Influence of Panicle Clipping, Flag Leaf Cutting and Shading on Ripening of Japonica and Indica Rice

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Various aspects concerning the developing rice kernel have previously been studied.^{3,4)} And it is claimed that rice kernels develop abnormally when the carbohydrate supply during the ripening period is inadequate. Nagato and Chaudhry claim that per panicle number of spikelets play a definite role in the kernel development and ripening process, as it has a relative correlation with the carbohydrate supply. Actually no detailed information is available on relationship of kernel development and number of spikelets per panicle. Particularly, the information was needed about the behaviour of kernel when the per panicle number of spikelets is decreased or the per panicle amount of nutrients is increased.

On the contrary, it was also thought apt to include in this experiment the cutting of flag leaf and shading treatments at various growth stages from the standpoint of knowing the likely adverse effect on the ripening. This paper therefore, deals with the partial thinning out of panicle at the time of panicle emergence, the cutting of flag leaf and shading trials to provide a base for understanding whether these treatments would or would not exert an influence on the development and quality of rice kernel.

MATERIALS AND METHODS

These studies were carried out during the years 1968 and 1969 in the crop science laboratory, university of Nagoya. In all, three experiments (1) panicle thinning (2) flag leaf cutting and (3) shading were conducted. In the first and second experiments six varieties that is, Dular, Karalath, Te-Tep, Bluebonnet, Kinmaze and

Towada were taken in to consideration, whereas in third experiment only three varieties (Te-Tep, Bluebonnet, Kinmaze) were used. Kinmaze and Towada are Japonica and Dular, Karalath, Te-Tep and Bluebonnet belong to indica type rice. Normally prepared nursery beds were seeded in the last week of April. Seedlings after having attained proper size were transplanted to the soil filled pots in the first week of June. The 1/2000 th of an acre size pots were used and five seedlings were sown in each pot. Three pots in each treatment within all the three trials were used for respective observations. All the cultural operations other than under study were normal and uniform for all the treatments.

(1) Panicle thinning trial: The thinning of each panicle was done when it emerged from flag leaf. The planned cuttings of partial panicle branches were carried out in a fashion that the respective panicles were treated early in the morning on the day of their emergence. The following treatments were employed for the objective of this experiment.

- (A) Control.....no cut
- (B) 1/2 Cut.....alternate branches of the panicle were cut.
- (C) 1/4 cut.....1/4th of every branch of panicle was cut.
- (D) 1/4 cut.....3rd or 4th and 7th branches (about 1/4 branches) of the panicle were cut.

(2) Flag leaf cutting trial: In this experiment entire flag leaf and half of the flag leaf were cut at two growth stages in the following way.

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- (C) control.....no cut
- (1) 1 cut.....entire flag leaf was cut before heading.
- (2) 1/2 cut.....half of the flag leaf was cut before heading.
- (3) 1 cut.....entire flag leaf was cut at heading stage.
- (4) 1/2 cut.....half of the flag leaf was cut at heading stage.

Individual flag leaf cuttings before heading were done when each flag leaf emerged fully. The cuttings of flag leaf at heading stage were done at panicle emergence from flag leaf. Each plant in both the cases was treated separately according to time of emergence of flag leaf or panicle.

(3) Shading trial: In this trial shade was provided to the plants with the help of a shading arrangement made of coarse cotton cloth and wooden sticks. Permeability of light was 67% and 50% in clear and cloudy weather respectively. Plants were kept under shade for one week duration at various growth stages and the treatments were

- (C).....control
- (O).....treatment started one week before heading stage.
- (1).....treatment started at heading stage.
- (2).....treatment started at one week after heading.
- (3).....treatment started two weeks after heading.

After maturity, samples were collected, worked out and analyzed for the intended purpose of these experiments. Observations were made separately on the upper, middle and lower panicle branches, which were further separated in to primary and secondary branches to know the positional effect clearly.

RESULTS

(1) Thinning Trial: In contrast to the control or no cut all the treatments employed in thinning out of the panicle at the time of panicle

emergence showed a remarkable influence in improving the ripening of rice kernel substantially, in both the japonica and indica type rice. The 1/2 cut treatment proved to be the most effective, imparting a positive effect on the ripening and kernel quality of rice. whereas the 1/4 cut treatments were almost at par with each other, 1/4 (C) being slightly better. All the six varieties responded in the same direction, irrespective of the varietal differences.

Bluebonnet (fig. 1)

Sterility: Occurrence of sterility tended to decrease by thinning on the secondary branches but showed a nominal effect on the primary branches. This may be contributed to the fact that the ripening of the primary branches even in the non treated plots is almost normal and ill ripened kernels always occur more frequently on the lower and secondary branches.

Abortive kernels: This type of kernels were found rare in primary branches but occur numerously in case of secondary branches. Occurrence of these kernels was markedly decreased in thinned plots. They rarely occur in B and C plots and slightly occur in D plots.

Opaque kernels: Such type of kernels also occur in secondary branches, especially in secondary branches of lower branches. A decrease in thinned plots was observed similar to that of abortive kernels.

Milky-white kernels: Also decreased in the same order as that of opaque kernels.

Deformed kernels: These kernels were rather found more frequently in treated plots, especially in secondary branches. These are such inferior spikelets which have had stopped their development and become abortive and opaque kernels in early and middle stages of kernel development if the supply of carbohydrates was extremely in want, but become translucent and grow in to deformed kernels if the supply of carbohydrates is not in want.

As noted above, on account of increase in nutrients (carbohydrates) per spikelet, occurrence

Fig. 1. Effects of thinning treatment on ripening (var. Bluebonnet)

Fig. 2. Effects of thinning treatment on ripening (Secondary branch)

of abortive and opaque kernels remarkably decreased and milky white kernels also decreased in thinned plots. These effects are more evident in B than in C, and in C than in D. As about 1/4 spikelets on the top of every primary branch were cut in C plots, whereas about 1/4 branches of a panicle were cut in D plots. Therefore, the spikelets which will develop more vigorously were thinned in C plots compared to D plots. For this reason the thinning was more effective in C plots.

Primarily, effects were more notable on the secondary branches which are essentially in want of nutrients and often grow in to ill ripened kernels than the spikelets on the primary branches. Due to this reason the influence of thinning is indicated in spikelets on the secondary branches only in case of other varieties. (fig. 2)

All other varieties resulted in a trend similar to that of Bluebonnet. Treatment B indicated the greatest influence and was followed by treat-

ment C.

Sterility: Occurrence of sterility in varieties Karalath, Te-Tep and Bluebonnet which originally produce large number of sterile kernels is highly reduced unlike varieties Dular, Towada and Kinmaze which originally do not produce much sterile kernels and are less influenced by thinning.

Abortive and Opaque kernels: Likewise, occurrence of this type of kernels is also decreased by thinning.

Milky-white kernels: Commonly, thinning of panicle has a favourable effect and occurrence of milky-white kernels is reduced but in varieties like Karalath and Te-Tep in which the occurrence of sterile, abortive and opaque kernels is greatly decreased, the occurrence of milky-white kernels is increased. Because the sterile, abortive and opaque kernels, which otherwise have had stopped their growth continue to grow and make the competition hard during early and middle stages of ripening, creating favourable conditions for

the occurrence of milky-white kernels.

Deformed kernels: Such kernels rather increased in treated plots.

White-belly kernels: Occurrence of these kernels resulted almost parallel to the milky-white kernels. A considerable reduction was seen in Kinmaze and no decrease was observed in Dular. In case of Te-Tep, if overall percentage of the all kernels is taken in to consideration there was no decrease but a decrease was resulted when sterile, abortive and opaque kernels were excluded and per centage of remaining kernels only was considered. White-belly kernels appear when the carbohydrate supply is not sufficient during the later stage of ripening.

Among the varieties, Dular which basically has comparatively less number of spikelets per panicle (table 1) and hence has less competition for nutrients among the spikelets was nominally influenced. Towada and Kinmaze which apparently are having a balance between the number of per panicle spikelets and available carbohydrate supply were not affected to the considerable extent. On the contrary the influence of thinning treatments was exerted more on Karalath and Te-Tep on account of more number of per panicle spikelets in these varieties, which creates a competition for carbohydrates to a large degree.

(2) Leaf cutting Trial: Like thinning treatments, secondary branches are influenced to a greater degree compared to primary branches although the effect of thinning is to the opposite direction. Entire leaf cutting treatment exerted greater negative influence on the ripening as compared to 1/2 leaf cutting treatment.

Cutting before heading: In one week before heading treatment, depending upon the varieties, some of the inferior florets especially on secondary branches appear as "White-husk," florets which stop growth in the early stage and appear as white, papery structures. (fig. 4). In this way the number of per panicle spikelets particularly on secondary branches is decreased (table

Fig. 3. White husks (wh) produced by leaf-cutting (Te-Tep)

Table 1. No. of spikelets per panicle in non-thinned plot

Variety	No. of spikelets		
	Primary branch	Secondary branch	Panicle
Dular	39.8	22.4	62.2
Towada	53.3	31.3	84.6
Karalath	56.2	72.6	128.8
Te-Tep	50.8	34.9	85.7
Kinmaze	46.7	36.4	83.1
Bluebonnet	63.0	45.5	108.5

2) and the supply of carbohydrates for the remaining spikelets is increased and hence results in better ripening. Again, in cutting before heading treatment, sterile, abortive and opaque kernels were found in an increasing trend. This increase was expected to be more than the cutting after heading treatment but in reality it was less. This is due to the fact that in before heading treatment per panicle spikelets are decreased (which in return will result in the decrease of sterile, abortive and opaque kernels). This is true in case of Dular and Karalath in which number of spikelets per panicle especially on secondary branches decreases considerably. In case of Towada and Kinmaze sterile etc. increase because the per panicle spikelets on secondary branches are not decre-

ased so much. Te-Tep and Bluebonnet behaved intermediately in reduction of per panicle spikelets and occurrence of sterility etc.

Cutting at heading: This treatment showed an increase in sterile, abortive and opaque kernels.

Milky-white kernels: Occurrence of milky-white kernels ranges from small to large degree depending upon the variety, and generally an increasing trend was found in all the tested varieties. But when the sterile, abortive and opaque kernels occur abnormally as in case of secondary branches of Dular, Towada, Karalath and Te-Tep, the competition for nutrients among the spikelets is ameliorated in the remaining kernels and as a result milky-white kernels are decreased.

White-belly kernels: Such kernels generally increase in treated plots but in case the number of spikelets per panicle decreases and sterile, abortive and opaque kernels occur numerous in cutting before heading treatment (Dular and Bluebonnet), the competition in later stage of ripening is decreased and consequently the

white-belly kernels are also decreased.

(3) Shading Trial: Influence of shading too is exerted more on secondary branches than those of primary ones. In shading before heading treatment occurrence of sterile, abortive and opaque kernels is clearly increased. Although in after heading treatment, sterile abortive and opaque kernels are increased but comparatively sterile and abortive kernels occur more in at heading treatment.

Milky-white kernels: Milky-white kernels have a tendency to increase by shading but like secondary branches of Te-Tep if sterile, abortive and opaque kernels occur in abundance the competition for carbohydrates in early and middle stages of ripening is decreased and due to the favourable conditions the occurrence of milky-white kernels is decreased.

White-belly kernels: Such kernels are also like wise increased by shading but when the carbohydrate supply during the later stage of ripening become adequate on account of the numerous occurrence of sterile, abortive and opaque kernels the white-belly kernels are de-

Fig. 4. Effects of leaf-cutting treatment on ripening

creased. This could be clearly understood in the secondary branches of panicle of Bluebonnet.

In general, influence of shading was least in Kinmaze, greatest in Te-Tep and medium in case of Bluebonnet. These results are parallel to the results obtained in thinning treatments with the difference that thinning treatments favoured the ripening where as shading treatments unfavoured it. This is due to the reason that in case of varieties like Kinmaze, which apparently has the balance between the number of spikelets per panicle and carbohydrate supply, there is a negligible effect on both the sides, whether the number of spikelets per panicle is decreased or carbohydrate supply is slightly decreased. But in case of Te-Tep which has too much spikelets per panicle and do not maintain the balance against the available carbohydrate supply, the effect of treatments is more and considerable.

DISCUSSION

In thinning at heading stage carbohydrate allocation per spikelet is increased therefore the ripening is favoured improve, whereas on the contrary in leaf cutting and shading treatments before heading and at heading stages carbohydrate allocation per spikelet is decreased and hence the ripening is not desirable. Depending upon the degree of competition for nutrients among the spikelets, ill ripened kernels appear easily when influenced by cutting and shading treatments. This effect is substantially remarkable in inferior spikelets particularly the 2nd and 3rd spikelets of secondary branches.^{1,3)}

Sterility occurs according to the failure of fertilization. A want of carbohydrates of carbohydrates only does not cause occurrence of sterility but when the carbohydrates are extraordinarily in want the sterility is encouraged occur. In Karalath and Te-Tep which primarily produce more sterile kernels thinning treatment is more effective and sterility occurrence is decreased. Sterility is least influenced by thinning

Table 2. No. of spikelets per panicle in leaf-cutting treatment

Variety	Plot	No. of spikelets		
		Primary branch	Secondary branch	Panicle
Dular	C	38.3	39.4	77.7
	1	37.7	25.6	63.3
	2	39.7	32.1	71.8
	3	39.0	33.7	72.7
	4	39.7	38.3	78.0
Towada	C	65.3	36.1	101.4
	1	64.2	30.8	95.0
	2	65.3	33.5	98.8
	3	64.6	37.2	101.8
	4	67.1	36.0	103.1
Karalath	C	48.4	48.3	96.7
	1	43.2	29.2	72.4
	2	52.0	40.0	92.0
	3	47.0	45.0	92.0
	4	50.8	42.8	93.6
Te-Tep	C	56.4	29.9	86.3
	1	49.7	23.5	73.2
	2	53.2	22.0	75.2
	3	53.6	27.4	81.0
	4	56.6	31.4	88.0
Kinmaze	C	38.4	30.9	69.3
	1	38.1	27.0	65.1
	2	38.9	27.5	66.4
	3	38.5	32.9	71.4
	4	37.7	31.0	68.7
Bluebonnet	C	84.2	38.9	123.1
	1	84.0	29.5	113.5
	2	85.2	32.9	118.1
	3	84.3	36.5	120.8
	4	82.4	38.0	120.4

in Dular, Kinmaze and Towada varieties which primarily produce less sterility. In flag leaf cutting treatments sterility is enhanced. This tendency is shown in all the varieties. 1/2 leaf cutting treatment did not exert a considerable influence. By shading treatments sterility in case of Te-Tep clearly increased but the effect in case of Kinmaze and Bluebonnet is very little.

Abortive kernels: In early stage of ripening when carbohydrate supply becomes extraordinarily short such kernels stop their development in early stage of ripening and appear as abortive

kernels.

Opaque kernels: When carbohydrates are not sufficient during early and middle stages of ripening, such kernels due to want of carbohydrates stop their development and become opaque kernels. This stage comes later than the stage when abortive kernels occur. Occurrence of both the abortive and opaque kernels is greatly influenced by different treatments. Such type of kernels are decreased in all the varieties when thinning is done. On the contrary they are favoured occur in leaf cutting and shading treatments. Wheather occurnce of abortive or opaque kernels will increase or decrease is decided by the stage and the degree of want of carbohydrates.

Milky-white kernels: These type of kernels occur when the carbohydrates are in want temporarily during early and middle stages of ripening.^{2,3,4)} Generally, these kernels showed a decreasing tendency under thinning treatments and an increasing tendency under cutting and shading tratments. But when sterile, abortive and opaque kernels are decreased substantially the competition among the surviving kernels is raised. In such conditions occurrence of milky-white kernels is favoured increase. On the contrary, in leaf cutting and shading treatments when sterile, abortive and opaque kernels occur abundantly competition among the remaining kernels is lowered and hence the occurrence of milky-white kernels is decreased. It can be seen in fig 4 and 5.

Deformed kernels: Deformed kernels occur when conjunction of lemma and palea is imperfect on their upper part and kernel development especially on breadth and thickness is prevented by desication. In such a case, if nutrient supply to those kernels is not enough as in A plot in thinning treatment, some of them stop developing and become abortive and opaque kernels. Nevertheless, when nutrient translocation is in abundance as in thinned plots, they become translucent and grow in to deformed kernels. Therefore, such kernels occur more frequently in thinned plots than non thinned ones. Moreover, imperfect conjunction of lemma and palea occurs more easily in the flowers on secondary branches than in those on primary branches. Therefore deformed kernels occur more on secondary branches.

White-belly kernels: This type of kernels occur when carbohydrate supply run short during the later stages of ripening.^{1,3)} Occurrence of these kernels is decreased with the thinning treatments whereas they showed an increasing tendency with the leaf cutting and shading treatments. But in leaf cutting before heading treatment when the number of per panicle spikelets is decreased or in other treatments when the sterile, abortive and opaque kernels occur numerously, the carbohydrate supply is left sufficient for the remaining kernels in later stages. In such cases white-belly kernels are decreased.

It could be concluded from above mentioned

Fig. 5. Effects of shading treatment on ripeninig

results that all the varieties showed a similar tendency under various treatments but the degree of influence is different with different varieties. Influence of thinning treatments on the varieties like Dular, Kinmaze and Tawada which apparently are maintaining balance between number of spikelets per panicle and carbohydrate supply, is very small. In varieties like Karalath and Te-Tep which basically produce a large number of spikelets per panicle, competition for carbohydrate supply is more and hence the effect of thinning treatments is quite significant.

In comparative terms, leaf cutting treatments exerted more influence on the ripening than that of shading treatments. This is due to the fact that in leaf cutting treatments the photosynthesis depression continued until the last stage of ripening whereas shading treatments were only for one week after which plants could use the sun light normally. Again, it is interesting to know that Kinmaze was influenced to a greater degree by leaf cutting compared to shading but this influence was reverse in case of Te-Tep which was influenced more by shading. It could be said that variety Kinmaze has small and erect type of leaves which have comparatively more photosynthetic ability under weak light conditions. Therefore, the effect of shading on this variety is little and that of cutting is more. In case of Te-Tep leaves are long and bending type which do not have much photosynthetic a-

bility under weak light conditions. Therefore, effect of shading on this variety is more than that of leaf cutting. Because in leaf cutting the photosynthetic activities of plant are compensated by other leaves in Te-Tep and hence the effect of cutting is little.

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〔和 文 摘 要〕

一穂粒数の制限、止葉剪除および日射の制限が日本型および
印度型水稻の稔実に及ぼす影響

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穂の一部を剪除して1粒当たり炭水化物の配給を多くしたり、逆に出穂前または出穂後に止葉を除き、あるいは1週間日射を制限して炭水化物の配給を少なくして稔実に及ぼす影響を調べた。

1. これらの処理の影響は元来炭水化物の不足しやすい弱勢籾特に下部二次枝梗の第2・3粒に著しい。

2. 不稔は本来受精障害により発生し、炭水化物の不足のみでは発生しがたいが、炭水化物が著しく不足するときは発生するものと考えられ、一穂粒数を減ずると、もともと不稔が著しく発生する Karalath・Te-Tep では明らかに減少し、不稔の発生が少ないトワダ・キンマゼでは影響が少ない。止葉剪除により不稔が増加する傾向があるが、止葉半切では影響はきわめて少ない。日射制限では明らかに増すが、キンマゼ・Bluebonnet では増加は少ない。

3. 発育停止は発育初期に著しく炭水化物の供給が少ないとき、その発育初期に発育を停止したもので、死米は発育の初中期に炭水化物の供給不足で停止したものであるから、これらの処理の影響は顕著である。粒数の制限で各品種とも著しく減じ、止葉剪除や日射制限で増す。処理によつて発育停止が増すか死米が増すかは、炭水化物の供給が不足する時期や不足の程度によるものである。

4. 乳白米は登熟初中期の一時的な炭水化物の供給不足によつて発生するから、一般に粒数制限で減じ、剪葉・日射制限で増す傾向があるが、粒数制限で不稔・発育停止・死米を著しく減じて残つた粒の間の競合が残る場合は乳白米はかえつて増加し、逆に剪葉や日射制限で不稔・発育停止・死米が著しく多発し、残つた粒の間の競合が軽減されると乳白米の発生は減る。

5. Bluebonnet に生じた奇形米は内外穎の上部の結合が不十分で乾燥のため米粒の発育特に幅と厚さの発育が抑えられたときに発生する。この場合、炭水化物の供給が不足しないときは透明になつて奇形米になり、不足するときは死米になる。従つて、このような奇形米は粒数を制限した区に多く発生した。なお、内外穎の結合不完全は弱勢籾に起こりやすいので、奇形米も弱勢籾に多い。この奇形米は搗精で碎米になる。

6. 腹白米は登熟後期に炭水化物の供給が不足したときに発生することがある。そのため一般に粒数制限で減じ、剪葉・日射制限で増す傾向があるが、出穂前の剪葉で粒数が減少したり、処理で不稔・発育停止・死米が多発して残つた粒への登熟後期の炭水化物供給が不足しない場合には腹白の発生が減ることもある。

7. 1穂粒数制限の影響は Dular・トワダ・キンマゼのように粒数と炭水化物の供給のつり合つた品種では小さく、Karalath・Te-tep など粒数多く競合のはなはだしい品種に著しい。

また、剪葉は光合成の抑制が登熟の終りまで続くから1週間の日射制限より影響が大きいと考えられ、特にキンマゼは葉が短かく直立し、弱光下の光合成能が大きく、日射制限の影響は剪葉より遙かに小さいが、Te-tep は葉長く下垂するため弱光下の光合成能は著しく低下するため日射制限の影響は大きく、反面剪葉（特に半切）の影響は小さい。この場合は、おそらく剪葉により日光の透射がよくなり補償されるためと考えられる。