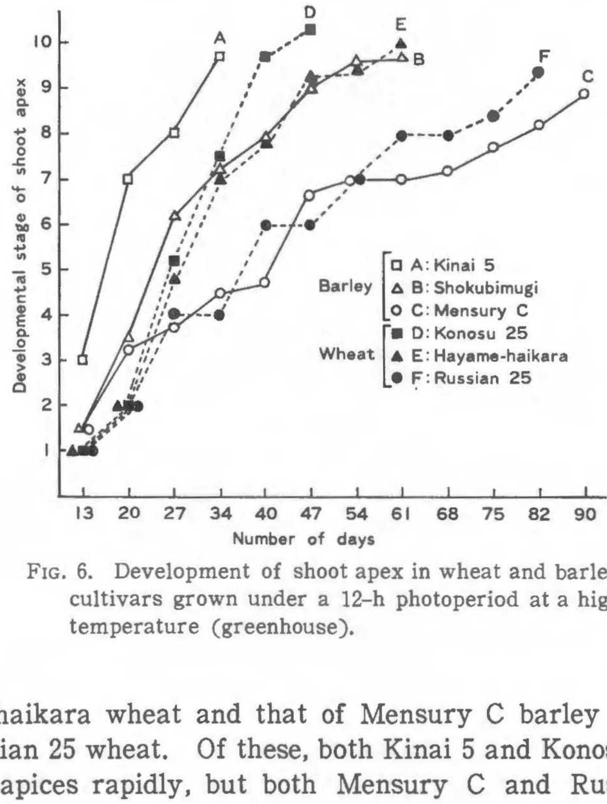


FIG. 6. Development of shoot apex in wheat and barley cultivars grown under a 12-h photoperiod at a high temperature (greenhouse).

of Hayame-haikara wheat and that of Mensury C barley was similar to that of Russian 25 wheat. Of these, both Kinai 5 and Konosu 25 developed their shoot apices rapidly, but both Mensury C and Russian 25 much retarded. Other varieties of barley and wheat also showed almost the same development of the shoot apex as the varieties mentioned above. Thus, it may be said that, when grown under short days at a high temperature, there is little difference between wheat and barley in their shoot apex development, but the varietal difference within each crop is much larger.

Wheat and barley plants, on the other hand, behaved quite differently when grown under long days at low temperature. Fig. 7 illustrates the changes in shoot apex development in three each of wheat and barley varieties with a highly spring habit. As seen in this figure, the wheat varieties did not show any significant change in size or form of shoot apex during the first 45~60 days after sowing, but within about 10 days after that date the shoot apices abruptly developed up to the 7th stage, and during the subsequent 3 weeks they reached the 10th stage, whereas the shoot apices of all the barley varieties began to develop as early as 13 days after sowing and reached the 7th stage within the subsequent 30~40 days.

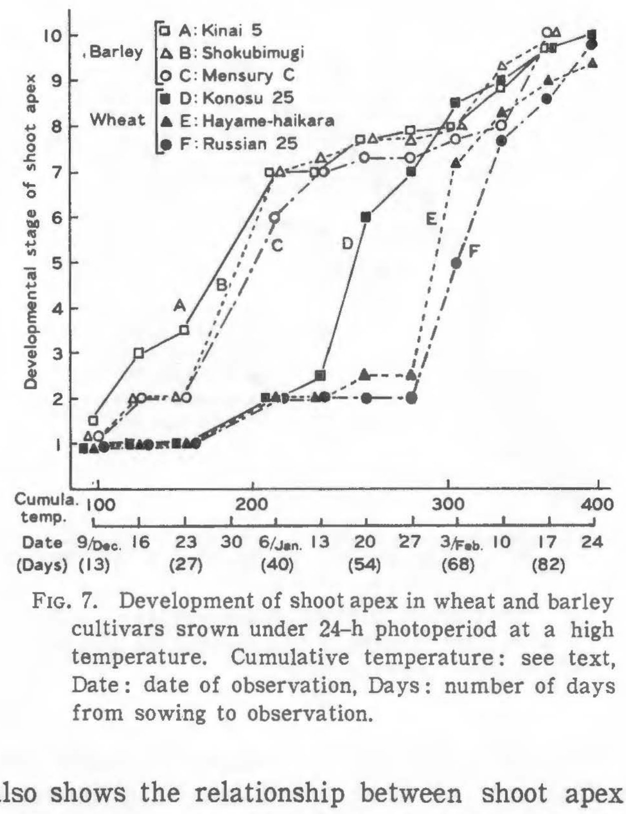


FIG. 7. Development of shoot apex in wheat and barley cultivars srown under 24-h photoperiod at a high temperature. Cumulative temperature: see text, Date: date of observation, Days: number of days from sowing to observation.

Fig. 7 also shows the relationship between shoot apex development and the cumulative temperature which is the sum of the daily temperature upper than 5°C at 9 a. m. during the growth period from early-December to late-February. Shoot apex development in wheat varieties progressed rapidly when the cumulative temperature exceeded 250°. In barley varieties, on the other hand, rapid differentiation of shoot apex occurred when the cumulative temperature was about 150°.

Weekly changes in stem and spike elongation of wheat and barley plants, which have been investigated under both short days at a high temperature and long days at a low temperature, will next be stated. In Experiment 1, the stem internodes of the wheat varieties grown at

TABLE 4. Stem lengths and lengths of shoot apices of spring wheat and spring barley cultivars grown under short days at a high temperature and under long days at a low temperature

| Crop | Name | Short day at high temperature | | | Long day at low temperature | | |
|---|---|---|---|---|---|---|---|
| | | Date of 7th stage* | Stem length** $\bar{x} \pm s$ | Shoot apex length $\bar{x} \pm s$ | Date of 7th stage* | Stem length** $\bar{x} \pm s$ | Shoot apex length $\bar{x} \pm s$ |
| | | | mm | mm | | mm | mm |
| Wheat | Konosu 25 | Dec. 29 | 5.5±0.68 | 1.5±0.06 | Jan. 27 | 7.2±0.21 | 1.2±0.03 |
| | Saitama 27 | Dec. 29 | 4.7±0.67 | 1.7±0.04 | Feb. 3 | 7.0±0.65 | 1.3±0.06 |
| | Go 2 | Dec. 29 | 5.2±0.61 | 1.3±0.11 | Feb. 3 | 11.6±1.20 | 1.7±0.09 |
| | Hayame-haikara | Dec. 29 | 4.0±0.54 | 1.1±0.11 | Feb. 3 | 4.7±0.18 | 1.3±0.21 |
| | Italy 64 | Jan. 20 | 24.5±2.57 | 1.7±0.21 | Jan. 27 | 8.2±0.45 | 1.1±0.04 |
| | Russian 25 | Jan. 20 | 37.8±2.25 | 1.5±0.10 | Feb. 10 | 15.3±1.12 | 1.4±0.15 |
| Barley | Kinai 5 | Dec. 16 | 0.9±0.02 | 1.0±0.09 | Jan. 6 | 4.5±0.44 | 1.0±0.09 |
| | Indo Omugi | Dec. 29 | 3.9±0.16 | 1.7±0.03 | Jan. 6 | 4.2±0.22 | 1.0±0.10 |
| | Shokubimugi | Dec. 29 | 3.3±0.36 | 1.3±0.12 | Jan. 6 | 4.0±0.61 | 1.0±0.11 |
| | Natsudaikon Mugi | Dec. 29 | 3.6±0.20 | 1.1±0.09 | Jan. 6 | 3.3±0.20 | 1.2±0.18 |
| | Sacksender | Dec. 29 | 5.6±1.14 | 1.5±0.11 | Jan. 6 | 4.8±0.62 | 1.0±0.07 |
| | Mensury C | Jan. 13 | 5.3±0.53 | 1.0±0.08 | Jan. 20 | 4.2±0.25 | 1.4±0.17 |

* Differentiation of shoot apex reached the 7th stage (spikelet initiation).

** Stem length less than 6 mm was not regarded as substantial stem internode elongation.

a high temperature began to elongate before complete conversion from winter growth habit to spring. In Experiment 4, the relationship between stem internode elongation and spikelet initiation in spring varieties was examined.

Table 4 shows the mean values of stem and spike length at the 7th or double ridge stage, though the values less than 6 mm in stem length were not regarded as substantial elongation of stem internodes. As shown in Table 4, none of the barley varieties started stem internode elongation at the 7th stage if they were grown under either short days at a high temperature or long days at a low temperature. On the other hand, the stems of the wheat plants more or less elongated before attaining the 7th stage, and the elongation was especially evident in Italy 64 and Russian 25 grown under short days at a high temperature and also in Italy 64 and Go 2 grown under long days at a low temperature.

As to spike length, there were no differences between wheat and barley plants. Weekly measurements of stem and spike elongation in wheat and barley plants gave parabola curves. Thus the regression coefficients of stem and spike lengths on number of days after sowing and also on cumulative air temperature in long days at a low temperature were calculated using a logarithmic scale. As shown in Table 5, the

TABLE 5. Regression coefficients of stem length (log.) and young spike length (log.) on the number of days after sowing and cumulative temperature for growth period*

| Crop | Name | Stem length | | | Young spike length | | |
|---|---|---|---|---|---|---|---|
| | | Short day high temp. | Long day low temp. | | Short day high temp. | Long day low temp. | |
| | | Days | Days | Cumu. temp. | Days | Days | cumu. temp. |
| Wheat | Konosu 25 | 4.58 | 2.76 | 0.733 | 4.71 | 2.15 | 0.584 |
| | Saitama 27 | 4.48 | 2.39 | 0.650 | 4.26 | 1.85 | 0.500 |
| | Go 2 | 4.43 | 2.44 | 0.652 | 3.90 | 1.92 | 0.517 |
| | Hayame-haikara | 4.62 | 1.84 | 0.500 | 3.67 | 1.84 | 0.493 |
| | Italy 64 | 4.05 | 2.42 | 0.649 | 1.62 | 1.77 | 0.469 |
| | Russian 25 | 3.98 | 2.51 | 0.666 | 1.36 | 1.70 | 0.447 |
| | (Mean) | (4.36) | (2.39) | (0.642) | (3.25) | (1.87) | (0.502) |
| Barley | Kinai 5 | 5.67 | 1.76 | 0.566 | 4.25 | 1.53 | 0.446 |
| | Indo Omugi | 4.56 | 2.65 | 0.825 | 4.09 | 1.83 | 0.539 |
| | Shokubimugi | 4.33 | 2.67 | 0.819 | 2.04 | 1.85 | 0.541 |
| | Natsudaikon Mugi | 4.36 | 2.36 | 0.720 | 1.76 | 1.81 | 0.534 |
| | Sacksender | 3.93 | 2.22 | 0.702 | 1.84 | 1.62 | 0.477 |
| | Mensury C | 1.23 | 1.98 | 0.630 | 1.22 | 1.73 | 0.510 |
| | (Mean) | (4.01) | (2.27) | (0.710) | (2.53) | (1.73) | (0.508) |

* Regression coefficients were represented by the scale ($\times 10^{-2}$).

rate of increase in stem and spike length, represented by regression coefficients, differed among varieties. These varietal differences were rather larger than the differences between wheat and barley, indicating there is no difference in the rate of increase in stem and spike length at an early stage of growth between wheat and barley.

## DISCUSSION

Various basic problems concerning the earliness and its related internal factors of barley and wheat plants have been studied previously by Yasuda and co-workers, mostly from physiological and genetical viewpoints under controlled conditions. In the present study made from ecological viewpoint, the relationship between earliness under natural environments and ear differentiation was chiefly analyzed using wheat and barley cultivars. The shoot apex of barley sown outdoors in fall at Kurashiki began to develop before completion of vernalization, whereas that of wheat began to develop 20 days or more after completion of vernalization (Fig. 5). This implies that wheat plants require a relatively higher temperature than barley for development to spike initiation from shoot apex development, indicating that the low temperature in the field is a limiting factor for spike initiation of wheat plants in early spring. In fact, in the Tohoku district wheat varieties with a pure winter habit do not begin spike initiation until the end of the winter cold even after completion of vernalization (Goto, 1975).

Another difference between wheat and barley sown in fall is in the process of shoot apex development. Namely, in barley, the shoot apex developed quickly at an early stage. The speed of development decreased once at around the stage of spikelet initiation (6th～7th stages) and then increased again until completion of the spike formation. On the other hand, shoot apex development of wheat progressed slowly at an early stage, and gradually progressed faster until spike formation. In other words, wheat varieties do not have a lag phase in the course of spike development, which is different from barley varieties. These differences in shoot apex development between barley and wheat were evident when the seeds were sown outdoors in fall or the seedlings were exposed to a low temperature, but not when they were grown at a high temperature. This may indicate that there is a marked difference between wheat and barley varieties in shoot apex development at a low temperature.

It has generally been believed that the stem internodes of wheat and barley elongate along with the spike formation. Findings supporting a close relationship between these two morphogenetic processes have already been reported (Yasuda and Takahashi, 1954). In the present study, however, the plants grown under long days at a high temperature set about elongation of their stem internodes before completion of vernalization and shoot apex development. Furthermore, the stem internodes of wheat plants with a spring habit started to elongate before reaching the double ridge stage (7th stage) when they were grown under short days at a high temperature. These facts may imply that if the growth condition is maintained at a high temperature the plants can start stem internode elongation, in spite of incomplete vernalization and short day conditions which are unfavorable for spike initiation. It is conceivable that the main external limiting factor for stem elongation is air temperature in contrast to the case of spike initiation for which air temperature and day length are both effective. This is more evident in wheat than in barley. Suetsugu (1949b), who investigated many wheat cultivars in the Kyushu and Hokuriku districts, pointed out that the relationship between the time of spike initiation and the beginning of stem internode elongation differed with the place and also with the season of growth. Accordingly, the results obtained in the present study support Suetsugu's view.

Finally, possibility of breeding wheat cultivars which maturate as early as the early-maturing barley cultivars will be discussed. Early ripening of wheat cultivars seems to be achieved by accelerating the initiation of the spike primordia which is followed by heading and flowering. The present study, however, indicates that the beginning of differentiation of spike primordia in shoot apices is markedly later in wheat than in barley when the plant is grown at a low temperature. Therefore, it can not be expected to accelerate the initiation of spike primordia in wheat cultivars sown in fall though there is some difference from variety to variety.

Another way to accelerate maturity is to hasten the time of heading and of flowering after initiation of spike primordia under natural conditions. To prevent injury by the cold in early spring, breeding by such method as retarding the jointing stage is now being done in the areas of central and south western Japan where warm spring weather comes later. This is to use the physiological characters peculiar to wheat; that is, development after initiation of spike primordia is faster in wheat than in barley. However, the problem that the first spike primordia appear clearly later in wheat cultivars remains.

Judging from these results, early maturity in wheat may be achieved by accelerating each stage of growth and development, and not by accelerating one stage alone.

## SUMMARY

The aim of this study was to obtain some fundamental knowledge to breed early maturing common wheat cultivars, comparing the course of shoot apex development for spike formation between wheat and barley. Four experiments were performed using common wheat and barley cultivars. The results obtained are as follows:

1) The relationship between grade of spring and winter habit and spike initiation were investigated under continuous illumination in a greenhouse using six varieties each of wheat and barley. Shoot apex development of both wheat and barley was slower the higher the grade of winter habit. Furthermore, it was found that in both wheat and barley, stem internodes elongation began before spikelet initiation.

2) The time when vernalization had completed in the plants sown in fall was determined by using a total of 12 wheat and barley cultivars differing in grades of winter habit. When sown in an open field on November 15, the wheat and barley plants with a grade of III (semi-winter) or IV were fully vernalized in mid-December and in early-January, respectively, and those with a grade of V or VI in late-January or early-February at the latest.

3) Weekly changes of shoot apex development in a total of 12 wheat and barley cultivars sown outdoors on November 15 were in-

vestigated from early-December to late-March. Shoot apices of barley plants reached the double ridge (7th stage) in mid-January, and then their differentiation did not progress further untill late-February to early-March. On the other hand, the shoot apex of the wheat plants began differentiation in late-January to mid-February, regardless of variety, and then their differentiations progressed continuously. When sown in fall, no relationship was found between the time of spike initiation and the grade of spring or winter habit in either wheat or barley.

4) In order to study further the differences between wheat and barley found in the fall-sown plants, the effects of day length and temperature on shoot apex development were investigated in six cultivars each of wheat and barley. Spike initiation of the wheat cultivars was markedly retarded by low temperature, but no differences in the date of spike initiation was found between wheat and barley at a high temperature even in short days.

5) Some problems concerning the breeding of earlier wheat cultivars as early as the early barley cultivars were discussed.

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