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Bhattacharya, Banidhan

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Effects of various ranges of day and night temperatures at the ripening period on the grain production in rice plants*

Banidhan BHATTACHARYA†

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* A part of the Thesis submitted for partial fulfillment of Doctorate degree in Kyushu University.

† Formerly Visiting Research Fellow, Kyushu University.

1. General introduction

For a long time an assured yield used to be obtained from the northern parts of Japan in comparison with the southern parts i. e., Kyushu. Recently this trend has changed completely. Now even in the southern part a constant high yield is being obtained. Saga, a prefecture in the southern region of Japan has been giving the highest average prefectural yield in the whole country constantly for the last few years.

Temperatures of the southern region of Japan at the ripening stage of rice are relatively high in comparison with the northern region and it is believed that a high night temperature at the ripening stage of rice is not conducive to higher yields.

It is known from the works of Takeda (1961) that a high temperature increases the respiration of the rice plants. The rate of respiration is doubled for each 10°C rise in temperature as Q_{10} of respiration is 2. The enhanced rate of respiration causes increased consumption of the materials produced by the photosynthesis which eventually causes a reduction in the carbohydrate contents of the plants and as a consequence the total dry weight of the plants is reduced and the grains fail to be fed properly.

Aimi et al (1966) and Matsushima and Wada (1959) have shown that high temperatures cause rapid translocation in the plants and at the ripening stage this rapidity of translocation hastens the filling up of grains and after a certain period, nearly towards the end, the grains lose receptibility. Low temperatures on the other hand retards the rate of translocation but the receptibility of the grains is maintained till the end. They have also found out optimum temperatures for each growth stage for maximum grain production.

Many works have been done on the effects of temperatures at different stages of growth of rice plants and their relations with the yield components and the yield at large. But no systematic works have been done on the effects of temperatures at the ripening period on the grain production in rice plants.

Reversed trend in the yielding ability of the southern region of Japan necessiated a thorough investigation on the effects of temperatures at the ripening period on the grain production.

Rice plants are cultivated in different regions of Japan with different climatic conditions. As winter in Japan is cold, this season is not favourable for rice cultivation and rice cultivation is restricted to only summer and autumn seasons. In summer season the mean night temperatures are high and in autumn season they are relatively low.

With a view to determining the real effects of the low and high night temperatures at the ripening period in different seasons on the grain production in rice plants the following four experiments were conducted.

Experiment No. 1 was conducted in autumn season and a medium maturing variety, Hoyoku was used. Experiment No. 2 was conducted in the summer season and an early maturing variety, Koshihikari was used.

Experiment Nos. 3 and 4 were conducted in summer and autumn respectively in order to reconfirm the trends of Experiment Nos. 2 and 1 respectively.

2. Experiment No. 1

Introduction

In Fukuoka and Saga prefectures, rice plants are generally grown in the autumn season. These regions are warm and the plants are harvested in autumn. Towards the later part of the ripening of the plants the temperatures become relatively low.

This experiment was conducted to determine the effects of low and high night temperatures at the ripening period in autumn season on the grain production in rice plants.

As is known from the works of many investigators that greater portions of the grains are filled up within 30 days after heading, the temperature treatments were continued up to this stage. And from then onwards up to the final stage of sampling all the plots were kept in the field under natural conditions.

Materials and methods

On the 18 th. May one litre of seed was collected from the Fukuoka Prefectural Experiment Station and the seed selection was made using solution of 1.3 specific gravity. The seeds which completely immersed were selected. The seeds were then rinsed in water well and then soaked in water for 18 hours. The seeds were then immersed in 3% formalin solution for disinfection and then washed in running water for three hours. The seeds were then dried in the shade.

Two days before sowing the seeds were put in a tray under about 2 cms. of water and were kept inside the incubator under 30°C for 48 hours. The uniformly sprouted seeds were sown on the seed beds (described below) on 23 rd. May. The seeding density was 1,000/ 2,500 cm^2.

The variety Hoyoku was used in this experiment. This variety is a medium matuing variety and originated from the Fukuoka Prefectural Experiment Station.

Two seed beds each being 50 cm. × 50 cm. in area were used. The lower soil layers were made compact so as not to allow penetration of roots. Over the compact soil layer a layer of loose sandy soil 5 cm. in thickness was placed and the following amount of fertilizers was applied in each seed bed:

$(NH_4)_2SO_4$	—	8.3 gms.
Super Phosphate	—	41.6 gms.
KCl	—	12.5 gms.

On the 18 th. June the seedlings were top dressed with 10 gms. (each bed) of $(NH_4)_2SO_4$.
400 vinyl pots were filled with shieved soils (6 to 7 kg. per pot). The pots were then filled with water and the soils were properly mixed by hands. Two days before transplantation each pot received the following amount of fertilizers:

NaH_2PO_4, $2H_2O$	—	2.2 gms.
NH_4Cl	—	1.9 gms.
KCl	—	0.95 gms.

Two plants were transplanted in each pot and these two plants constituted one hill. The pots were arranged in such a way that no mutual shading occured.

Insecticides were occasionally applied to check the attack of insects.

On 2 nd. August 0.3 gms. of nitrogen was applied in each pot as top dressing. The top dressed plot (to be explained later) received a special dose of 0.2 gms. of nitrogen per pot at the heading stage..

Samplings were started from the heading stage. Before heading uniform plants were selected on tiller number and height basis. The heading stage was determined at a date when 50 % of panicles of all plants emerged.

The plants were devided into four plots, the Control, High night temperature, Low night temperature and Top dressed. These plots hereinafter would be refered as Cont., H. N., L. N., and Top dressed respectively. The Top dressed plot was maintained as a contrast to the control plot. Each plot consisted of about 40 plants (pots).

The plants of the L. N. plot were shifted in the evening to a room which contained a room cooler and the temperature of the room was adjusted to about 5°C below the normal temperature. Next morning the plants were taken out of the room and were replaced in their original positions in the field. Likewise the plants of the H. N. plot were shifted in a room in the evening in which the temperature was adjusted to about 5°C above the normal temperature (average). The pots were then taken out of the room next morning and replaced in their original positions in the field. These operations were repeated every day from the heading stage up to the 30 th. day after heading. After this period all the pots were kept in the field under natural conditions till maturity which was determined to be at 45 days after heading for all the plots. The plants of the Cont. and the Top ressed plots were kept in their original positions in the field and were not shifted. Daily temperatures of the different plots were recorded by automatic recorders.

Samplings were done at the heading stage and at 10, 20, 30 and 45 days after heading. At the time of samplings the plants were uprooted, washed and the roots and the dead parts were eliminated. Leaf blades, leaf sheaths and panicles were seperated from the culms and the following observations were made:

Number of culms and panicles (not reported), dry weights of leaf blades, leaf sheaths and culms and panieles, total areas of green leaves, carbohydrate contents of leaf blades, leaf sheaths and culms.

Carbohydrate contents were determined by Weinmann's (1947) method (Carbohydrate means Total availablecarbohydrate).

At each stage 6 to 8 plants per plot were sampled.

Results

Fig. 1 shows the temperatures of the ripening period from the heading to maturity. As seen in the figure the daily mean temperatures were relatively high at the begining of the ripening stage but showed a declining trend towards the end.

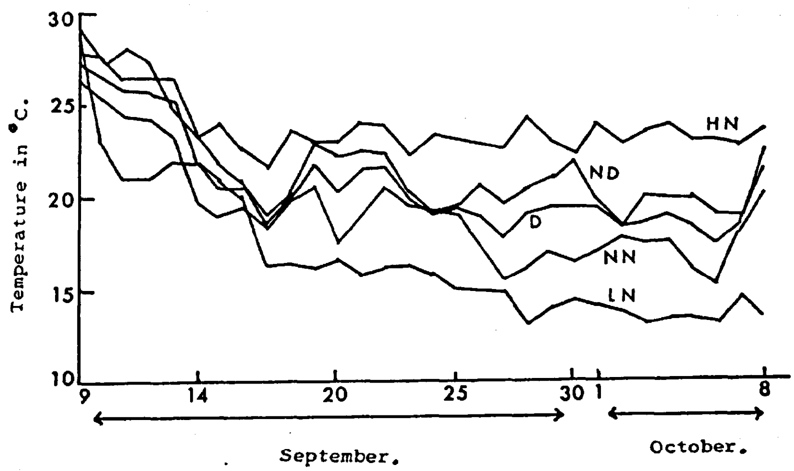

Fig. 1. Mean of the daily temperatures (day and night) of the ripening period. D-Mean of the whole day, ND-Normal day, NN-Normal night, HN-High night and LM-Low night.

The mean night temperatures of the ripening period (from heading to the 30th. day after heading) were 24.4°C for the H. N. plot, 19.3°C for the Cont. and the Top dressed plots and 16.6°C for the L. N. plot. The mean temperature of the day was same for all the plots and was 22°C.

Panicle weights

Fig. 2 shows the dry weights of of panicles. As seen in the figure the filling up of grains was very rapid in the Cont., Top dressed and the H. N. plots but was very slow in the L. N. plot. At the initial stage the rapidity was highest in the Cont. plot but was surpassed by the Top dressed plot later on in between the 10 th. day and the 20 th. day after heading. In the case of the H. N. plot the rapidity was moderate and no increase in the panicle weight was seen after the 30 th. day after heading and this plot showed the lowest panicle weight at the end. The filling up of grains in the L. N. plot was very slow in speed but was steady up to the end and the L. N. plot showed the highest panicle weight at the end. The panicle weights of the Top dressed and the Cont. plot came next in order.

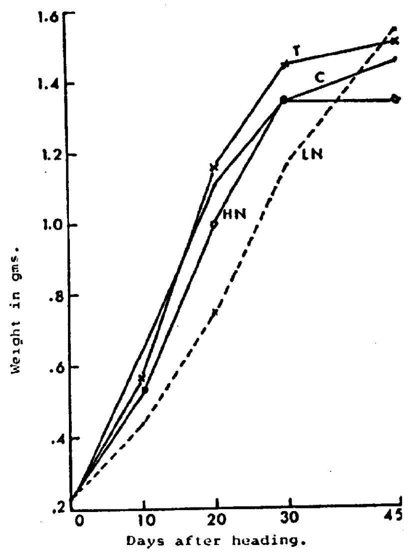

Fig. 2. Dry weight of panicles (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

Leaf area

Fig. 3 shows total areas of green leaves. As seen in the figure the total leaf areas of all the plots decreased gradually from heading to maturity. The Top dressed plot had the largest leaf area and the Cont. plot had the smallest. The leaf area of the L. N. plot was a little smaller than that of the Top dressed plot but larger than those of both the Cont. plot and the H. N. plot. The H. N. plot had larger leaf area than that of the Cont. plot.

The leaf areas of the L. N. plot and the top dressed plot showed increase up to the stage the 10 th. day after heading but these trends were unnatural. At the heading stage only 4 leaves per tiller were measured and all the green leaves were not considered. From the next stage of sampling, i. e., the 10 th. day after heading all the green leaves of the tiller were measured. Hence the discrepancies arose.

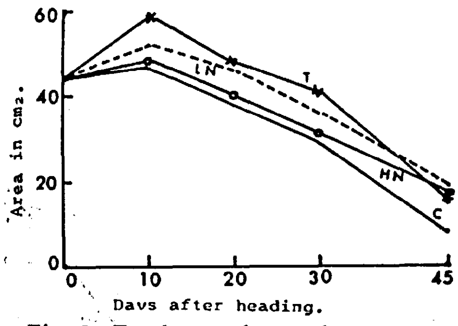

Fig. 3. Total area of green leaves (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

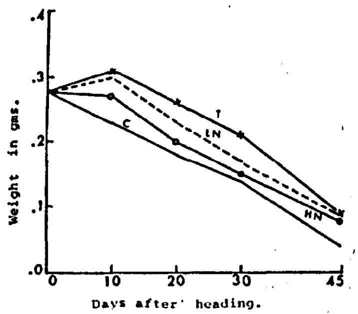

Fig. 4. Dry weight of leaf blades* (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

* Leaf blades mean green leaf blades. Hereinafter leaf blades would mean green leaf blades except where otherwise mentioned.

Dry weights of leaf blades, leaf sheaths and culms

Figs. 4 and 5 show dry weights of leaf blades and leaf sheaths respectively. Dry weights of leaf blades in all the plots showed decrease from the heading onwards till maturity. This decrease was maximum in the Cont. plot and minimum in the Top dressed plot. The decrease in the L. N. plot was also relatively smaller. Dry weights of leaf sheaths also showed similar trends as those of leaf blades but in the case of the L. N. plot it increased up to the 10 th. day after heading, showed maximum value and then decreased gradually.

Fig. 6 shows the dry weights of culms. As seen in the Figure the dry weights of culms of all the plots increased up to the 10 th. day after heading and the increase was maximum in the L. N. plot and minimum in the Cont. plot. But from the 10 th. day after heading onwards the dry weights decreased gradually in all the plots. The decrease was maximum in the H. N. plot but this plot showed an increase from the 30 th. day after heading onwards. It appeared that the receptibility of the grains of the H. N. plot was nearly lost at the end.

Carbohydrate contents of the leaf blades, leaf sheaths and culms

Figs. 7 to 12 show the carbohydrate contents of the leaf blades, leaf

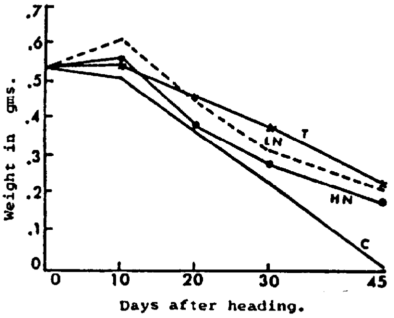

Fig. 5. Dry weight of leaf sheaths* (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

* Leaf sheaths mean living leaf sheaths. Hereinafter leaf sheaths would mean living leaf sheaths except where otherwise mentioned.

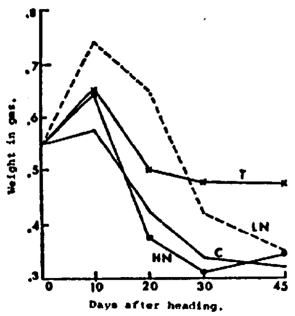

Fig. 6. Dry weight of culms (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

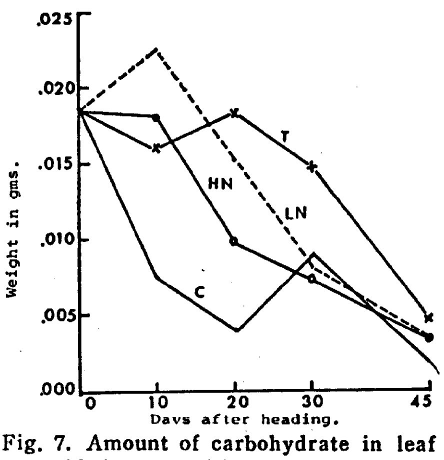

Fig. 7. Amount of carbohydrate in leaf blades (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

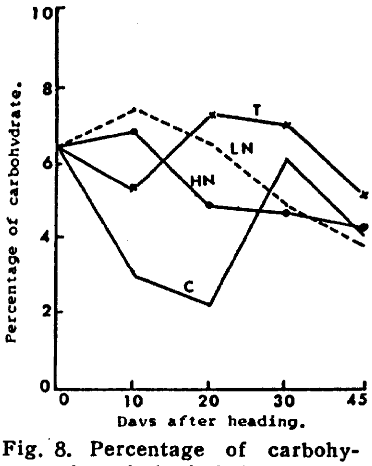

Fig. 8. Percentage of carbohydrate in leaf blades. C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

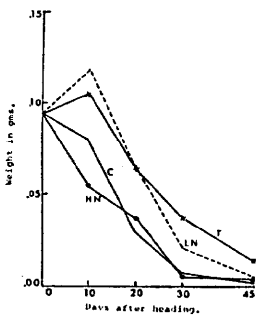

Fig. 9. Amount of Carbohydrate in leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

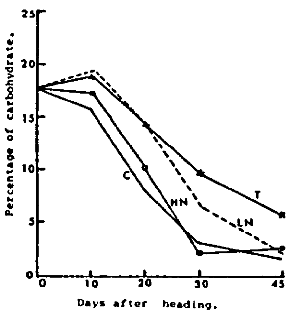

Fig. 10. Percentage of Carbohydrate in leaf sheaths. C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

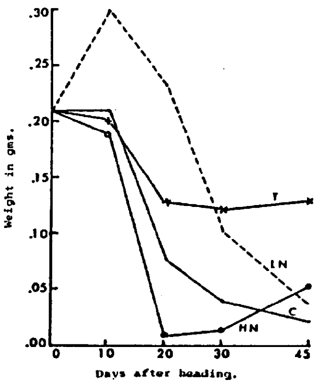

Fig. 11. Amount of carbohydrate in culms (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

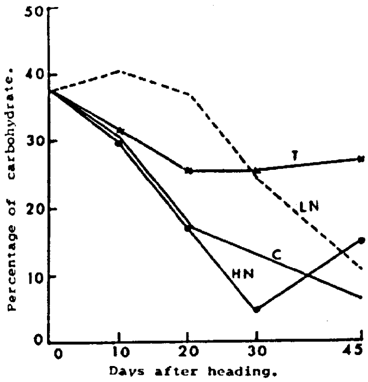

Fig. 12. Percentage of carbohydrate in culms. C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

sheaths and culms and their corresponding percentages. The curves of carbohydrate contents of leaf blades, leaf sheaths and culms roughly corresponded with their respective dry weight curves but in the case of the leaf blade curve the Top dressed plot showed a sudden increase from the 10 th. day after heading to the 20 th. day after head ing and the Cont. plot from the 20 th. day after heading to the 30 th. day after heading. It could be assumed from these trends that during these periods the carbohydrates remained deposited in the leaf blades and were not translocated.

Dry weights of the top parts

Fig. 13 shows dry weights of the top parts. As seen in the Figure the dry weight of top of the Top dressed plot was the highest. In the Top dressed plot it showed an increase upto the 30th. day after heading and then showed a little decrease. In all other plots the dry weights increased upto the 10 th. day after heading, remained nearly constant from the 10th. day after heading to the 30th. day after beading and then decreased a little except in the L. N. plot where it showed slight increase from the 30th. day after heading onwards.

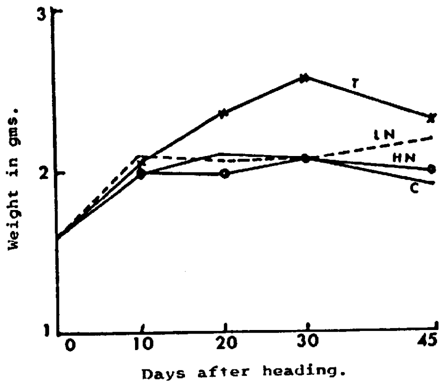

Fig. 13. Dry weight of top (per tiller). C-Control plot, HN-High night temperature plot, LN-Low night temperature plot and T-Top dressed plot.

Percentage of sterility of the grains

Table 1 shows the percentage of the sterility of the grains. As seen in the Table, the percentage of sterility was highest in the Cont. plot and lowest in the Top dressed plot. The L. N. plot showed rather low percentage of sterility.

Table 1. Percentage of sterility of the grains.

Plots	Percentage of grains of over 1.04 sp. gr.	Percentage of grains of over 1.00 sp. gr.	Percentage of sterile grains.
Cont.	83.5	2.90	13.6
H. N.	88.0	1.06	11.0
L. N.	88.4	2.10	9.6
Top dressed	90.4	1.60	8.0

Cont.: Control plot, H. N.: High night temperature plot, L. N.: Low night temperature plot.

Grain straw ratio

Table 2 shows the grain straw ratio. As seen in the Table, the grain

Table 2. Grain straw (living) ratio.

Plots	Grains	Straw
Cont.	100	32.2
H. N.	100	46.0
L. N.	100	42.9
Top dressed	100	53.0

Cont.: Control plot, H. N.: High night temperature plot, L. N.: Low night temperature plot.

straw ratio was highest in the Cont. plot and lowest in the Top dressed plol.

Discussion

The highest panicle weight (Fig. 2) of the L. N. plot might be considered to have resulted from the larger leaf area (Fig. 3) of the plot. Though the H. N. plot had a relatively larger leaf area (Fig. 3) associated with the larger dry weights of the leaf blades (Fig. 4) and leaf sheaths (Fig. 5) a rapid decrease in dry weight of the culms (Fig. 6) suggested a larger volume of translocation. Aimi et al (1966) and Matsushima and Wada (1959) have shown that higher temperature increases the rate of translocation. But this larger volume of translocation did not result in larger panicle weight (Fig. 2) as high temperature of the H. N. plot eaused increased consumption as respiration increased with the high temperature (Takeda, 1961). Moreover receptibility of the grains was nearly lost towards the end (Aimi et al, 1966), as evidenced by the sudden rise in the dry weight of the culms (Fig. 6) from the 30th. day after heading onwards.

In the Cont. plot though the leaf area (Fig. 3), was small still a constant translocation took place. As the temperature was moderate at night consumption due to high temperature was relatively less. Larger dry weights of leaf blades (Fig. 4), leaf sheaths (Fig. 5) and culms (Fig. 6) supported this assumption.

In the L. N. plot the rate of translocation was very slow but it continued upto the end (Fig. 2) Aimi et al (1966) have also reported similar trends. The higher dry weights of leaf blades (Fig. 4), leaf sheaths (Fig. 5) and culms (Fig. 6) in comparison with those of the H. N. plot and the Cont. plot suggested that the consumption of dry matters was very low in the L. N. plot as the temperature of the plot was low at night. Higher dry weight of the top part (Fig. 13) suggested that the dry matter production in the L. N plot was larger and it could be assumed that quite a considerable portion of the dry matters of the grains of this plot came from the photosynthesis of the plants after heading as though much amount of straw was left at the end (Table. 2) the panicle weight of this plot was highest.

The Top dressed plot showed higher panicle weight (Fig. 2) than that of the Cont. plot. It could be assumed that due to the increased application of nitrogen longevity of the leaves increased and the dry matter production as a consequence became high. But as evidenced from the higher values of dry weights of leaf blades (Fig. 4), leaf sheaths (Fig. 5) and culms (Fig. 6) some unbalance between the dry matter production and the translocation existed in this plot which accounted for its lower panicle weight in comparison with that of the L. N. plot.

3. Experiment No. 2

Introduction

In many regions of Japan, early varieties of short growth durations are cultivated. In warmer regions these early varieties are cultivated because in the autumn season these regions are affected by typhoons and AKIOCH and the plants are harvested earlier so that the plants are not damaged. In the warmer regions, the mean night temperatures of the ripening period of rice are considerably higher.

This experiment was conducted to clarify the effects of low and high night temperatures at the ripening period in summer season on the grain production of rice plants.

Materials and methods

The variety Koshihikari was used in this experiment. This variety is an early maturing variety and originated from Fukui prefecture of Japan.

Seed selection was made in the same way as described in Experiment No. 1. The beds were also similarly prepared and the areas of the seed beds were also the same. Each seed bed received the following amount of fertilizers:

$(NH_4)_2SO_4$	—	8.3 gms.
Super phosphate	—	41.6 gms.
KCl	—	12.5 gms.

Uniformly sprouted seeds were sown on the seed beds on the 3rd, April. The seeding density was $1{,}000/2{,}500cm^2$. The seedlings received a dressing of 10 gms. of Ammonium sulphate on the 30th. April.

Pot preparations were in the same way as described in Experiment done No. 1. Each pot received the following amount of basal fertilizers in the form of diluted solution:

P_2O_5	—	1 gm.
N	—	0.5 gms.
KCl	—	0.95 gms.

Two seedlings were transplanted in each pot on the 12th. May. The arrangements of the pots were done in the same way as described in Experiment No. 1.

As the plants showed symptoms of potassium deficiency all the pots received dressings of 0.5 gms./per pot of potassium on the 20th. June. Moreover the pots received dressings of 0.3 gms./per pot and 0.2gms./ per pot of nitrogen on the 20th. June and 21st. July respectively.

Before the heading stage selection of the plants were done in the same way as described in Experiment No. 1.

The pots were devided into 3 plots, the High night temperature plot, the Low night temperature plot and the Control plot (the H. N., the L. N. and the Cont. respectively) and each plot consisted of about 30 pots (plants). Temperature treatments of different plots were done in the same way as described in Experiment No. 1. Daily temperatures were recorded by automatic recorders.

Samplings started from the heading stage and were done at 15 days interval upto 45 days after heading. 4 to 8 plants per plot were sampled at each stage.

At the time of samplings the plants were uprooted, washed and the roots were eliminated. Panicles, leaf blades and leaf sheaths were seperated from the culms and the following characters were observed:

Dry weights of panicles, leaf blades, leaf sheaths and culms, total areas of green leaves and number of panicles and culms at each stage. The grain straw ratio and the percentage of sterility of the grains were examined only at the final stage.

Results

Fig. 14 shows the temperature of the ripening period. The daily variation in the temperature could be seen from this figure. In general the temperatures did not show any declining trend towards maturity.

The mean temperatures of the ripening period for different plots were as follows:

Night temperature of the H. N. plot −30.04°C, the L. N. plot −20.42 °C and the Cont. plot −27.48°C. The mean day temperature of all the plots was same and it was 30.11°C.

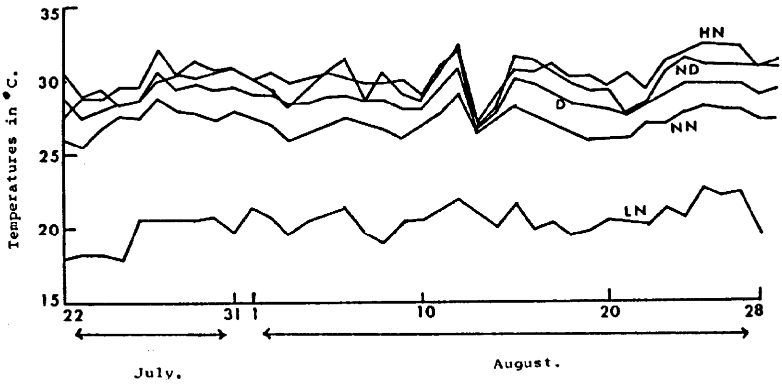

Fig. 14. Mean of the daily temperatures (day and night) of the ripening period. D-Mean of the whole day, ND-Normal day, NN-Normalnight, HN-High night and LN-Low night.

Dry weight of panicles

Fig. 15 shows the dry weights of panicles. As seen in the figure the filling up grains in the Cont. plot was most rapid from the very begining. The rate was very slow in the L. N. plot and the H. N. plot showed an intermediate trend. At the end the L. N. and the H. N. plot showed nearly the same values (the L. N. plot showed slightly higher value than that of the H. N. plot) and the Cont. plot showed the lowest.

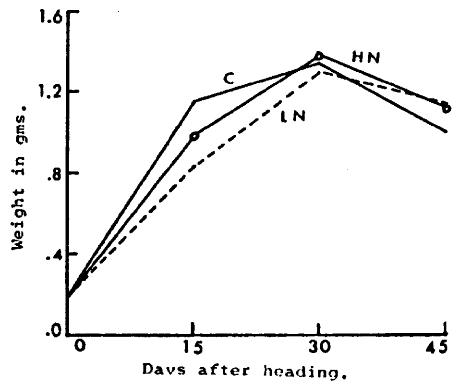

Fig. 15. Dry weight of panicles (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

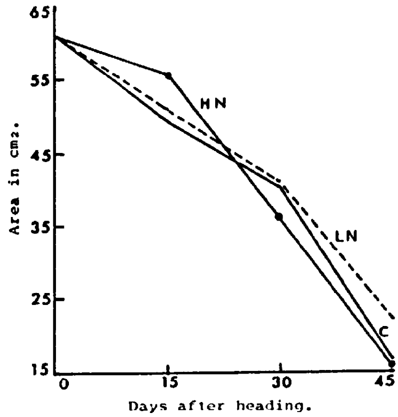

Fig. 16. Total area of green leaves (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

From the 30th. day after heading onwards all the plots showed decrease. This trend seemed unnatural and it appeared that due to the smaller number of plants sampled and the larger variations amomg the individual plants this unnatural trend occvred.

Leaf areas

As seen in Figure 16 the leaf area of H. N. plot was very large at the begining but it began to decrease suddenly from the 15th. day after heading and this decrease was uniform upto the end. At the end this plot showed the lowest value. The leaf area of the Cont. plot was the lowest at the begining but the decrease was gradual and showed the intermediate value at the end. The leaf area of the L. N. plot was a little smaller than those of the H. N. and the Cont. plots at the begining but the rate of decrease was very slow and it showed the highest value at the end.

Dry weights of leaf blades, leaf sheaths and culms

As seen in Figure 17 decrease in the dry weight of leaf blades was same for the H. N. and the Cont. plot upto the 30th. day after heading but after that the decrease in the Cont. plot was more than that of the H. N. plot and consequently the Cont. plot showed the lowest value at the end. The rate of decrease in the L. N. plot was low from the very begining and this plot showed the highest value at the end.

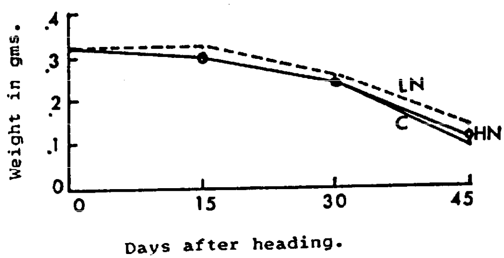

Fig. 17. Dry weight of leaf blades (per tiller). C-Control plot, HN High night temperature plot and LN-Low night temperature plot.

Figure 18 shows the dry weights of the leaf sheaths. As seen in the figure the rate of decrease was maximum in the H. N. plot but was nearly same in the Cont. plot and in the L. N. plot. From the 30th. day after heading onwards the difference between the H. N. plot and the Cont. plot was levelled off and L. N. plot showed the highest value at the end.

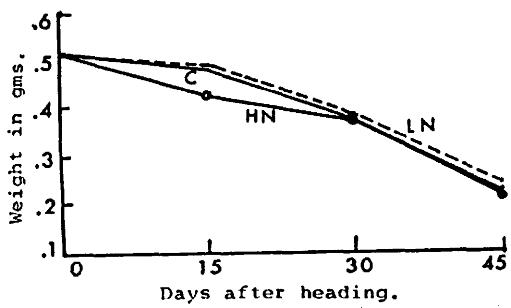

Fig. 18. Dry weight of leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night tem temperature plot.

Figure 19 shows the dry weights of culms. As seen in the figure the dry weights of all the plots showed an increase upto the 30th. day after heading. But the rate of increase was maximum in the L. N. plot and minimum in the H. N. plot. The Cont. plot showed a slightly lower value than that of the L. N. plot on the 15th. day after heading and decreased slightly between the 15th. day after heading and the 30th. day after heading. From the 30th. day after heading onwards all the plots showed steady decrease upto the end. At the end the L. N. plot showed the highest value and the H. N. plot the lowest.

Dry weights of the top parts

Figure 20 shows the dry weights of the top parts excluding the dead leaf blades and the dead leaf sheaths. As seen in the figure the dry

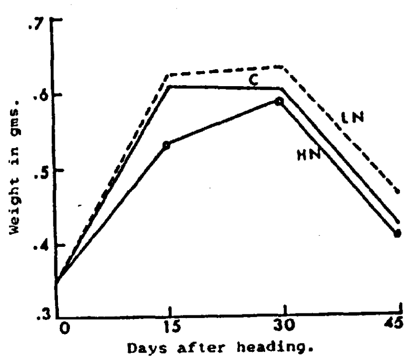

Fig. 19. Dry weight of culms (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

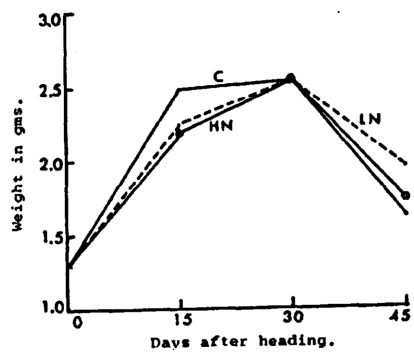

Fig. 20. Dry weight of top (per tiller). C-Control plot, HN-High night temperature plot andLN-Low night temperature plot.

weight of the top part was the highest in the Cont. plot at the begining but from the 30th. day after heading onwards decreased and showed the lowest value at the end. The increases in the top weights of the L. N. and the H. N. plot were slow at the begining but the L. N. plot showed the highest value at the end. The H. N. plot showed an intermediate value.

Percentage of sterility of the grains

As seen in Table 3 the sterility percentage was the highest in the L. N. plot and the lowest in the H. N. plot.

Table 3. Percentage of sterility of the grains.

Plots.	Percentage of grains of over 1.06 sp. gr.	Percentage of grains of over 1.00 sp. gr.	Percentage of sterile grains.
Cont.	82.37	2.90	14.73
H. N.	85.33	2.67	12.00
L. N.	80.53	4.00	16.37

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

Grain straw (living) ratio

Table 4 shows the grain straw ratio. As seen in the Table the grain straw ratio was the highest in the H. N. plot and was the lowest in the L. N. plot.

Table 4. Grain straw (living) ratio.

Plots	Grains	Straw
Cont.	100	64
H. N.	100	56
L. N.	100	70

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

Discussion

The highest panicle weight (Fig. 15) of the L. N. plot could be assumed to have resulted from the larger leaf area of the plot as seen in Fig. 16. Takeda (1961) reported similar trend. Though the total area of green leaf (Fig. 16) was smaller in the H. N. plot still the panicle weight (Fig. 15) of this plot was larger than that of the Cont. plot. It could be assumed that the translocation in the H. N. plot was more rapid and continuious than that of the Cont. plot (Aimi et al, 1966 and Matsushima and Wada, 1959). Decrease in the dry weights of leaf sheaths and culms as seen in Figs. 18 and 19 supported this assumption. The grain straw ratio (Table 4) also indicated that in the Cont. plot a considerable portion of the dry matter remained deposited in the straw without being translocated which accounted for the larger straw weight of the plot in comparison with the H. N. plot.

Decreases in the dry weights of leaf blades (Fig. 17) leaf sheaths (Fig. 18) and culms (Fig. 19) were smaller in the L. N. plot in comparison with the Cont. and the H. N. plots which suggested that due to the larger leaf area (Fig. 16) of the L. N. plot the amount of photosynthesis was large (Takeda, 1961) and a considerably large pontion of the carbohydrates of the grains came from the photosynthesis after heading. The grain straw ratio (Table 4) also supported this assumption. The straw weight was the highest in the L. N. plot (Table 4) which showed that a large amount of carbohydrate was produced after heading and remained deposited in the straw.

4. Experiment No. 3

Introduction

This experiment was carried out in order to confirm whether the trends seen in the Experiment No. 2 could be seen in this experiment also. In the Experiment No. 2 only 4 to 6 plants per plot were sampled and the variations among the individual plants were high. So in this experiment 10 plants per plot were sampled at each stage of sampling.

At the time of conducting the Experiment No. 2. the necessity of more thorough investigations was felt and so in addition to the characters observed in the Experiment No. 2 the following investigations were made:

Nitrogen contents of leaf blade,s dry weights of dead leaf leades and dead leaf sheaths, carbohydrate contents of the leaf blades, the leaf sheaths and the culms and the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of the dry matters produced before heading.

Materials and methods

The variety Koshihikari was used in this experiment. Seed selection and seed bed preparations were done in the same way as described in the Experiment No. 1. Each seed bed reeeived the following amount of fertilizers:

NH_4Cl	—	21.2 gms.
KH_2PO_4	—	30.0 gms.

The sizes of the seed beds and the seeding densities were same as those of the Experiment No. 1. The pre sprouted seeds were sown on these beds on the 21st. April.

Each seed bed received a dressing of 7.6 gms. of NH_4Cl on the 10th. May.

Pot preparations were done in the same way as described in the Experiment No. 1. Each pot received the following amount of basal fertilizers in the form of diluted solutions:

NH_4Cl	—	3.8 gms.
KH_2PO_4	—	2.0 gms.

One seedling per pot was transplanted on the 5th. June. The pots were kept immersed in artificial tanks containing water in order to prevent the soil temperatures of the pots from rising very high as a very high soil temperature would cause soil reduction.

Each pot received dressings of 0.5 gms. of urea and 0.38 gms. of KCl on the 7th. August.

Uniform plants were selected before the heading stage on height and tiller number basis. At the heading stage a small vinyl bag was attached to each pot and all the falling dead leaves and dead leaf sheaths were collected in the bag from the heading stage onwards.

At the heading stage the selected pots were devided into 3 plots, the Cont. the H. N. and the L. N.. Each plot consisted of 30 plants. Temperature treatments were done in the same way by shifting the pots of the H. N. and the L. N. plots every evening to the respective rooms as described in the Experiment No. 1. The temperature treatments were continued upto the final stage of sampling i. e., maturity. The times of maturity of all the plots were determined by visual observation at the stages when the stalks of the panicles became yellowish.

Samplings started from the heading stage and were done on the 15th. day after heading, the 30th. day after heading and at maturity. 10 plants per plot were sampled each time.

The following characters were observed:

Dry weights of panicles, living and dead leaf blades, living and dead leaf sheaths and culms, total areas of green leaves, nitrogen contents of green leaves, carbohydrate contents of leaf blades, leaf sheaths and culms, percentage of sterility of the grains, grain straw ratio and the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plante after heading and through the translocation of materials produced before heading.

The distribution of the dry matters to the grains through the photosynthesis was determined in the following way:

Let 'A' be the total increase of the dry weight of the panicles from the heading to the maturity, 'B' the total decrease in dry weight of straw from the heading to maturity and 'C' the total increse in the dry woights of dead leaf blades and dead leaf sheaths from heading to maturity. Then the amount of the dry mstters of the panicles contributed by the photosynthesisn of the plants after heading would be:

A-(B-C).

If this value, (B-C) is substracted from the dry weight of panicles, A, then the amount of the dry matters of the panicles contributed by the translocation of the materials produced before heading could be obtained.

The nitrogen contents were determined by Kjeldahl's methods and the carbohydrate contents (TAC) by Weinmann's (1947) methods.

Results

The temperatures of the ripening period from the heading to maturity are shown in Fig. 21. The temperatures of all the plots were slightly lower at the later stage of ripening in comparison with the former experiment (Experiment No. 2).

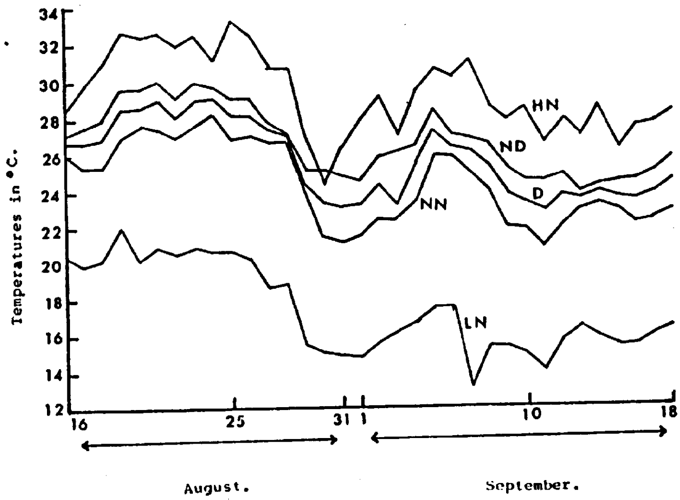

Fig. 21. Mean of the daily temperatures (day and night) of the ripening period. D-Mean of the whole day, ND-Normal night, HN-High night and LN-Low night.

The mean of the night temperatures of the H. N. plot was 29.26°C, that of the Control plot was 24.34°C and that of the L. N. plot was 17.36°C. The mean temperatures of the day of all the plots was same and was 26.56°C.

Dry weight of panicles

Fig. 22 shows the dry weight of panicles. As seen in the figure the dry weight of panicles of all the plots showed steady increase from the heading stage upto the 30th. day after heading and the rate of increase was highest in the Control plot and lowest in the L. N. plot. Then the rate of increase in the Control plot slowed down and the L. N. plot showed the highest value at the end. The H. N. plot showed the lowest value and the Control plot the intermediate value at the end.

The same trend was seen in the Experiment No. 2 also (Fig. 15) But in the Experiment No. 2 (Fig. 15) on the 30th. day after heading the panicle weights of all plots showed decrease upto the end. At the end the H. N. plot showed higher value than that of the Control plot.

This decrease in the penicle weights of all the plots in the Experiment No. 2 (Fig. 15) from the 30th. day after heading onwards seemed quite unnatural. A small number of plants was sampled and the variations among the individual plants were high. It appeared that for these reasons these unnatural trends resulted.

Leaf area

Fig. 23 shows leaf area. As seen in the figure the leaf areas of all

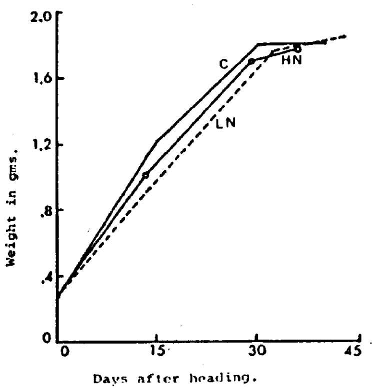

Fig. 22. Dry weight of panicles (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot,

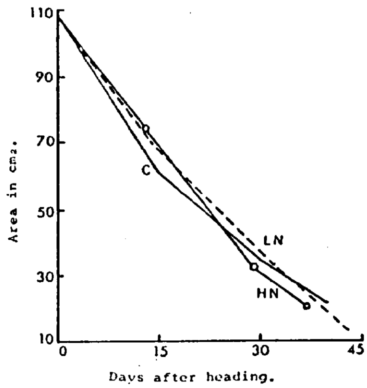

Fig. 23. Total area of green leaves (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot,

the plots decreased continuously from the heading stage onwards upto the maturity. The leaf area of the Control plot showed the highest value at the end and that of the L. N. plot the lowest value, though the dates of the final samplings were different as could be seen from the figure. The L. N. plot showed an overall large leaf area throughout the ripening period though the differences among the plots were small.

In the Experiment No. 2 (Fig. 16) also the same trend was seen. In the Experiment No. 2 on the 15th. day after heading the H. N. plot showed considerably larger leaf area than those of the Control and the L. N. plot. The L. N. plot showed the largest leaf area at the end. Possibly the differences were brought about by the variations in the individual plants as only 4 plants were sampled in each stage in the Experiment No. 2.

Dry weights of leaf blades, leaf sheaths and culms

Fig. 24 shows the dry weights of leaf blades. As seen in the figure, the dry weights of leaf blades of all the plots showed decrease from the heading stage upto the stage of maturity. The rate of decrease was relatively low in the L. N. plot but was about the same in the Control and in the H. N. plots. All the plots showed nearly the same values at the end.

In the case of Experiment No. 2 (Fig. 17) the rates of decrease in the Control plot and in the H. N. plot were same upto the 30th. day after heading but that of the L. N. plot was slower. From the 30th. day after heading onwards all the plots showed the same rates of de-

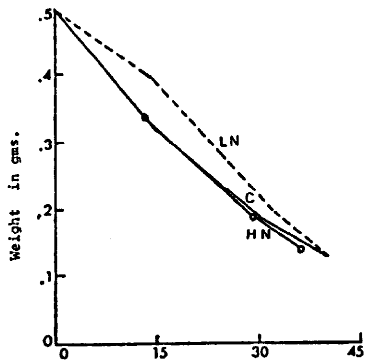

Fig. 24. Dry weight of leaf blades (per tiller). C-Control plot, HN-High night temperature plo and LN-Low night temperature plot.

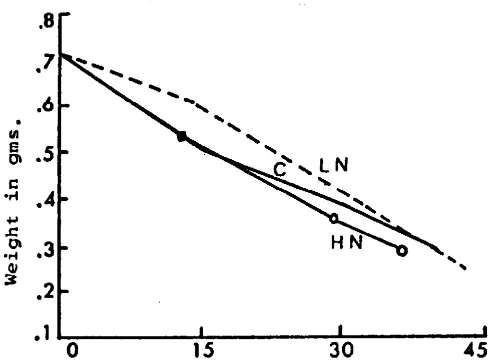

Fig. 25. Dry weight of leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

crease and at the end the L. N. plot showed the highest value and the H. N. plot the lowest value.

Though the dry weight of leaf blades showed the same trend in both the Experiment Nos. 2 and 3 (Figs. 17 and 24) the rate of decreaase was more in Experiment No. 3. This disecrepancy seemed to have resulted from the variations in individuel plants in Experiment No. 2 as only 4 plants per plot were sampled in this experiment.

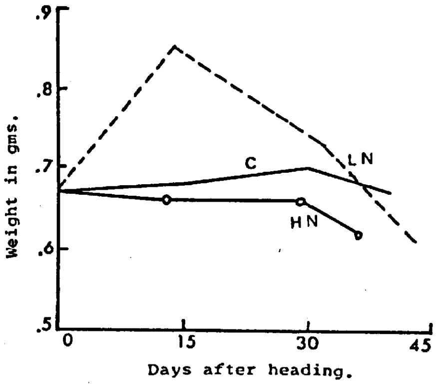

Fig. 26. Dry weight of culms (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

Fig. 25 shows the dry weights of leaf sheaths. As seen in the figure the dry weights of leaf sheaths of all the plots decreased as the plants approached maturity. The rate of decrease was very low in the L. N. plot and was nearly same in the Control and in the H. N. plots. upto the 15th. day after heading and from this stage the decrease in the H. N. plot was steady but that of the Control plot was not so. At the end the Control plot showed a slightly higher value than those of the H. N. and the L. N. plots.

In the case of the Experiment No. 2 (Fig. 18) the rates of decrease in the L. N. plot and in the Control plot were same all along but in the H. N. plot the rate of decrease was very high upto the 15th. day after heading and then slowed down a little and from the 30th. day after heading the rates of decrease were uniform in all the plots.

Fig. 26 shows the dry weights of culm. As seen in the figure the dry weight of culm increased very rapidly in the L. N. plot upto the 15th. day after heading and then showed a gradual decrease upto the end. The Control plot showed a slight increase upto the 30th. day after heading and then decreased a little towards the end. The dry weight of culm in the H. N. plot was nearly constant upto the 30th. day after heading and then showed a decrease upto the end.

In the Experiment No. 2 the dry weights of culm (Fig. 19) of all the plots increased rapidly upto the 15th. day after heading. In the H. N. plot it increased further upto the 30th. day after heading but those of the Control plot and the L. N. plot remained constant from the 15th. day after heading upto the 30th. day after heading. From the 30th. day after heading onwards the dry weights of all the plots decreased in the same rate upto the end and at the end the L. N. plot showed the highest value and the H. N. plot the lowest.

Decrease in the dry weights of leaf blades (Fig. 24), leaf sheaths (Fig. 25) and culms (Fig. 26) were more in the Experiment No. 3 in comparison with those of the Experiment No. 2 (Figs. 17, 18 and 19). At could be seen in Figs. 15 and 22, the dry weights of panicles increased more steadily in the Experiment No. 3 and it could be assumed that in the Experiment No. 3 the translocation in general was better than that of the Experiment No. 2.

From figures 24, 25 and 26 it could be seen that translocation from leaf blades and leaf sheaths took place uniformly but much of the dry matter remained deposited in the culm and was not translocated. In the case of the L. N. plot the dry weight of culm increased very rapidly upto the 15th. day after heading and then decreased. These decreases in dry weights of leaf bleades (Fig. 24) and leaf sheaths (Fig. 25) were associated with the corresponding increases in the panicle weights (Fig. 22) upto the 30th. day after heading but after that though the dry weights of leaf blades (Fig. 24), leaf sheaths (Fig. 25) and culms (Fig. 26) decreased, corresponding increases in the panicle weights (Fig. 22) could not be seen as on one hand the grains lost considerable receptibility and on the other hand the consumption was high due to high temperature.

The same assumption could be made from the Experiment No. 2 also (Figs. 15, 17, 18 and 19).

Nitrogen contents of leaf blades (green)

In this experiment nitrogen contents of the leaf blades were deter-

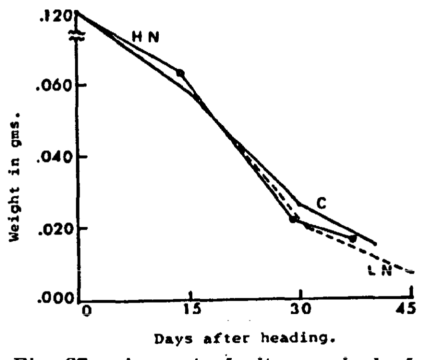

Fig. 27. Amount of nitrogne in leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

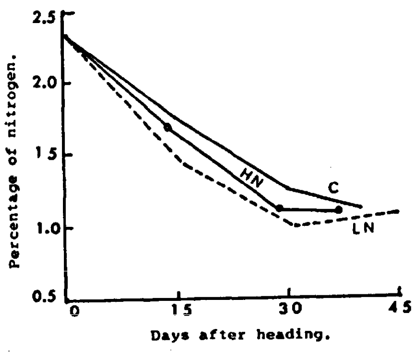

Fig. 28. Percentage of nitrogen in leaf blades. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

mined as the nitrogen contents of the leaf blades were known to indicate the photosynthetic capacity of the leaf blades.

Figs. 27 and 28 show the amounts and the percentages of nitrogen respetively in the leaf blades (living). At seen in Fig. 27 the amounts of nitrogen were nearly same in all the plots. As the heading stage the amounts were highest but decreased steadily upto the end. But the percentages of nitrogen (Fig. 28) were highest in the Control plot. and lowest in the L. N. plot from the stage of heading upto the 30th. day after heading but at the end all the plots showed nearly the same values.

Carbohydrate contents of leaf blades, leaf sheaths and culms

Figs. 29 to 34 show the amounts and the respective pereentages of carbohydrates in the leaf blades (Figs. 29 and 30), leaf sheaths (Figs. 31 and 32) and culms (Figs. 33 and 34). The carbohydrate content curves nearly corresponded with the dry weight curves (Figs. 24, 25 and 26).

In the case of leaf blades (Figs. 29 and 30) the amounts of carbohydrate showed an increase from the 30th. day after heading upto the end in the H. N. plot and the percentages of carbohydrate in both the Control and the H. N. plots showed increase from the 30th. day after heading up to the end and this increase was very high and sudden in the H. N. plot. These trends showed that the receptibility of the grains of both the Control and the H. N. plots (Figs. 22) decreased considerably towards the end. Both the amount and the percentage of carbohydrate in the L. N. plot were much higher than those of the H. N. and the Control plots and it could be assumed that the consumption was low in the L. N. plot as the temperature of the L. N. plot was low.

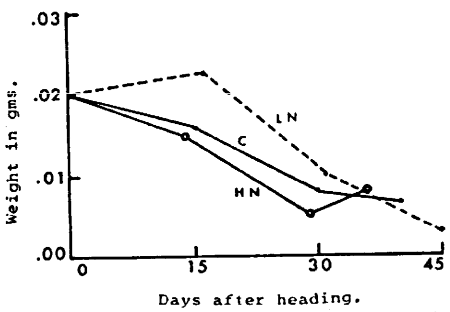

Fig. 29. Amount of carbohydrate in leaf blades (per tiller). C-Control plot, HN-High night temerature plot and LN-Low night temperature plot.

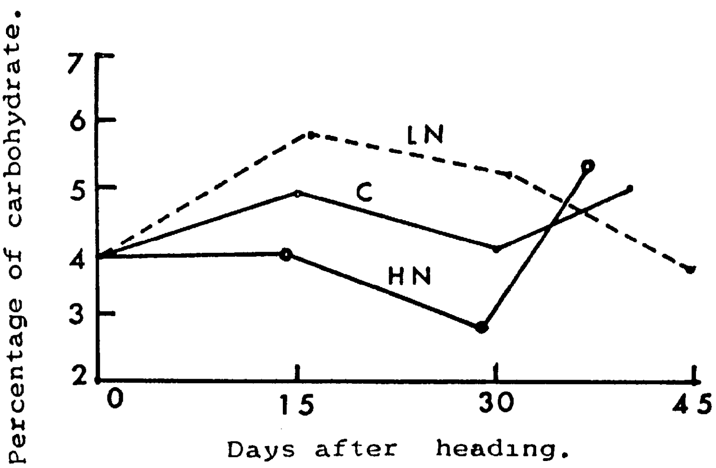

Fig. 30. Percentage of carbohydrate in leaf blades. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

In case of leaf sheaths (Figs. 31 and 32) the decrease of both the amount (Fig. 31) and the percentage (Fig. 32) were nearly same in the Control and in the H. N. plots. In the L. N. plot both the amount and the percentage of carbohydrate were higher in comparison with those of the Control and the H. N. plots (Figs. 31 and 32).

In the case of culms both the amount (Fig. 33) and the percentage (Fig. 34) of carbohydrate increased upto the 15th. day after heading but showed a steady decrease thereafter upto the end. In the H. N. plot and in the Control plot both the amount and the ercentage decreased from the heading stage onwards and this decrease was maximum in the H. N. plot but the percentage of carbohydrate in H. N. plot showed an increase from the 30th. day after heading onwards upto the end. This trend also showed that the receptibility of the grains of the H. N. plot decreased considerdably toward the end.

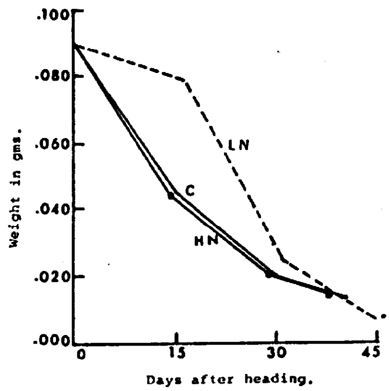

Fig. 31. Amount of carbohydrate in leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

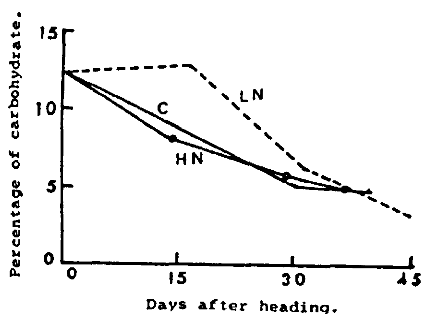

Fig. 32. Percentage of carbohydrate in leaf sheaths. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

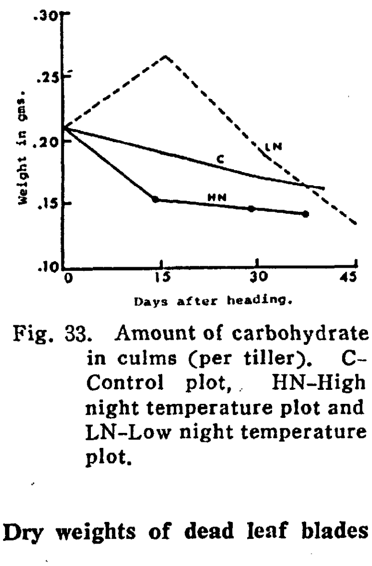

Fig. 33. Amount of carbohydrate in culms (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

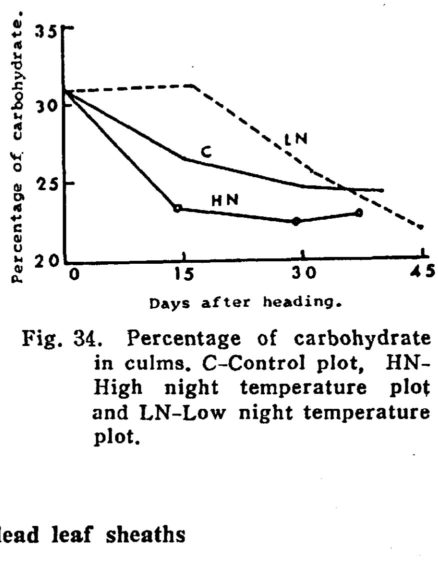

Fig. 34. Percentage of carbohydrate in culms. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

Dry weights of dead leaf blades and dead leaf sheaths

In this experiment the dry weights of the dead leaf blades and the dead leaf sheaths were measured in order to determine the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and the translocation of the materials produced before the heading.

Figs. 35 and 36 show the dry weights of dead leaf blades and dead leaf sheaths respectively. As seen in the figures the dry weights of dead leaf blades (Fig. 35) and dead leaf sheaths (Fig. 36) increased most rapidly in the H. N. plot and increased relatively less rapidly in the Control and in the L. N. plots. It could be assumed that the higher

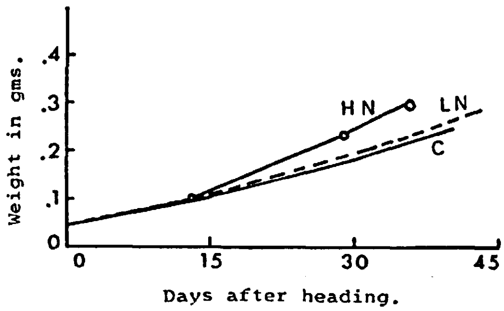

Fig. 35. Dry weight of dead leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

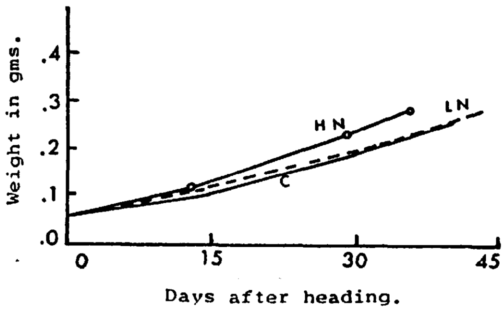

Fig. 36. Dry weight of dead leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

temperature of the H. N. plot caused earlier senecence of leaves in the H. N. plot.

Dry weight of top parts

Fig. 37 shows the dry weight of the top parts. As seen in the figure the dry weights of top parts in all the plots increased rapidly upto the 30th. day after heading and then remained constant in the L. N. and in the H. N. plots but in the Control plot it decreased a little upto the end. At the end the dry weight of top parts was the highest in the Control plot but was nearly same in the L. N. and in the H. N. plots.

The same trend was seen in the Experiment No. 2 also (Fig. 20). But in experiment No. 2 dry weights of top parts of all the plots showed decreast from the 30th. day after heading onwards upto the end.

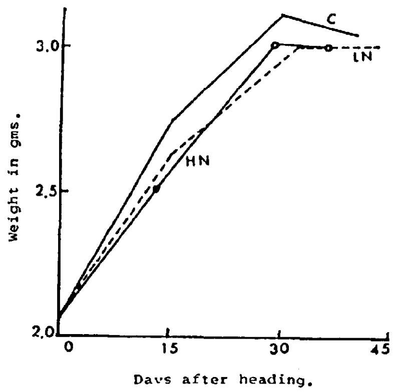

Fig. 37. Dry weight of top (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

The dry weight of the top parts was highest in the L. N. plot at the end and in the Control it was the lowest. Possibly these differences in the dry weights of top parts in experiment Nos. 2 and 3 resulted from the fact that dry weights of dead leaf blades and dead leaf sheaths were not included in the case of experiment No. 2.

Distribution of dry matters and assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of the materials produced before heading

In this experiment the above refered valucs were calculated by the procedure explained in the "Materials and eethods".

As seen in Figs. 38, 39 and 40 the overall translocation in the Control plot was very uniform from the begining upto the end whereas in the other plots the uniformities of translocation were occasionally broken. In the L. N. plot the translocation was rapid at the former stage of ripening but not so during the latter stages as it appeared that the low temperat ure of this plot retarded the speed of translocation whereas in the H. N. plot the consumption due to high temperature was high and the grains lost considerable receptibility at the end. Hence the rate of translocation was disturbed.

Table 5 shows the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before heading. As seen in the Table nearly three fourth of the dry matters of the grains in all the plots came from the photosynthesis of the plants after heading. As only one fourth (nearly) of the dry matters of the

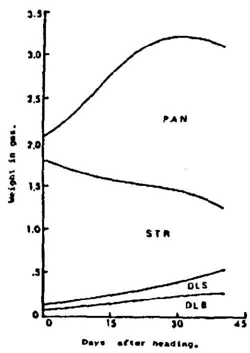

Fig. 38. Distribution of dry matters (per tiller) in Control plot.PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

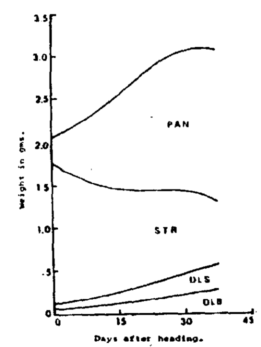

Fig. 39. Distribution of dry matters (per tiller) in the High night temperature plot.PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

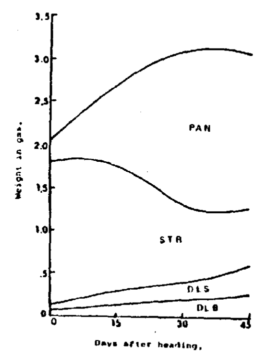

Fig. 40. Distribution of dry matters (per tiller) in the Low night temperature plot.PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

Table 5. Assumed percentages of dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before heading.

Plots	Percentage of dry matters of the grains supplied through photosynthesis of the plants after heading.	Percentage of dry matters of the grains supplied through translocation of materials produced before heading.
Cont.	74.59	25.41
H. N.	74.29	25.71
L. N.	76.76	23.24

Cont. : Control plot, H. N. : High night temperature plot and L. N. : Low night temperature plot.

grains of all the plots came from the translocation of materials produced before heading, it could be assumed that the consumption was high in the summer season due to higher temperature of the season.

Grain straw ratio

Table 6 shows the grain straw ratio. As seen in the Table the grain straw ratio was highest in the L. N. plot and lowest in the H. N. plot. The Control plot showed an intermediate value. The high grain straw ratio of the L. N. plot could be assumed to have resulted

Table 6. Grain straw ratio.

Plots	Grains	Straw
Cont.	100	72
H. N.	100	75
L. N.	100	67

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

from the fact that the translocation in the L. N. plot continued upto the end and the grains did not lose receptibility even towards the end. Whereas the lowest grain straw ratio of the H. N. plot showed that the grains of the H. N. plot lost considerable receptibility at the end and the dry matters (considerable) remained deposited in the straw without being translocated.

In the case of the Experiment No. 2 (Table 4) the grain straw ratio was highest in the H. N. plot and was lowest in the L. N. plot. In this experiment dry weights of dead leaf blades and dead leaf sheaths were not considered and it appeared that due to this reason this discrepancy arose.

Percentage of sterility of the grains

Table 7 shows the percentage of sterility of the grains. As seen in the Table the percentage of sterility of the grains was highest in the Control plot and lowest In the L. N. plot. The H. N. plot showed an intermediate value. The percentage of sterility was lowest in the L. N. plot as the receptibility of the grains was considerably high even towards the end. But as the rate of translocation was slow the grains were not as heavy as those of the H. N. plot and the Control plot. It could be seen from the Table that the grains of specifie pravity higher than 1.06 were 39.3% in the case of the H. N. plot and 31 % in the case of the Control plot but were only 8.3% in the case of

Table 7. Percentage of sterility of grains.

Plots	Percentage of grains of over 1.06 sp. gr.	Percentage of grains of over 1.00 sp. gr.	Percentage of sterile grains.
Cont.	31.0	54.7	14.3
H. N.	39.3	48.2	12.5
L. N.	8.3	81.8	10.0

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

the L. N. plot. The percentage of sterilty was less in the H. N. plot in comparison with the Control plot as the grains of the H. N. plot were more compact and the higher rapidity of translocation due to higher temperature of the H. N. plot helped filling up of the grains quickly.

The same trend was found in the Experiment No. 2 also (Table 3). But the percentage of sterility was highest in the L. N. plot. This discrepancy could be thought to have brought about by the lesser number of plants sampled and larger variations among the individual plants.

Discussion

The highest weight of panicles (Fig. 22) of the L. N. plot could be assumed to have resulted from the presence of a relatively larger leaf area (Fig. 23) of the plot throughout the ripening period (Takeda, 1961). The H. N. plot showed the lowest panicle weight (Fig. 22) and this low value of the panicle weight could be assumed to have resulted from the earlier senecence of leaves as could be seen in Fig. 35. The leaf area (Fig. 23) of the H. N. plot was small towards the later stage of ripening. Dry weights of leaf blades (Fig. 24), leaf sheaths (Fig. 25) and culms (Fig. 26) and their corresponding carbohydrate contents (Figs. 29 to 34) suggested a rapid translocation in the H. N. plot but this rapid translocation was not associated with higher panicle weights (Fig. 22). It could be assumed that much of the carbohydrate was consumed through respiration as higher temperature of the H. N. plot increased the rate of respiration (Takeda, 1961).

The Control plot showed higher panicle weight (Fig. 22) than that of the H. N. plot but lower than that of the L. N. plot. The Control plot had larger leaf area (Fig. 23) than that of the H. N. plot. Though the translocation in the Control plot was less rapid in comparison with the H. N. plot, still it was more uniform. The higher carbohydrate contents (Figs. 29 to 34) of the Control plot than those of the H. N. plot suggested a lesser amount of consumption.

The percentage of nitrogen in the leaf blades (Fig. 28) was highest in the Control plot but the L. N. plot showed the highest panicle weight (Fig. 22) because the consumption in the L. N. plot was very low as evidenced by the constant higher dry weights (Figs. 24, 25 and 26) as well as the carbohydrate contents (Figs. 29 to 34) of leaf blades, leaf sheaths and culms of the L. N. plot in comparison with the Control plot and the H. N. plot. The translocation at the later stages of ripening was very uniform and rapid in the L. N. plot.

5. Experiment No. 4

Introduction

This experiment was carried out in order to assertain whether the trends seen in experiment No. 1 could be seen in this experiment or not. In the Experiment No. 1 only 4 to 6 plants were sampled in each stage and the variations among the individual plants were high. So, in this experiment, 10 plants per plot were sampled at each stage.

At the time of conducting experiment No. 1 it was felt that investigations of a few more characteristics would throw more light on the matter and so many additional characteristics, same as those explained in the introduction of Experiment No. 3 were investigated in this experiment also (besides the characteristics explained in the introduction of Experiment No. 2).

Materials and methods

The variety Hoyoku was used in this experiment.

Seed selections and seed bed preparations were made in the same way as described in the Experiment No. 1. Sizes of the seed beds were also the same. Each seed bed received the following amount of fertilizers:

NH_4Cl	—	21.2 gms.
KH_2PO_4	—	30.0 gms.

Uniformly sprouted seeds were sown on the seed beds on the 2nd. June. The seeding densities were same as those of the Experiment No. 1. The seedlings did not receive any top dressings.

Pot preparations were done in the same way as described in the Experiment No. 1. Each pot received the following amount of fertilizers:

4 gms. of 'Farmer's cooperative fertilizers for N P K'. This fertilizer contained 15% N (8% in the form of urea and 7% in the form of NH_4), 15% P_2O_5 and 15% K.

On the 13 th. July 2 seedlings were transplanted to each pot. The pots were kept immersed in the artificial tanks containing water as described in the Experiment No. 3.

Each pot received dressing of 1 gm. of urea on the 26th. August and 1 gm. of urea and 0.38 sms. of KCl on the 12th. September.

A few days before heading selections of uniform plants were made on tiller number and height basis as described in the Experiment No.

Collections of dead leaf blades and dead leaf sheaths were done in the same way as described in the Experiment No. 3. At the heading stage the divisions of the plots were done in the same way as described in the Experiment No. 3. Temperature treatment of the plots were done in the same way as described in the Experiment No. 1 and the temperature treatments were continued upto the 30th. day after heading.

Samplings started from the heading stage and were done at the same stages as described in the Experiment No. 3. In this experiment also 10 plants per plot were sampled at each stage of sampling.

Observations of the same characters were done as described in the Experiment No. 3.

Results

Fig. 41 shows the temperatures of the ripening period. As seen in the figure the temperatures of all the plots became gradually lower as the plots approached maturity.

The mean night temperatures of the ripening period were 24.6°C for the H. N. plot, 13.9°C for the L. N. plot and 22.2°C for the Control plot. The mean day temperature was same for all the plots and was 21.5°C.

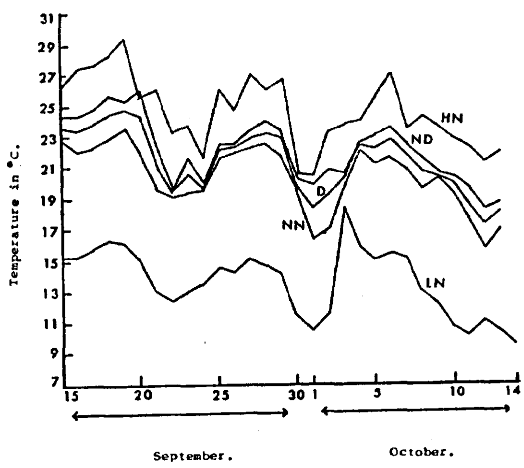

Fig. 41. Mean of the daily temperatures (day and night) of the ripening period. D-Mean of the whole day, ND-Normal day, NN-Normal night, HN-High night and LN-Low night.

Dry weights of panicles

Fig. 42 shows the dry weight of panicles. As seen in the figure the dry weight of panicles in all the plots increased steadily from the heading stage upto the end. The rate of increase was highest in the H. N. plot and lowest in the L. N. plot upto the 30th. day after heading but from the 30 th. day after heading onwards the rate of increase was high in the L. N. plot and slow in the H. N. plot and in the Control plot. The L. N. plot showed the highest panicle weight at the end and the Control plot the lowest.

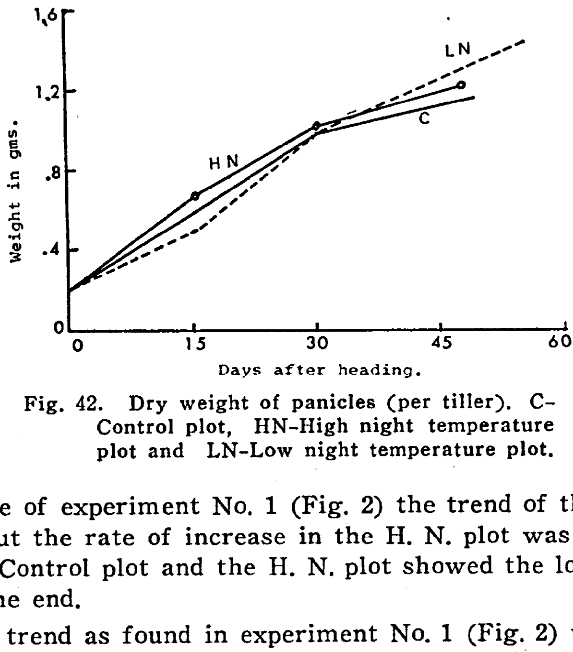

Fig. 42. Dry weight of panicles (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

In the case of experiment No. 1 (Fig. 2) the trend of the L. N. plot was same but the rate of increase in the H. N. plot was slower than that of the Control plot and the H. N. plot showed the lowest panicle weight at the end.

The same trend as found in experiment No. 1 (Fig. 2) was found in the Experiment No. 3 also (Fig. 22).

Leaf area (green)

Fig. 43 shows the total areas of green leaves. As seen in the figure, the leaf areas decreased in all the plots as the plots approached the stage of maturity. The leaf area was largest in the L.N. plot. The H. N. plot showed a little larger leaf area than that of the Control plot at the begining but showed the same value as that of the Control plot at the end.

In the case of Experiment No. 1 (Fig. 3) the same trend was found. But in this experiment the leaf areas showed an increase upto the 10

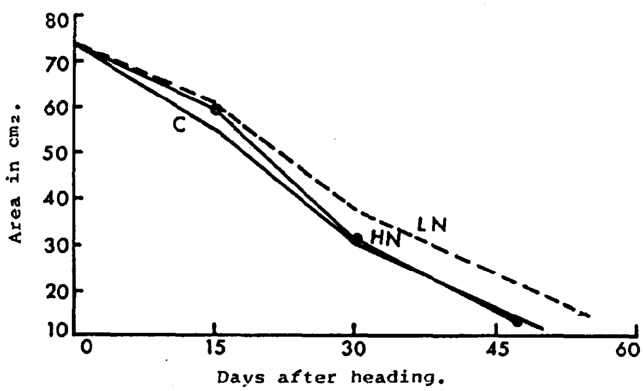

Fig. 43. Total area of green leaves (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

th. day after heading. This was possibly due to an experimental error as at the heading stage only 4 green leaves per tiller were measured but from the subsequent stage all the green leaves of the tillers were considered. Whereas in the Experiment No. 3 (Fig. 23) the rate of decrease increased very rapidly in the H. N. plot from the 15th. day after heading onwards and showed the lowest value at the end.

Dry weights of leaf blades, leaf sheaths and culms

Fig. 44 shows the dry weight of leaf blades. As seen in the figure the dry weights of leaf blades showed decrease in all the plots as the plots approached the stages of maturity. The L. N. plot showed the largest values all along and the H. N. and the Control plots showed nearly the same values though upto the middle stage the dry weight of the H. N. plot was slightly higher than that of the Control plot.

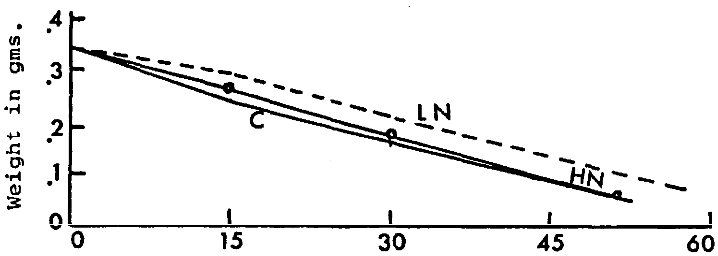

Fig. 44. Dry weight of leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

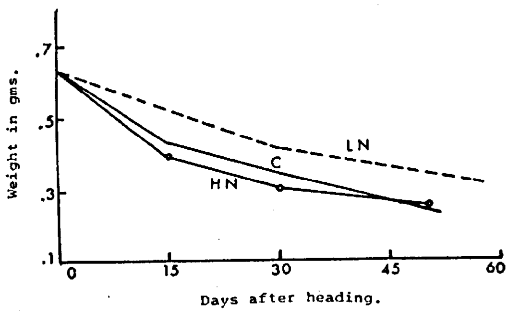

Fig. 45. Dry weight of leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot. and LN-Low night temperature plot.

Nearly the same trends were found in the Experiment No. 1 (Fig. 4) and in the Experiment No. 3 (Fig. 24).

Fig. 45 shows the dry weights of leaf sheaths. As seen in the figure the dry weight decreased in all the plots as the plots approached the stages of maturity. The rate of decrease was maximum in the H. N. plot and minimum in the L. N. plot. The Control plot showed an intermediate value at the former stage but at the end the H. N. plot and the Control plot showed nearly the same values.

In the case of Experiment No. 1 (Fig. 5) though the same trend was found the rate of decrease became very rapid in the Control plot from the 30th. day after heading onwards. In the Experiment No. 3 (Fig. 25) the rate of decrease became less rapid in the Control plot from the 15th. day after heading onwards.

Fig. 46 shows the dry weight of culms. As seen in the figure the dry weight of the L. N. plot showed an increase upto the 15th. day

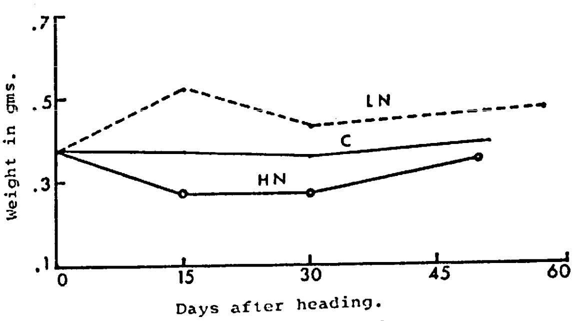

Fig. 46. Dry weight of culms (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

after heading, then decreased a little but again increased from the 30th. day after heading onwards. The dry weight of the Control plot remained constant upto the 30th. day after heading and from then showed a slight increase upto the end. The H. N. plot showed decrease upto the 15th. day after heading, then remained constant upto the 30th. day after heading and from then showed a slight increase upto the end.

In the Experiment No. 1 at the former stage the dry weights (Fig. 6) of all the plots increased upto the 15th. day after heading and this increase was maximum in the L. N. plot and minimum in the Control plot. From the 30th. day after heading the dry weights showed increase in the H. N. plot. (Fig. 6).

In the Experiment No. 3 the dry weights of culm (Fig. 26) increased very rapidly in the L. N. plot upto the 15th. day after heading and then started decreasing upto the end. In the H. N. plot the dry weight of culm remained constant upto the 30th. day after heading and in the Control plot it increased slightly upto the 30th. day after heading. From the 30th. day after heading onwards the dry weights of culm in the Control and in the H. N. plots both decreased upto the end.

From the figures 4, 5, 6, 24, 25, 26, 44, 45 and 46 of the Experiment Nos. 1, 3 and 4 it could be seen that the decrease in the dry weights of leaf blades, leaf sheaths and culms were more in the summer season (Experiment No. 3) as due to the higher temperatures of the season the consumptions of dry matters were relatively higher (Takeda, 1961, showed that higher temperatures enhanced the rates of respiration and as a consequence the consumptions of dry matters increased). In the autumn seasons (Experiment Nos. 1 and 4) the decrease in the dry weights of leaf blades, leaf sheaths and culms (Figs. 4, 5, 6, 44, 45 and 46) were relatively less as the temperatures were low in the autumn seasons and consequently the consumptions were also less.

Nitrogen contents of the leaf blades

Figs. 47 and 48 show the amounts of nitrogen and their corresponding percentages in the leaf blades. As seen in the figures, both the amounts and the percentages of nitrogen were highest in the L. N. plot. The amounts of nitrogen in the H. N. and in the Control plots were nearly same all along but the percentage was highest in the H. N. plot at the end.

In the Experiment No. 3 (Figs. 27 and 28) though the amounts of nitrogen were nearly same in all the plots, the percentages of nitrogen were highest in the Control plot and lowest in the L. N. plot at the former stage.

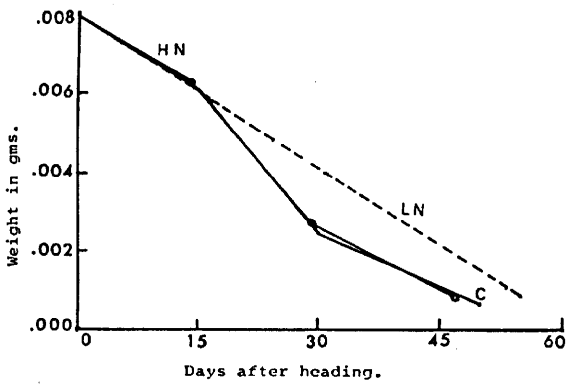

Fig. 47. Amount of nitrogen in leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

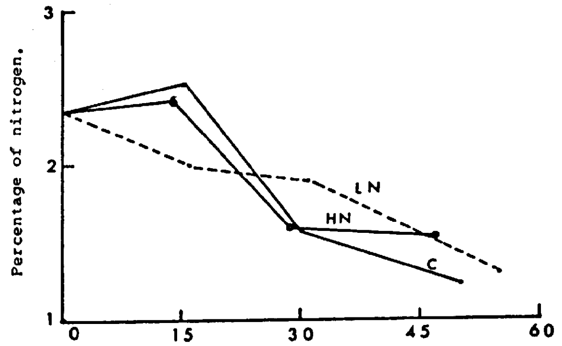

Fig. 48. Percentage of nitrogen in leaf blades. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

Carbohydrate contents of the leaf blades, leaf sheaths and culms

Figs. 49 to 54 show the carbohydrate contents and the respective percentages of the leaf blades, leaf sheaths and culms. As seen in the figures, both the carbohydrate contents curves and the carbohydrate percentages curves corresponded nearly with their respective dry weight curves (Figs. 44, 45 and 46).

In the case of leaf blades (Figs. 49 and 50) the amounts of carbohydrate in the L. N. plot remained constant upto the 30 th. day after heading and then decreased. In both the H. N. and the Control plots

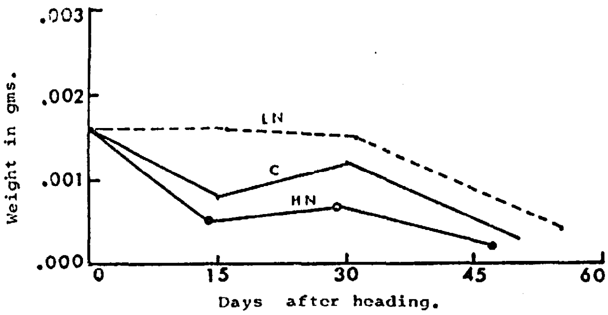

Fig. 49. Amount of carbohydrate in leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

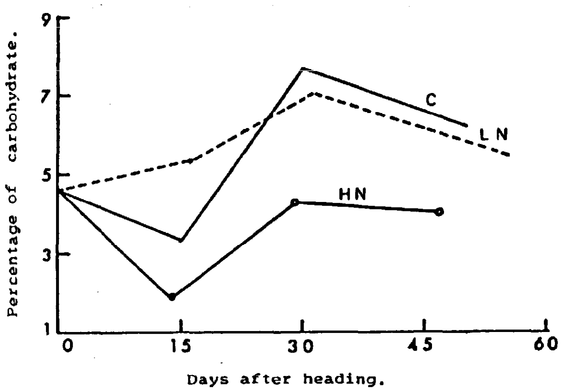

Fig. 50. Percentage of carbohydrate in leaf blades. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

the amounts decreased upto the 15th. day after heading, then increased upto the 30th. day after heading and from then onwards decreased upto the end. The Control plot showed higher values than those of the H. N. plot. The percentages of carbohydrate also showed nearly the same trend.

In the case of leaf sheaths (Figs. 51 and 52) both the amounts and the percentages were highest in the L. N. plot and lowest in the H. N. plot. The Control plot showed intermediate values.

Both the amounts and the percentages of carbohydrate of culms (Figs. 53 and 54) showed the same trend as those of the corresponding dry weight curves (Fig. 46) in all the plots.

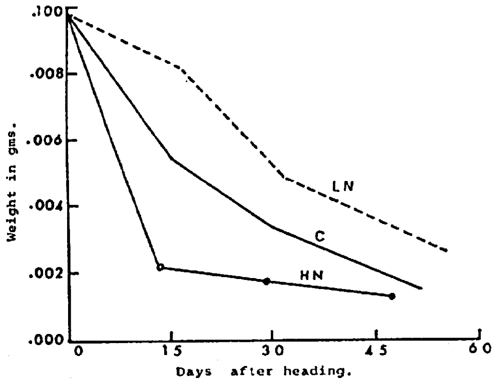

Fig. 51. Amount of carbohydrate in leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

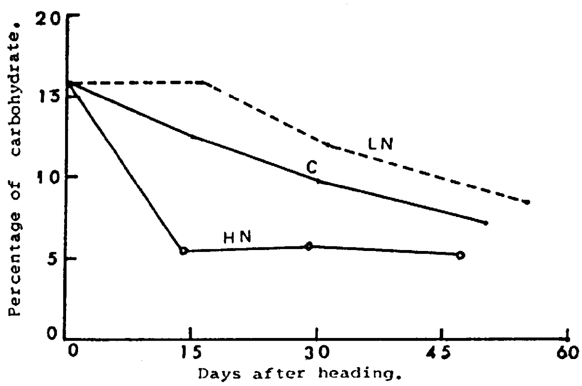

Fig. 52. Percentage of carbohydrate in leaf sheaths. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

In the Experiment No. 1 (Figs. 7 to 12) though nearly the same trend was found but in the case of the leaf blades (Figs. 7 and 8) and leaf sheaths (Figs. 9 and 10) the rates of decrease of both the amounts and percentages of carbohydrate in the Control plot were more than those of the H. N. plot. In the case of the culms (Figs. 11 and 12) nearly the same trend as that of Experiment No. 4 (Figs. 53 and 54) was seen.

In the Experiment No. 3 (Figs. 29 to 34) no increase in the amount of carbohydrate in the Control plot and in the H. N. plot was seen

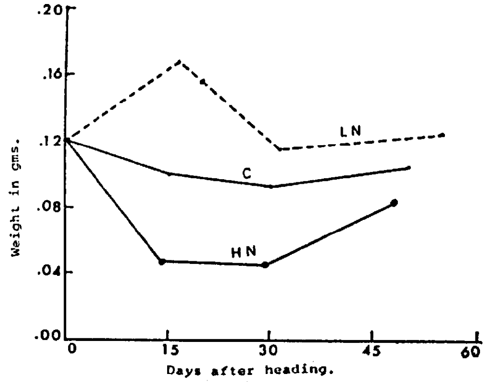

Fig. 53. Amount of carbohydrate in culms (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

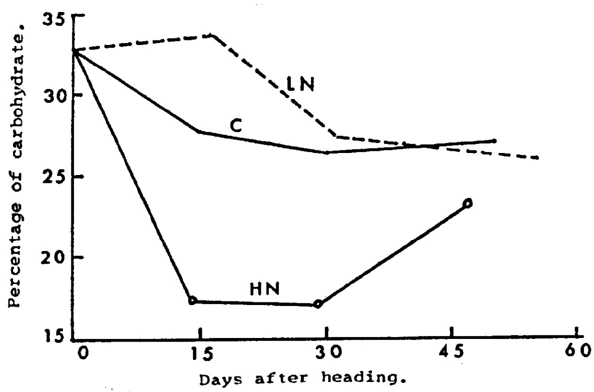

Fig. 54. Percentage of carbohydrate in culms. C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

either in the leaf blades (Fig. 29), leaf sheaths (Fig. 31) or culm (Fig. 33) at the former stages though in the control plot the percentage of carbohydrate (Fig. 30) showed increase from the heading stage upto the 15th. day after heading. Both the amounts and the percentages of carbohydrates in the leaf blades, leaf sheaths and culms (Figs. 29 to 34) were higher in the L. N. plots.

From these figures it could be seen that the carbohydrate contents of the L. N. plot were always higher in all the seasons as due to the low temperature of the plot the consumption was less. The overall decrease in the carbohydrate contents were more in the summer season (Experiment No. 3 Figs. 29 to 34) as consumptions due to high temperature of the season was more in summer (Takeda, 1961).

Dry weights of dead leaf blades and dead leaf sheaths

Figs. 55 and 56 show the dry weights of dead leaf blades and dead leaf sheaths. As seen in the figures the dry weight of dead leaf blades was highest in the L. N. plot and lowest in the H. N. plot at the end. The Control plot showed slightly lower values than those of the L. N. plot. In the case of dead leaf sheaths (Fig. 56) the dry weights were highest in the Control plot and lowest in the H. N. plot at the 30th. day after heading. The dry weight of the L. N. plot was low at the begining but showed the highest value at the end.

In the Experiment No. 3 (Figs. 35 and 36) the dry weights of dead leaf blades and dead leaf sheaths of the H. N. plot increased more

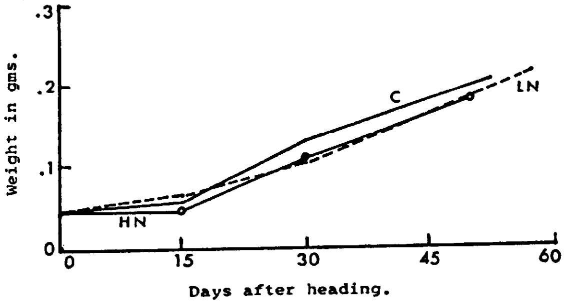

Fig. 55. Dry weight of dead leaf blades (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

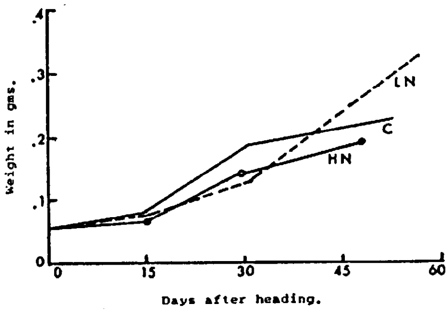

Fig. 56. Dry weight of dead leaf sheaths (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

rapidly than those of the L. N. plot and the Control plot. It could be assumed that in the summor season due to higher temperatures the senecence of the leaves in the H. N. plot was hastened.

Dry weights of top parts

Fig. 57 shows the dry weights of top parts. As seen in the figure the dry weight of top parts was highest in the. L. N. plot and the increase of the dry weight was nearly linear from the begining upto the end. The dry weights of top parts of the Control and the H. N. plots were nearly same.

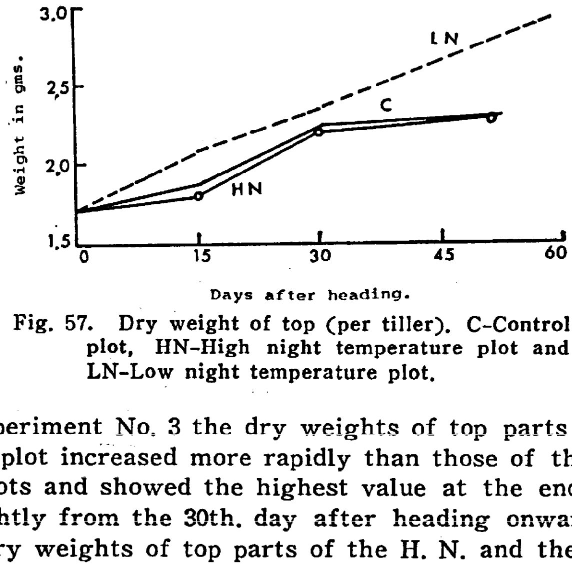

Fig. 57. Dry weight of top (per tiller). C-Control plot, HN-High night temperature plot and LN-Low night temperature plot.

In the Experiment No. 3 the dry weights of top parts (Fig. 37) in the Control plot increased more rapidly than those of the H. N. and the L. N. plots and showed the highest value at the end though decreased slightly from the 30th. day after heading onwards upto the end. The dry weights of top parts of the H. N. and the L. N. plots showed nearly the same rate of increase.

From these differences in dry weights of Top parts in the Experiment Nos. 3 and 4 (Figs. 37 and 57) it could be assumed that in the summer season the overall consumptions were higher due to higher temperatures and consequently the dry weights of the top parts were relatively low.

Distributions of dry matters and assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before heading

As seen in figures 58, 59 and 60 translocation of dry matters to the grains was most uniform in the H. N. plot in comparison with the L. N. plot and the Control plot. The total increase however was maxi-

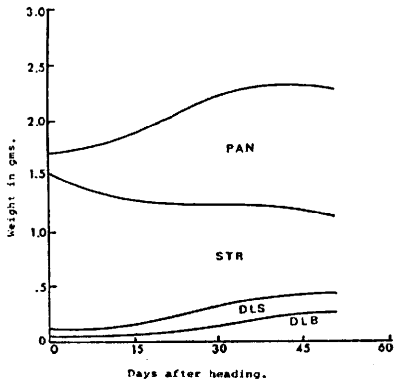

Fig. 58. Distribution of dry matters (per tiller) in the Control plot. PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

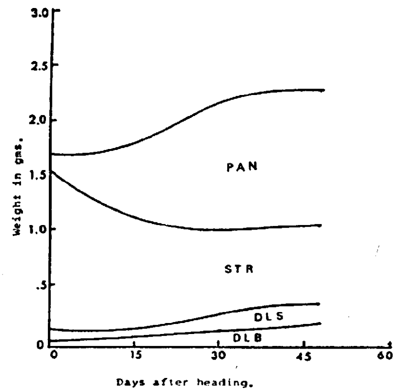

Fig. 59. Distribution of dry matters (per tiller) in the High night temperature plot. PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

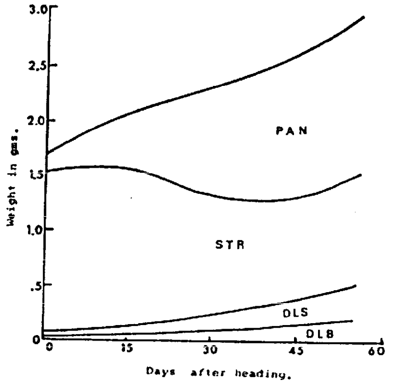

Fig. 60. Distribution of dry matters (per tiller) in the Low night-temperature plot. PAN-Panicle, STR-Straw (living), DLS-Dead leaf sheaths and DLB-Dead leaf blades.

mum in the L. N. plot and minimum in the Control plot.

Table 8 shows the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before heading. As seen in the Table more than 99 % of the dry matters of the grains of the L. N. plot came through the photosynthesis of the plants after heading. In the H. N. plot and in the Control plot 63.9% and 68.4 % of the dry matters of the grains came from the photosynthesis of the plants after heading respectively.

In the Experiment No. 3 (Figs. 38, 39 and 40) the translocation was more uniform in the Control plot than in those of the H. N. and the L. N. plots. As seen in Table 5, nearly three fourth of the dry matters of the grains of all the plots came from the photosynthesis of the plants after heading, as a considerable portion of the dry matters was consumed due to the higher temperatures of the summer seasons. In the autumn season (Experiment No. 4, Table 8) quite a considerable

Table 8. *Assumed percentages of dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before heading.*

Plots	Percentage of dry matters of the grains supplied through photosynthesis of the plants after heading.	Percentage of dry matters of the grains supplied through translocation of materials produced before heading.
Cont.	68.42	31.58
H. N.	63.94	36.06
L. N.	99.30	0.70

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

portion of dry matters of the grains came through the translocation of materials produced before heading in the H. N. and in the Control plots. The production of dry matters was highest in the L. N. plot (after heading) and a considerable amount of dry matter remained deposited in the straw without being translocated and increased the top weight (Fig. 57) of the plot.

Grain straw ratio

Table 9 shows the grain straw ratios. As seen in the Table, the ratio was largest in the H. N. plot and smallest in the L. N. plot. The Control plot showed an intermediate value. In the L. N. plot production of dry matter through the photosynthesis after heading was high and a portion of the dry matter remained deposited in the straw without being translocated. In the Control plot the grain straw ratio was small as the translocation was disturbed at the end. Whereas in the H. N. plot the translocation was fair and also consumption was more in comparison with the L. N. plot and the Control plot.

In the Experiment No. 3 the grain straw ratios (Table 6) were larger in all the plots. It seemed that consumptions due to higher temperatures were more in the summer season and consequently the amount of straw was less in comparison with the autumn season.

Table 9. Grain straw ratio.

Plots	Grains	Straw
Cont.	100	102
H. N.	100	89
L. N.	100	106

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

Pereentage of sterility of the grains

Table 10 shows the percentage of sterility of the grains. As seen in the Table the percentage of sterility was highest in the Control plot and lowest in the H. N. plot. The L. N. plot showed slightly higher percentage of sterility than that of the H. N. plot.

Table 10. Percentage of sterility of the grains.

Plots	Percentage of grains of over 1.06 sp. gr.	Percentage of grains of over 1.00 sp. gr.	Percentage of sterile grains.
Cont.	15.70	51.80	32.44
H. N.	28.40	56.60	15.03
L. N.	41.50	42.50	16.05

Cont.: Control plot, H. N.: High night temperature plot and L. N.: Low night temperature plot.

The highest percentage of sterility in the Control plot was due to the fact that translocation in the Control plot was not very rapid and at the end the grains lost considerable receptibility (Fig. 46). The fact that the percentage of grains of more than 1.06 sp. gr. was only 15.7% in the Control plot showed that the grains failed to be fed properly.

In the Experiment Nos. 1 and 3 also (Tables 1 and 3) the percentage of sterility was highest in the Control plots though in neither case was as high as that seen in this experiment.

Discussion

The highest panicle weight of the L. N. plot (Fig. 42) could be assumed to have resulted from the largest leaf area (Fig. 43) of the plot (Takeda, 1961). This large leaf area helped produce a large amount of dry matters as evidenced from the larger dry weights of the leaf blades (Fig. 44), leaf sheaths (Fig. 45) and culms (Fig. 46) and their corresponding carbohydrate contents (Figs. 49 to 54). Both the amount and the percentages of nitrogen (Figs. 47 and 48) in the leaf blades were highest in the L. N. plot which suggested larger photosynthesis as also evidenced from the fact that more than 99% of the dry matters of the grains in the L. N. plot (Table 8) came from the photosynthesis of the plants after heading. The panicle weight of the H. N. plot (Fig. 42) was higher than that of the Control plot but lower than that of the L. N. plot. Though the translocation was very rapid in the H. N. plot at the begining, it fell at the end as the receptibility of the grains decreased. Dry weight (Fig. 46) and Carbohydrate contents (Figs. 53 and 54) of the culms supported this assumption. The Control plot showed the lowest panicle weight (Fig. 42). The Control plot had lowest leaf areas (Fig. 43) throughout the ripening period. The translocation was also not uniform in this plot as evidenced from the dry weight of culms (Fig. 46) and the carbohydrate contents of leaf blades, leaf sheaths and culms (Figs. 49 to 54). Moreover, the grain straw ratio (Table 9) also suggested that the stored carbohydrate which was not translocated remained deposited in the straw and increased the top weight (Fig. 57) of thi splot.

6. General discussions

Both the Experiment Nos. 1 and 4 were conducted in the autumn-season and the same variety Hoyoku was used in both the experiments. The dry weights of panicles were highest in the L. N. plots (Figs. 2 and 42) in both the experiment. The H. N. plot showed lowest panicle weight in the Experiment No. 1 (Fig. 2) and the Control plot showed the lowest panicle weight in the Experiment No. 4 (Fig. 42). The mean temperatures of the ripening periods (Figs. 1 and 41) were not much different though the daily variations were. Even though the leaf areas of the Control plots (Figs. 3 and 43) in both the experiments were smaller, fair amount of translocation took place in the case of experiment No. 1 as evidenced from the dry weights of the leaf blades, leaf sheaths and culms (Figs. 4, 5 and 6) and their corresponding carbohydrate contents (Figs. 9 to 14). Whereas in the Experiment No. 4 considerable amount of carbohydrate remained deposited in the culm as could be seen from the dry weight (Fig. 46) and the carbohydrate content (Fig. 53) of the culm. The grain straw ratio (Table 2) was larger in the Experiment No. 1. In the Experiment No. 4 the untranslocated carbohydrate remained deposited in the straw and increased the top weight (Fig. 57) of the plot. In experiment No. 4 the percentage of sterility (Table 10) was high and specially in the Control plot it was very high and as a result the dry weight of panicle (Fig. 42) showed the lowest value. In the Experiment No. 1 only 6 plants per plot ware sampled and the variations among the individual plants were very high. It seemed that the number of plants sampled in experiment No. 1 was small.

Experiment Nos. 2 and 3 were conducted in the summer season and the same variety Koshihikari was used in both the experiments. The L. N. plots showed the highest panicle weights (Figs. 15 and 22) in both the experiments. The Control plot showed the lowest panicle weight (Fig. 15) in the Experiment No. 2 and the H. N. plot showed the lowest panicle weight in the Experiment No. 3 (Fig. 22). In Experiment No. 2 the panicle weights (Fig. 15) of all the plots showed decrease from the 30th. day after heading onwards and this trend appeared to be abnormal. In Experiment No. 2 only 4 plants per plot were sampled and the variations among the individual plants were high and it seemed that due to this reason this abnormal trend was seen.

When experiment Nos. 3 and 4 are compared interesting differences are observed. Experiment No. 3 was conducted in the summer season and 4 in the autumn season and different varieties were used in experiment Nos. 3 and 4. In both the experiments the L. N. plots showed the highest panicle weights (Figs. 22 and 42). In the summer season the panicle weight of the Control plot was higher than that of the H. N. plot but in the autumn season it was lower than that of the H. N. plot. In the autumn season the H. N. plot had larger leaf area (Fig. 43) and as higher temperature enhances the rapidity of translocation (Aimi et al, 1966) filling up of the grains was rapid in the H. N. plot in the autumn season (Fig. 42). Whereas in the summer, due to the higher temperature of the season this rapidity of translocation was associated with higher consumption of carbohydrates as high temperature increased the rate of respiration (Takeda, 1961). Hence the panicle weight of the H. N. plot in the summer season showed lower value than that of the Control plot. In the case of the autumn season due to the relatively low temperature, the H. N. plot showed higher panicle weight than that of the Control plot as the consumption was less in comparison with the summer season. In the autumn season, it could be seen from the figures 44, 45 and 46 that uniform translocation did not take place in the Control plot. The untranslocated materials remained deposited in the culm (Fig. 46) and increased the top weight (Fig. 57) of this plot.

In comparison with the autumn season the consumptions were high in the summer season in all the plots as could be seen from the grain straw ratio (Table 6) and the assumed percentages of the dry matters of the grains supplied through the photosynthesis of the plants after heading and through the translocation of materials produced before the heading (Table 5). In Experiment No. 4 nearly all the carbohydrates of the grains of the L. N. plot came from the photosynthesis of the plants after heading (Table 8) and in the Control and the H. N. plots over 30% of the dry matters of the grains came from the translocation of the materials produced before the heading and top weights (Fig. 57) of all the plots showed increase upto the end. Whereas in the summer season even in the L. N. plot 24% of the dry matters of the grains (Table 5) came from the translocation of materials produced before heading, and the top weights (Fig. 37) of all the plots showed decrease from the 30th. day after heading onwards. In the summer season consumptions were high in all the plots, due to high temperatures and so the amount of straw was small in all the plots (Table 6). Whereas in the autumn season due to the relatively low temperatures consumptions were less in all the plots and the amount of straw was large (Table 9) in all cases.

The L. N. plots showed highest panicle weights in all the seasons. The Control plot showed slightly higher panicle weight than that of the H. N. plot in the summer season but a little lower panicle weight than that of the H. N. plot in the autumn season. The filling up of the grains in the L. N. plot was slow in speed but continued upto the end whereas in the H. N. plot filling up of the grains was more rapid than that of the Control plot in autumn season but less rapid in the summer season. Though high temperature increased the rapidity of translocation (Aimi et al, 1966, Matsushima and Wada, 1959) the grains of the H. N. plot were filled up less rapidly than that of the Control plot in the summer season. It could be assumed that in the summer season the consumption in the H. N. plot was very high due to high temperature (Takeda, 1961). In autumn season though at the later stage of ripening the temperatures of all the plots were same the L. N. plot showed highest panicle weight as the receptibility of the L. N. plot was unique upto the end and the dry weight increase of panicle was linear from the begining upto the end.

It the autumn season the temperature of the Control plot was also relatively low but it failed to show higher panicle weight than that of the L. N. plot. Though the speed of translocation was higher in the Control plot but at the end the grains of this plot lost considerable receptibility whereas in the L. N. plot the dry weight of panicles (Fig. 42) showed steady increase from the begining upto the end. Dry matter production was very high in the L. N. plot due to the larger leaf area (Fig. 43). Surplus amount of dry matters, activities of the leaves and fine receptibilties of the grains of the L. N. plot favoured it to show higher panicle weight than that of the Control and the H. N. plots.

From the above investigations the following conclusions could be drawn:

1. A low night temperature at the ripening stage of rice plant is favourable to higher grain production both in the summer season and in the autumn season. Low night temperatures prolong the longevity of the leaves and dry matter production as a consequence increases and as consumption due to low temperature is low and receptibility of the grains does not decrease the grain production becomes high.

2. A high night temperature at the ripening stage of rice plant is not favourable to higher grain production in the summer season.

High temperature of the summer season hastens the senecence of leaves and as a consequence dry matter production is reduced. Moreover, respiration increases with high temperature and as a result the dry matter consumptions become high. Hence higher grain production is not favourable.

3. A high night temperature at the ripening stage of rice plant is relatively favqurable to higher grain production in the autumn season. The consumptions due to high temperature does not become as high as those of the summer season, because of the relatively low temperature of the autumn season. As high temperature enhances the rapidity of translocation and consumptions are also relatively less, considerable amount of dry mattor is made available for supplying to the grains. Hence the grain production becomes high.

7. Summary

Objective

Uptil recently the ceiling in the rice yield of the south western regions of Japan was considered to be put by the high temperature, specially the high night temperature of the ripening period of these regions — in other words the small differences in the day and night temperatures at the ripening period. But the recent changes in the trend towards higher yield of the regions of northern Kyushu brought discrepancies to such concept.

From the works so far been done it could not be said with certainty that prevalence of the high temperature at the ripening period actually produced ill effect on the rice yield, and one of the objectives of this experiment was to confirm this effect. The second ceiling in the rice yield in the regions of Kyushu started posing a problem and another objective was to clarify both physiologically and ecologically, the relationship of the high temperature at the ripening period with the yield and to find out some definite way to break this ceiling in yield.

Experimental methods

According to the objectives mentioned before, representing two rice croppings (annual) of the south western Kyushu, that is, early season and ordinary, different varieties Koshihikari and Hoyoku were used for respective experiments. In each experiment, three plots were prepared on the basis of the temperature (nigh) of the ripening period, High night temperature plot (about 2-3°C higher than that of the average temperature), Control and Low night temperature plot (about 2-3°C lower than that of the average temperature) and the ripening

conditions of the different plots were examined and at the same time the changes in the dry weight contents, leaf area, nitrogen contents and carbohydrate contents, assimilation of dry matters, consumptions through respiration and translocation of carbohydrate were observed.

Results and discussions

In both the seasons the low night temperature plot showed the highest yield. And in the early season the Control plot showed the next higher yield and the high night temperature plot showed the lowest. Whereas in the ordinary cropping season the High night temperature plot showed the second highest yield and the Control plot the lowest.

1. The reasons for the Low night temperatures 'plots' showing highest yield in both the seasons were that, on the one hand, the decrease in the activity of the assimilatory organs with time was checked by the low temperature of the plot and on the other hand the decrease in the power of receptibillity of the organs as 'sink' with time was also checked by the low temperature of the plot.

2. One of the reasons of the High night temperature plot's showing the lowest yield in the early cropping season was that though the rate of translocation increased with the high temperature of the plot the amount of 'source' became limited by the excessive consumption due to high temperature. Moreover, the decrease in the ability of the assimilatory organs and in the receptibility of the grains were enhanced by high temperature of the plot.

3. In the ordinary cropping season the High night temperature plot showed a little higher yield than that of the Control plot and the reasons were as follows:

One of the reasons was that in the case of the ordinary cropping, the season was autumn and the temperature of the High night temperature plot was relatively lower in comparison with the early cropping season and as a result the consumptions through the respiratory activities were comparatively lower. Moreover, as the temperature of the High night temperature plot was higher than that of the Control plot, the rate of translocation was rapid. Though the temperature of the Control plot was lower than that of the High night temperature plot and the dry matter production was comparatively large due to the low temperature the rate of translocation was slow and as the night temperature of this plot was higher than that of the Low night temperature plot, the fallling in the ability of the organs as 'sink' with time was enhanced and the receptibility of the grains as a consequence decreased. And for this reason it could be assumed that the panicle weight of this plot could not reach as high as that of the High night temperature plot.

4. There are many factors which determine the grain yields, and these factors are variously inter-related. Finally, if it is assumed that the stored materials of the grains are starch, then at the ripening stage specially, the synthesizing of starch, its translocation and the receptibility of the organs are considered to be very important factors.

The effect of high night temperature at the ripening period is considered to be determined by the degree of its action on the interrelationships of these three main important factors. And so far as the relation of temperature (in this case night temperature) with these factors are concerned, it could be assumed that for each of these factors an optimum temperature exists.

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