Improvement of Heading Time of High Quality Rice (Oryza sativa L. cv. Hitomebore) in Cold Regions

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Improvement of Heading Time of High Quality Rice (*Oryza sativa* L. cv. Hitomebore) in Cold Regions

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Summary

This study was conducted in order to find a method for improving the heading date of Hitomebore rice in cold regions. The heading date of rice in pot seedling plots (4.8-6.2 of leaf age) was 5 days earlier than those in mat seedling plots (3.7-4.3 of leaf age). The cumulative temperatures for 40 days after heading of rice in pot seedlings were 20-26°C larger than those in mat seedlings. The heading of rice in nursling seedling was delayed about 8 days in comparison with that in pot seedlings. The early transplanting of pot seedlings of Hitomebore rice on the 7th of May put forth its panicles 5 days earlier than that of the late transplanting on the 14th and 21st of May. Late transplanting of pot seedlings decreased the number of leaves per shoot (15.2 and 14.7 in 1992 and 1993, respectively) when compared to earlier transplanted ones (16.0 and 15.0 in 1992 and 1993, respectively). The cumulative mean air temperature for 40 days after heading of rice in pot seedling plot was 9-32°C greater in earlier transplanting than that in late transplanting. From the above results, improvement of heading date of Hitomebore in cold regions could be highly possible by early transplanting of pot mature seedlings.

In Japan the total area of rice harvested has decreased drastically since 1970 due to political control of rice cultivation because of over production (Showa Nogyoshi, 7). Therefore nowadays, for farmers, the quality of rice is becoming a greater issue than quantity, because the price of high quality rice is much higher than that of average rice. To date, there is no high quality rice which is recommended for cultivation in cold regions. However, the farmers in hilly and mountainous areas of Miyagi prefecture are actually earnest about eultivating the high quality rice of Hitomebore because of its relatively high resistance to cold. However, the cultivation of this variety is not recommended in the areas above 100 m in altitude (Miyagiken Noseibu, 6), because it requires 880°C of cumulative mean air temperature during 40 days after heading for repining.

The fluctuation of growth rate and heading date of Hitomebore rice in different locations seems to be related to different climatic conditions and cultural

practices. Especially, in the cold region, the effect of temperature on growth and heading of rice is the most prominent among climatic factors. Delayed heading tends to increase the sterility and decrease both quantity and quality of rice by reducing the ripening (Tanaka, 8). After heading, temperature affects grain filling favorably through acceleration of translocation of carbohydrates and other substances (Yoshida, 9), and also the rate of growth per kernel increases with temperature (Evans and Wardlow, 2).

Therefore in cold regions, it is very important to get heading of rice within a period which avoids the unsuccessful ripening of rice by cool air temperature in autumn. Generally, the rice varieties of northern Japan are temperature sensitive. Therefore, it is possible to hasten the heading of rice by using mature seedlings grown at higher temperature in the nursery house and early transplanting of this seedlings.

The objective of this study is to improve the heading date of high quality rice "Hitomebore" in cold regions with respect to seedling age and transplanting time.

Materials and Methods

This experiment was mainly carried out on Andisol at the Experimental Farm of Tohoku University, Kawatabi (hilly area), Naruko, Miyagi prefecture, in 1992-1994, using high quality rice (*Oryza sativa* L. cv. Hitomebore) as a test crop.

The relationship between heading date, growth characteristics and seedling age were studied using 4.8-6.2 leaf age of pot seedlings and 3.2-4.3 leaf age of mat seedlings and nursling seedlings (2.0 of leaf age). They were transplanted on the 7th of May, with a planting density of 24 hills per m^2. The transplanting date was determined by considering the frosting probability ($<30\%$). Bulk blend compound fertilizer (15-20-15) was applied at the rate of 7 g N per m^2 (containing 80 % polyolefin coated urea).

The relationship between the transplanting time and heading date of pot seedlings was studied using 4.8-5.3 leaf age of pot seedlings. They were transplanted on the 7th and 14th of May in 1992, and the 7th, 14th and 21st of May in 1994. Planting density, type of fertilizer, and rate of applications were same as above mentioned.

Three and five seedlings were transplanted in pot and mat seedling plots, respectively. Leaf number including the incomplete leaf of the main culm was recorded (Hoshikawa, 3). Heading date was determined at the time when 50% of the panicles in each plot have appeared. Heading date of Hitomebore grown at the farmer's field of Furukawa (flat area) and Onikobe (mountainous area) were also measured. Climatic data at Kawatabi was obtained from the Automated Meteorological Data Acquisition System (AMeDAS).

Maximum and minimum air temperature °C during the growing season of rice

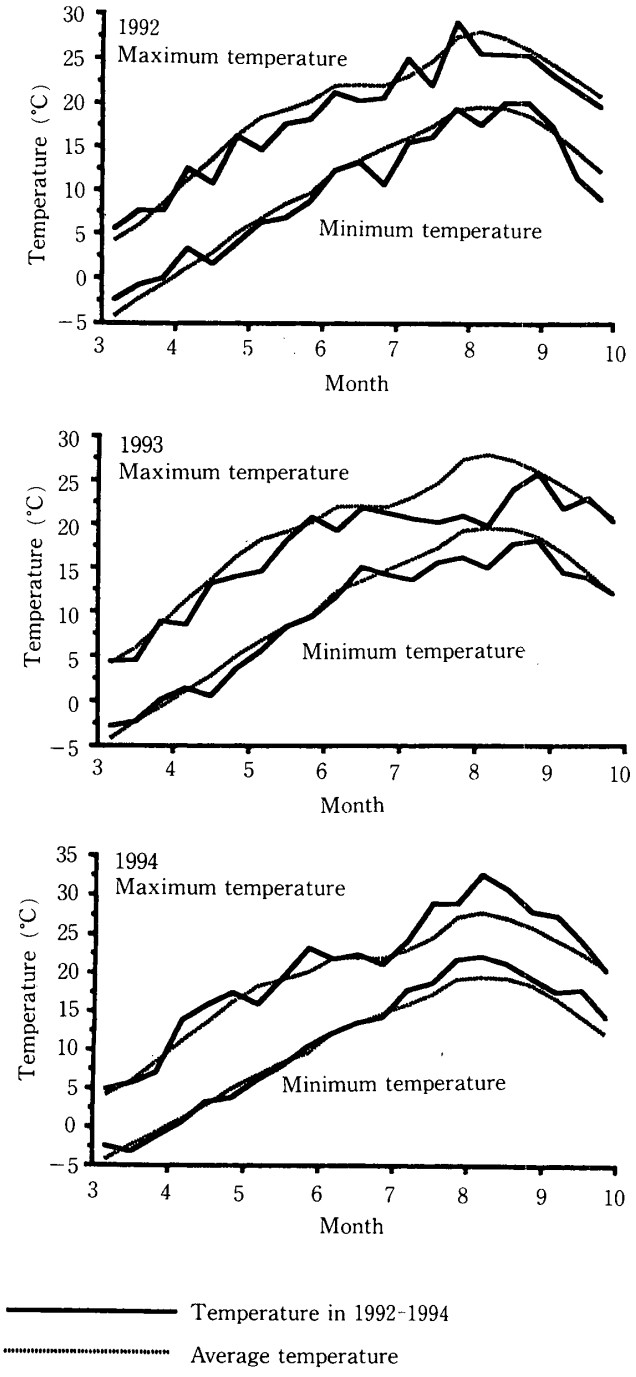

FIG. 1. Fluctuation of maximum and minimum air temperature during the growing season of Hitomebore at Kawatabi in comparison with average years.

in 1992-1994 as compared with the averages of the last 22 years were shown in Fig. 1. In 1992, the daily minimum air temperature was below the average year except in the middle of July and August. Daily maximum air temperature was greater than the average in the end of June, the middle of July, and the end of August. In 1993, the daily minimum and maximum air temperatures were

significantcly lower than the average, especially from the middle of May through the middle of August. In 1994, the daily minimum and maximum air temperatures were greater than the average, especially from July. From the above data, the climate of 1993 was extraordinarily cold weather, and might appear once in 100 years, whereas the climate of 1992 was similar to the average and the climate of 1994 was much better than an average.

Results and Discussion

The heading dates of Hitomebore rice grown at Furukawa, Kawatabi and Onikobe were shown in Table 1. In 1992, it was found that the heading date of rice at Furukawa was 7 and 14 days earlier than that at Kawatabi and at Onikobe, respectively. In 1993, the heading date of Hitomebore at Furukawa was 8 days earlier than that grown at Kawatabi. In 1994, the heading date of Hitomebore at Furukawa was 1 day earlier than that grown at Kawatabi. From the above results, it is clear that the heading date of Hitomebore grown at Kawatabi (hilly area) seems to be related to temperature and was significantly delayed compared to that grown at Furukawa (flat area). Therefore we attempted to improve the heading date of Hitomebore with respect to seedling age and transplanting time.

a) Relationship between heading date, growth characteristics and seedling age

The plant height of rice in pot and mat seedling plots in 1992-94 are shown in Fig. 2. In 1992, up to the end of June, the height of rice in pot seedling plot was larger than that in mat seedling plot. At the end of June, the plant height of rice in mat seedling plot was superior to that in pot seedling plot. In 1993, the plant height of rice in pot seedling plot was larger than that in mat seedling plot through all growing stages. Plant height in pot and mat seedling plots was

TABLE 1. *Heading date of Hitomebore grown at Furukawa, Kawatabi, and Onikobe*

Year	Location (Date of transplanting)	Leaf number at transplanting time	Heading date
1992	Furukawa (8th May)	4.5	7th Aug.
	Kawatabi (7th May)	4.3	14th Aug.
	Onikobe (13th May)	4.5	21st Aug.
1993	Furukawa (6th May)	4.2	14th Aug.
	Kawatabi (7th May)	3.7	23th Aug.
1994	Furukawa (10th May)	4.3	3rd Aug.
	Kawatabi (10th May)	5.3	4th Aug.

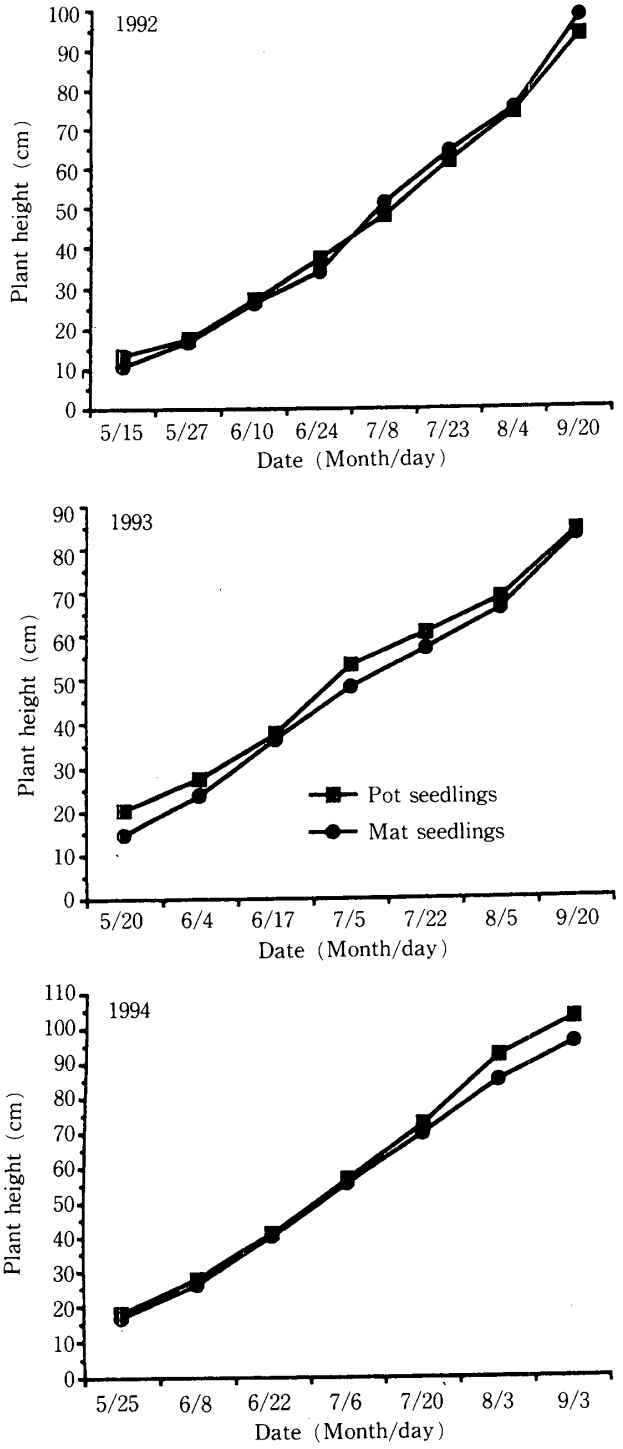

FIG. 2. Plant height of rice in pot and mat seedling plots.

considerably smaller in 1993 than in 1994 due to extremely cool weather. Tanaka (8) reported that low temperature reduces the culm length. Hoshikawa (3) reported that cool weather reduces the culm length, especially the peduncle of panicle. In 1994, the plant height of pot seedlings was larger than that in mat

TABLE 2. *Effects of leaf number at the transplanting time of different types of seedllings on number of leaves per shoot, heading date, and cumulative mean air temperature from transplanting to heading and for 40 days after heading.*

Year	Type of seedlings	Leaf number at transplanting time	Total leaf number/ main culm	Heading date	Cumulative mean air temperature (°C)		
					Sowing to transplanting	Transplanting to heading date	For 40 days after heading
1992	Pot mature seedlings	4.8	16.0	9th Aug.	630	1667.1	847
	Mat seedlings	4.3	15.3	14th Aug.	523	1748.3	821
1993	Pot mature seedlings	5.7	15.0	18th Aug.	791	1742.3	768
	Mat seedlings	3.7	14.6	23th Aug.	561	1847.5	744
	Mat seedlings	3.2	14.8	24th Aug.	499	1869.1	736
	Nursling seedlings	2.0	14.0	24th Aug.	180	1916.5	715
1994	Pot mature seedlings	6.2	15.8	31st July.	890	1540.0	987
	Mat seedlings	3.8	14.3	4th July.	600	1621.9	967

seedlings throughout the growing stage.

It was shown that rice in pot seedling plot produces larger number of leaves per main culm than that in mat seedling plot (Table 2). It was shown that leaf age in pot seedling plot was larger than that in mat seedling plot throughout the growing stage (Fig. 2), and total number of leaves per main culm at heading time was about 1 leaf higher in pot seedling plot than in mat seedling plot (Table 2).

Number of culms per m^2 in pot and mat seedling plots in 1992-94 are shown in Fig. 3. In 1992, it was found that rice in pot seedling plot produced fewer culms/m^2 than that in mat seedling plot throughout the growing stage. Finally the number of culms in pot and mat seedling plots were 437 and 509/m^2, respectively. In 1993-1994, the number of culms in pot and mat seedling plot were almost same by the end of June. After that, the number of culms in mat seedling plot was higher than that in pot seedling plot. Finally the number of culms in pot and mat seedling plots were 474 and 534/m^2, and 529 and 560/m^2 in 1993 and 1994, respectively. Therefore, the tillering capacity of pot seedlings was smaller than that of mat seedlings.

Although the differences between the leaf age of pot and mat seedlings at transplanting time were 0.5, 2.0 and 2.4 in 1992 and 1993 and 1994, respectively (Table 2), the heading dates of pot seedlings were 5-6 days earlier than those of mat seedlings. In 1993, heading date of rice in pot seedling plot was 8 days earlier than that of nursling seedling plot.

In 1993, the heading date of all types of seedlings was delayed significantly in comparison with those in 1992 and 1994 due to extremely cool weather. From

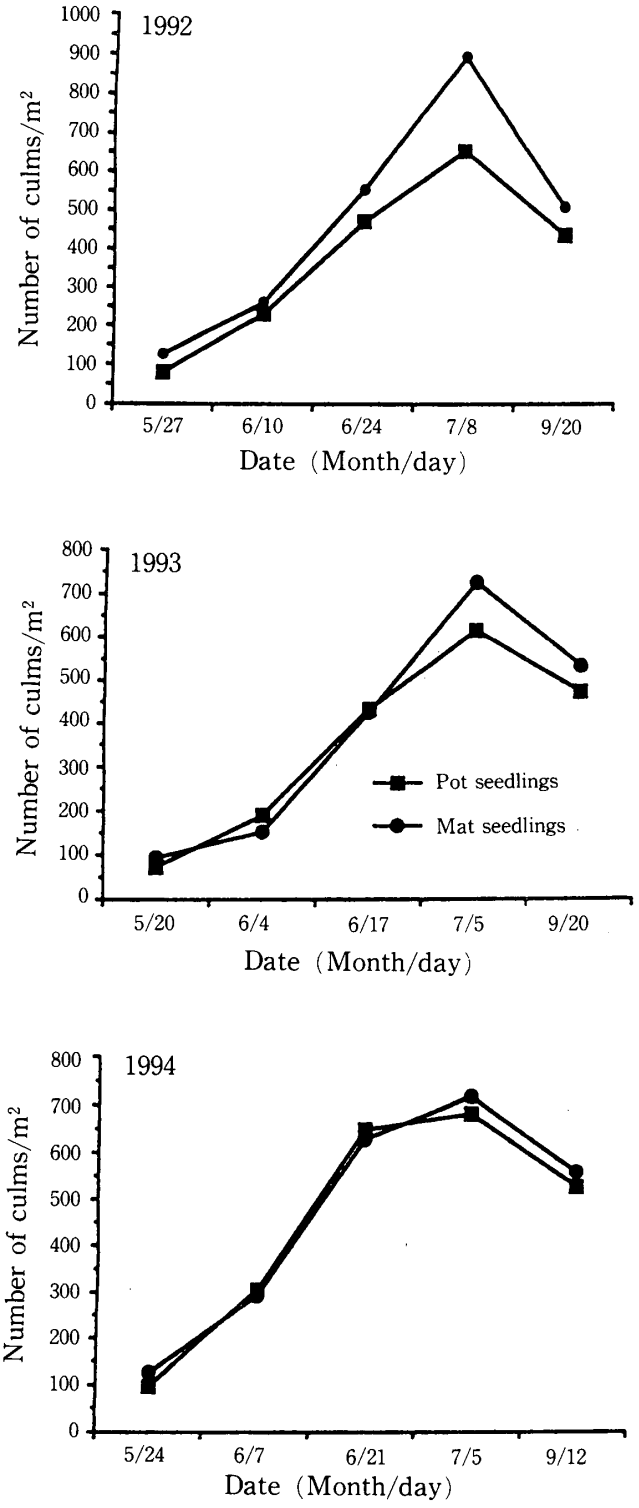

FIG. 3. Number of culms of rice in pot and mat seedling plots.

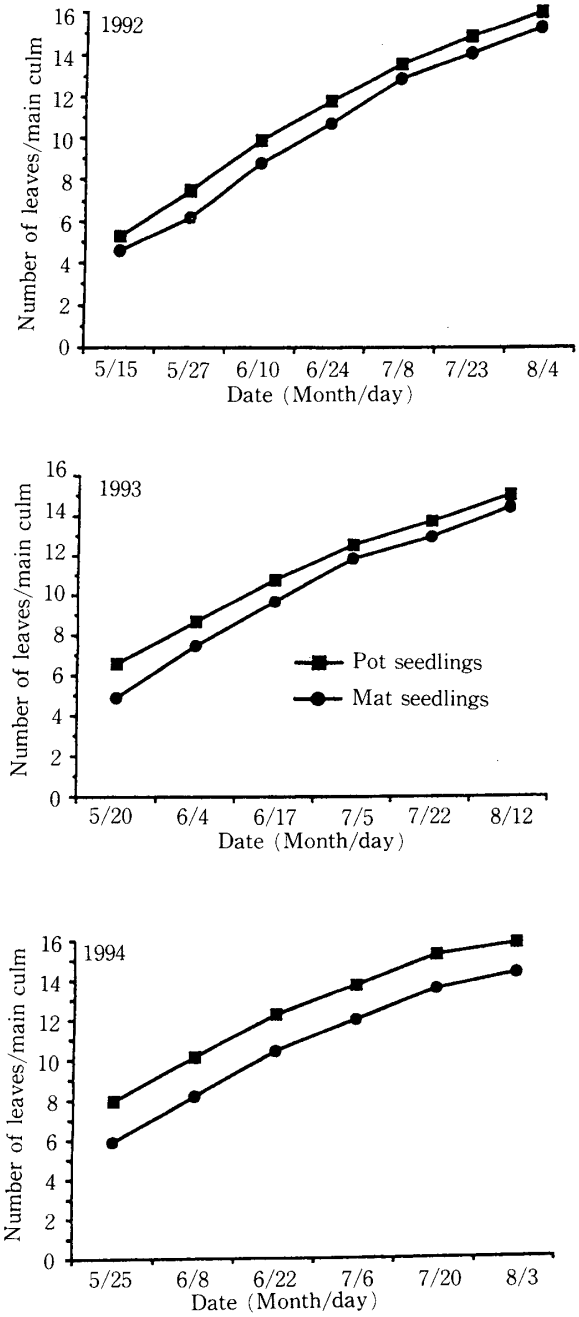

FIG. 4. Leaf age of rice in pot and mat seedling plots.

Table 2 it is clear that the differences of heading dates among the different types of seedlings were not very big in comparison with the leaf age at transplanting time. However, rice in pot seedling plot produced a larger number of leaves per shoot than that in mat seedling plot. It seemed that the vegetative phase of rice in pot seedling plots was advanced more than that in mat seedling plots because the leaf age was always larger in pot seedlings.

In 1992-1994, the cumulative mean air temperatures from transplanting time

to heading time of pot seedlings were lower than those of mat seedlings, but those from sowing time to transplanting time of pot seedlings were larger than that of mat seedlings as shown in Table 2.

In 1992, the cumulative mean air temperature for 40 days after heading of pot seedlings was 847°C, whereas that of mat seedling plot was 821°C. This was 26°C larger than that of mat seedling plot, but it did not fulfill the requisite cumulative air temperature for Hitomebore (880°C). In 1993, heading of all types of seedlings delayed significantly due to abnormal climatic conditions during the vegetative and reproductive stages (Fig. 1). The heading date of rice in pot seedling plot in 1993 was delayed 9 days compared to that of 1992, consequently the cumulative mean air temperature for 40 days after heading was significantly smaller than those in 1992. In 1994, both types of plots fulfilled the requisite cumulative temperature for 40 days after heading. Namely, the cumulative temperature for 40 days after heading of pot seedling was 987°C, whereas that in mat seedlings usually was 967°C. Hoshikawa (3) reviewed that heading of mat young seedlings was usually delayed 7-10 days as compared to that of mat mature seedlings. Amano (1) and Hosoi (4) also showed that the mature seedlings put forth their panicles earlier than the young seedlings, and also increased the number of leaves per shoot compared to young seedlings.

b) Relationship between the transplanting time and heading date of pot seedlings

The effect of transplanting time of pot seedlings on heading date is shown in Table 3. In 1992, the heading date of pot seedlings, transplanted on the 7th of May, was 9th August, which was one day earlier than that transplanted on 14th of May. In 1993, the heading dates of Hitomebore transplanted on the 14th and 21st of May were delayed 4 and 6 days, respectively in comparison with that

TABLE 3. *Effects of transplanting time of pot seedlings on number of leaves per shoot, heading date, and cumulative mean air temperature from transplanting to heading and 40 days after headings.*

Year	Transplanting time	Leaf number at transplanting time	Total leaf number/ main culm	Heading date	Cumulative mean air temperature (°C)	
					Transplanting to heading date	For 40 days after heading
1992	7th May	4.8	16.0	9th Aug.	1667.1	847
	14th May	4.8	15.2	10th Aug.	1614.0	838
1993	7th May	5.7	15.0	18th Aug.	1742.3	768
	14th May	5.3	14.7	22th Aug.	1730.0	749
	21st May	5.3	15.0	24th Aug.	1687.5	736

transplanted on the 7th of May. From Table 3, it was found that a relatively smaller cumulative mean air temperature was required for heading in late transplanting plots, while the number of leaves per shoot were decreased compared to early transplanting plots, except the plot transplanted on May 21, 1993.

The cumulative mean air temperature for 40 days after heading of pot seedlings was larger in earlier transplanting plots than in late transplanting plots. In this study, we recognized that early transplanting of pot seedlings improved the heading date more than late transplanting. Hosoi (5) reported that in late sowing rice, the influence of photosensitivity on growth duration decreased, basic vegetative growths became more important, and thermo-sensitivity played some role on heading time. He also reported that in very late sowing rice, basic vegetative growth contributed to a great degree on heading date, more than photo-sensitivity or thermo-sensitivity. Therefore it can be said that the heading and number of leaves per shoot for late planted Hitomebore were regulated not only by the cumulative mean air temperature but also by the interaction effects of photo-sensitivity, basic vegetative phase and thermo-sensitivity.

From the above discussions, it is clear that the heading date of Hitomebore in cold regions can be improved by using pot mature seedlings and by early transplanting, and pot mature seedlings produce a larger leaf number per main culm than that of mat young seedlings. Therefore we may conclude that the improvement of yield and grain quality of Hitomebore in cold regions could be highly possible by earlier transplanting of pot mature seedlings.

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