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Effect of time of nitrogen application on spikelet differentiation and degeneration of rice

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Abstract. A study was conducted in the field to identify the N application stages which greatly determine spikelet differentiation and degeneration of rice (*Oryza sativa* L.). Spikelet differentiation and degeneration were greatly influenced by time of N application. N application at the neck-node differentiation stage significantly increased spikelet differentiation and that at the active meiosis stage significantly reduced spikelet degeneration. N absorption at the spikelet differentiation and heading stages was significantly correlated with both greater spikelet differentiation and percent degeneration, respectively. Degeneration was mainly induced by the degeneration of spikelets on the secondary rachis-branch. Four equal splits of 100 kg N/ha at the early tillering, active tillering, neck-node differentiation, and active meiosis stages were found good for efficient rice production.

Keywords: *Oryza sativa* L.; Spikelet degeneration; Spikelet differentiation.

Abbreviations: AM, active meiosis; **AT,** active tillering; **DAT,** days after transplanting; **NND,** neck-node differentiation; **RCB,** randomized complete block; **SPD,** spikelet differentiation; **SRD,** secondary rachis-branch differentiation.

Introduction

Differentiation and degeneration of spikelets are the two important processes that determine final spikelets per panicle. In reproductive phase two stages, the SRD and AM stages, are the most critical in determining final bearing spikelets per panicle (Matsushima, 1992). At the SRD stage, spikelets are ready to be born, and their development is positively increased. At the AM stage, it is decreased by degeneration; thus, the final number of spikelets is determined by the difference between the number of grains differentiated at the SRD stage and the number of grains degenerated in the later period. Climatic, biological and nutritional status at those stages greatly influences the spikelet determination process and subsequently the yield.

Among nutritional factors, N plays a very important role in the differentiation and degeneration of spikelets (Wada and Cruz, 1990). Split application of N is very often used in rice cultivation to increase its availability in the critical growth stages. Therefore, this experiment was undertaken (**1**) to investigate influence of N spilts at different growth stages on the differentiation and degeneration of spikelets and (**2**) to identify the suitable time of N topdress for good harvest with reasonable panicles and spikelets.

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Materials and Methods

Twenty-two-day old rice (*Oryza sativa* L. cv. Kinuhikari) seedlings were transplanted in the experimental field at Tsuskuba International Agricultural Training Centre on May 10, 1995 at 30 × 18 cm^2 spacing. The experiment was laid-out in loamy mixed mesic soil in RCB design with 3 replications. The treatments were application of total 100 kg N/ha in the form of urea (46% N) at different stages of rice growth as follows: $\mathbf{T_1}$-all at a time at 7 DAT ; $\mathbf{T_2}$-in three equal splits at 7 DAT, AT and NND stages; $\mathbf{T_3}$-in three splits at the ratio of 50:25:25 at 7 DAT, NND and SPD stages; $\mathbf{T_4}$-in three splits at the ratio of 50:25:25 at 7 DAT, SRD and AM stages. Active tillering was identified as the stage when the tillering rate per day was the highest. NND, SRD and SPD stages as mentioned by Yoshida (1981) were identified through microscopic observation and measurement of the young panicle length. The AM stage, mentioned by Matsushima (1992) and De Datta (1981), was identified as the stage when the collar of the flag leaf and that of the penultimate leaf coincided at the same level. Basal fertilizer of 120 kg P_2O_5/ha and 80 kg K_2O/ha were also applied in all the plots one day before transplanting. During flowering 20 kg K_2O/ha was also top dressed. Other cultural management practices were adopted as and when necessary.

Differentiation and degeneration of spikelets on both primary and secondary rachis-branches were studied from the panicle samples collected after maturity. Differentiated spikelets were the total spikelets primordia born on the panicle, and generated and degenerated spikelets were

spikelets which could and could not finally be expressed on the panicle, respectively. Vestiges of rudimentary rachis-branches or spikelets left on the panicle were counted as degenerated rachis-branches or spikelets. The sum of the generated spikelets with the degenerated ones gave the total differentiated spikelets per panicle (Matsushima, 1992 and Hoshikawa, 1989). Tiller growth was observed at a 6 to 15 day interval starting from the early tillering to meiosis stage. Grain yield was determined from a sampling area of 5 m^2 at the centre of the unit plot and expressed as t/ha of brown rice at 15% moisture content. Immature grains were separated by dipping the grain sample in a salt solution of specific gravity 1.06, and spikelet maturity was expressed as percentage of total generated spikelets per panicle. Per cent N in the plant samples were measured at three critical stages of reproductive phase, viz. the NND, SPD, and heading stages through destructive sampling at those stages. Per cent N was determined by an automatic N/C analyzer (NC80 Sumitomo Chemical Co. Ltd. Tokyo), and N absorption (g/m^2 dry matter) was estimated by multiplying the dry matter/m^2 with per cent N at the respective stages.

Results and Discussion

The results of the study reveal that spikelet differentiation and degeneration were greatly influenced by the time of N application, and the differences among the treatments were statistically significant (Table 1). The highest spikelet differentiation (130/panicle) was observed in T_2 treatment followed by T_3. The T_2 and T_3 treatments had received N topdress at the NND stage, and the other two treatments (T_1 and T_4), which did not receive N topdress at NND, had lower spikelet differentiation. The results may be explained by the N absorption pattern at the SPD stage (Table 2). Here, the highest N absorption (6.70 g/m^2) was found in the T_2 treatment, resulting in the highest spikelet differentiation, and the lowest N absorption (5.30 g/m^2 dry matter) was found in the T_4 treatment, resulting in the lowest differentiated spikelets (95/panicle). The higher the N absorption at SPD stage, the higher the spikelet differentiation and vice versa, and the positive correlation (r=0.96) was statistically significant.

On the other hand, the fewest degenerated spikelets (7/panicle) were observed in the T_4 treatment followed by T_3 where N was applied at or near the active meiosis stage. The other two treatments (T_1 and T_2), which did not receive N topdress at or near the active meiosis stages had higher spikelet degeneration. N absorption data at heading stage reveals that the higher the N absorption at the heading stage, the lower the degeneration and vice versa, and the negative correlation (r = -0.98) between N absorption at heading stage and per cent degeneration was statistically significant. The results of the positive correlation of N absorption at SPD with spikelet differentiation and the negative correlation of N absorption at heading stage with per cent degeneration are in agreement with the findings of Matsushima (1992) and Wada et al. (1989).

Table 1. Effect of time of N application on spikelet differentiation and degeneration.

Time and amount (kg/ha) of N application	Differentiated spikelets	Degenerated spikelets	
	(no./panicle)	(no./panicle)	(%)
T_1 = 7 DAT 100	108c	21ab	19.44
T_2 = 7 DAT + AT + NND 33.3 3.33 33.3	130a	26a	20.00
T_3 = 7 DAT + NND + SPD 50 25 25	119b	15b	12.60
T_4 = 7 DAT + SRD + AM 50 25 25	95d	6c	6.32
CV (%)	4.26	22.06	

Table 2. Effect of time of N application on N absorption at NND, SPD and Heading stages of reproductive phase.

Time and amount (kg/ha) of N application	N absorption (g/m^2 dry matter)		
	NND	SPD	Heading
T_1 = 7 DAT 100	5.02	6.01	8.13
T_2 = 7 DAT + AT + NND 33.3 33.3 33.3	3.65	6.70	8.31
T_3 = 7 DAT + NND + SPD 50 25 25	3.21	6.62	8.67
T_4 = 7 DAT + SRD + AM 50 25 25	3.31	5.30	9.29
Correlation with spikelet differentiation	-0.09NS	0.96*	-0.63NS
Correlation with per cent spikelet degeneration	0.64NS	0.67NS	-0.98*

Differentiated spikelets on both primary and secondary rachis-branches were significantly different among the treatments (Figure lA, B). The highest differentiated spikelets on both primary as well as on secondary rachis-branches were observed in T_2 treatment and the lowest in T_4 treatment. The generated spikelets on primary rachis-branches were the highest in T_2 treatment, but on secondary rachis-branches were the highest in T_3 treatment, where the total generated spikelets per panicle was also the highest (Figure lC). The results imply the close association of generated spikelets on secondary rachis-branches with the total generated spikelets on the panicle. The close association is clearly observed in Figure 2B where the correlation (r=0.99) of generated spikelets on secondary rachis-branches with those on the panicles was statistically significant. But the correlation (r=0.81) of generated spikelets on primary rachis-branches with those on the panicles

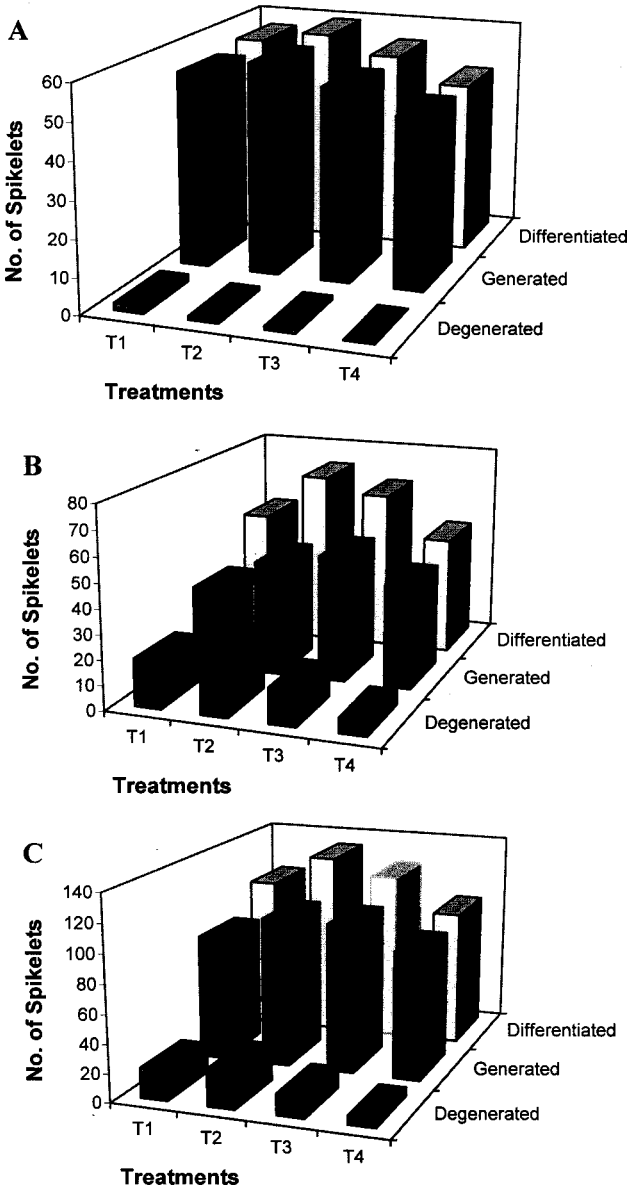

Figure 1. A, Spikelets on primary rachis-branch; B, Spikelets on Secondary rachis-branch; C, Total spikelets on panicle.

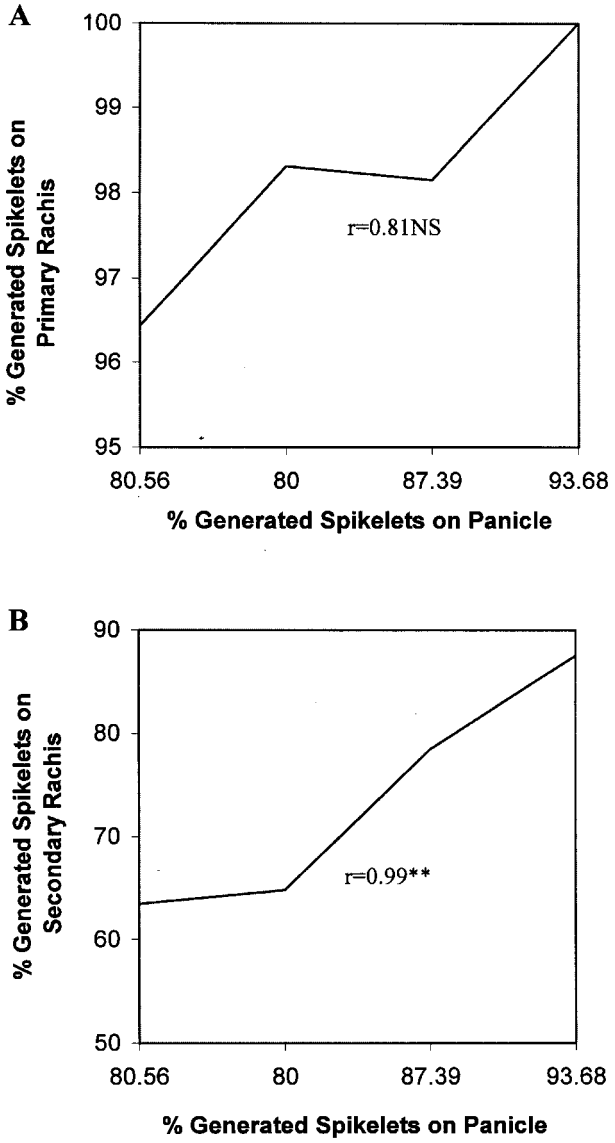

Figure 2. A, Association of per cent generated spikelets on primary rachis-branch and panicle; B, Association of per cent generated spikelets on secondary rachis branch and panicle.

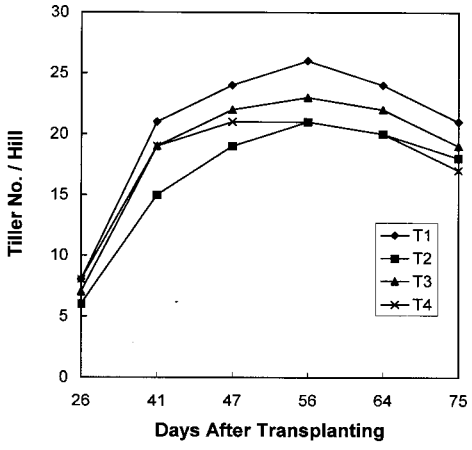

Figure 3. Tiller growth as influenced by N application at different growth stages.

Table 3. Effect of time of N application on yield and yield components.

Time and amount (kg/ha) of N application	Brown rice yield (t/ha)	Panicles (no./m^2)	Generated spikelet (no./panicle)	Spikelets maturity (%)
T_1 = 7 DAT 100	5.18a	319a	87b	86.88
T_2 = 7 DAT + AT + NND 33.3 33.3 33.3	5.70a	306a	104a	87.38
T_3 = 7 DAT + NND + SPD 50 25 25	5.85a	324a	104a	88.63
T_4 = 7 DAT + SRD+AM 50 25 25	5.35a	293a	89b	87.90
CV (%)	8.98	9.41	4.20	–

was insignificant (Figure 2A). Irrespective of treatments the total degeneration was mainly induced by the degeneration of spikelets on secondary rachis-branches. Similar results were also obtained by Lai et al. (1996).

For good yield, N must be applied at appropriate stages, such that both panicles/m^2 and spikelets per panicle remain well balanced. In this study panicles/m^2, per cent spikelets maturity, and yield differences with the different stages of N application were insignificant (Table 3). Although panicles/m^2 were statistically the same in all the treatments, a similar yield with the lowest panicles/m^2 was obtained in T_4 treatment, where spikelet degeneration was the lowest. Despite the low degeneration in T_4 treatment generated spikelets were still fewer in that treatment (Table 3) due to the lowest differentiation. The modern strategy of growing less panicles with high generated spikelets per panicle (Khush, 1996) was materialised in T_2 treatment where the number of generated spikelets per panicle was high but panicles/m^2 was low and the yield (5.7 t/ha) was next to the highest. The tiller growth curve (Figure 3) also reveals that tiller growth remained uniform throughout the growing period in that treatment. With the lowest tiller growth up to the maximum tillering stage it was able to produce equivalent yield as produced by the other treatments. Hence T_2 treatment was the most efficient in producing maximum economic yield with minimum vegetative growth. The only demerit of T_2 treatment was that it had the highest spikelet degeneration, which could, however, be reduced by applying N at or near the active meiosis stage as mentioned in the previous discussion. In that case, instead of three equal splits as were done in T_2 treatment, four equal splits at, the 7 DAT, AT, NND, and AM stages may be recommended for efficient production.

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