A STUDY ON SPIKELET DEGENERATION IN RICE (*Oryza sativa* L.) AT DIFFERENT STAGES OF PANICLE DEVELOPMENT

DIGITIZED

A Dissertation
Submitted to the Department of Botany
The University of Dhaka in partial
Fulfillment for the Degree of
DOCTOR OF PHILOSOPHY

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বিশ্ববিদ্যালয়
গ্রন্থাগার

By
ARABINDA DAS

Bangladesh Rice Research Institute
Joydebpur, Dhaka

January 1984

The dissertation hereto attached, entitled : "A STUDY ON SPIKELET DEGENERATION IN RICE (*Oryza sativa L.*) AT DIFFERENT STAGES OF PANICLE DEVELOPMENT", submitted by ARABINDA DAS of the Department of Botany, the University of Dhaka (Registration no. 150, 1982-1983), in partial fulfillment of the requirements for the degree of Doctor of Philosophy is hereby accepted.

Supervisors

DIGITIZED

Id. Zaman

Dr S M H Zaman
Director
Bangladesh Rice Research Institute
Joydebpur, Dhaka

20.1.84
(Date signed)

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A.S. Islam

Dr Ahmad Shamsul Islam
Professor of Botany
The University of Dhaka

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ACKNOWLEDGEMENT

The author wishes to express his profound sense of gratitude and sincere thanks to his supervisors, Drs. S.M.H. Zaman and A.S. Islam, respectively Director of the Bangladesh Rice Research Institute (BRRI) and Professor of Botany, the University of Dhaka, for their invaluable suggestions, constant encouragement and guidance.

The author finds no words to express his heart felt gratitude to Dr. S.M.H. Zaman for the tremendous amount of time he spent in assiduously giving him guidance in his work and critically reviewing the manuscript.

Sincere thanks are due to Dr. M.S. Ahmad, BRRI Associate Director and scientists for their helpful suggestions and cooperation they extended him most ungrudgingly in his work. It was indeed a great pleasure and learning for him to have met and worked with fellow BRRI scientists.

Dr. A.C. Roy, head of the Soil Chemistry Division, helped the author with soil analysis and he remains grateful to him.

Sincere thanks are also extended to the Statistics Department, BRRI for helping him analysis of data. The author is greatly indebted to BRRI Breeding Division for providing him with needed laboratory facilities and research materials. Messers Abdul Baten, Khorshed Alam, and other field and laboratory assistants always extended their helpful hands whenever required.

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Grateful appreciation is due to his teachers of Botany Department for their valuable advice and keen interest they showed in his work. Sincere thanks are also due to the office staff of the Botany Department for their cooperation and help in the official formalities.

Grateful thanks are also due to the International Rice Research Institute (IRRI) in the Philippines, its representative in Bangladesh, Dr. Frank W. Sheppard, Jr., to Dr. L.F. Myers of the Division of Plant Industry, Commonwealth Scientific and Industrial Organization, Canberra, Australia, and to BRRI and Dhaka University Librarians and their respective staff for providing him with reprints of scientific papers for study and reference.

The author gratefully acknowledges the award of the University Grants Commission to prosecute this study and the Ministry of Education for the grant of deputation to make this study possible.

Deepest gratefulness is also extended to professor A.S. Islam for editing the draft of this dissertation but for whose help the thesis could not have come in the present form .

Deepest gratefulness is also extended to Mr. Mohammad H.R. Talukdar, BRRI's Technical Editor, for editing the manuscript with meticulous care and attention, to graphics assistant Mr. Abu Daud for designing the plates, to Messers A. Baten, Mohammad Ibrahim, and Bimalendu Barua, for their excellence in the arduous task of typing the manuscript.

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He is grateful to his mother, sister Monika Dutta, and innumerable friends and well-wishers who constantly prayed for his success. His brother Tulsi Das, BRRI Principal Scientific Officer, also constantly assisted him in his work and the author owes him gratitude.

The author is grateful to his wife Kabita, Assistant Professor of the Carmichael University College, Rangpur, and daughter Sangita and Aparajita for their sacrifice and utmost forbearance of his long absence from their midst without which this work would never have been completed.

Above all, he thanks the Almighty creator, the Unseen, Most Merciful and Beneficient to work and bringing the work to a successful end and presenting the work of a Ph. D. thesis.

Last but not the least he takes the opportunity to dedicate whatever little work he has done in the elucidation of spikelet degeneration as a contributory factor to the yield of the most important crop of Bangladesh, to the rice scientists working throughout the globe.

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INTRODUCTION

Rice, the synonym food in Bangladesh, has been the traditional source of carbohydrate and protein since the pre historic days. It constitutes nearly 80% of food intake of the average Bangladeshis and supplies nearly 90% of the protein supplement in the diet of rural people (Kaul *et al* 1982). Rice is essential for certain social functions. For many farmers it is the only cash crop in addition to his principal source of food. Therefore, a good rice crop harvest means fortune for the farmer and prosperity for this rice consuming country.

The versatile use and importance of rice is also evident from its wide coverage : 80% or 10.00 million hectares are planted exclusively to rice annually in Bangladesh (loc.cit.). This land produced 11.76 million tons of clean rice for its 85 million people in 1977-78, leaving a deficit of about 2.80 million tons. This shortfall had to be met through imports at a cost of huge amount of foreign exchange. By 1981, the production increased and the food gap was reduced to 1.20 million tons. However, by that time population increased by another six millions and offset the increased cereal production. Unless controlled, the population may exceed 120 millions by at the turn of the century requiring at least an additional amount of 9 million tons of food-grains.

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The most difficult thing about rice production is its unpredictability. Although rice is grown all the year round in the three major rice seasons (Aus, Aman and Boro), the deficit results from unstable and poor yield rather than the total hectareage under rice. No doubt, some progressive farmers produce 6-7 t/ha from the cultivation of the modern high-yield potential rice varieties, the average yield (1.8 t/ha) is much below the world average of 6.0 t/ha (De Datta 1980). In spite of their high-yield potentials modern varieties were planted to only about 23% of the total rice area in 1983.

Among the major reasons for low yields are :

- The age-old land tenure system that discourages improved cultivation,
- Meagre income of the farmers,
- Lack of proper irrigation and management.

Rapid population increase and urbanization are already neutralising Government efforts to meet food deficits. With no possibility of further increase of land under rice cultivation, increased per hectare production of rice by using all known cheap and readily available resources and technological knowhow are the only other alternative to save the population from near starvation.

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Therefore, it is important to stabilize yield components which are not in the least influenced by environmental fluctuations. The relationship between yield and its components are shown in the following equation :

$$Y = PN \times GN \times GW$$

where, Y = yield per unit area,

PN = panicle number per unit area,

GN = grain number per panicle, and

GW = grain weight.

From the above equation it is clear that under normal production practices grain weight does not differ much within the variety. Yield may either increase or decrease by the corresponding increase or decrease in PN or GN per unit area and grains per panicle which in turn are greatly influenced by both genetical, environmental and cultural factors.

However, some of the yield components, such as number of panicles, grains per panicle may be increased by the application of suitable doses of nitrogen (N), phosphate (P) and potassium (K) at different stages of crop growth. This is because, tiller potentiality is increased to a certain limit by fertilizer application. It is not fully known what factors, apart from genetics, affect the number of grains per panicle.

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Although the causes for an increase or decrease in panicle number per plant have been fairly known, there has hardly been any study on the causes for reduction in the number of grains per panicle.

Extensive research work has been reported on spikelet sterility, but very little work has been done on the degeneration of spikelets in the panicle. Matsushima (1966) suggested that the spikelet reduction results from the degeneration of panicle branches and spikelets. Sometimes the percentage of degenerated spikelets may exceed more than 30% under general field conditions thereby reducing drastically the yield by that amount. What is more interesting is the fact that this amount of spikelet degeneration remains unnoticed because degenerated spikelets drop off during panicle emergence.

There are reasons to believe that variation in the number of spikelets might occur all along the developmental stages. The number of spikelets per panicle may get reduced due to the suppression or failure of the development (degeneration) of either branches or spikelets. Any variation in the number of panicle branches and spikelets will exert influence on grain yield. However, several factors may influence the developmental stages, especially from panicle initiation to grain development, but the magnitude of variation caused by such factors are not

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well known. If one can identify the factors contributing to the reduction of spikelets on the growing panicle, one can quantify it, particularly the one arising from spikelet degeneration.

Research on this direction is, therefore, of prime importance to identify the factors related to the degeneration of spikelets for substantially increasing the yield.

The present work has been undertaken to study the following aspects of rice :

- Panicle development and spikelet degeneration.
- Amount of spikelet degeneration among the three rice varieties - BR3, BR4 and Latisail.
- The effect of seasonal variation on the extent of spikelet degeneration.
- The effect of seedling ages both in the transplant Aman and Boro seasons at the time of transplantation.
- The effect of time of sowing and seedling age in both the transplant Aman and Boro seasons and transplanting seedlings within same date.
- The effect of pruning n, n-1, n-2, n-3, and n-4 leaf blades in the different growth stages, where, n indicating the flag leaf and those followed by numerical figures being the older ones in succession below the flag leaf.

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- The effect of different numbers of tillers per plant on spikelet degeneration and yield.
- The effect of variable photoperiods on spikelet degeneration and other yield components in the photoperiod-sensitive, slightly sensitive and insensitive varieties.
- The effect of seed rates on spikelet degeneration and yield.
- The effect of seedling density in seedbeds on spikelet degeneration

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Chapter I

REVIEW OF LITERATURE

I.1. Panicle Development in Rice

Many workers studied the organogenesis of the shoot apex in grasses, bamboos, wheat, oat, and rice plants. Arber (1926) studied the shoot apices of cereal, bamboo and grasses. Hitchcock (1935) diagrammetically represented the development of shoot apices in grasses. Bonnett (1935, 1936, 1937) described more elaborately the morphological changes of shoot apices in barley, wheat, oat, maize, and rye. The organogenesis of the rice shoot apices was studied by many workers : Roschevicz (1931), Akimoto and Togari (1939), Sharma (1945), Sircar and Sen (1953), Matsuo (1957), Hasanuzzaman (1958), Kaufman (1959), Saha (1954, 1963, 1969), Nasiruddin (1963), Matsushima (1966), Ikeda (1970, 1972, 1975), Sharma and Shrivastava (1971) and Dutta *et al* (1972).

The rice plant passes through three growth phases : vegetative, reproductive, and ripening phases. In between the vegetative and the reproductive phases the shoot apex passes through two stages of development; in the first stage, leaves and tillers develop, and, in the second stage, internodes of the stem elongate and panicle components start differentiation (Vergara and Chang 1976).

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Development of rice panicles is different from that of spikes of other cereals (Sircar and Sen 1953). Rice inflorescence is a complex raceme or panicle. Spikelet growth proceeds from upper to lower spikelets (Arai *et al* 1978) and the development of spikelets proceeds downwards in the mother axis and also lateral ones (Hasanuzzaman 1958). In the differentiating stages, the basal branches initiate first but the spikelet initiation is basipetal in development making it a determinate type of inflorescence (Nasiruddin 1963). The inflorescence of wheat, barley, and rye are spikes. The panicle consists of the main axis with alternately arranged branches, and the spikelets are pediceled. On the other hand, the spike is unbranched and sessile spikelets develop on the main axis (Bonnett 1935, 1936, and 1937). Rice inflorescence is determinate with a terminal single flowered spikelet.

In rice the development of the shoot apex at the panicle initiation stage has been studied by many workers (Terada 1923, Sharma 1945, Matsushima *et al* 1953, 1954, Saha 1954, 1963, Kaufman 1959, and Ikeda 1970). During the early vegetative phase of the rice plant, the growing tip is short and conical with a number of developing leaves surrounding it (Saha 1954, Kaufman 1959). In the later stages, the apical dome gets widened and is transformed

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into the hemispherical appearance (Nasiruddin 1963). The apical meristem then ceases to initiate any more new foliar organs and gradually elongates up to 0.2 to 0.3 mm according to Saha (1969), and 0.35 to 0.4 mm according to Terada (1923). Panicle initiation starts with the differentiation of bract primordium in the neck-node differentiating stage (Matsushima *et al* 1953, 1954, Ikeda 1970), and the formation of a single ridge initial (Saha 1969). In wheat, spike initiation starts with the formation of double-ridged spikelet initials (Bonnett 1936).

In rice, panicle initiation starts with the appearance of lobed or dome-shaped projections of the apical meristerm (Akimoto and Togari 1939, Hasanuzzaman 1958, Nasiruddin 1963) and alternate projections in wheat spike or oat panicles (Bonnett 1936, 1937). But Saha (1969) reported that the lobed structure appears 3-5 days after neck-node differentiation (Matsushima 1966, Ikeda 1970). However, neck-node differentiation is the beginning of the reproductive stage. But the period from neck-node to branch formation is not always complete at the reproductive stage and the rice plant partially remains in the vegetative stage. Some exceptional cases were reported on the reversion of the reproductive to the vegetative phase

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(Noguchi *et al* 1971). Nasiruddin (1963) reported the presence of rudimentary leaves in all the panicle developmental stages. The reproductive phase is followed by the development of leaf and internode elongation and morphological change in the plant (Matsuo 1957, Matsushima 1966). Saha (1969) reported that during panicle initiation, the third internode, lying between the third and the fourth leaf from the top, may not elongate but the next one, however, elongates completely.

Anatomical studies on the development of the shoot apex and the differentiation of panicle components or spike components have been reported by many workers. Tiller and leaf buds development in rice initiates from tunica and corpus (Hasanuzzaman 1958). The panicle primordium cells originate from tunica and corpus by periclinal and anticlinal divisions (Nasiruddin 1963). In grasses, panicles and branches develop from both tunica and corpus. The spikelet, rachilla, and glumes develop from tunica, but lemma, palea and the stamens develop from both tunica and corpus. However, both the floral and foliar initials appear laterally on the growing apical meristem; the floral initials are small and develop rapidly (Saha 1969).

Bonnett (1937) described elaborately the development of the oat panicles. In oat the panicle formation is first

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indicated by the appearance of single, lateral alternate projections in the axils of leaf initials below the growing points. The dome-shaped projections are the primordia of the first order branches. At the latter developmental stage, the primordia of the second order branches appear alternately on the first order branches. The primordia of the third order branches develop from the second order branches.

Sircar and Sen (1953) reported that the development of the rice panicle is different from the development of spikes. In rice prior to panicle initiation (PI) the vegetative shoot apex elongates considerably. This is followed by a depression at the tip. The cells below the epidermis differentiate to form the panicle branches with more than one spikelet. The differentiating cells are specialized cells due to the presence of a large nuclei and rich in protoplasm. Sircar and Sen (1963) observed no double ridges in rice as in wheat, barley, and rye (Arber 1926).

Hasanuzzaman (1958) observed that PI in rice begins with the appearance of a single, lateral and alternate projection in the axil of a leaf initial below the shoot apex. Bonnett (1937) made similar observations in oat, and Nasiruddin (1963) in rice. Successive dome-shaped structures develop laterally which form the branch

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primordia of the first order. The primordia of the second order branches develop on the branches of the first order. The apex of the branch primordia is the region in which spikelets are differentiated.

The development of panicle components such as branches and spikelets proceed successively after the neck-node differentiating stage (Matsuo 1957, Matsushima 1966, Ikeda 1970). After the differentiation of primary and secondary branches, multicellular hair growth starts from the base of the lobed-structure. The hairs develop in each joint of the secondary lobes or branches. The hairs remain active up to the reduction division stage (Matsushima 1966, Saha 1969).

Normal spikelets have two projections at the base of the future pedicel which forms the rim or cupshaped receptacle. The first and second glumes appear just above the receptacle. The development of lemma and palea occur in acropetal succession. At this stage, the primordia of anthers and carpel develop in succession (Hasanuzzaman 1958).

Saha (1963) observed that the differentiation of floral parts in rice spikelets starts with the appearance of two alternate fertile glumes as large transverse ridges and lemma, palea, and lower empty glumes appear after the fertile ones.

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Arber (1926) classified grass spikelets into bamboo and grass types. In the bamboo type, the two glumes enclose two florets with a single lemma and a palea, six stamens in two whorls, three lodicules and one carpel. The grass type differs from the bamboo type in the absence of three stamens in the inner whorl and the posterior loducule. The rice spikelets have a single floret with the terminal floret being reduced.

Arber (1934), however, reported three types of spikelets. In the first type, the first and the second florets are fully developed; the rudimentary third floret may be present. In the second type, only the basal floret is fertile and developed, the other two represent as a lemma or a palea. In the third type, basal floret is either reduced or sterile, the terminal floret is fertile and developed. A rice spikelet stands in between the first and the third types. In the rice spikelet, six stamens are present and the posterior or the third lodicule is absent. A rudimentary third stigma may be present (Hasanuzzaman 1958).

Hitchcock (1935) considered the grass spikelet as a modified shoot and the rachilla homologous with the shoot axis, bearing a reduced leaf (bract) at each node. Moreover, both the spikelet primordia and tiller buds develop in the axils of the leaf primordia. The primordia that forms first (4-5) develop into leaves. The growth of

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the subsequently formed leaf primordia is usually suppressed by the precocious spikelet growth.

Panicle components such as branches and spikelets develop rapidly after the differentiation of spikelets. The growing spikelets undergo various developmental changes. The panicle reaches its full length after the completion of meiosis. The panicle emerges through the flag leaf sheath at the heading stage marking the beginning of the flowering stage. This stage is considered important for yield, because the grains are filled as a result of fertilization (Sharma 1945, Matsuo 1957, Matsushima *et al* 1954, 1957, Saha 1954, 1969).

The developmental period from PI to anthesis is divided into various stages by many workers. Based on the duration of stages of development, Matsushima (1966) divided the developmental period into 21 stages of which 8 were grouped under the neck-node differentiation to the end of the secondary branch differentiating stages, 4 stages for spikelet differentiation, 4 for meiotic division, and 5 for the development of pollen grains.

Matsushima (1966) again divided the 21 stages into two main periods based on the leaf number index and panicle length increase. The first period is the young panicle formation which begins from neck-node differentiation and ends up in the late stage of spikelet differentiation.

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During this stage the young panicle attains its length measuring from 0.5 to 15 mm with a leaf number index of 76-92. On the other hand, the panicle pregnancy period starts from pollen mother cell (PMC) differentiation and ends up at the mature stage of pollen grains. During this stage the panicle attains from 1.5 cm to its full length with the leaf number index of 76-92.

Ikeda (1970) divided the developmental period into seven stages beginning from the neck-node differentiation to the end of the meiosis stages. He designated the stage before neck-node differentiation as the 'O' stage and the successive stages as the primary rachis branch primordial stage, secondary branch primordial stage, early and late stage of flower primordia, PMC forming stage, and the early and late meiotic divisions stages. Datta *et al* (1972) described the developmental stages of the vegetative shoot apex as the differentiation of bract into primordia, spikelet differentiation, the meiotic and the early heading stages.

Matsushima (1966) described the development of floral parts in detail. The stamen gets differentiated into filament and anther when the panicle reaches to a length of 5 to 10 mm. PMC differentiation starts when the panicle length reaches 1.2 - 4.0 cm. In the meiotic division stage, the spikelet length is about 3 mm and panicle length ranges

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from 5 cm to 70% of its full length.

Arai *et al* (1978) reported that the spikelet growth in rice proceeds from the upper to lower spikelets with the maximum growth being reached within 16 days before flowering. At meiosis, the anther length did not vary but spikelet length varied with its position on the branches.

I.2. Factors Affecting Panicle Development and Flowering

Variety, season, day length, and temperature greatly influence the development of panicle and flowering, either singly or in combination (Sircar 1948, Morinaga and Kuriyama 1954, Gangulee 1955, Matsushima 1966). The variation in the development of a young panicle has been reported to be due to varieties and the time of planting (Matsushima 1957). Flowering response of the transplant Aman varieties is largely due to the critical day length not exceeding 13 hours (Gangulee 1955).

Sircar (1948) found the floral primordia initiation earliest in the summer (Aus) rice and latest in the winter (Boro) rice. This is due to the relative sensitivity of the summer rice to day length, temperature, and humidity. These factors make a short duration crop. According to Morinaga and Kuriyama (1954) the vegetative period becomes slightly longer under high temperature and short-day than under normal temperature and short-day. Although the day

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length controls PI of the photoperiod-sensitive varieties, low temperature delays PI and heading. Day length and temperature often are interrelated (Sircar and Sen 1950, 1953, Naguchi *et al* 1971). According to Best (1959), high temperature (35-37°C) accelerates panicle development and temperature below 25°C retards panicle primordium development, delays panicle exertion and flowering in rice. Yoshida (1978) identified the critical temperature in the growth of rice. Yoshida found the critical temperatures lying between 15 and 30°C for primordia formation to panicle differentiation between 22 and 36°C for anthesis.

Kaneda and Beachell (1974) observed low temperature causing poor germination, slow and retarded growth, irregular heading, spikelet degeneration, higher sterility, and abnormal spikelets. Low temperature in the Boro season inhibits plant growth and leaf emergence. Temperature greatly influences development of plant height, tiller number, and dry weight (Bardhan 1980). A temperature range of 30 to 35°C increases plant height, tiller number and shoot weight, but a temperature range of 35 to 45°C causes them to decrease (Yoshida *et al* 1981). According to Kobayashi (1977), the optimum temperature for flowering in rice lies between 17.5 and 18°C, but Yoshida (1973) believes that flowering induces earlier at 28°C. Falaism *et al* (1978) reported that the high temperature and short

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photoperiod increase plant height and tiller per plant, but some cultivars do not flower in short photoperiod and high night temperature at 22°C (Lin and Chang 1976).

Low temperature at the PI stage induces malformed spikelets (Futshara *et al* 1979). Similar morphogenetic abnormalities have been reported by Takeoka and Shimizu (1973). Low temperature (14-18°C) at the primordial differentiation stage induces morphogenetic abnormalities in rice (Kuno and Shimizu 1973).

I.3. Effect of Photoperiod

Rice is a short-day plant and generally sensitive to photoperiod. Varieties show a wide range of photoperiod sensitivity. Long days can prevent flowering or delay in flowering (Wada 1952, Yoshii 1962) in photoperiod-sensitive varieties. Based on photoperiod sensitiveness, rice plants have been classified into three groups :

- Photoperiod insensitive,
- weakly photoperiod sensitive, and
- strongly photoperiod sensitive (Vergara and Chang 1976).

According to Ikeda (1970) the floral development is influenced by the photoperiodic condition in rice. The first bract (neck-node) formation is inhibited by long-day treatments; photoperiod beyond 16 hours has the

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similar effect as a continuous light treatment. The plants are greatly induced to flower under 9 to 12-hour photoperiod. The spikelet number increases at 10-hour photoperiod irrespective of the plant age (Ikeda 1975).

Photoperiod sensitivity of rice varieties does not appear until the plants attain a certain physiological age. In rice plants, the ageing effect on flowering is also recognized (Kondo *et al* 1933, Misra and Khan 1973). Photoperiod sensitivity is secured before the five leaf stage and floral initiation occurs at the apparent plastochrome age of five (Ikeda 1975). The effective flower induction requires a 20 short-day cycle on 10-to 30-day-old seedlings.

Photoperiod greatly influences formative and gametogenetic phases of Panicum miliaceum L. (Tayal and Nanda 1980). The length of the vegetative period is greatly influenced by day length and short-day induction decreases the length of the vegetative period; whereas long-day induction affects the ear initiation (Tayal and Nanda 1980).

Heading is greatly influenced by the intensity of light, day length and temperature (Hosoi 1979). Rice varieties also differ in photoperiod-sensitive response to low and high temperatures at various growth stages (Chang and Vergara 1971).

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Yokoo *et al* (1977, 1978) reported from the results of six crosses with the aid of close linkage with blast resistance. He found that the heading of rice is controlled by an important loci Lm which, to the sensitivity to day length and differentiated alleles, help the plant to adapt in various day lengths. The photoperiod sensitivity in rice is thought to be controlled by one or two dominant genes and the weakly sensitive response is controlled by multigenes (Jennings *et al* 1979). The photoperiod-sensitive phase involves genetic system of major genes or inhibitors on isomeric-genes, poly-genes and complex interaction among genes (Chang and Vergara 1971).

I.4. Factors Affecting the Spikelet Number per Panicle

Since the spikelet number is one of the major yield components any increase or decrease in the number of spikelets influences the yield. The development of spikelets has been reported to be influenced by various factors and it is still confusing. There are opinions on the number of days or periods from which the spikelet number is determined. The spikelet number is determined on 38 days from heading (Fuke and Kodo 1939), 40 days before heading (Tanaka 1943), 50 days before heading (Wada and Matsushima 1962), and the time corresponds to panicle length of 0.5 cm (Enomoto and Hitomi 1942). However, Matsushima (1966) observed that spikelets per panicle are

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determined mainly during the neck-node differentiating to the end of the reduction division stages. He has specially stressed on the reduction division stage.

Yoshida (1973) observed that the temperature was the most important decisive factor for determining the spikelet number. He showed that the spikelet number per panicle increases with the decrease in temperature and the number of degenerated spikelets increase with the increase in temperature. The critical temperature vary between 15 and 30°C for primordial development and differentiation of panicle components in rice.

Rahman *et al* (1977) reported strong dependence of the rate of spikelet initiation in wheat on environmental factors. Although the spikelet initiation is a heritable trait and is governed by the gene the rate of spikelet initiation is influenced by the photoperiod-sensitive gene. The spikelet number was found to be under genetic control with dominance for a high spikelet number under controlled temperature and photoperiod (Rahman *et al* 1978a).

The length of the shoot apex, the period for the vegetative phase, and short day length increased spikelet number in some wheat cultivars (Khatri 1964, Pugsley 1965, Rawson 1970, Lucas 1972). Rahman *et al* (1977d) showed that the spikelet number per ear in wheat is the product of the rate of duration of spikelet initiation and the number of

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double ridges present in the floral initiation. The spikelet number has been reported to increase with the delay in floral initiation of wheat that produced larger spikes at the double ridge stage with a larger number of spikelet sites (Rawson 1970, Lucas 1972). The light intensity at an increased rate influenced early flowering and a higher rate of spikelet differentiation in wheat (Friend *et al* 1963). In rice, low light intensity during the monsoon is supposed to be one among various factors that causes spikelet number reduction (Venkat eswarlu *et al* 1977). The quantum of solar radiation at the panicle initiation and differentiation stages affects the spikelet number at the ripening phase and the filled grain numbers (Stansel *et al* 1965, Yoshida and Parao 1976).

Srivastava *et al* (1974) found a significant and positive association between panicle length and the number of spikelets per panicle. The number of secondary branches per primary branch of a rice panicle is mostly effective in increasing the number of spikelets per panicle. According to Sharma and Srivastava (1971) panicle ramification is the sole factor determining the number of spikelets in a panicle. As the number of secondary branches increases on the primary branch, the total number of spikelets increases parabolically.

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Futsuhara *et al* (1979) investigated the gene action between the dense panicle gene and the dwarf gene. The individual effect of the dense panicle gene increases the number of branches and spikelets but, when coexisted, the number of the degenerated branch increases and the spikelet number decreases. The leaf area index at flowering has a correlation with the spikelet number per unit area (Fagade and De Datta 1971).

Thinning of plants or fertilizer application has been shown to increase the panicle length, the length of the primary branches, and rachis diameter. The spikelet number increases due to the increase of panicle components and the presence of a few degenerated spikelets (Arai and Kono 1978). The time of nitrogen fertilizer application significantly affects the spikelet number (Wada *et al* 1971, Khind and Dutta 1975). Split application of nitrogen - one-half at transplanting and the other half at PI has been found to be the specific time for a higher spikelet number (Tanaka *et al* 1959b, Chandraratna *et al* 1962, Narsaiah and Rao 1967). The nitrogen level and temperature have been shown to have a greater effect on wheat spikelet number, but day length affects much more than the nitrogen level (Lucus 1972).

Hedayetullah and Chakravarty (1937) made a first hand report on the abnormal spikelets in rice. The abnormality consisted of innumerable variations in the number of glumes,

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stamens and overies (Nasiruddin 1963). The number of potential spikelets decreases with the increase in abnormal or proliferative spikelets in rice. Abnormal spikelets develop either due to a seasonal change or by low temperature. The proliferative spikelets are of three types : spikelet type, pistilate type, and leafy shoot type.

The formation of abnormal spikelets has been reported by some workers. Takeoka and Shimizu (1979) identified the causes of abnormal spikelet formation which is being greatly induced by environmental disorders, e.g. cold weather, dry weather, over flooding, high salt concentration and genetical factors. They observed four types of proliferative spikelets : (a) the spikelets developed without floral organs;(b) normal development of pistil with degenerated stamens; (c) multiple pistil like organs; and (d) spikelet developed into leafy shoot with the degeneration of stamens and pistil. They concluded that the sterile spikelets develop from one of the stages.

Matsushima (1966) suggested that the increase of spikelet number is dependent on the development of strong and large tillers before the neck-node differentiation stage. He observed that the excessive panicle number decreased the spikelet number per panicle. He also suggested proper field management at the time of neck-node differentiation avoiding any damage caused by insects and diseases for

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for increasing the spikelet number.

Matsushima (1966) from his experimental observations (1953 and 1954) pointed out that the number of spikelets per panicle was greatly influenced by the number of degenerated spikelets. He observed that the percentage of degenerated spikelets often rose to more than 30% in the field. But, under the same cultural condition, the percentage of degeneration varied little. According to his observations, the most common causes of degeneration of spikelets and rachis branches were nutrient deficiency, particularly nitrogen and weather conditions.

Langer and Hanif (1973) observed that in wheat distant florets degenerated before ear emergence, but the ones in intermediate positions (fertile florets) continued to develop until soon after the fertilization of the lower florets. These authors also noted that the potentially fertile florets needed a first rate of development to reach the critical size for pollination, although the mechanism which triggered the degeneration of these florets was a matter of conjecture.

Dougherty *et al* (1974, 1975) reporting from carbohydrate analysis (wheat) said that the degeneration of potentially fertile florets occurred when carbohydrate levels in developing ears fell to the sub-critical levels. Bingham (1972) also concluded that the ultimate cause of floret failure in normal conditions was due to insufficient assimulatory supply.

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I.5. Factors Affecting Sterility

According to Satake (1978) the main cause for reduction of grain yield is the low temperature at the meiotic division stage of PMC. The most sensitive phase for inducing sterility in rice is the effect of low temperature, 15-17°C from early microspore to tetrad stage. Pollen sterility is maximum in winter rice, medium in summer rice, and minimum in spring rice (Datta *et al* 1972).

Nishiyama and Satake (1979) reported that sterility can be induced by low temperature treatment (15 - 17°C) for 82 hours at the booting stage. The higher sterility of rice is influenced by cool night temperature below 15°C (Rutger and Peterson 1979). Sterility increases at the 13.5 - 31°C temperature range in the wet season (Sahu and Murty 1978).

Suzuki (1978) found the cold injury of rice resulting in deformity of anther tissues and growth inhibition of anther loculi that caused higher sterility in rice. In IR8 the critical temperature for inducing higher sterility was 21°C (Vergara *et al* 1970).

Ota and Yamada (1965) reported that the application of nitrogen at the reproductive stage influenced a higher percentage of sterility. The rice plant grown without nitrogen induced higher sterility when nitrogen was applied at the reproductive phase only. The higher level of nitrogen increased sterility (Khan 1973). The high level of nitrogen

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supply is the cause for incomplete dehiscence of anthers and abnormal behaviour of filaments at anthesis (Togari and Kashivakura 1958).

Sikder and Dasgupta (1976) found a positive correlation between grain yield and sterility percentage. Sterility was higher in the lower than in the upper parts of the panicle. They concluded that the variation in the sterility percentage is due to the competition for carbohydrates between early and late flowered spikelets of a panicle.

Low-light intensity affects the leaf function and results in a greater portion of unfilled spikelets or sterility (Venkateswarlu 1976). The removal of the flag leaf after emergence is reported to increase sterility but it did not affect grain number (Mitra and Biswas 1976). The main causes of sterility are extreme temperature, lodging, and hybrid sterility or genetic compatibility (Jennings 1979).

I.6. Factors Affecting Yield Components and Yield

Rice yields are influenced by many interrelated and biological factors. The relation between the grain yield and yield components is that the former is a product of the latter. Yield components are the number of panicles, the number of spikelets per panicle, the percentage of filled spikelets, and 1000-grain weight. According to Ishizuka (1969), IRRI (1972) and Yoshida *et al* (1972) the grain yield is correlated with the number of spikelets per unit area.

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According to Murata (1969 and 1976), the grain yield of rice is dependent on the number of panicles/m^2 land, the number of spikelets per panicle and grain size, and grain weight. Since the grain size of rice is more or less a stable character (Matsushima 1967), there is considerable scope for the increase of panicle number as well as fertile spikelets per panicle in order to increase the grain yield.

An adequate number of spikelets per unit area is a pre-requisite for the required yield target (Moriya 1968, Koyama *et al* (1973). A strong correlation between the number of spikelets per unit area and the amount of nitrogen uptake was observed by many workers (Wada 1969, Wada and Matsushima 1969).

Matsuo (1959, 1965), observed an optimum tillering temperature in Japan at 32 - 34°C. Tillers with four green leaves or more bear panicles, while all tillers with one or two leaves develop no panicle (Matsushima 1953). Panicle bearing tillers can be identified before panicle emergence by their proportionate height and the number of green leaves (Tanaka and Garcia 1965). Also, tillers which develop in the later stage of panicle emergence cannot bear panicles (Katayama 1951, 1959).

Jennings *et al* (1979) showed a compensatory association between panicle size and tiller number; as one increases, the other decreases. But the panicle character does not strictly cause or determine yield. There are many

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reports on the contribution of the flag leaf to grain yield. The flag leaf is the primary supplier of photosynthate directly to the panicle (Tripathi and Purohit 1971).

Saini and Nanda (1979) studied the effect of culm number on grain yield in wheat. In a panicle the grain weight bears an inverse relation with the final ear number irrespective of treatment or density. They observed that the grain yield of the mother shoots alone was much less at a lower density and was no better than either control or restricted tillering at a higher density.

I.6.1. Seedling age. Enyi (1963) reported that early (30-day-old seedling) transplanting resulted in a greater tiller number and leaf number, a greater plant height, and a higher yield. The number of days for panicle emergence was considerably reduced in early transplanting. Twenty or 40-day-old seedlings did not affect grain yield, but complete defoliation increased the tiller number (Das and Samui 1979). Twenty-day-old seedlings (Pusa 2-21 and Jaya) yielded higher than 40- or 60-day-old seedlings (Sharma *et al* 1979).

Murty and Sahu (1979) investigated four photoperiod-insensitive varieties with seedling ages of 20, 40, and 60 days at transplanting. They observed that a higher seedling age (60-day-old) increased the total duration, but drymatter production, grains per panicle, plant height, and yield decreased. The sterility percentage was much higher in

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60-day-old seedlings. On the other hand, 40-day-old seedlings yielded higher than 20 or 60-day-old seedlings. The higher seedling age is reported to reduce tiller production and grain yield of a short duration variety. Medium and long duration varieties, at a higher seedling age, yielded higher (Singh *et al* 1975, 1978). They also observed delayed flowering and reduced tillering in 52-day-old seedlings.

Padalia (1980) observed that when transplanted in August maturity of rice decreased with the increase in seedling ages from 20 to 60 days. Delay in transplanting increased plant mineral content but produced fewer tillers and yielded lower (Lin *et al* 1977).

I.6.2. Time of planting. Khan and Swarnkar (1980) reported reduced yield when the date of sowing was shifted. Sowing in the first week of January yielded better than the third or the fourth week of December due to low temperature in December. Seven-week-old seedlings performed better than six-week-old seedlings. Delay in sowing from 1 to 31 May decreased yield (Ram *et al* 1978); July planting of SR26B produced better yield (Bhattacharya 1977).

Shamsuddin *et al* (1977) studied the effect of delayed sowing of Latisail. When Latisail was planted on 23 September, plant height and spikelets per panicle decreased, but straw weight increased. Nitrogen response decreased due to delayed

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sowing (Souza *et al* 1980). Grain yield sharply declined when planting date was shifted from 1 to 30 September. An increased nitrogen level (60 kg/ha) did not improve yield at a late planting of Nizersail and DA29 (BRRI 1978, 1979).

Kim *et al* (1980) investigated the heading time of different seedling ages transplanted at the same date. Results indicated that heading dates ranged from 2 to 8 days. On the other hand, when the seedlings of different ages were transplanted on different dates, the heading time differed from 0 - 8 days. The number of days to heading decreased when seeds were sown early, transplanted early, and seedlings of higher ages were used.

Bardhan *et al* (1980) observed the effect of low temperature on the Boro crop when sown on different dates. Sowing in mid-November gave a higher yield and 26 November sowing gave 22% less yield. The lowest yield was obtained from December sowing. The yield reduced by 30% when sown on 10 December. Crop duration in the wet season was shorter due to reduction in grain filling period from 7 to 10 days (Urs 1977).

I.6.3. Plant density and spacing. Chandler (1963) considered the plant density as a very important yield determinant. Matsuo (1965) observed different results. When plant density exceeded a certain level, plant growth decreased with the resultant yield reduction. However,

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Kanda and Sato (1963) reported that during the early growth stages dry weight per unit area increased with a higher density. Lee (1965) observed a reduced number of panicles and panicle length with the increase in plant density.

Quddus and Huda (1975) observed wide spacing significantly inducing more tillers per plant than narrow spacing. They explained that wider spaced plants removed more nutrients, soil moisture, and encountered less competition between plants. Consequently, more tillers per plant were produced. However, observations were in close agreement with Nagi (1959) and Ghosh (1960). Many workers also reported an increased yield from close planting due to increase into panicle number (Itsieh *et al* 1966, Srinavasan *et al* 1968, Singh *et al* 1972).

Shamsuddin *et al* (1977) observed a considerably reduced plant height in Latisail when it was transplanted in September. Spikelets per panicle and grain yield also decreased. They suggested that for better yield, a photoperiod-sensitive variety like Latisail, when planted late, should be spaced at 10 cm fertilized with 42-54-27 kg $N-P_2O_5-K_2O$/ha.

Tanaka *et al* (1964) reported that optimum spacing at a low nitrogen level is closer than that at a higher nitrogen level. They also observed retarded assimilation and restricted nutrient absorption by roots due to a higher

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density. The effect is more severe at the late growth stage (Tanaka and Garcia 1965).

Kakizaki (1965) reported that a greater density suppressed the elongation of tillers at lower nodal positions, bringing them to early death. Tillers at the higher nodal positions also formed floral primordia. Parao (1970) observed a 10 x 10 cm spacing optimum for low tillering improved varieties and 20 x 20 cm spacing for high tillering improved varieties. He also observed a considerably reduced number of panicles and grains at a higher density of plant population. Yield increase in close planting was mainly due to an increase in the total number of panicles, grains, and panicle weight (Hsieh *et al* 1966).

Bhattacharya (1977) observed close row spacing with wide plant distance yielding higher for maximum utilization of solar energy. Mondal and Mahapatra (1970) reported a higher grain yield (3204 kg/ha) from sowing at a 15 x 15 cm spacing than at 22.5 x 15 cm or 7.5 x 15 cm spacing. Koregave and Khuspe (1970) found insignificant grain yield of Chinoor at 9 x 9 cm, 9 x 12 cm, 9 x 15 cm, and 9 x 18 cm spacings. The highest number of panicles/m^2 came from 10 x 10 cm and 25 x 15 cm spacings. Higher spacing (30 x 30 cm) however produced the lowest number of panicles/m^2. The number of grains per panicle had a reverse relation with spacing (BRRI, 1978-1979). Bains and Singh (1967)

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suggested closer spacing in transplanted rice for a higher yield. Bhuiyan (1980) observed no increased grain yield from a higher plant density. Singh *et al* (1972) reported higher yields from IR8; IR49 yielded higher at a 15 x 15 cm spacing in Nawabganj and Rudrapur (India). Panicle bearing plants increased significantly with a wider spacing (Sood and Singh 1971).

Jennings (1979) observed heavy seed rates affecting the length of the flag leaf than other leaves due to nutritional deficiency. A higher density suppressed tillering, caused early death to secondary tillers, and reduced plant growth (Kakizaki 1965). At a higher density, plants remain dwarf (small) and flower early (Chang and Yang 1966). A higher seed rate increases plant height but significantly decreases the number of effective tillers and days to flowering and maturity (Shukla 1974).

Chandler (1963) observed that a seed rate of 130 kg/ha increased grain yield due to wide spacing. The spacing of 15 x 15 cm yielded better at a fertilizer level of 0-0-0 (N-P-K), but 25 x 25 cm spacing yielded better at the 90-90-90 (N-P-K) fertilizer treatment. IRRI experiments with plant density and nitrogen doses indicated that grain yields up to a certain level was dependent on the rate of fertilizer application or an increased plant density or combination of both (De Datta 1978).

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Dougherty *et al* (1975) studied the effect of a higher density of plants in wheat. According to them the competition between tillers at a higher density resulted in reduced grain setting. The number of grains formed in each panicle is supposed to be largely determined by competition of assimilates during pre-anthesis floret growth (Dougherty *et al* 1974, Dougherty and Langer 1974).

I.6.4. Defoliation. Mallick and Ghosh Hazra (1977) observed in rice more detrimental effect of both partial and complete defoliation of leaf blades at the reproductive stage than at the vegetative stage. Partial and complete defoliation respectively yielded 4.2 and 58.4% at the reproductive stage, but 1.3 and 35.3% at the vegetative stage. Grain weight also decreased, and yield per panicle reduced by 14.2 and 19% respectively when 50 and 100% of the flag leaves were severed at panicle emergence. The number of spikelets also reduced to 4.8 and 12.7% respectively. Grain and straw ratio also reduced by 33 and 60% in 50 and 100% leaf pruning (Tripathi and Purohit 1971). Mitra and Biswas (1976) observed that when the flag leaf was removed following complete emergence of the panicle, there was a reduced number of filled grains per panicle and panicle yield, but this did not affect the panicle length or the total number of spikelets. Complete

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defoliation of the first two leaves decreased yield, but the third leaf contributed some to grain yield (Palit *et al* 1979).

BRRI entomologists (1981) studied the effect of rice hispa (Dicladispa armigera, Oliv.). The extent of yield loss was 30% at the early tillering to the mid-tillering stages and 36% at the maximum tillering stage.

Murugesan and Chelliah (1983) studied the effect of leaf-folder (Cnaphalocrocis medinalis, Guen.) on 55-day-old seedlings of IR20. The yield loss was about 49 - 57% and sterility increased by 26-29%. They reported that 10% increase in the flag leaf damage increased the percentage of unfilled grains to 45%.

Rahman *et al* (1977) studied the defoliation treatment in wheat. Defoliation increased the length of the vegetative and the spikelet initiation phases. It also affected the spikelet number at the stage before floral initiation and at floral initiation. They reported a positive correlation existing between spikelet numbers and duration of the vegetative phase.

I.6.5. Fertilizer and micronutrients. Rice varieties respond to nitrogen differently. The response of the rice plant to added nitrogen is greatly influenced by soil fertility, environment and management practices. Extensive research has been done on fertilizer response of the rice

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plant. Some positive response of rice to nitrogen fertilization has been reported by many workers (Abichandani and Patnaik 1959, IRRI 1964, 1967). Varieties showed two stages of vigorous nitrogen uptake; the first stage occurred up to the maximum tillering stage and the second stage at the PI stage (Tanaka *et al* 1959a and 1959b). Matsushima (1965) pointed out that nitrogen requirement at the vegetative growth phase is maximum and minimum at the reproductive growth phase.

Kimura and Chiba (1943) reported only of two periods for maximum nitrogen absorption. Increasing nitrogen uptake at the maximum tillering stage increased tillering rate and determined the effective tiller numbers. From panicle initiation to flowering a higher nitrogen uptake increased the number of filled grains and grain weight. According to Matsushima (1966), the four critical growth stages of japonica rice, where nitrogen supply is essential for higher grain yields, are :

1. at the active tillering stage to increase the number of effective tillers;
2. at the neck-node differentiating stage to increase the number of spikelets per panicle;
3. at the meiotic division stage to prevent degeneration of differentiated spikelets; and

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4. at the full heading stage to increase the percentage of ripened grains.

IRRI scientists (1968) and Yoshida and Hayakawa (1970) reported the need for adequate nitrogen during the tillering stage to influence tillering. Tanaka *et al* (1964) observed proportional tillering to nitrogen content of the leaf blade and correlated with nitrogen absorption rate (Fagade and De Datta 1971). Nitrogen increases the number of panicles, grains and protein content (Lai *et al* 1977).

Kumura (1956) observed a close correlation between the number of spikelets per panicle and nitrogen content of the plant during the PI stage. According to him, grain weight increased with the increase in nitrogen content. According to Takahashi *et al* (1976) the maximum nitrogen absorption rate by the rice plant reaches a maximum point just before the neck-node differentiation stage. Moreover, the amount of plant nitrogen per unit area at the spikelet differentiation stage was positively correlated with the panicle number per unit area as also correlated to the number of spikelets per unit area. Nitrogen application at the vegetative lag phase increased tiller number and sterility (Khan 1973).

Prasad *et al* (1970) reported two split applications of nitrogen for a better yield one-half at transplanting and the other half at PI stage. Khind and Datta (1975) applied a single dose of nitrogen at flag leaf emergence and at

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heading. The application had no effect even with a higher dose of nitrogen. Ota and Yamada (1965) applied nitrogen 5 and 3 weeks prior to heading. This increased yield, but, when applied during the reproductive period, yield decreased.

Bhuiyan (1980) reported a very low nitrogen requirement of rice during the first 2 weeks after transplanting, but, nitrogen requirement at the beginning of the maximum tillering stage, 45 days after transplanting, was associated with the increase in inorganic nitrogen level. Nitrogen content in plant tops was high at the early growth stage. There was a strong correlation between tiller number at the maximum tillering stage and nitrogen content. IRRI findings indicated that dry matter increase between panicle initiation and maturity was highly correlated with grain yield (De Datta *et al* 1968).

Nitrogen applied at planting might have helped seedlings to get quickly established and make a good start as opined by Abichandani and Patnaik (1959). Meelu and Gupta (1980) applied nitrogen five days after transplanting and observed a better utilization of nitrogen in increasing the grain yield.

Narsaiah and Rao (1967) reported increased grain yield (5824 kg/ha) of HR 19 from two equal split applications of nitrogen. He applied one-half at planting and the other half 50 days after planting. The time of nitrogen application on grain yield was significant. The grain yield was

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42.8% higher in split application over control. Agarwala (1978) reported an increased grain yield with the increase in nitrogen rate, but, when P_2O_5 was increased from 0 to 120 kg/ha, yield remained unaffected. Dasgupta *et al* (1970) obtained a higher yield from dwarf rice varieties with the increase in fertilizer doses. Bhapkar *et al* (1979) also obtained a higher yield from dwarf TN1 and IR8 with two equal split applications of 80 kg N/ha: one-half at transplanting and other the half at the maximum tillering stage.

Nitrogen topdressing at 6-7 days before PI produces unproductive tillers (IRRI 1978). Production is affected by sowing date, nitrogen rate, and rice varieties. When nitrogen is applied before flowering, absorption of O_2 and dry matter accumulation increases (Kranook and Petibskaya 1974). This also increases the protein content and solube carbohydrates by 1.5 and 1.4 times, respectively.

According to Dixit and Singh (1979), the effect of nitrogen application up to 80 kg/ha increased significantly panicles per plant, panicle length, grains per panicle and grain yield. Application of 80 kg N/ha produces 15 and 48% more yields than the two treatments of 40 and 0 kg N/ha, respectively. Experimental findings of IRRI (1974) indicated that the amount and the time of nitrogen application for a higher grain yield can be predicted based on the

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capacity of the soil to supply nitrogen. Chandraratna *et al* (1962) obtained higher grain yields with ammonium sulphate topdressed at the PI stage at 30 days before heading. Abichandani and Patnaik (1959) obtained a higher yield in a long duration variety (160 days) in three split-application of nitrogen. A nitrogen dose of 22 kg/ha was applied basal 11 kg/ha, 30 days after planting and 11 kg/ha, 30 days before flowering.

Application of NPK reportedly increased grain yield significantly. The combination of N and P also increased grain yield in the Aus (64%), transplant Aman (57%), and Boro (50%) seasons; the combination of NPK respectively yielded 92, 78 and 62% higher in the Aus, transplant Aman, and Boro seasons (Rahman 1981).

According to De Datta (1978), soil properties, temperature and moisture are some of the important factors that affect the liberation of soil nitrogen. Nitrogen utilization by the rice plant at the farm level is affected by soil types, crops, environmental and management factors.

Sasaki and Wada (1975) found a significant effect of N and P. They used Eiko rice varieties in pot experiments fertilized with some possible combinations of nitrogen, phosphoric acid, and potash. The results indicated significant effect of N and P and higher sterility in more N application and less P in combination. The main effect of

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P was not significant on the percentage of sterile grains. Haque and Khan (1976) observed a slight and insignificant increase in dry matter, tiller number, and plant height when phosphate alone was applied. Application of K at the PI stage significantly increased dry matter production, but the combination of both P and K influenced tiller production (Ball 1950). Protein content was mostly affected by N level and slightly by P and K (Heu *et al* 1974). Phosphate increased the spikelet number in wheat (Rahman *et al* 1977).

Shukla (1972) studied the yield of IR8 and BG 79. The effect of nitrogen on yield was significant with the increase in flag leaf area. But the application of 22 - 22 kg K_2O-P_2O_5/ha did not affect yield in waterlogged soil.

Biswas and Choudhuri (1977) studied the effect of zinc (Zn) and hormones on the grain yield of rice. Application of kinetin and Zn increased yield, but K_2HPO_4 application decreased the number of panicles. Hormones and nutrients were found most effective when applied at the post flowering stage. Yield could be modified by proper application of hormones and nutrients.

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Chapter II

MATERIALS AND METHODS

Twenty-four experiments (9 in field, 11 in greenhouse, and 4 in seedbed) were conducted between July 1978 and December 1982. This study included 16 experiments (7 in field, 7 in greenhouse, and 2 in seedbed) to study and identify the factors affecting spikelet degeneration at various developmental stages of the rice panicle. Further studies were made to find the consequences of the spikelet degeneration on the yield of the tested varieties.

The following factors were selected for study to determine their effects on panicle development and spikelet degeneration :

- o Varieties
- o Seasons
- o Seedling ages
- o Time of transplanting
- o Fertilizers (NPK)
- o Seeding rates
- o Tiller pruning
- o Leaf pruning
- o Photoperiod
- o Seedbed (over population and crowded condition

The effect of factors like varieties, seasons, seedling ages, time of transplanting, seeding rates, and individual effect of NPK fertilizers were studied in the field. The transplant Aman season (July-November) experiments were repeated in the Boro season (November-May) to

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evaluate the seasonal variation on spikelet degeneration and other yield components.

Greenhouse experiments studied the normal panicle development and the effects of tiller pruning, leaf pruning, and variable photoperiods on spikelet degeneration and other yield components.

Seedbed experiments studied the effect of overcrowded seedlings on the developmental stages of panicle, spikelet degeneration, and other quantitative characters.

In these perspectives, 16 experiments were conducted covering two major rice crop seasons of Bangladesh namely transplant Aman and Boro. Materials and methods for field, greenhouse and seedbed experiments have been individually described in the following paragraphs.

VARIETIES

Since Bangladesh rice varieties are either photoperiod-sensitive or -insensitive, varieties (Latisail, BR4 and BR3) with varying degrees of photoperiod sensitivity were used. Latisail (DA17) is a local improved transplant Aman variety with a marked degree of photoperiod sensitivity. Brrisail (BR4) is a new cultivar growing in the transplant Aman season with a weakly photoperiod sensitivity. Biplab (BR3) is a photoperiod-insensitive variety. Further description of each variety is given in appendix B.

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SEASON

Both the transplant Aman and Boro seasons were used for growing the test crops for this study.

Within these two major factors viz, variety and season, the following experiments were conducted.

FIELD EXPERIMENTS

SEEDLING AGE

Different seedling ages were used to investigate their effect on panicle development, spikelet degeneration and other yield components. The transplant Aman experiment was repeated in the Boro season.

Experiment B1. Effect of seedling ages at transplanting in the transplant Aman season 1978

Seedbed preparation. A medium highland (9.74 m R.L) measuring about 1.5 x 27m was selected for seedbeds. The land was thoroughly puddled using the local plough. Levees were raised to create 15 equal plots of 1 x 8m each. Provisions were made to draw off excess water. Individual plots were then again thoroughly puddled using the hand-shovel before and after fertilizer incorporation. The seedbeds were fertilized with 80-60-40 kg N-P_2O_5-K_2O/ha, one day before seeding.

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Seed germination. Seeds were first treated with 0.01% mercuric chloride solution for 12 hours, washed in tapwater and kept flooded for another 12 hours. The floating seeds were discarded. After soaking for 24 hours the seeds were placed in gunny bags and kept well covered with straw for germination. This started after about 24 hours.

Seeding. The germinated seeds were seeded on 15 July 1978. The seed rate was 150 g/m^2. One seedbed was used for each of the age group of seedlings. Since there were three varieties and five seedling age groups, the total number of seedbeds were 15.

Cultural practices. The growing seedlings were irrigated as and when necessary. The seedlings were kept weed-free and pest infestations. Lebaycid 50 (Baycid, Fenthion, Mercaptops) was applied as a foliar spray at 1.4 kg mixed with 1000 lit. of water/ha as necessary to control insect pests.

Field preparation. The field for transplantation was prepared using the local plough and ladder. Soil samples were collected from different locations for physico-chemical analysis (result in Table 27). Levees were constructed to create 60 sub-plots of 3.1 x 25.9m each. For proper

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irrigation,drains were constructed all round the main field plots with provisions to draw off excess rainwater.

Fertilizers. The individual plots were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha before the last ploughing and well-incorporated in the soil.

Layout. The experiment was laid out in a split-plot randomized block design with four replications. The varieties were placed in the main plots and seedling ages in the sub-plots.

Transplanting. Seedlings were raised from seedbeds at 10-day intervals and one healthy seedling was planted per hill at a 20 x 30 cm spacing. Seedlings aged 30, 40, 50, 60 and 70 days were transplanted on 15 and 25 August and on 4, 14 and 24 September 1978. Seedlings from the border areas were not used for the test crop. The plant rows were from north to south.

Management of the test crops. In the absence of rains the individual plots were irrigated from the third day after transplanting with water level maintained at 3-5 cm deep for the entire period. The levees were 6 cm high which could draw off excess water. The crop was kept weed free and pest infestations.

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Sampling. Plants were randomly selected and the main culm per plant was labelled by a replaceable wire rings. Tillers, which emerged from the leaf sheath of the main culm were kept outside the wire ring. This process was continued for the entire tillering period. The main culms were collected at 3-day intervals from PI to heading stages. Shortly after sampling the plant samples were kept in water, the shoot apices were dissected under a binocular microscope (Carl Zeiss) at the early panicle stage.

Observations were recorded at different developmental stages of the panicle viz, panicle initiation, heading, anthesis, and maturity. The degenerated panicle branches and spikelets were counted from the panicles at the pre-emerging stage. At maturity of grains, plant height, tillers and panicles per plant, panicle length, grains per panicle and grain weight were recorded for statistical analysis. For yield determination crops from the undisturbed portions of the land were harvested and grains were separated by handthreshers. Grains were cleaned for total grain weight. The moisture percentage was recorded from moisture meter; grain weight was adjusted to 14% moisture level.

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Experiment B2. Effect of seedling ages at transplanting in the Boro season 1978-1979

Seeding. Seeds were sown on 1 November 1978 in well-prepared seedbeds of 3 x 8m each, similar to experiment B1. Seedbeds were kept weed free and pest infestations.

Plot preparation and fertilizer incorporation. The plots were thoroughly puddled and levelled similar to experiment B1. Levees were raised for 60 sub-plots of 3 x 25m each. Before transplantation the individual plots were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha.

Layout. The experiment was laid out in a split-plot randomized block design similar to experiment B1. Soil samples were collected before the final plot preparation. Physico-chemical properties of soil samples are given in Table 27.

Transplanting. Seedlings aged 40, 50, 60, 70 and 80 days were transplanted on 10, 20 and 30 December, and on 9 and 19 January. One seedling was transplanted per hill at a 20 x 30 cm spacing. The plant rows were from north to south.

Management of the test crops. The individual plots were irrigated every alternate day to maintain water level at 3-5 cm throughout the growing period. The plots were kept weed-free. Lebaycid was applied as and when necessary.

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Sampling. The main culm per plant was sampled among the randomly selected plants for each treatment and variety similar to experiment B1. The shoot apices were dissected under binocular microscope to study the number of developing and degenerated panicle branches and spikelets. Dates of PI, heading, anthesis, and full maturity of grains were recorded from each treatment. Observations were also recorded on plant height, tillers and panicles per plant, grains per panicle and 1000-grain weight. The grain yield was determined similar to experiment B1.

TIME OF TRANSPLANTING

Time of planting is one of the factors for development of yield components. Seedlings planted beyond the normal season are greatly influenced by environmental factors and were considered for this study. The experiment was undertaken to find out the effect of seeding dates and seedling ages on the development of panicles, degeneration of spikelets, and other quantitative characters of BR3, BR4 and Latisail. The transplant Aman experiment was repeated in the Boro season.

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Experiment C1. Effect of seedling ages at transplanting from seedlings sown on five different sowing dates in the transplant Aman season 1979

Seedbed preparation. A strip of medium highland (9.74 m R.L.) measuring about 2 x 32 m was selected for seedbeds. The land was thoroughly puddled with local plough and levelled with local ladder. Seedbeds were prepared as for experiment B1.

Fertilizer incorporation. Seedbeds were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha. The beds were randomized for the five different sowing dates.

Seeding. Seeds were germinated as for experiment B1 and sown in the seedbeds on 30 June, 10, 20 and 30 July, and on 9 August 1979. The seed rate used was 150 g/m^2.

Cultural practices. Seedlings were irrigated every alternate day. Seedbeds were hand-weeded and kept weed-free. The growing seedlings were kept free from pest infestations too.

Plot preparation. The plot was prepared similar to experiment B1. Levees were constructed to create 60 sub-plots of 3 x 9 m each.

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Fertilizer incorporation. The experimental plots were fertilized with 80-60-40 kg N-P_2O_5-K_2O/ha. Nitrogen was applied in two equal doses, one-half with the basal dose just before last puddle. The remaining half was top-dressed 30 days after transplanting.

Layout. The experiment was laid out in a split-plot randomized block design with four replications. Seedling ages were placed in the main plot and varieties in the sub-plots.

Transplanting. Seedlings aged 30, 40, 50, 60 and 70 days were transplanted on 9 September 1979. One seedling was planted per hill at a 20 x 30 cm spacing. The plant rows were from north to south.

Management of the test crops. The plots were irrigated with the water level being maintained 3-5 cm throughout the growing season, hand weeded, and kept weed-free. Lebaycid was applied as a foliar spray as and when necessary. The crop was protected from pest infestations.

Sampling. Plants were randomly selected in the effective areas. The main culm per plant was labelled by replaceable wire ring similar to experiment B1 and collected from the PI to heading stages. The young panicles were

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dissected from leaf sheaths and preserved in Formalin-Aceto-Alcohol (FAA) solution for microscopic study.

At different stages of panicle development observations were recorded similar to experiment B1. The number of degenerated panicle branches and spikelets were counted from the panicles before emergence. For yield determination the undisturbed portions of the sub-plots were harvested and grains were carefully separated by hand thresher. Similar to experiment B1, the grain yield per sub-plot was separately recorded.

Experiment C2. Effect of seedling ages at transplanting from seedlings sown on five different sowing dates in the Boro 1979-1980

Seedbed preparation and fertilizer incorporation. Similar to experiment C1.

Seeding. Seeds were germinated as for experiment B1 and seeded on 20 and 30 December 1979, and on 9, 19 and 29 January 1980.

Seedbed management. Seedbeds were irrigated properly, kept weed-free and pest infestations similar to experiment C1.

Plot preparation and fertilizer incorporation. Similar to experiment C1.

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Layout. Similar to experiment C1.

Transplanting. Seedlings aged 40, 50, 60, 70 and 80 days were transplanted on 10 March 1980 using one seedling per hill at a 25 x 30 cm spacing. The plant rows were from north to south.

Management of the test crops. The plots were irrigated with water level maintained at 3-5 cm throughout the growing season. Plants were kept weed-free and pest attacks.

Sampling. Plants were randomly selected as for experiment B1 for sampling and microscopic observations.

At the different panicle developmental stages observations were recorded similar to experiment C1.

FERTILIZERS

Since fertilizer affects the growth and development of rice plant, the effects of N, NP, NK and NPK were studied on the development of panicle, degeneration of spikelets and some quantitative characters of BR4.

Experiment D. Effect of seedling ages and fertilizers on BR4 rice variety in the transplant Aman season 1979

Seedbed preparation and fertilizer incorporation. Seedbeds were prepared as for experiment B1 and fertilized with 80-60-40 kg N-P_2O_5-K_2O/ha.

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Seeding. Seeds were germinated similar to experiment B1 and seeded on 15 July 1979. The seed rate used was 150 g/m^2.

Cultural practices. The growing seedlings were irrigated every alternate day. The seedbed was hand-weeded and kept free from pest infestations. Lebaycid 50 EC was applied as a foliar spray at 1.4 kg mixed with 1000 lit of water/ha as and when necessary to control insect pests.

Plot preparation. The plot was prepared similar to experiment B1. Soil samples were collected from 10 different locations for physico-chemical analysis (result in Table 27). Levees were raised to create 100 equal sub-plots of 3 x 5 m each. The sub-plots were puddled individually by using the hand shovel and levelled before and after fertilizer incorporation.

Fertilizer treatment	Fertilizer (kg/ha)		
	N	P_2O_5	K_2O
Control	0	0	0
N	60	0	0
NP	60	60	0
NK	60	0	40
NPK	60	60	40

Sources of nitrogen (N), phosphate (P) and potash (K) were respectively urea (45% N), triple superphosphate (42% P_2O_5) and muriate of potash (60% K_2O). Nitrogen was applied

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in two equal splits : one-half with the basal dose and the other half was top-dressed at the PI stage.

Transplanting. Seedlings aged 30, 40, 50, 60 and 70 days were raised from the seedbed and transplanted respectively on 15 and 25 August and on 4, 14 and 24 September 1979. Seedlings from border areas were not used for the test crops, because these were usually more vigorous and better than the rest. This was done to reduce the heterogeneity of the seedlings. One seedling per hill was transplanted at a 20 x 30 cm spacing. The plant rows were from north to south.

Layout. The experiment was laid out in a split-plot randomized block design with four replications. Fertilizer treatments were placed in the main plot and seedling ages in the sub-plots.

Management of the test crops. Three days after transplanting the individual plots were irrigated from drains surrounding the main plots. The water level was maintained at 3-5 cm deep during the entire growth period. The raised levees allowed the excess water draw off the plots. During the dry season plots were irrigated daily to keep water at the desired level.

Sampling. Plants were randomly selected from the effective areas and the main culm per plant was labelled for

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sampling by replaceable wire rings. These were sampled to ensure the date of panicle initiation. The shoot apices were dissected under a binocular microscope and the number of developing and degenerated spikelets were counted as for experiment B1.

At different growth stages observations on the dates of PI, heading, anthesis and full caryopsis development were recorded. At harvest, plant height, total tillers and panicles per plant were recorded. For yield determination the undisturbed portions of the sub-plots were harvested similar to experiment B1. The grain yield per treatment was separately determined.

SEEDING RATE

Since, plant population per unit area affect yield, various seeding rates were used in this experiment to find out the effect on panicle development, spikelet degeneration and other quantitative characters of the test varieties. The experiment was conducted in the transplant Aman and Boro seasons.

Experiment E1. Effect of seeding rate in the Boro season 1980-1981

Plot preparation. A medium highland (9.74 m R.L.) was selected for this experiment. The experimental plot was thoroughly puddled and levelled. Levees were raised

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for 72 equal sub-plots of 2 x 3 m each. The individual sub-plots were then puddled by using a hand shovel and levelled before and after fertilizer incorporation.

Fertilizer incorporation. The sub-plots were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha. Nitrogen was applied in two equal splits : one-half was applied at transplanting and the remaining half was top-dressed 50 days after seeding.

Layout. The experiment was laid out in a randomized split-plot design with four replications. Seeding rates were placed in the main plot and varieties in the sub-plots.

Seeding. Seeds were germinated as for experiment B1 and seeded uniformly in the plots on 20 December 1980, using 6.25, 12.50, 25, 50, 100 and 200 g/m^2.

Management of the test crops. Similar to experiment B1. The crop was kept weed-free and pest infestations.

Sampling. Plants were randomly selected and marked by putting bamboo sticks. The main culm per plant was labelled by replaceable wire rings for sampling and sampled at PI and 15-25 days after PI. The number of developing and degenerated branches and spikelets were counted from the 50-100 sampled main culms from each treatment and replication.

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At different panicle developmental stages, observations were recorded for :

- o Dates of panicle initiation, heading, anthesis and maturity of grains,
- o Panicles per plant,
- o Total panicles per m^2,
- o Plant height at maturity of grains,
- o Panicle length at harvest,
- o Grain yield.

Experiment E2. Effect of seeding rate in the transplant Aman season 1981

Plot preparation. The plots were prepared and fertilized with NPK fertilizers as for experiment E1.

Layout. The experimental plots were laid out similar to experiment E1.

Seeding. Germinated seeds were sown uniformly on the plots on 20 July 1981. The seeding rates used were 6.25, 12.50, 25, 50, 100 and 200 g/m^2 similar to experiment E1.

Management of the test crops. The plots were irrigated with water level maintained at 3-5 m throughout the growing season. Plants were kept weed-free and pest attacks.

Sampling. Plants were randomly selected and main culms were sampled for observation as for experiment E1. At

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different panicle developmental stages, observations were recorded similar to experiment E1.

GREENHOUSE EXPERIMENTS

NORMAL PANICLE DEVELOPMENT

The experiment was conducted to study the normal sequences of panicle development and spikelet degeneration of BR3, BR4 and Latisail. The experiment of the transplant Aman was repeated in the Boro season to investigate the effect of season on panicle development and spikelet degeneration of the three varieties.

Experiment A. Panicle development in the transplant Aman and Boro seasons 1978-1979

Seed germination. Seeds were first treated with 0.01% mercuric chloride solution for 24 hours and thoroughly washed in tapwater. After discarding the floating ones, randomly selected healthy seeds of each variety were put in petridishes over filter paper soaked in distilled water. The petridishes were labelled and kept in the incubator at 30°C for uniform germination.

Soil. The soil was collected from the experimental plots, airdried and then pulverized. The pulverized soil was passed through a 5 mm sieve and mixed several times before potting. A 5 kg of the soil was used for each potting.

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Potting. Bottom-sealed earthen pots measuring 23.5 cm in upper internal diameter and 18.5 cm in height were used. The pots were cleaned and washed several times and kept for airdrying. Sixty such pots, 20 for each variety, were used for planting the germinated seeds.

Fertilizers. The soil of the individual pots was thoroughly mixed with 5 g each of urea and triple superphosphate, and 3 g of muriate of potash. The pot soil was puddled with tapwater after fertilizer incorporation and kept ready, two days before planting.

Planting. Three germinated seeds were planted in each pot at a uniform distance on 15 July and on 1 November 1978. The experiment was set up in a completely randomized design.

Cultural practices. The growing seedlings were irrigated daily. As far as possible, a constant level of water inside each pot was maintained throughout the experimental period and kept weed-free and pest infestations. The pots were moved at 5-day intervals to avoid position effect.

The main culm of each plant was labelled by a replaceable wire rings for observation and sampling. At the tillering stage, tillers were kept out of the wire ring. Dates of tiller development and the number of tillers developed at PI stage were recorded.

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The main culms and other tillers were sampled 3-5 days interval from the date of panicle initiation. The young panicles were dissected out of the leaf sheaths under a binocular microscope (Carl Zeiss). In the early developmental stages of the panicle the shoot apices were cleaned in tapwater and placed inside 10 N Hcl solution for about 1-4 minutes for removing thickly grown hairs surrounding the spikelets and panicle branches. The young panicles were again cleaned in tapwater and finally in distilled water. Microscopic observations were made from PI to the spikelet differentiating stages. These panicles were lightly stained with safranin solution and mounted with 5% glycerine in a clean slide. At the same time the shoot apices were fixed in a standard formaline, acetic acid and ethyl alcohol solution (Johansen 1940). The duration of the fixing and killing was altered from 12 to 24 hours according to the nature of the plant materials. All plant materials were washed three times with 70% ethyl alcohol and finally stored for microtome section as scheduled (Johansen 1940).

Photo-micrographs and macro-photographs of the panicle developmental stages were made by Nikkon camera using close-up lenses. Black and white prints were made on Kodak printing papers. Similarly, coloured slides were prepared on Kodak Ektachrome film. The slides and prints were processed at BRRI.

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Observations were recorded on :

- o Dates of panicle initiation and periods for the developmental stages of panicles.
- o The number of primary and secondary branches per panicle.
- o The number of developing and degenerated spikelets per panicle.
- o Dates of heading, anthesis, and full development of mature caryopsis.

TILLER PRUNING

The experiment was set up to study the effect of tiller number on spikelet degeneration and other quantitative characters of the three varieties. The transplant Aman experiment was repeated in the Boro season to find the effect of seasonal variation on the varieties.

Experiment F1. Effect of tiller pruning in the transplant Aman season 1978

Seedbed preparation. Seedbeds were prepared as for experiment B1. Levees were constructed so as to raise three equal size seedbeds of 1 x 2 m each.

Fertilizer incorporation. Fertilizer incorporation was similar to experiment B1.

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Seed germination and seeding. Seeds were germinated within three days and were sown on 15 July 1978 using 150 g/m^2 similar to experiment B1. The growing seedlings were irrigated as and when necessary and kept weed-free and pest infestations.

Soil and potting. The soil was collected as for experiment A. Earthen pots, measuring about 27 cm in upper internal diameter and 20 cm height, were used. The pots were cleaned, and washed several times and kept airdrying. The soil was then pulverized and passed through a 5 mm sieve and mixed several times before potting.

Fertilizer incorporation. In each pot 1 kg airdried and powdered cowdung was mixed thoroughly with 5 kg soil and puddled in tapwater.

Transplanting. Thirty-day-old healthy and uniform seedlings were uprooted from the seedbed and transplanted on 15 August 1978. A total of 180 pots were planted with the three varieties, 60 pots for each, using one seedling per pot. The experiment was set up in a completely randomized design.

Treatment. The experiment was set up with six treatments. The tiller number was maintained by pruning the excess tillers.

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Treatments	Tillers (no./plant)
T*	0
T_1	1
T_2	2
T_3	3
T_4	4
Tn**	Control

T* = Main culm. Tn** = All tillers per plant.

Cultural practices. Tapwater was added 3 days after transplanting and the water level was maintained 2-3 cm above the soil throughout the entire growth period. The pots were kept weed-free and pest infestations.

During the tillering stage, excess tillers were pruned according to treatments and the number of tillers was maintained. Extra tillers were removed as far as feasible, from within the leaf sheaths without damaging the main culm or growing leaves. Removal of superfluous tillers was continued as long as they appeared. Main culms and other tillers were sampled between the PI and heading stages.

Observations. At different developmental stages observations on the dates of PI, heading and anthesis were recorded. The number of developing and degenerated spikelets were counted from the panicles sampled 3-5 days before panicle emergence.

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Apart from spikelet degeneration, observations data on plant height, panicle length, grains per panicle, grain weight and grain yield per tiller were recorded and statistically analysed.

Experiment F2. Effect of tiller pruning in the Boro season 1978-1979

Seedbed preparation and fertilizer incorporation. Similar to experiment B1.

Seeding. Germinated seeds were sown on 1 November 1978 as for experiment B2.

Soil, potting and fertilizer. Similar to experiment F1.

Transplanting. Forty-day-old seedlings were transplanted on 10 December 1978. A total of 180 pots were planted with the three varieties, 60 pots for each, and 10 pots for each treatment similar to experiment F1.

Treatment. Similar to experiment F1.

Cultural practices and observations. Similar to experiment F1.

LEAF PRUNING

This study was conducted to find the individual effect of leaf loss either partially or fully on the development of

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panicle in general and spikelet degeneration in particular of the three varieties. The investigation was conducted both in Boro and transplant Aman seasons.

Experiment G1. Effect of leaf pruning treatments, Boro season 1978-1979

Seedbed preparation and fertilizer incorporation. Seedbed was prepared similar to experiment B1. Seeds were sown on 1 November 1978 and seed rate used was 200 g/m^2.

Soil and potting. Similar to experiment F1.

Fertilizer incorporation. As for experiment F1.

Transplanting. Forty-day-old seedlings were transplanted on 10 December 1978. A total of 110 pots for each variety and 10 pots for each treatment were used for transplantation. One seedling was transplanted per hill and three seedlings per pot at uniform distance. The experiment was set up in a completely randomized design.

Treatment. At the tillering stage the main culm and the first two tillers were kept per plant and other tillers were removed by pruning. The flag leaf was designated as the n-leaf (last leaf) and the leaves, descending the flag leaf were represented by n-1, n-2, n-3 and n-4 according to the successive positions. The treatments

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consisted of pruning of a specific leaf per plant after its complete emergence either 50% or 100% of the leaf blade. The pruning treatments were made only on the main culm per plant. The leaf blade was pruned with the help of a pair of scissors.

Treatment	Leaf number	Pruning (%)
1	n*	100
2	n	50
3	n-1**	100
4	n-1	50
5	n-2	100
6	n-2	50
7	n-3	100
8	n-3	50
9	n-4	100
10	n-4	50
11	control	no pruning

n* = flag leaf, n-1** = the leaf below the flag leaf.

Cultural practices. The experimental pots were watered every day to maintain the water level of 2-3 cm throughout the growing season. The main culm and first two tillers were kept per plant and the extra tillers were removed by pruning or by pulling out of the emerging leaves.

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Observations. At different developmental stages of the main culm observations on the dates of emergence of (n-4, n-3, n-2, n-1 and n) leaves, PI, heading, anthesis and full maturity of grains were recorded. The number of degenerated panicle branches and spikelets were counted under binocular microscope. Apart from spikelet degeneration observations were made on plant height, panicle length, filled and unfilled grains per panicle and grain weight.

Experiment G2. Effect of leaf pruning treatments, transplant Aman season 1979

Seedbed preparation, fertilizer and seeding. Similar to experiment G1.

Potting and fertilizer incorporation. Similar to experiment G1.

Transplanting. Thirty-day-old seedlings were transplanted on 15 August 1979. A total of 330 pots were used for planting three varieties, 110 pots for each variety and 10 pots for each treatment. One seedling was planted per hill and three seedlings per pot at uniform distance. The experiment was laid out in a completely randomized design.

Treatment and cultural practices. As for experiment G1.

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PHOTOPERIODS

The photoperiod experiment studied the effect of normal day length and different day-length treatments on the panicle development, spikelet degeneration and other quantitative characters of BR3, BR4 and Latisail.

Experiment H. Effect of variable photoperiods on spikelet degeneration and other quantitative characters.

Soil. The soil was collected from experimental plots, dried and pulverized, and passed through a 5 mm sieve. The soil was mixed five times before potting.

Potting. Bottom-sealed earthen pots of 27 cm internal diameter, 20 cm internal height, and 1.74 kg dry pot weight were used for this experiment. Pots were cleaned, washed several times in tapwater, and airdried. The pulverized soil weighing 6 kg was put in each pot. Forty pots for each variety and 10 pots for each treatment.

Fertilizer. The soil of the individual pots was mixed thoroughly with 5 g of urea, 5 g of triple superphosphate, and 3 g of muriate of potash.

Planting. Seeds were germinated as per experiment A and three well-germinated seeds were planted in each pot on 1 April 1979.

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Treatment. The plants were exposed to four different day lengths from 20 April. The day length was measured from sun rise to sun set.

Treatment	Day length (hours)
T_0	Normal day length
T_1	10
T_2	8
T_3	6

Cultural practices. Twenty-day-old seedlings were exposed to normal day length, 10, 8 and 6 hours. The day length was controlled by shading the pots. The pots were placed inside the iron frames, having rectangular bases with a triangular top used for each treatment. The iron rod (1.25 cm diameter) frames measured 2.5 m in length, 1.5 m in breadth, and 1.5 m in height. The pots were placed, treatment-wise, inside the frames. Each frame was completely shaded by a piece two-ply heavy black marking cloth.

Surrounding each iron frame a rectangular drain, measuring about 10 cm width and 15 cm depth, was made to cover the frames 15 cm below the base. It was done for complete shading. Pot positions were changed every fifth day. The main culm was labelled by replaceable wire ring for sampling and was sampled at the PI stage, 3-5 days

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before heading and at full maturity of grains. The pots were weeded and irrigated daily. The plants were protected from disease and pest infestations.

Observations were recorded on the following:

- Dates of PI, heading, anthesis and development of caryopsis.
- The number of developing and degenerated panicle branches and spikelets.
- Panicles per plant and panicle length.
- Filled grains per panicle and 100-grain weight.
- Plant height.
- Drymatter content at harvest.

SEEDBED EXPERIMENT

PANICLE DEVELOPMENT

Due to various reasons the farmer always cannot transplant seedlings of rice varieties at optimum age and time. As a result, older seedlings and delayed plantings adversely affect the growth and development of rice plants. The experiment was conducted to find out the effect of continuous growing rice in the seedbed on spikelet degeneration and other quantitative characters of the tested varieties. The experiment of the transplant Aman season was repeated in the Boro season to determine the seasonal effect on panicle

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developmental stages and spikelet degeneration.

Experiment I. Effect of growing rice in seedbeds during the transplant Aman and Boro seasons.

Seedbed preparation. Seedbeds were prepared as for experiment B1.

Fertilizer incorporation. Seedbeds were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha, puddled before and after fertilizer incorporation, one day prior to seeding.

Seeding. Seeds were germinated similar to experiment B1 and well-germinated seeds were sown on 15 July and on 1 November 1978. The seed rate used was 150 g/m^2.

Cultural practices. The growing seedlings were irrigated every alternate day and kept weed-free. Lebaycid 50 was applied as and when necessary to control insect pests. Randomized plant samples were made from 10 cm inside the border areas. In order to ensure the date of PI and subsequent developmental stages, shoot apices were dissected from 20 days before PI. The developing shoot apices were dissected under a binocular microscope.

Observations on the following were recorded for statistical analysis :

- Dates of PI, heading, anthesis, and full development of caryopsis.
- Developmental stages of panicle.

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- The number of degenerated panicle branches spikelets before panicle emergence.
- The number of filled and unfilled grains per panicle.
- Plant height and panicle length.
- Panicles/m^2.
- Grain weight.
- Drymatter content at different developmental stages of the panicles.

Experimental designs and sample analyses for all experiments were calculated following Cochran and Cox (1957); Steel and Torrie (1960); Little and Hills (1972), and Zaman, Rahim and Howlader (1982).

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Chapter III

EXPERIMENTAL RESULTS AND OBSERVATIONS

EXPERIMENT A : Normal Panicle Development

The normal sequence of the development of rice panicle was studied first in order to find degeneration of spikelets affected by different factors. A full description of the development of panicle has been provided in the following paragraphs.

A.1. Neck-node differentiating stage

The shoot apex prior to panicle initiation (PI) remained surrounded by developing leaves and leaf primordium. The shoot apex gradually changed into dome-shaped structure. In the basal part of the dome the first bract primordium developed like an annular structure (Plate 1, figures 1-3). The subtending node of this bract became the neck-node on the internode (Plate 1, figure 3). Above this neck-node the development of dome-shaped projections followed a definite pattern on the main axis (Plate 1, figures 3-4). The development of the successive primordia of the first order branches followed the formation of primordia of the second order branches in a basipetal way (Plate 1, figures 5-7). All the primordia of the lateral branches developed on the axils of each rudimentary leaf. The number of branch primordia was different among the three varieties and it was higher in BR4 than BR3 and Latisail.

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When sown on 15 July the development of neck-node commenced in 70-75 days in BR3, 80-85 days in BR4, and 85-90 days in Latisail. In first November sowing the neck-node development was delayed by 30-40 days in all the varieties studied (c f Table 1).

At the PI stage, two morphological changes occurred : internode elongation and rapid development of the leaves. It was observed that the last three leaves i.e., n, n-1 and n-2 (n= flag leaf and n-1= leaf below the flag leaf) remained inside the leaf sheath at the time of PI and n-4 leaf emerged earlier at the PI stage. The commencement of elongation of the internodes and the development of n-3 leaf occurred simultaneously at the PI stage. Panicle initiation in the main culm took place 5 to 15 days earlier than other tillers.

A.2. Primary branch forming stage

The first order panicle branch primordium at the base of the main axis developed spirally from the lateral domes (Plate 1, figures 3-4). The development of primary branch initials continued for 5-8 days after PI and showed little variation between transplant Aman (T.Aman) and Boro seasons. However, variation in the number of dome was found between the varieties and season. The dome structures developed into

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primary branches and were arranged alternately either singly (BR3 and Latisail) or in paired condition (BR4). The apical dome of the main axis terminated into spikelet at the later stage of development (Plate 1, figure 9). The main culm per plant produced maximum panicle branches compared to other tillers. The number of primary branches per panicle of the main culm and tillers varied from 11.07 to 7.02 in BR3, 12.01-8.15 in BR4 and 8.20-6.98 in Latisail.

A. 3. Secondary branch forming stage

The secondary branch initials gave rise to dome-shaped structure and developed basipetally and alternately from the base of the primary branches (Plate 1, figures 5-7). The period for the development varied from 8 to 10 days after PI and showed insignificant variation between the varieties and seasons. The number of secondary branches in a primary branch varied from 0-5. Their number gradually increased from the middle to the basal primary branches of a panicle. In the early stage of development, the earlier initiated domes exclusively formed branches of the second order; the terminal initials of these were transformed into spikelets. The number of spikelets on the secondary branches varied from 2 to 5 and was more in lower panicle branches.

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The main axis along with its component structures elongated rapidly and the initials of the primary, secondary branches and spikelets could be clearly distinguished by their size and orientation on the panicle branch. Tertiary branches developed on the secondary branch especially at its basal part. In BR4, 2-3 spikelets developed at each tertiary branches which were few in number.

The development of snow white multicellular hairs found associated with panicle branches began with the development of panicle branch initials (Plate 1, figure 6).The development of hairs started with the initiation of primary branches at about 5-8 days after PI. The protective dense hairs were found to fade away following meiosis. It may be mentioned that the spikelets grow rapidly at this stage.

A. 4. Spikelet developing stage

Spikelets were found to develop on the terminal region of each branch 10-15 days after PI. The floral organization on the primary branches followed a basipetal succession (Plate 1, figures 8-9) and represented a determinate inflorescence. The initiation of the spikelets on the secondary branches followed the initiation of spikelets on the primary branches.

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The spikelet primordia developed alternately on the panicle branches and differentiated into rachilla and pedicel at the basal part. The primordia of the glumes developed laterally from a point, a little above the rachilla, one after another. The primordia of lemma and palea originated laterally and alternately above each of the glumes (Plate 1, figure 11). The primordia of the stamens originated in two whorls (3+3) and appeared as club-shaped structure. The stamens continued to grow along with the spikelet and differentiated into filament and anther lobes. The two lodicules originated as lateral protuberances from the lateral part of the thalamus. The style developed from the anterior part of the ovary. The tip of the style branched dichotomously and formed two divergent feathery stigmas.

The length of the panicle and branches increased rapidly and at that time antherlobe and stigma differentiated. The panicle length was about 3-20 mm within 10-15 days after PI. The spikelets developed rapidly from the top to the basal direction along with the mother axis or the primary and secondary branches. Complete formation of spikelets was indicated by the emergence of n-2 leaf.

A.5. Pollen mother cell forming stage

The terminal spikelets of the primary panicle branches developed earlier than spikelets of the secondary branches.

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The length of spikelets in the pollen mother cell forming stage had a range of 3.5-4.5 mm in BR3, 3.6-4.1 mm in BR4 and 3.4-4.0 mm in Latisail. The panicle length at that time varied from 3.5-4.0 cm in BR3, 4.0-9.5 cm in BR4 and 3.5-7.5 cm in Latisail (Table 2). The anther lobes in the early stage of development showed homogeneous parenchymatous tissue surrounded by a single layered epidermis. The primary sporogenous tissue after differentiation in the central part of each lobe developed into pollen mother cells. The tapetal layer disintegrated and the pollen mother cells increased in size and became spherical in shape.

A.6. Meiotic division stage

At the time of meiosis the length of the panicle was found to range from 3.8-18.5 cm in BR3, 8.5-21.5 cm in BR4 and 6.5-20.5 cm in Latisail. The length of the anther lobe also varied from 0.6-1.2 mm in all the three varieties and in the transplant Aman and Boro seasons (Table 2). Pollen mother cells (PMC) increased in size and became spherical in shape. The meiotic division commenced 10-12 days before heading time and continued 3-5 days before heading. At this time the flag leaf exerted from the boot to an approximate extent of three-fifths to four-fifths of its full length.

At the time of meiosis in the primary branched spikelets, variation in the spikelet length became more pronounced

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between primary and secondary panicle branches (Plate 2, figures 4-9). Some of the spikelets both primary and secondary panicle branches ceased to develop marking the beginning of degeneration of spikelets. Further the degenerated spikelets could be easily found in any position of the panicle branches (Plate 8, figures 1-3). The number of degenerated spikelets was higher in the secondary branches compared to primary panicle branches. The basal secondary branches produced higher number of degenerated spikelets indicating that there might be a relationship between the position of a spikelet in the panicle and its extent of development. The spikelet degeneration commenced 5-10 days after spikelet initiation and the percentage was maximum within 10 days before heading.

A.7. Heading stage

The booting stage commenced 5-7 days before heading and 3-4 days before heading, the n-1 internode (n = top internode) completed elongation. The top internode elongated rapidly with the emergence (heading) of the panicle out of the leaf sheath. The time taken from panicle initiation to heading varied from 28-32 days (Table 2). The complete emergence from the boot took about 5-8 days.

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A.8. Anthesis stage

Anthesis (flowering) continued 2-8 days after heading. During anthesis lemma and palea opened for a short time. In a clear sunny day anthesis began at about 08.30 hours and was completed at about 11 a.m. and then decreased to a zero level by 13 hours.

A.9. Ripening stage

The development of caryopsis began after fertilization. The grain filling period varied slightly (30-35 days) in the three varieties (Table 1).

EXPERIMENT B : Effect of Seedling Age on the Development of Panicle, Degeneration of Spikelets and other Yield Components

Field experiments were conducted in the transplant Aman and Boro season to determine the effect of seedling ages at transplanting on the development of panicle, degeneration of spikelets and other yield components. The results of the experiments are given under separate heading.

Experiment B1. Effect of seedling age at transplanting in the transplant Aman season

Seeds were sown on 15 July 1978 and seedlings were transplanted after 30, 40, 50, 60 and 70 days from the date of sowing. The results of the experiment are given in the following paragraphs.

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B1.1. Effect on panicle development. The effect of seedling age on the developmental period of panicle is shown in Table 3. Prior to PI, the plant developed tillers in quick succession. The time taken by the variety to reach the maximum tillering stage varied. Irrespective of the variety, the 30, 40, 50 and 60 days old seedlings after transplantation in the field produced about 75% of total tillers before PI, whereas, 70-day-old seedlings produced maximum tillers only after PI in the main culm (Table 3). When the seedlings were transplanted in the field at an intervals of 10 beginning from 30 days, those transplanted earlier produced panicles earlier. However, in some BR3 plants PI took place right in the seedbed after 70 days from sowing. When 30-day-old BR3 seedlings were transplanted on 15 August PI of the main culm took place 45 days after transplanting, whereas 70-day-old seedlings when transplanted on 24 September, PI occurred 5 days after transplanting. However, according to age, PI took place at 75 days. When 60-day-old seedlings were transplanted on 14 September, PI occurred at 27 days after transplanting i.e. at the age of 87 days. Similarly PI for 50- and 40-day-old seedlings commenced at the ages of 85 and 80 days respectively. This was however, reduced to 75 days when 30-day-old seedlings were used for transplantation. On an average PI occurred at the mean age of 80.6 days for various seedling ages of

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BR3. The chi-square test indicated insignificant variation (Table 3).

In BR4 and Latisail PI occurred at the mean ages of 90 and 83 days respectively. In both the cases the time taken for PI in the different seedling ages was not significantly different. The period for the subsequent developmental stages of the panicles also showed insignificant variation for the seedling ages (Table 3).

B.1.2. Effect on the panicle branch development. Differences between seedling ages on the development of primary and secondary branches per panicle were significant (Table 4). The total primary branches per panicle (main culm) of 30-day-old seedlings were significantly higher than 70-day-old seedlings (Plate 2, figures 4-6 and Plate 3, figures 1-6). The number of panicle branches differed between the varieties.

The correlation between seedling age and the number of panicle branches (primary or secondary) was negative. Correlation coefficients for primary branches were highly significant for BR3 and BR4 but significant for Latisail (Table 6). The effect of higher seedling age decreased the number of panicle branches and it was higher in BR3 compared to BR4. The effect of higher seedling age

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suppressed the panicle branch formation and it was higher for secondary branches.

B1.3. Effect on panicle branch degeneration. Varieties differed in their extent of panicle branch degeneration and the differences were highly significant due to varieties and seedling ages (Table 4). However, interaction of variety x seedling age was also significant. Degeneration of primary branches occurred in the few panicles of 70-day-old seedlings (Plate 3, figures 1-2). The percentage of panicle branch degeneration was higher in the secondary branches.

Correlation between seedling age and panicle branch degeneration was positive for BR3 and BR4 but negative in Latisail. Coefficient of correlation was significant in all the three varieties (Table 6).

B1.4. Effect on spikelet number per panicle. The effect of seedling age on the number of spikelet formation is shown in Table 4. Depending on the seedling age the spikelet number per panicle varied (Plate 2, figures 4-6 and Plate 3, figures 1-6). Variations of spikelets per panicle of the main culm were highly significant for the varieties and seedling ages. The interaction of variety x seedling age was insignificant.

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Correlation between seedling age and number of spikelets produced in the main culm was negative for the three varieties. The correlation coefficients were highly significant for BR3 (R^2 = 0.880) and BR4 (R^2 = 0.932), whereas only significant for Latisail (R^2 = 0.823). Among the varieties spikelet reduction was highest in BR3 (Table 4).

The t-test showed that the regression coefficient of spikelet number in seedling ages was highly significant in BR3 (b = 3.688) and BR4 (b = 3.248) and significant in Latisail (b = 1.531). Result showed that for each day of delay in transplanting, the number of spikelets per panicle (main culm) was reduced in the order of 3.69, 3.25 and 1.53 respectively for BR3, BR4 and Latisail.

B1.5. Effect on spikelet degeneration. Percentage of spikelet degeneration in the various seedling ages is shown in Table 4. The interaction of variety x seedling age was highly significant. Percentages of spikelet degeneration were significantly highest in 70-day-old seedlings of BR3 and BR4 but in 30-day-old Latisail seedlings spikelet degeneration was the highest. Among the varieties, spikelet degeneration was highest in BR3 and lowest in BR4. Spikelet degeneration in 30, 40 and 50 days old seedlings were statistically similar in BR3 and BR4. In Latisail the

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picture was different. In this variety degeneration was same among seedling ages 40, 50, 60 and 70 days, whereas it was significantly different in 30-day-old seedlings.

The correlation between seedling ages and spikelet degeneration was of quadratic nature. Coefficient of correlation was significant (Table 6) in BR3 (R^2 = 0.705), BR4 (R^2 = 0.772) and Latisail (R^2 = 0.666). The correlation indicated different rate of spikelet degeneration among the varieties, the rate of change being highest in BR3 with higher seedling ages. Forty-day-old BR4 seedlings showed less spikelet degeneration than 30-day but the trend was reversed when older seedlings were transplanted. In Latisail the percentage of spikelet degeneration decreased as older and older seedlings were transplanted except 70-day-old seedlings.

B1.6. Effect on panicle length. The panicle length at harvest is shown in Table 3. The panicle length significantly decreased when 70-day-old seedlings were transplanted (Plate 2, figures 4-6 and Plate 3, figures 1-6). The panicle length decreased with the increase in seedling age. However, transplanting seedlings of 30, 40, 50 and 60 days old showed insignificant variation of panicle length.

A significant negative correlation was found between the seedling age and the panicle length. Correlation

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coefficient (Table 6) was highly significant in BR3 (R^2 = 0.944) and Latisail (R^2 = 0.926), but it was only significant in BR4 (0.815).

B1.7. Effect on plant height. Irrespective of the variety, plant height reduced with the increase in seedling age (Table 4). The transplanted 30-day-old seedlings were the tallest plant and those transplanted after 70 days were the shortest.

The correlation between plant height development and seedling age was negative. The coefficient of correlation was highly significant for the varieties (Table 6).

B1.8. Effect on tiller number. The varieties showed a significant variation in the number of tillers per plant. Compared to 30, 40, 50 and 60 days old seedlings, 70-day-old seedlings produced minimum number of tillers after transplantation (Table 5). In most cases non-panicle bearing (unproductive) tillers were produced after PI in the main culm. Thirty, 40, 50 and 60 days old seedlings produced 10-15% unproductive tillers, whereas in 70-day-old seedlings of BR3, BR4 and Latisail respectively produced 30, 20 and 15% unproductive tillers per plant. Consequently the number of panicles per plant significantly reduced with the increase in seedling age.

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The effect of various seedling ages on the number of panicles per plant was negatively correlated. The correlation coefficient was highly significant in the varieties (Table 6).

B1.9. Effect on spikelet sterility. In BR3 and BR4 the percentage of spikelet sterility increased with an increase of the seedling age and in Latisail reverse trend was found (Table 5). The interaction of variety x seedling age was highly significant. Among the varieties BR4 showed highest percentage of spikelet sterility and was significantly lowest in Latisail.

The correlation between spikelet sterility and seedling age was positive for BR3 and BR4 but negative in Latisail. Coefficient of correlation was highly significant for the varieties (Table 6).

B1.10. Effect on grains per panicle. The number of filled grains per panicle on the main culm decrease significantly with the increase of seedling age. The average filled grains per panicle in the tillers varied significantly from those on the panicle of the main culm. The number of grains in the tillers were reduced significantly with the increase of seedling ages (Table 5).

The correlation between the two characters in both main culm and tillers was found to be negative in all the

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varieties. Correlation coefficients were highly significant for BR3 and BR4 but only significant for Latisail (Table 6).

B1.11. Effect on grain weight. One thousand grain weight differed significantly among the varieties (Table 5). The grain weight of 70-day-old seedlings of all the varieties was comparatively lighter than other lower seedling age group. Among the varieties BR3 produced heavier grains than BR4 and Latisail.

B1.12. Effect on grain yield. Regardless of the variety, the grain yield of 30-day-old seedlings was highest than that obtained from seedlings transplanted at higher ages (Table 5). Reverse was the case in the 70-day-old seedlings of all the varieties. Variation of grain yield per plant or yield per plot was highly significant for the varieties and seedling ages. The yield loss in seedlings of different age groups (40, 50, 60 and 70 days) compared to 30-day-old seedlings were : 5, 13, 31 and 78% in BR3; 4, 20, 23 and 52% in BR4, and 6, 13, 18 and 43% in Latisail. The yield performance in BR4 was found to be superior at other seedling ages but most pronounced at the 30-day-old seedlings.

The correlation between grain yield and seedling ages was negative. The coefficient of correlation was highly

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significant for BR4 and Latisail and only significant for BR3 (Table 6).

Experiment B2. Effect of seedling age at transplanting in the Boro season

In the Boro experiment seeds were sown on 1 November 1978. Seedlings aged 40, 50, 60, 70 and 80 days were transplanted on 10, 20 and 30 December 1978 and on 9 and 19 January 1979. On account of the seasonal difference in this set of experiment the first transplantation was delayed by 10 days and the last transplantation was made when the seedlings were 80 days old.

B2.1. Effect on panicle development. Variation for the dates of PI differed in the varieties for all seedling ages (Table 7). In the seedbed, PI occurred at 114, 120 and 118 days in BR3, BR4 and Latisail respectively, whereas in 40-day-old seedlings when transplanted on 10 December, PI was delayed by 2-6 days and PI was further delayed with an increase in seedling age. However, in the Boro field PI in BR3 averaged 126.20 days against 114 days in the seedbed. The chi-square test indicated significant variation among the seedling ages.

Similarly PI averaged 127.8 and 126.2 days in BR4 and Latisail respectively. On the other hand when left in the

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seedbed PI took place 6-8 days earlier. The chi-square tests indicated insignificant variation due to seedling ages. Regardless of the seedling age at transplanting, the plant produced 90% of the total tillers 10-15 days prior to PI (Table 7). In this case 40-day-old seedlings of the varieties PI occurred 80-82 days after transplanting. On the contrary, 80-day-old seedlings when used for transplantation, the PI in the main culm took place 35 days after transplanting. The result clearly showed that the field duration i.e. from transplanting to panicle initiation in the main culm significantly decreased with the increase in seedling age (Table 7).

In all the varieties, 40-day-old seedlings headed earlier. The period from neck-node development to the heading stage varied 29-33 days. The total duration from transplanting to harvesting reduced significantly when older seedlings were used for transplantation (Table 7).

B2.2. Effect on the panicle branch development. The number of primary and secondary branches per panicle on the main culm has been shown in Table 8. A significant difference in the number of primary and secondary branches per panicle of the main culm was observed between BR4 and the two other varieties. However, within the variety the total number of panicle branches differed slightly irrespective of the time of transplantation. Among the varieties BR4 developed

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the highest number of secondary branches per panicle and lowest number was found in BR3 (Plate 2, figures 7-9 and Plate 4, figures 1-6).

B2.3.. Effect on the panicle branch degeneration. Panicle branch degeneration observed in the seedlings transplanted at an interval of 10 days from 40 days onwards to 80 days showed significant variation among the varieties but none within the variety (Table 8). The percentage of panicle branch degeneration was highest in Latisail. The percentage of panicle branch degeneration in the varieties ranged from 9.91-11.62 in BR3, 11.71-15.61 in BR4 and 16.52-21.01 in Latisail. Primary branch degeneration was hardly found in the panicles. The percentage of panicle branch degeneration was highest in Latisail. The percentage of panicle branch degeneration showed no significant correlation with the seedling age for the varieties. The correlation coefficient was insignificant (Table 10).

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B2.4. Effect on spikelet number per panicle. The number of spikelets per panicle after initiation on the main culm has been shown in Table 8. Variation was found in the varieties and seedling age (Plate 2, figures 4-6 and Plate 4,figures 1-6). Table 8 shows that any delay in transplantation resulted a reduction in the number of spikelet initiation. The number of spikelets per panicle

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of the main culm decreased with the increase in seedling age from 40 to 80 days. Percentages of spikelet reduction from 40-day-old seedlings to the successive higher seedling ages were : 4.0, 4.0, 6.6 and 7.5 in BR3; 4.0, 6.6, 10.4, and 10.92 in BR4; and 0.81, 2.8, 7.6, and 15.5 in Latisail. These variations were significantly different for the varieties and seedling ages. The result clearly indicated that the greater was the delay in transplantation the fewer was the spikelet number. In terms of percentage this was more pronounced in Latisail.

The correlation between seedling age and the number of spikelets was found to be negative in all the varieties. Coefficient of correlation was highly significant in every variety (Table 10).

B2.5. Effect on spikelet degeneration. Irrespective of the variety, the percentage of spikelet degeneration decreased with the increase of seedling age at transplanting (Table 8). In BR3 and BR4 spikelet degeneration percentages showed an increasing trend from 60-day-old seedlings onwards, whereas reverse was the case in Latisail. The extent of spikelet degeneration was the highest in Latisail and lowest in BR3 regardless of the seedling ages.

The correlation between seedling age and percentage of spikelet degeneration was found significant. The

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coefficient of correlation (Table 10) was highly significant for Latisail (R^2 = 0.732), while only significant for BR3 (R^2 = 0.732) and BR4 (R^2 = 0.746).

B2.6. Effect on the panicle length. The effect of seedling on the development of panicle length is shown in Table 8. Variation in panicle length in the plants grown from seedlings of different ages was significantly different in the varieties. The effect of seedling age was insignificant.

B2.7. Effect on the plant height. The plant height at harvest is shown in Table 8. Variations of plant height were highly significant for the variety and seedling age. The interaction effect was also significant. Irrespective of the varieties plant height decreased with higher seedling ages (70 and 80 days old).

The correlation between seedling age and plant height was positive for the varieties. Correlation coefficient (Table 10) was highly significant for BR3 (R^2 = 0.876) and significant in BR4(R^2 = 0.800) and Latisail (R^2 = 0.801).

B2.8. Effect on the tiller number. Varieties showed significant variation of total tillers per plant. Forty-day-old seedlings when transplanted on 10 December produced highest number of tillers per plant but 80-day-old

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seedlings when transplanted on 19 January produced the lowest number of tillers per plant (Table 8). The number of panicles per plant were significantly highest in 40-day-old seedlings than 80-day-old seedlings. However, when compared to other seedling ages, 80-day-old seedlings produced significantly the highest percentage of unproductive tillers (Table 8). The percentage of unproductive tillers significantly differed in the varieties.

A significant negative correlation was found between seedling ages and number of panicles per plant. Correlation coefficient was highly significant for BR3 and Latisail and only significant for BR4 (Table 10). The correlation between seedling ages and the percentage of unproductive tillers was positive. The correlation coefficient was highly significant for BR4 and Latisail, but it was only significant for BR3 (Table 10).

B2.9. Effect on spikelet sterility. Percentages of spikelet sterility for the various seedling ages is shown in Table 9. Spikelet sterility decreased with the increase in seedling age of BR3 and significantly different from other two varieties.

The correlation coefficient (Table 10) was highly significant for BR3 ($R^2 = 0.946$) but insignificant for BR4 ($R^2 = 0.294$) and Latisail ($R^2 = 0.126$).

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B2.10. Effect on the filled grains per panicle. The effect of seedling ages on the number of filled grains per panicle is shown in Table 9. The number of grains per panicle decreased with the increase in seedling age. The correlation between seedling age and number of grains per panicle was found negative in BR4 and Latisail. Correlation coefficient (Table 10) was highly significant for BR4 (R^2 = 0.886) and Latisail (R^2 = 0.845), whereas it was insignificant for BR3 (R^2 = 0.399).

B2.11. Effect on the grain weight. One thousand grain weight differed significantly in the varieties. Seedling ages had no significant effect on the variety. Among the varieties a heavier 1000-grain was found in BR3 (28.99 g) and lighter in BR4 (19.06 g). However, 70-day-old seedlings of BR3 and BR4 and 80-day-old seedlings of Latisail transplanted, these had comparatively higher grain weight.

B2.12. Effect on the grain yield. The grain yield per plant and plots is shown in Table 9. Grain yield differences between the seedling ages varied within 5.97-6.64 t/ha in BR3, 6.25-7.35 t/ha in BR4, and 4.69-5.73 t/ha in Latisail. The grain yield showed a negative correlation with the seedling ages only in Latisail.

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The correlation coefficient was significant in Latisail but insignificant for BR3 and BR4 (Table 10). The result showed that seedling ages (40-80 days old) for the Boro season had comparatively less effect on yield than the transplant Aman season (Tables 5 and 9).

EXPERIMENT C : Effect of Seedling Age at Transplanting from Seedlings Sown on Different Dates on the Development of Panicle, Degeneration of Spikelets and Other Yield Components

Seedlings of the five different sowing dates were transplanted on the same date. The experiments were conducted both transplant Aman and Boro seasons in order to determine the degeneration of spikelets and other related characters in the three varieties as influenced by the seasonal variation. The results of the experiments are given under separate headings for the transplant Aman and the Boro seasons.

Experiment C1. Effect of seedling age at transplanting from seedlings sown on different dates in the transplant Aman season

Seeds were sown on 30 June,10, 20 and 30 July, and 9 August. On the 9 September seedlings were of different ages; 70, 60, 50, 40 and 30 days old were transplanted on that day. The experimental results are given in the following paragraphs.

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C1.1. Effect on panicle development. Seedlings of five different ages indicated variation on the date of PI in the three varieties (Table 11). The development of panicle after transplantation took smaller period in the seedlings transplanted at the younger age. In other words younger the age of transplanted seedlings earlier was the panicle initiation. Therefore, it may be concluded that unlike in two previous experiments (in which sowing was done at the same date) in the present one, delayed sowing brings forward the time of panicle initiation.

In BR3, BR4 and Latisail the age of PI was found 65, 72 and 64 days respectively. When the seedlings originated from seeding of 30 June, the age of PI was found to be 70, 103 and 97 days for BR3, BR4 and Latisail varieties respectively (Table 11). The Chi-square test indicated significant variation between the age of PI and date of sowing in BR3 and BR4 (Table 11). The variety BR3 showed insignificant variation for the age of PI.

The effect of earlier seeding was much more marked in BR4 and Latisail in respect of PI than BR3. The reason for such difference lie in the photoperiod sensitivity of the first two varieties (cf Table 11).

Seventy-day-old seedlings of BR3 were transplanted when PI already occurred. The field duration from trans-

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planting to PI was found insignificant from the Chi-square tests for the varieties BR4 and Latisail but significant in BR3. The mean ages for PI were found 68.60, 86.40 and 80 days for BR3, BR4 and Latisail varieties respectively. The field duration for PI were 18.60, 36.40 and 30 days respectively in BR3, BR4 and Latisail and significantly different for the varieties (Table 11). Chi-square tests also showed insignificant variation for heading dates for BR4 and Latisail varieties but significant for BR3 (Table 11). The developmental periods from PI to heading, heading to anthesis and anthesis to full development of caryopsis (ripening phase) were found to vary from 25-28, 2-4 and 30-34 days respectively in the varieties. Differences between the panicle developmental stages with the ages were not significantly different for the varieties.

C1.2. Effect on the number of panicle branches. The number of primary branches developed per panicle of the main culm decreased with the increase in seedling age (Table 12). The number of primary branches in the different seedling ages were found highly significant for the varieties and seedling ages with interaction effect (Table 14). The interaction effect of variety x seedling age showed significant variation for 70-day-old seedlings of BR3 and Latisail but the effects of 40, 50, 60 and 70 days old seedlings of BR4 were similar (Table 12).

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Correlation between the number of primary branches per panicle with the seedling ages was negative for the varieties. The coefficient of correlation was significant at 1% level for BR3 and BR4 and significant at 5% level for Latisail (Table 16).

The number of secondary branches per panicle of the main culm decreased with the increase in seedling ages (Table 12). Among the seedling ages 70-day-old seedlings developed the lowest number of secondary branches per panicle among the other lower seedling ages. The interaction effect of variety x seedling ages was highly significant (Table 14). The interaction of variety x seedling ages indicated similar effects for the seedlings aged 30, 40 and 50 in BR3, 30, 40, 50 and 60 days in BR4 and all the seedling ages in Latisail (Table 12).

Correlation between seedling ages and the number of secondary branches per panicle was negative for all the varieties. The correlation coefficient was significant at 1% level for Latisail and significant at 5% level for BR3 and BR4 (Table 16).

C1.3. Effect on panicle branch degeneration. Percentages of panicle branch degeneration increased with the higher seedling ages. Irrespective of varieties percentage of panicle branch degeneration was found the highest

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in the 70-day-old seedlings (Table 12). Variation of panicle branch degeneration was found highly significant for varieties and seedling ages with interaction effect (Table 14). The interaction of variety x seedling ages indicated similar effects for the age group 40,50,60 and 70 days old in BR3, 30, 40, 50 and 60 days old in BR4 and 30, 40 and 50 days old seedlings in Latisail (Table 12).

Correlation between seedling age and percentage of branch degeneration was positive for all the three varieties and the correlation coefficient was significant at 5% level (Table 16).

C1.4. Effect on the number of spikelets per panicle. Spikelets per panicle of the main culm differed between the varieties and showed variation in the seedling ages (Table 12). The interactions of variety x seedling ages were also highly significant (Table 14). The effect of seedling age showed similar effects for the seedling ages - 30 and 40 in BR3; 30, 40, 50 and 60 in BR4 and Latisail. Regardless of the variety 70-day-old seedlings initiated lowest number of spikelets per panicle of the main culm. The seedling ages 50, 60 and 70 were significantly different in BR3 according to the spikelet production (Table 12). Thirty-day-old seedlings produced the highest number of spikelets. Spikelet reduction between 30

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40, 50, 60 and 70 days old seedlings in BR3 were 1.82, 4.88, 14.44 and 52.65% respectively. Similarly, differences between the seedling ages from 30 with other seedling ages with respect to spikelet reduction were; 1.66, 1.75, 1.76 and 5.85% in BR4, and 4.06, 6.23, 6.34 and 9.03% in Latisail.

The correlation between seedling ages and the number of spikelets developed per panicle (main culm) was found negative for all the varieties. The correlation coefficient (Table 16) was significant at 1% level for Latisail (R^2= 0.915) but significant at 5% level for BR3 (R^2 = 0.725) and BR4 (R^2 = 0.739).

C1.5. Effect on the degeneration of spikelets. Degenerated spikelets were found much more on the secondary branches than developed on the primary branches. Moreover, the number of degenerated spikelets was higher on the lower most secondary branches. The percentage of degenerated spikelets in the panicle of main culm increased with the corresponding increase in seedling age (Table 12). Transplanting 70-day-old seedlings, the extent of spikelet degeneration was highest from other lower seedling ages and it was reverse for 30-day-old seedling (Table 12). Variation for the percentage of spikelet degeneration was highly significant for the varieties and seedling ages. The interaction of variety x seedling ages was found

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insignificant (Table 14). The effect of seedling age on BR3 was similar for the seedling ages of 50, 60 and 70 day old. In BR4 it was similar for the seedling ages 30, 40, 50 and 60. The effect was similar for the seedling ages 30, 40 and 50 days old in Latisail (Table 12).

Correlations between seedling age and percentage of spikelet degeneration was positive. The correlation coefficient (Table 16) was significant at 5% level for BR3 ($R^2 = 0.837$), BR4 ($R^2 = 0.730$) and Latisail ($R^2 = 0.822$).

C1.6. Effect on panicle length. The panicle length of the main culm per plant showed variation in length between the seedling ages (Table 12). The panicle length was highly significant for the varieties and seedling ages with significant interaction effect (Table 15). Seventy-day-old seedlings produced significantly smallest panicles in BR3 and Latisail. Similar effects of seedling ages on the panicle length was observed for age group of 30, 40, 50 and 60 days old in BR3 and 30, 40 and 50 days old in BR4 and 40, 50,and 60 days old in Latisail.

C1.7. Effect on plant height. Thirty-day-old seedlings produced the tallest plants among the other higher seedling ages. Seedlings of 70-day-old produced

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shorter plant in comparison to the other seedling ages (Table 13). The main culm of 70-day-old seedlings was much shorter than the other primary tillers. The height of the main culm decreased progressively with the increase in seedling age.

There was a negative correlation between seedling age and plant height in the varieties. The correlation coefficient (Table 16) was significant at 1% level in BR4 (R^2 = 0.915) and Latisail (R^2 = 0.963) and at 5% level in BR3 (R^2 = 0.796).

C1.8. Effect on the number of panicles per plant. The number of panicles per plant increased with the increase in seedling age (Table 13). Seventy-day-old seedlings when transplanted on 30 June produced more panicles per plant among the other higher seedling ages (Table 13). The interaction of variety x seedling age was highly significant (Table 15).

The panicles per plant were positively correlated with the seedling ages. The correlation coefficient (Table 16) was significant at 1% level in Latisail (R^2 = 0.848) and significant at 5% level for BR3 (R^2 = 0.798) and BR4 (R^2 = 0.837).

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C1.9. Effect on spikelet sterility. The sterility percentage in general decreased with the increase of seedling age (Table 13). Seedlings of 70-day-old which were obtained from 30 June seeding produced less sterile grains than 30-day-old seedlings. Thirty-day-old seedlings which were obtained from 09 August seeding produced the highest percentage of sterile grains in all the varieties (Table 13). The sterility percentages increased with the shifting of sowing dates from 30 June to later dates. Variation of the spikelet sterility percentage in the seedling age was highly significant for varieties and seedling ages (Table A15).

The correlations between seedling ages and percentages of spikelet sterility were negative for all the three varieties and their coefficients (Table 16) were significant at 1% level for BR3 (R^2 = 0.853), BR4 (R^2 = 0.941) and Latisail (R^2 = 0.995).

C1.10. Effect on grain yield. The grain yield per plant was lower in plants grown from 70-day-old seedlings (Table 13). The highest yield came from 60-day-old seedlings of BR4 and 50-day-old seedlings of BR3 and Latisail. Seedlings which were transplanted from 20 July seeding showed a decreasing effect on the grain yield. Yield

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differences between 50-day-old seedlings and 70, 60, 40 and 30 days old seedlings were 15.78, 6.05, 8.38% in BR3 and 13.96, 4.40, 7.61 and 7.54% in Latisail. Similarly yield differences in BR4 between 60-day-old seedlings and 70, 50, 40 and 30 days old seedling were 3.80, 0.85, 1.41 and 1.85% respectively. Variation of grain yield per plant and total grain yield per plot was found highly significant for varieties and seedling ages. The interaction of variety x seedling ages were insignificant (Table 15).

The correlation between seedling ages and grain yield was negative and its coefficient was significant at 5% level only for Latisail (Table 16).

Experiment C2. Effect of seedling age at transplanting from seedlings sown on different dates in the Boro season

Seeds were sown on 20 and 30 December, and on 9, 19, and 29 January 1979. On the 10 March seedlings were of different ages; 80, 70, 60, 50 and 40 days old. The different aged seedlings were transplanted on 10 March. The results of the experiment are given in the following paragraphs.

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C2.1. Effect on panicle development. The effect of sowing dates and seedling ages on the development are given in Table 17. The duration from sowing to PI in the main culm differed significantly in the varieties and in the seedling ages. However, the field duration for PI was less when the older seedlings were transplanted. Variation of the field duration for PI was found insignificant for BR3 and BR4 (Table 17). On the contrary the age for PI was significant for the seedling ages. The mean ages for PI were 104.60 and 121.00 days for BR3 and BR4 respectively. The mean field duration for BR3 and BR4 were 44.60 and 61 days respectively. Eighty-day-old seedlings of BR3 and BR4 initiated panicle earlier than other lower seedling ages. In Latisail only 80-day-old seedlings produced panicle only on the main culm but hardly in the tillers but seedlings of other lower ages did not initiate panicle which came from the seedings of 30 December and 9,19, and 29 January.

C2.2. Effect on the number of panicle branches. The number of primary branches developed per panicle of the main culm differed among the seedling ages. Eighty-day-old seedlings of BR3 and BR4 developed the highest number of primary branches per panicle (Table 18). The variation between the seedling ages was highly significant for

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varieties and seedling ages. The interaction effect of variety x seedling age was insignificant (Table 20).

The number of secondary branches per panicle of the main culm increased with the corresponding increase in seedling age (Table 18). The variation in the number of secondary branches was highly significant for varieties and seedling ages. The interaction effect was also highly significant (Table 20). The variety BR4 produced significantly higher number of secondary branches than BR3. The effect of seedling ages 40, 50, 60 and 70 was similar in BR3. In BR4 the effect of seedling ages 50, 60, 70 and 80 days was similar. The result showed that the mean effect of seedling ages 60 and 70 days was similar and significantly different from other seedling ages. Seedling ages 40, 50 and 80 days were significantly different from one another. However, in BR3 and BR4 the highest number of secondary branches developed in the 70-day-old seedlings and the lowest in the 40-day-old seedlings for both the varieties.

The correlation between seedling ages and the number of secondary branches per panicle of the main culm was positive. The coefficient of correlation (Table 21) was significant at 1% level for BR4 ($R^2 = 0.886$) and significant at 5% level for BR3 ($R^2 = 0.730$).

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C2.3. Effect on panicle branch degeneration. The percentage of panicle branch degeneration showed variation between the seedling ages (Table 18) and between the varieties. The percentage of panicle branch degeneration increased with the decrease in the seedling age of BR3, but it decreased in BR4. The variation was found highly significant for the varieties and seedling ages with interaction effect of variety x seedling age. The variety BR4, degenerated the highest percentage of panicle branches and significantly different from BR3. The effect of seedlings aged 40, 50 and 60 days was similar for BR3 and 60, 70 and 80 days for BR4 (Table 18). However, the effect of 30-day-old seedlings were significantly different from 60 and 70 days old BR3 seedlings. In BR4 the effect of 40-day-old seedlings was significantly different from other higher seedling ages.

The correlation between seedling ages and the percentage of panicle branch degeneration was negative in BR3 but positive in BR4. In both the cases the correlation coefficient was significant at 1% level(Table 21).

C2.4. Effect on the number of spikelets per panicle. The results indicate that spikelets per panicle decreased with the increase in seedling age for the varieties (Table 18). Eighty-day-old seedlings of BR3 and BR4

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developed the highest number of spikelets per panicle and the lowest number was found in the seedlings of 40-day-old.

The reduction of spikelets per panicle of the main culm from 80-day-old seedlings to other lower seedling ages was significant for BR3 and BR4. Differences in spikelet reduction from 80 to 70, 60, 50 and 40 days old seedlings were 3.45, 3.92, 5.44 and 8.51% in BR3 and 1.19, 4.48, 5.34 and 9.55% in BR4. The number of spikelets per panicle of BR4 was almost double than that of BR3 for all seedling ages.

The variation in the spikelet number of different seedling ages was significant at 1% level in the varieties and seedling ages. The interaction of variety x seedling age was also highly significant (Table 20). The variety BR4 produced the highest number of spikelets per panicle (320.20) and significantly different from BR3 (159.14). The effect of seedling ages 50, 60 and 70 days was similar in BR3 but significantly different from 40 or 80-day-old seedlings.

In BR4 the effect of seedling ages 50 and 60 was similar but significantly different from 40, 70 and 80 days old seedlings.

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The correlation between seedling ages and the number of spikelets per panicle of the main culm was positive for the two varieties. The coefficient of correlation (Table 21) was significant at 1% level in BR3 (R^2= 0.940) and BR4 (R^2=0.954).

C2.5. Effect on the spikelet degeneration. The extent of spikelet degeneration differed between the varieties irrespective of the seedling age (Table 18). The variation in the five seedling ages was highly significant for varieties and seedling ages with interaction effect (Table 20). A comparison between the variety mean levels showed the varieties differing significantly in the percentage of spikelet degeneration. The extent of spikelet degeneration was higher in BR4 (30.41%) than BR3 (13.97%). Eighty-day-old seedlings of Latisail degenerated the highest percentage (41.40) of spikelets although it produced single panicle per plant. A comparison between seedling ages at the 1% level showed similar effect for seedlings aged 60, 70 and 80 but 40-day-old seedlings differed significantly from all other seedling ages. Fifty-day-old seedlings significantly differed from 40, 70 and 80 days old seedlings. Similar effect was observed in BR3 for the seedlings aged 40, 50 and 60 days and in BR4 seedlings aged

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50, 60, 70 and 80 days (Table 18).

The correlation between the seedling age and the percentage of spikelet degeneration was negative for BR3, but positive for BR4. The coefficient of correlation (Table 21) was significant at 1% level for BR3 (R^2= 0.923) and BR4 (R^2= 0.909).

C2.6. Effect on the panicle length. The panicle length of the main culm decreased with the corresponding increase of seedling age (Table 18). Forty-day-old seedlings from 29 January seeding were comparatively taller than seedlings from early seedings. The panicle lengths varied from 22.85 - 23.75 cm in BR3 and 33.25-34.38 cm in BR4.

The correlation between seedling age and panicle length was negative for BR3 and BR4. The correlation coefficient (Table 21) was significant at 1% level (P = 0.01) for BR3 (R^2= 0.865) and at 5% level for BR4 (R^2= 0.786).

C2.7. Effect on the plant height development. At maturity of grains plant heights of the varieties differed significantly (Table 19). The differences of plant height resulted from different seedling ages were not significant. The mean plant heights varied from

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81.35 - 88.88 cm in BR3, 111.12 - 111.47 cm in BR4.

C2.8. Effect on the panicle number. The effect of seedling age and time of sowing on the number of panicles per plant is shown in Table 19. Panicles per plant were significantly highest in BR3 than BR4. The panicles per plant decreased in BR3 but increased in BR4 with the increase in seedling age. However, the percentage of unproductive tillers were found to increase with the increase of seedling age for the two varieties. The variety Latisail produced panicle only on the main culm from 80-day-old seedlings and panicles were not found on plant grown from other seedling ages. Among the varieties 40-day-old seedlings produced minimum tillers per plant than seedlings of higher ages. The variation due to seedling ages for the numbers of panicles per plant was found to be highly significant with interaction effect (Table 20).

The correlation between seedling ages and the number of panicles per plant was positive for BR4 but negative for BR3. On the contrary the correlation of seedling ages and percentage of unproductive tillers were positive for both the varieties. The coefficient of correlation for both the characters were significant

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at 1% level for the varieties (Table 21). The result clearly indicated the effect of late seeding in the Boro season on BR4 where the number of panicles decreased in spite of lower seedling age at transplantation.

Percentage of unproductive tillers was positively correlated with the seedling ages for the two varieties. The correlation coefficients (Table 21) were highly significant for BR3 (R^2= 0.889) and BR4 (R^2= 0.945).

C2.9. Effect on spikelet sterility. The percentage of spikelet sterility increased in BR4 with the increase in seedling age but reverse was the case in BR4 (Table 19). Variation between the varieties was significant. The spikelet sterility between the seedling ages varied 19-16-21-24% in BR3 and 24.79 - 25.48% in BR4.

The correlation between seedling age and spikelet sterility was positive for BR4 but negative for BR3. The correlation coefficient in both the cases was significant at 1% level (Table 21).

C2.10. Effect on the grain number per panicle. The number of filled grains per panicle increased in BR3 but decreased in BR4 with the corresponding increase in seedling age (Table 19). The correlation between seedling ages and the number of grains per panicle was

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positive for BR3 but negative for BR4. The correlation coefficient was significant at 1% level for both the varieties (Table 21).

C2.11. Effect on grain yield. The effect of seedling age and time of sowing had no significant effect on 1000-grain weight. One thousand grain weight varied from 28.38 - 28.88 g in BR3 and 21.29 - 26.59 g in BR4. The grain yield per plant or total yields per plot decreased in BR3 with the increase in seedling age, but reverse was the case for BR4 (Table 19). Variation of grain yield was highly significant for the varieties and seedling ages. Forty-day-old seedlings of BR3 yielded higher, but lower in BR4 among the other seedling ages. The reduction of grain yield in BR3 from 40-day-old seedlings with other successive higher seedling ages were 0.28, 2.26, 2.42 and 3.80%. However, in BR4 yield reduction from 80-day-old seedlings with other successive lower seedling ages were 5.94, 19.07, 22.75 and 32.99%. The yield difference between the seedling ages varied from 4.99 - 4.80 t/ha in BR3 and 5.25 - 3.52 t/ha in BR4.

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Correlation between grain yield and seedling ages was negative for BR3 but positive for BR4. The correlation coefficient was highly significant for both the varieties. The result indicated that the effect of late sowing (29 January) decreased the grain yield significantly in BR4 but higher seedling age affected grain yield in BR3.

EXPERIMENT D : Effect of Seedling Age and Fertilizers (NPK) on the Development of Panicle, Degeneration of Spikelets and Other Quantitative Characters of BR4

The details of the methods and materials used for this experiment are given in Chapter II. The results of the experiment is given in the following paragraphs.

D.1. Effect on panicle development

The periods for the different stages of panicle development is given in the Table 22. The developmental stages of the panicle was recorded from the main culm of randomly selected plant. The field duration from transplantation to PI of the main culm decreased with the increase in seedling age. Seventy-day-old seedlings which were transplanted on 24 September initiated panicle in the main culm at the 10th day after transplanting. Thirty-

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day-old seedlings initiated panicle 60th day after transplanting. The field duration significantly decreased with the increase in seedling age. However, the total age for PI showed differences between the seedling ages but the effect of fertilizer on the date of PI varied slightly. The total age for PI decreased in the plants obtained from the 70-day-old seedlings which initiated panicle much earlier than other lower seedling ages. The age for PI increased in plants which were obtained from 50 and 60 days old seedlings. The field duration for PI were significant. The mean age for PI was 91 days and mean field duration for PI was 41 days. The PI in the other tillers delayed with the increase in seedling ages. Seventy-day-old seedlings produced panicle in the main culm at about 25 days earlier than the first tiller. Moreover, the PI in the late tillers was irregular and took place even after the ripening stage of the main culm. The period between PI and heading took place 25-26 days and anthesis in the spikelets occurred within 3-5 days with the emergence of the panicle. The development of caryopsis continued for 32-34 days after anthesis. Application of fertilizers had no significant effect on the period for the panicle developmental stages.

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D.2. Effect on the number of panicle branches

The main effect of the NPK fertilizers over control for the development of primary branches differed slightly (Table 23). However, the effect of nitrogen alone was significant than that of P, K or PK combination over the control. The main effect of the fertilizers (NPK) over control for the increase of primary branches were N = 0.70, NP = 0.30, NPK = 0.57. Application of nitrogen singly produced maximum panicle branches, whereas the combination of N with P, K or PK showed negative effect on the panicle branch number.

The effect of higher seedling age significantly decreased the number of primary branches of the panicle from main culm. Variations between the seedling ages of 30, 40 and 50 days were insignificant for the development of primary branches. However, 60 and 70 days old seedlings produced significantly reduced number of primary branches in comparison to other seedling ages (Table 25).

The main effects of fertilizers over control for the increased number of secondary branches were N = 1.31, NP = 0.99, NK = 1.26 and NPK = 2.03. The effect of nitrogen alone and combination of N, P and K showed positive effect (Table 23). However, application of fertilizer increased the number of secondary branches per panicle. Number

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of secondary branches per panicle of the main culm showed significant at 1% level for the seedling ages and fertilizers with interaction effect (Table 26). Variation between 30, 40 and 50 days old seedlings were insignificant (Table 25). However, 70-day-old seedlings produced significantly the lowest number of secondary branches per panicle of the main culm than other lower seedling ages (Table 25).

D.3. Effect on panicle branch degeneration

The extent of panicle branch degeneration comparatively increased in the plants which received either NK or NPK (Table 23). The main effects of fertilizers over control were; N = 0.73, NP = 0.59, NK = 0.26 and NPK = -0.08. The individual effect of nitrogen was much higher for decreasing the degeneration of panicle branches than combination of NP, NK or NPK. The percentage of branch degeneration between seedling ages and fertilizers was significant at 1% level for the seedling ages and fertilizer treatments. The interaction of seedling age x fertilizer treatment was insignificant (Table 26).

D.4. Effect on the number of spikelets per panicle

The effect of fertilizer treatment on the number of spikelets per panicle is shown in Table 23. The number of spikelets per panicle of the main culm in the fertilizer treatments was significantly different (Plate 5, figures 1-6).

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The mean effects of N, NP, NK or NPK significantly increased the number of spikelets per panicle than the control. The response of NPK and N was comparatively higher than combination of NP and NK for the development of spikelet number. However, response of K was significantly higher than P.

Spikelets per panicle of the main culm reduced significantly with the increase in seedling ages (Table 25). Thirty-day-old seedlings produced the highest number of spikelets than seedlings of 70-day-old. Seventy-day-old seedlings when transplanted produced the lowest number of spikelets than the other lower seedling ages. When compared to 30-day-old seedlings, reduction of spikelets per panicle from 40, 50, 60 and 70 days old seedlings were 3.24, 5.38, 16.26 and 33.46% respectively. The variation of spikelet number per panicle of the main culm was significant at 1% level for fertilizer treatments and seedling ages with interaction effect (Tables 23 and 25).

The result showed that the effect of fertilizer increased the number of spikelets per panicle but application of fertilizer on higher seedling ages (60-70 days old) had no significant effect.

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D.5. Effect on spikelet degeneration

The effect of fertilizers, N, NP, NK or NPK showed insignificant variation for the percentage of spikelet degeneration. However, the highest percentage of the degenerated spikelets were found in the control (Table 23). The effect of fertilizer on the spikelet degeneration was significant for the reduction of spikelet degeneration (Table 23). The effect of N alone and NP showed higher percentages of spikelet degeneration than NK and NPK treatments.

The mean effect of fertilizer (NPK) for various seedling ages showed variation among the seedling ages (Table 25). The percentage of spikelet degeneration was comparatively highest in the 70-day-old seedlings. However, 40-day-old seedling produced the lowest percentage of degenerated spikelets. Variations of spikelet degeneration percentages between the treatments for the respective seedling ages varied significantly(1% level) for the seedling age and fertilizer (NPK) treatment (Table 26). The interaction of seedling age and fertilizer treatment was insignificant.

D.6. Effect on panicle length

The response of NPK was significant for the increased panicle length compared to the other fertilizer treatments.

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The response of P was positive but that of K negative (Table 24). The development of panicle length in the seedling ages of 30, 40 and 50 days old showed insignificant variation, but differed from 60 and 70 days old seedlings. Seedlings of 70-day-old when transplanted, the main culm produced the smallest panicle among the seedling ages. The effect of fertilizer had no significant effect on the higher seedling age (Table 25). Variation of panicle length between the main culm and panicles of first six tillers of the same plant from 70-day-old seedlings were significant. However, the variation of panicle length between the panicles of first six tillers were not significantly different.

D.7. Effect on plant height

The development of plant height showed variation between the treatments. Application of fertilizer on plant height development was significant (Table 24). The plant height was much shorter in the control treatment than other fertilizer treatments. The response of P was negative, but K positive, whereas combination of PK with N was positive. Variations of plant heights over control were 3.28, 2.80, 4.32 and 4.60 cm for N, NP, NK and NPK combinations respectively (Table 24). The mean effect of fertilizers over control was 3.25 cm.

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The plant height reduced with the increase in seedling age (Table 25). Variations among 30, 40 and 50 days old seedlings were insignificant for plant heights, but differed significantly from 60 and 70 days old seedlings. Seedlings of 70-day-old were much shorter in height than other lower seedling ages. Variations of plant height among the fertilizer treatments were significant at 1% level both with seedling ages and fertilizer treatments. The interaction effect of seedling age and fertilizer treatment was insignificant (Table 26).

D.8. Effect on panicle number per plant

The main effects of N, NP, NK and NPK over control were 1.29, 1.40, 1.69 and 2.40 respectively for increasing the number of panicles per plant (Table 24). The effect of NPK was much better for higher panicle number than N, NP and NK combinations. The response of K was comparatively higher than P (Table 24). The number of panicles per plant increased with the corresponding increase in seedling age. Seventy-day-old seedlings produced maximum panicles per plant in comparison with the lower seedling ages (Table 25). The variation of panicle number per plant was significant at 1% level for fertilizer treatments, seedling ages with interaction effect (Table 26).

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D.9. Effect on spikelet sterility

The percentage of spikelet sterility was apparently higher in the control than other fertilizer treatments (24). Variation of sterility percentages over control were 0.41, 0.89, 1.13 and 1.28 in N, NP, NK and NPK respectively. Percentages of sterility got numerically reduced with NPK application.

Percentages of sterility differed slightly between the seedling ages (Table 24). Thirty-day-old seedlings when transplanted on 15 August produced the lowest percentage of spikelet sterility. From the statistical point of view the percentage of spikelet sterility was rather apparent and not significant for fertilizer treatments and seedling ages (Table 26).

D.10. Effect on grain yield

Application of fertilizers had no significant effect on the grain weight. However, transplanting 70-day-old seedlings, 1000-grain weight reduced slightly. The mean grain weight in BR4 varied from 22.38 - 22.45 g/1000 grains. The grain yield per plant decreased in the control treatment. The mean differences between the control with N, NP, NK or NPK combinations were significantly different (Table 24). The grain yield per plant was much higher in NPK treatment than other treatments. Application of N alone had higher

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grain yield but it was comparatively higher in NP and NK combinations.

The variation of grain yield per plant between the seedling ages 30, 40, 50 and 60 days old were insignificant but significantly different from 70-day-old seedlings. The yield differences between the treatments and seedling ages were significant at 1% level for the treatments and seedling ages. The interaction effect of fertilizer treatment x seedling age was insignificant (Table 26).

EXPERIMENT E : Effect of Seeding Rate on the Development of Panicle, Degeneration of Spikelets and some Quantitative Characters of BR3, BR4 and Latisail

The experiment was undertaken to evaluate the effect of plant density at different levels on the panicle development and spikelet degeneration. Seeds of BR3, BR4 and Latisail rice varieties were seeded at the seeding rate of 6.25, 12.50, 25, 50, 100 and 200 g/m^2. Agronomic traits were measured from 50 plants sampled randomly from each treatment and per replication. The experiment of the Boro season was repeated in the transplant Aman season to find the effect for seasonal variation. The results of the experiments are given under separate headings for the Boro and the transplant Aman seasons.

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Experiment E1. Effect of seeding rates, Boro 1980-81

Seeds were sown directly in the plot on 20 December 1980. The treatments consisted of six different seeding rates of 6.25, 12.50, 25, 50, 100 and 200 g/m^2. The results of the experiment follow.

E1.1. Effect on panicle development. The effect of various seeding rate on the developmental period for panicle developmental stages is shown in Table 28. Among the three varieties, Latisail did not initiate panicle in any one of the treatments. The PI took place earlier in the seed rates of 200 g/m^2 in BR3 and BR4 varieties. However, the result from the Chi-square test showed insignificant variation regarding the age for panicle initiation. The mean ages for panicle initiation in BR3 and BR4 were 121.83 and 126.50 days respectively. The periods from PI to heading, heading to anthesis and from anthesis to full development of caryopsis varied from 26-29 days, 3-5 days and 30-34 days respectively in BR3 and BR4.

E1.2. Effect on the number of spikelets per panicle. The number of spikelets developed per panicle of the main culm and tillers per plant decreased with the increase in seed rate (Table 29). Among the seed rates the lowest seed rate (6.25 g/m^2) produced numerically maximum spikelets and in the highest seed rate (200 g/m^2) produced minimum spikelets per panicle. Plants from the highest seed rate

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developed a single panicle per plant. The variation of spikelet number per panicle in different seed rate was significant at 1% level for the varieties and seed rates. The interaction effect of variety x seed rate was also significant at 1% level (Table 31). The comparison between seeding rate means at the 1% level indicated significant differences in treatments. A comparison between varietal means level also showed significant effect for the variety.

As the seed rate was increased, the number of spikelets per panicle decreased. A strong negative correlation was found between seed rate and spikelets per panicle of the main culm or tillers per plant. The coefficient of correlation (Table 33) was significant at 1% level in BR3 (R^2= 0.894) and BR4 (R^2= 0.956) for the main culm per plant, it was also true for the tillers per plant.

E1.3. Effect on the degeneration of spikelets. The extent of spikelet degeneration in the panicle of the main culm and tillers per plant showed significant variation between the seeding rates. The effect of seed rate showed significant variation for spikelet degeneration in BR3 and BR4 varieties. The percentages of degenerated spikelets increased with the increase in the seeding rate (Table 29).

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The variation of spikelet number per panicle was significant at 1% level for the varieties, seeding rate with interaction of variety x seeding rate (Table 31).

The percentage of spikelet degeneration was positively correlated with the seeding rate and their coefficients for correlation (Table 33) were significant at 1% level in BR3 (R^2= 0.958) and BR4 (R^2= 0.963). The result indicated that the higher was the seed rate, higher was the percentage of spikelet degeneration for the two varieties.

E1.4. Effect on the panicle length. The panicle length at harvest showed variation of length in the different treatments (Table 29). The panicle lengths between the treatments were found 11.43 - 21.75 cm in BR3 and 12.56 -25.59cm in BR4. Compared to other seeding rates the highest seeding rate produced plants with smallest panicle. Variation of panicle length between the treatments were significant at 1% level for the varieties and treatments, and the interaction of variety x treatment (Table 32).

The correlation between seed rate and panicle length was negative for the two varieties and their coefficient of correlation was significant at 1% level (Table 33).

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E1.5. Effect on the plant height. The plant height showed variation between seeding rates for the varieties (Table 29). Among the treatments the highest seed rate (200 g/m^2) produced much shorter plants. Variation in plant height among the seeding rates was significant at 1% level for the varieties and seeding rates. The interaction effect of variety x seeding rate was insignificant (Table 32).

The correlation between seeding rate and plant height in maturity of grains was negative for the two varieties. The correlation coefficient (Table 33) was significant at 1% level for BR3 (R^2= 0.990) and BR4 (R^2= 0.932).

E1.6. Effect on the panicle number. Tillers per plant decreased and tiller mortality increased with the increase of seed rate. Panicles per plant increased with the lowest seed rate (6.25 g/m^2) and decreased with the highest seed rate (200 g/m^2). Individual seedlings of 200 g/m^2 remained as it was without producing any tiller per plant. The number of unproductive tillers also significantly increased with the highest seed rate (200 g/m^2). The variation for the panicles per plant increased along with the increase in seed rates (Table 30). The analysis of variance showed a high significant difference only

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for the seed rate but was insignificant for the varieties. The interaction of varieties x seed rates was also insignificant (Table 32).

The number of panicles developed per plant showed a negative correlation with the seed rate. The coefficient of correlation was significant at 1% level (Table 33). However, the number of panicles per m^2 increased with the increase in seed rates for the varieties (Table 30). The correlation coefficient (Table 33) was significant at 1% level for BR3 (R^2= 0.973) and BR4 (R^2= 0.948). The number of panicles per m^2 showed a significant positive correlation with the seeding rates. The correlation coefficient was significant at 1% level for the two varieties (Table 33).

E1.7. Effect on the number of grains per panicle. Grains per panicle showed significant variation with different seed rates for the varieties (Table 30). The highest grain number per panicle was obtained by using the lowest seed rate (6.25 g/m^2) and vice-versa. The variation in the number of grains per panicle was significant at 1% level for the seed rates and the two varieties.

Grains per panicle was negatively correlated with the seeding rate. The correlation coefficient was

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significant at 1% level for the varieties (Table 33).

E1.8. Effect on spikelet sterility. The percentage of spikelet sterility increased with the corresponding increase in seed rate (Table 30). Variations were found between the varieties and among the various seed rates. Such variation was significant at 1% level for the seeding rate and varieties with interaction effect of seed-rate x variety (Table 32).

The correlation between seed rates and sterility percentages was found to be positive. The correlation coefficient (Table 33) was significant at 1% level for BR3 (R^2= 0.974) and BR4 (R^2= 0.893).

E1.9, Effect on the grain weight. The grain weight differed in the seeding rates (Table 30). One thousand grain weight was comparatively heavier in the seed rate of 6.25 g/m^2 and lighter in the seed rate of 200 g/m^2. The variations in grain weight was highly significant for the 200 g/m^2 seed rate.

A significant negative correlation was found between the seeding rate and grain weight. The correlation coefficient was significant at 1% level for the two varieties (Table 33).

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E1.10. Effect on grain yield. The effect of seeding rate on grain yield in different seeding rate showed significant variation between the seed rate and the variety. Among the two varieties, BR3 yielded much higher than BR4 in all the seed rates (Table 30). Variation in grain yields was significant at 1% level for the seeding rates and the varieties with the interaction effect of the grain yield x seeding rate (Table 32).

The correlation between seeding rate and yields was negative for the two varieties. The correlation coefficient was significant at 1% level for BR3 and BR4 (Table 33).

Experiment E2. Effect of seeding rate, transplant Aman 1981

The experiment as described in E1 was repeated in the transplant Aman season to observe the seasonal effects of the seeding rates on the spikelet degeneration and other yield components of BR3, BR4 and Latisail.

E2.1. Effect on panicle development. The periods taken for the development of different stages of panicle are given in the Table 34. Although PI differed in the different seeding rates, the difference was insignificant. The mean ages for PI of the varieties were found 71.67,

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86.33 and 80.66 days for BR3, BR4 and Latisail varieties respectively (Table 34). The PI between the main culm and first tiller per plant varied from 3-5 days. However, the developmental stages were found earlier in the seeding rates of 25, 50, 100 and 200 g/m^2. The lower seeding rate delayed PI in all the varieties. The period for the panicle developmental stages varied 25-28 day from PI to heading, 3-5 days from heading to anthesis and 32-34 days from anthesis to maturity (Table 34).

E2.2. Effect on the spikelet number per panicle. The spikelet number per panicle decreased with the increase in seeding rate (Table 35 and Plate 7, figures 1-8). With a seeding rate of 6.25 g/m^2 the highest number of spikelets developed on the main culm of a plant. The lowest number of spikelets developed in the highest seeding rate for all the three varieties. Variation of spikelet number between the seeding rates was significant at 1% level for the varieties, treatments and interaction effect of variety x treatment (Table 37). The mean number of spikelets per panicle between the different seeding rates showed that seed rate had significant effect on the number of spikelets per panicle.

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The correlation between seeding rate and the number of spikelets per panicle was negative. The correlation coefficient (Table 38) was significant at 1% level for BR3 (R^2= 0.959), BR4 (R^2= 0.941) and Latisail (R^2= 0.960).

E2.3. Effect on the spikelet degeneration. The percentage of spikelet degeneration differed between the treatments for all the varieties (Table 35). Higher seeding rate increased the degeneration percentage for the varieties. The percentage of spikelet degeneration was minimum in the lowest seeding rate of 6.25 g/m^2(Plate 7, figures 1-8). The effect of seeding rate on spikelet degeneration was significant at 1% level for the varieties and seeding rates with interaction of variety x seeding rate (Table 37).

The correlation between seeding rate and spikelet degeneration was positive for all the varieties. The correlation coefficient (Table 38) was highly significant at 1% level for BR3 (R^2= 0.932), BR4 (R^2= 0.904) and Latisail (R^2= 0.986).

E2.4 Effect on the panicle length. The effect of different seeding rate on the development of panicle length of the main culm is given in Table 36).

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The panicle length was shorter with the highest seeding rate (200 g/m^2). Variations of panicle length between the seeding rates were found 10.16 - 19.16 cm in BR3, 10.29 - 21.12 cm in BR4 and 10.10 - 18.83 cm in Latisail varieties. Such variation were significant at 1% level for the seeding-rate and the varieties with interaction effect (Table 37).

The correlation between the seeding rates and panicle length was negative and correlation coefficients were highly significant for the varieties (Table 38).

E2.5. Effect on the plant height. The effect of seeding rates on the increase of plant heights at harvest is given in the Table 36. The highest seeding rate produced the shortest plants and lowest seeding rate produced the tallest plant. The variation of plant heights with the seeding rate was significant at 1% level for varieties, seeding-rates and interaction of variety x seeding rate (Table 37).

The increase of plant heights in the treatments showed a strong negative correlation. The correlation coefficients were significant at 1% level for all the three varieties (Table 38).

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E2.6. Effect on the number of panicles per plant. Panicles per plant decreased in all the varieties with the increase in seeding rate (Table 36). Variances for panicle number per plant were highly significant at 1% level for varieties, seeding rates and interaction of variety x seeding rate (Table 37). The panicles per plant in the different seeding rates indicated a strong negative correlation. The correlation coefficients were significant at 1% level for the varieties (Table 38).

The number of panicles/m^2 increased along with the increase in seeding rates (Table 36). Variation of the total number of panicles/m^2 was highly significant for seeding rates and varieties. Irrespective of the varieties, the highest seeding rate (200 g/m^2) produced the highest number of panicles/m^2 (Table 36).

The number of panicles/m^2 indicated a strong positive correlation with the seeding rate. The correlation coefficients were significant at 1% level for the varieties (Table 38).

E2.7. Effect on the number of grains per panicle. Grains per panicle decreased along with the increase in seeding rate (Table 36). The variation of grains per panicle was comparatively higher in 50, 100 and 200 g/m^2 than the lower seeding rates.

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The correlation between the seeding rates and grains per panicle was found negative for the three varieties. The correlation coefficients were highly significant for the varieties (Table 38).

E2.8. Effect on the spikelet sterility. The percentage of spikelet sterility showed a significant variation among the seeding rates (Table 36). Such variation of spikelet sterility was significant at 1% level for the seeding rate and varieties (Table 37). However, the interactions of variety x seeding rates were insignificant. The percentage of spikelet sterility was lowest in the lowest seeding rate (6.25 g/m^2) and vice versa. The correlation between spikelet sterility and seeding rate was positive. The coefficient of correlation was significant at 1% level for all the varieties (Table 38).

E2.9. Effect on the grain weight. One thousand grain weight differed between the seeding-rates and varieties (Table 36). The differences were significant at 1% level for the varieties, seeding-rates and interaction between them. The lowest seeding rate of 6.25 g/m^2 produced comparitively heavier grains than the highest seeding rate of 200 g/m^2.

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The correlation between 1000-grain weight and seeding rate was found negative for all the varieties and the correlation coefficients were at 1% level for the varieties (Table 38).

E2.10. Effect on grain yield. The grain yield (kg/ha) differed in the seeding rates (Table 36). The highest grain yield was obtained from BR3 and the lowest from Latisail. The difference of grain yield was significant at 1% level for the varieties and seeding rates with interaction effect (Table 37). The variation of grain yield in the different seeding rates indicated a significant negative correlation. The correlation coefficients were highly significant for the varieties (Table 38).

EXPERIMENT F: Effect of Tiller Pruning on the Development of Panicle, Degeneration of Spikelets and Other Quantitative Characters of BR3, BR4 and Latisail

This experiment was done in the green house to find the effects of tiller number on the development of panicle and degeneration of spikelets. Three rice varieties BR3, BR4 and Latisail were used for the experiment. The experiment was set up with six different treatments. The treatments consisted of the main culm (T) and different number of tillers per plant : (T+0) = T; (T+1) = T_1; (T+2) = T_2;

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(T+3) = T_3; (T+4) = T_4, and all the tillers intact = T_n. The desired number of tillers were maintained by continuous removal of other tillers immediately after emergence by pruning out of the sheath axis. The transplant Aman experiment was repeated in the Boro season to evaluate the effect of seasonal variation on spikelet degeneration and other yield components. The results of the experiments are given under separate headings for the transplant Aman and Boro seasons.

Experiment F1. Effect of tiller pruning in the transplant Aman season 1978

Thirty-day-old seedlings were transplanted on 15 August 1978. The results of the experiment are given in the following paragraphs.

F1.1. Effect on panicle development. The field durations for the panicle developmental stages are given in the Table 39. Variations between treatments for PI in the main culm differed slightly. In all the varieties PI was dealyed, when the main culm was kept alone and all tillers were pruned (T). The field duration showed insignificant variation (Table 39). Among the varieties, Latisail initiated panicle earliest. The Chi-square tests indicated insignificant variation for the dates of heading, anthesis, and ripening. The

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difference between PI and heading time were 28.66, 28.50 and 29.17 days for BR3, BR4 and Latisail varieties respectively. The period from heading to anthesis varied from 3.66 - 4.17 days and period from anthesis to ripening stage 28.50 - 33.50 days for the varieties (Table 39).

F1.2. Effect on the number of panicle branches. The number of primary branches differed between the treatments (Table 40). Differences for the pruning treatments were highly significant for the varieties, treatments, and interaction of variety x treatment (Table 42). In BR3, the treatments T_2, T_3 and T_4 were similar but T_1, T_2 and T_n were significantly different from one another. In BR4, were insignificant between T and T_1, T_2 and T_3 were insignificant but significantly different from T or T_n (Table 40). The interaction of variety x treatment indicated significant differences between T and T_n treatments. Irrespective of varieties, primary branches per panicle of the main culm were highest in the treatment T and lowest in the T_n.

The number of secondary branches decreased with the addition of tiller number per plant (Table 40). The highest number of secondary branches per panicle of the main culm was found in the treatment T, while T_n developed the lowest number of panicle branches. The number of secondary

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branches per panicle of the main culm was significant at 1% level for the varieties, treatments, and interaction of variety x treatment (Table 42). The interaction effects showed significant differences for the treatment T and T_n. The mean treatment effect of the varieties was similar for T_1, T_2, T_3 and T_4 but, it was different significantly from T or T_n at 1% level. The varieties were also significantly different. The mean value for the number of secondary branches per panicle were 43.36, 59.91 and 51.86 for BR3, BR4 and Latisail varieties respectively.

F1.3. Effect on the spikelet number per panicle. The number of spikelets developed per panicle of main culm and tillers per plant in the treatments is given in the Table 40. Among the treatments, T_1 produced the highest number and T_n produced the lowest number of spikelets. The main culm alone (T) did not produce the highest number of spikelets from other treatments. The variation of spikelets per panicle of main culms or tillers was significant at 1% level for varieties, treatments and interaction of variety x treatment (Table 42).

The interaction (Table 40) showed significant differences for T and T_n. However, the mean effect of treatments at the 1% level were similar for T_1 and T_2, but T, T_3 and T_n were significantly different from one another.

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The mean effect of the treatments for the number of spikelets on the panicle of tillers, showed that T and T_1 were similar and T_2, T_3, T_4 and T_n were significantly different from each other. A comparison between variety mean level at 1%, the varieties were significant for the spikelets per panicles.

F1.4. Effect on the degeneration of spikelets. The percentage of spikelet degeneration for the panicle of main culm per plant slightly differed between the T_2, T_3 and T_4 treatments for all the varieties (Table 40).However, spikelet degeneration was higher in the panicles of tiller when compared with the main culm per plant. The variation of spikelet degeneration of main culm and tillers was highly significant for varieties and treatments. The interactions of variety x treatment was highly significant for tillers but only significant for main culms (Table 42).

The effect of treatments in the varieties was similar in T_1, T_2, T_3 and T_4. Among the treatments, T_1 and T_n were significant. Among the varieties, BR4 degenerated the lowest percentage of spikelets and was significantly different from BR3 and Latisail. The extent of spikelet degeneration were 12.13, 8.42 and 11.66% for BR3, BR4 and Latisail varieties respectively.

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The percentage spikelet degeneration of the tillers of the treatments T, T_1, T_2, T_3 and T_4 were insignificant for BR3 but T_n differed significantly from other treatments. The effects of T, T_2, T_4 were similar in BR4 and T, T_1, T_2 and T_3 were similar in Latisail (Table 40). The comparison between the treatments means at 1% level of significance indicated that T, T_2, T_3 and T_4 had similar effects for spikelet degeneration and significantly different from T_1 and T_n but T_1 and T_2 were insignificant. Among the varieties, percentage of spikelet degeneration was lowest in the variety BR4 but BR4 was significantly different from BR3 and Latisail at 1% level of significance. Variation between BR3 and BR4 for spikelet degeneration was insignificant. The mean of spikelet degeneration were 12.30, 9.28 and 13.88% for BR3, BR4 and Latisail respectively.

F1.5. Effect on plant height. Variances for plant height were significant at 1% level for the varieties and treatments. The interaction of variety x treatment was also significant at 1% level (Table 43). In BR3, the effect of T, T_1, T_2 and T_4 were insignificant but it was significantly different from T_n. The treatment T_3 was significantly different from T_2. The effects of treatment in BR4 were insignificant between T_1 and T_3 and T_2 and T_4. The treatments T and T_n were significantly different from other treatments.

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In Latisail T and T_1 had similar effect and significantly different from T_3, T_4 and T_n.

The effect of T_1, T_2, T_3 and T_4 on plant height was insignificant, but T and T_n were significantly different from other treatments. The mean plant heights in BR3, BR4 and Latisail were 74.00, 101.94 and 91.10 cm respectively which were significantly different from one another.

F1.6. Effect on the panicle length. The effect of tiller number on the panicle length of the main culm is shown in Table 41. The treatment T had the largest panicle and smallest panicle was found in the T_n. Variation of panicle length in the treatments was highly significant for varieties and treatments. The interaction of variety x treatment was insignificant (Table 43). Although treatments within varieties showed significant effect of T but T_3, T_4 and T_n were insignificant for all varieties. The treatment T_2 in BR4 and T_1 and T_2 in Latisail were also insignificant. The mean panicle length of the treatments for the respective varieties were 25.27, 26.44 and 25.30 cm for BR3, BR4 and Latisail respectively.

F1.7. Effect on spikelet sterility. The percentage of spikelet sterility for the varieties is given in Table 41. Variances for the percentage of spikelet sterility were highly significant for the varieties, treatments and interaction (Table 43). The percentage of spikelet sterility was signi-

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ficantly higher in T and T_n treatments for all the varieties. The interaction of variety x treatment showed insignificant variation for sterility percentages in T_n of BR3 with T_1, T_2, T_3 and T_4 of BR4. The treatment T_n of BR4 was insignificant for T_1, T_2, T_3 and T_4 of Latisail.

Treatments T_1, T_2, T_3 and T_4 were insignificant but significantly different from T and T_n. The treatment T was also significantly different from T_n. The spikelet sterility percentage in the T was significantly higher among the other treatments. The varieties were significantly different. The mean percentages of spikelet sterility were 15.04, 23.22 and 25.50 in BR3, BR4 and Latisail respectively.

F1.8. Effect on the grains per panicle. For all the varieties grains per panicle of the treatments T_1, T_2, T_3, T_4 and T_n decreased with the increase in tiller number per plant (Table 41).

Variations in grain number per panicle in the treatments were highly significant for varieties, treatments, and interaction of variety x treatment (Table 43). The interaction effect among the varieties was insignificant for T_1, T_2, and T_3 in BR3, T_3 and T_4 in BR4 and T_1, T_2 and T_3 in Latisail (Table 41).

The treatments T_4 and T_n were significantly different from T_1 and T_2 but T, T_3 and T_4 were insignificant. The

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mean grain number per panicle was 172.89 in BR3, 192.87 in BR4 and 162.16 in Latisail. Among the varieties BR4 was significantly different from BR3. The number of grains per panicle was significantly higher in BR4.

F1.9. Effect on grain yield. The grain yield increased with the corresponding increase in tiller number per plant (Table 41). Variation for the grain yield per plant were highly significant for the variety, treatments and interaction of variety x treatment. The interaction effect of T and T_1 was similar for the varieties (Table 41) but the treatments within the varieties were significantly different. The yield per panicle decreased in the treatment T but increased in T_1 and T_2. The yield per panicle decreased with the increase in panicle numbers per plant. The grain yield per panicle decreased significantly in T_n, but yield per plant increased in T_n.

Experiment F2. Effect of tiller pruning in the Boro season 1978-1979

Forty-day-old seedlings were transplanted on 10 December. The desired number of tillers per plant were kept by pruning other tillers. The result of the experiment is given under the following headings.

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F2.1. Effect on the panicle development. Among the varieties, BR3, initiated panicle earliest in all the treatments. Irrespective of the varieties, panicles initiated earliest in T_n treatment. However, PI was delayed in T_0, T_1, T_2, T_3 and T_4 (Table 44). All of these variations were statistically insignificant.

F2.2. Effect on the number of panicle branches. The number of primary branches per panicle of main culm decreased with the increase in tiller number per plant (Table 45). Among the treatments, T developed the highest and T_n developed the lowest number of primary branches. The variation of primary branches per panicle was highly significant for varieties and treatments. The interaction of variety x treatment was found insignificant (Table 47). Among the varieties, the treatment T_n significantly differed from the rest. Variation between T, T_1, T_2 and T_3 were insignificant for BR3, but T_4 significantly differed from T. However, T_1, T_2 and T_3 of BR4 had similar effect and different from the rest. The treatments T_1, T_2 and T_3 in Latisail were insignificant but T_1 significantly differed from T_4. The varieties were significantly different at 1% level. The treatment means of primary branches per panicle of the main culm were 11.37, 12.33 and 10.33 for BR3, BR4 and Latisail respectively.

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The effect of treatments indicated variations on the number of secondary branches developed per panicle of the main culm or tillers per plant (Table 45). Variances for the numbers of secondary branches were highly significant for varieties, treatments, and interaction of variety x treatment (Table 47). The effects of T, T_1, and T_2 and T_3 and T_4 were statistically similar in BR3 but each differed significantly from T_3 and T_n. Furthermore, T_1, T_2 and T_3 of BR4 had similar effect but differed significantly from the rest. The effect of the treatments in Latisail was similar among the T, T_1 and T_3 and T_2 and T_n but T_4 significantly different from T, T_1, T_2 and T_n (Table 45).

Secondary branches per panicle of the main culm decreased with the increase in tiller number except for the T treatment. The number of secondary branches decreased in T and again increased from T_1 treatment. Among the varieties BR4 produced the highest number of secondary branches per panicle and differed significantly from BR3 and Latisail.

F2.3. Effect on the spikelet number per panicle. The number of spikelets per panicle of the main culm and tillers in the various treatments are given in Table 45. The number of spikelets differed in the treatments and in the varieties. Irrespective of varieties, treatment T_n developed the lowest

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number of spikelets per panicle of the main culm and its tillers. The number also decreased in T but increased in T_1. The variation of spikelet number in the different treatment was highly significant for varieties and treatments with interaction effect (Table 47).

In BR3 the effect of the treatments T, T_1, T_2 and T_3 and T, T_3 and T_4 was similar, but T_n differed significantly from other treatments. The treatment T_1 was also different from T_4. The treatment effect in BR4 showed similar effects based on the level of insignificance in three groups (T_1 and T_2); (T_2, T_3 and T_4) and T, T_3 and T_4). The treatment T_n was significantly different from all other treatments. In Latisail T_1, T_2, T_3 and T_4 and T, T_4 and T_n were insignificantly different from each other but T and T_n differed significantly from T_1, T_2 and T_3.

In BR3 spikelets per panicle of the tillers showed similar effect for T, T_1, T_2 and T_3. However, T_4 and T_n were significantly different from all other treatments. In BR4 the effect for T, T_1 and T_2 and T_2, T_3 and T_4 was similar and differed significantly from T_n. In Latisail the treatment groups T, T_1, T_2 and T_3 and T_2, T_3 and T_4 were similar and differed significantly from T_n. Among the varieties, the BR4 produced the highest number of spikelets per panicle and Latisail produced the lowest number. The number of spikelets

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per panicle of tillers were 178.85, 322.98 and 136.47 for BR3, BR4 and Latisail respectively.

F2.4. Effect on spikelet degeneration. The effect of treatments on the percentage of spikelet degeneration of the varieties is given in Table 45. Percentages of degenerated spikelets showed variation between the treatments and in the varieties. The variation of spikelet degeneration percentages was found between the panicles of main culm and tillers Such variation was highly significant for varieties, treatments and interaction of variety x treatment (Table 47).

The treatment differences for the varieties indicated significant effect for T_n in BR4 and Latisail. In BR3, T, T_3, T_4 and T_n were similar and T_2 differed significantly from T, T_4 and T_n. However, the effect of T_1, T_2, T_3 and T_4 was similar in Latisail, but the T and T_n were significant. Furthermore, the treatment groups T, T_3 and T_4 and T_1 and T_2 were significant and different from T_n. The mean percentages of degenerated spikelets per panicle of main culm were 18.86, 13.41 and 16.22 in BR3, BR4 and Latisail respectively. The mean spikelet degeneration percentages in the varieties differed significantly among the varieties.

In BR3 the effect of T_3, T_4 and T_n was similar and differed significantly from T_3, T_4 and T_3. The effect of T_1, T_2, T_3 and T_4 was similar in BR4 but differed significantly

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from T and T_n. In Latisail T_2, T_3 and T_4 were similar and significant from T and T_1. The treatment T_n differed significantly from all other treatments.

The mean percentages of the degenerated spikelets were 20.11, 13.96 and 17.92 in BR3, BR4 and Latisail respectively. The percentage of spikelet degeneration in tillers was significant for the varieties.

F2.5. Effect on the plant height. The effect of treatments on plant height is shown in Tanle 46. Among the treatments, T_n had the minimum plant height for all the varieties. Variances for plant height were highly significant for varieties and treatments along with interaction of variety x treatment (Table 48). In BR3 there was similar effect for T_1, T_2, T_3 and T_4 but T differed significantly from T_1 and T_n from all other treatments. In BR4 similar effects could be observed in T_1, T_2, T_3 and T_4 but T_n differed significantly from all other treatments. In Latisail T, T_1, T_3 and T_4 and T_n were significantly different from T_1, T_3 and T_4. However, T_1 differed significantly from all other treatments. The mean plant heights were, 66.38, 72.75 and 82.85 cm respectively for BR3, BR4 and Latisail.

F2.6. Effect on the panicle length. The treatment effect on the panicle length is shown in Table 46. The panicle length in T_n was comparatively shorter in all the

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three varieties. The variation of panicle length was significant at 1% level for varieties and treatments. The interaction of variety x treatment was only significant at 5% level. The treatment effect on the panicle length was found insignificant for BR3 but all significantly differed in Latisail from those of T and T_1. The treatment effect in BR4 was insignificant for T, T_1, T_2, T_3 and T_n but T_4 was significantly different from T, T_1 and T_2. In Latisail, T_2, T_3, T_4 and T_n were similar but significantly different from T and T_1. The mean panicle lengths were 25.41, 27.60 and 26.22 cm for BR3, BR4 and Latisail respectively. Among the varieties BR4 produced the largest and BR3 the smallest panicle in the main culm.

F2.7. Effect on spikelet sterility. The percentages of spikelet sterility were comparatively higher in T and T_n for all the varieties (Table 46). Variances for sterility percentages were highly significant for varieties, treatments and interaction (Table 48). The effect of T_1, T_2, T_3 and T_4 in BR3 was similar and differed significantly from T and T_n (Table 46). In BR4 similar effect was found in T, T_1, T_2, and T_4 and T_3 differed significantly from T and T_n. However, the T_n was significantly different from all other treatments.

The mean . kelet sterility for BR3, BR4 and Latisail were 16.18, 23.64 and 25.75% respectively. The mean spikelet sterility percentage in BR3 was significantly lower than BR4

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and Latisail.

F2.8. Effect on the grains per panicle. The number of filled grains per panicle decreased with the increase in tiller number per plant (Table 46), except the T treatment which produced much lower number of filled grains than T_1 and T_2. Variation of filled grains per panicle was highly significant for varieties and treatments. The interaction of variety x treatment was also highly significant.

The effect of the treatments T, T_1, T_2 and T_3 was similar in BR3, but T_4 differed significantly from T, T_1, T_2 and T_n. Furthermore, T_n was different and significant from all other treatments. In BR4, effects were similar for T_1, T_2, T_3 and T_4 but these differed significantly from T_1 and T_n. The treatment T_n was significantly different from all other treatments. The treatment effect in Latisail was similar for T, T_1 and T_2 and T_3 and T_4. The treatment T_n was significantly different from T_3, and T_4 was significantly different from T_1, and T_n was significantly different from T_3, and T_4 was significantly different from T_1 and T_n.

The treatment T_n was significantly different in all the varieties and produced the lowest number of grains per panicle. The mean of all the treatments per varieties indicated significant varietal difference for the development of the number of filled grains per panicle. The highest number (212.80) of grains per panicle was found in BR4 and the lowest number

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(85.54) in Latisail.

F2.9. Effect on grain yield. The grain yield per plant increased with the increase in tiller number (Table 46). The grain yield per plant was found highest in T_n and the lowest in the T. On the contrary the grain yield per panicle decreased with the increase in panicle number per plant except the treatment T. The grain yield for T was much lower than T_1 treatment. The variation of grain yield per plant was found highly significant for varieties and treatments with interaction effect (Table 48).

In BR3 the effect of T, T_1, T_2 and T_n for grain yield per plant was different and significant. The yield difference between T_3 and T_4 was insignificant. In BR4 all the treatments were significantly different. In Latisail, T was significantly different from T_2, T_3, T_4 and T_n. The difference between T_3 and T_4 was insignificant but these were significantly different from all other treatments. The treatment T_n was significantly different from all other treatments. The mean grain yield per plant of BR3, BR4 and Latisail were 13.65, 17.49 and 8.71 gms respectively. The grain yield per plant of each variety was significantly different. Among the varieties BR4 yielded significantly higher than BR3 and Latisail.

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EXPERIMENT G : Effect of Leaf Pruning on the Development of Panicle, Degeneration of Spikelets and Other Quantitative Characters of BR3, BR4 and Latisail

The experiment studied the effect of leaf loss by pruning either partially or fully on the development of panicle in general and spikelet degeneration in particular. The investigation was conducted both in Boro and transplant Aman seasons (1978-79) with three rice varieties (BR3, BR4 and Latisail).

The experimental methods has been described in chapter II. The results of the two experiments (Boro and transplant Aman)are given under separate heading.

Experiment G1. Effect of leaf pruning in the Boro season 1978-1979

Seeds were sown on 01 November 1978. Forty-day-old seedlings were transplanted on 10 December. The results of the experiment are given in the following paragraphs.

G1.1. Effect on panicle development. A leaf was pruned when it emerged out of the leaf sheath. This was indicated by the appearance of leaf collar (Junctura), paired auricles and ligule. The duration for the emergence of the individual leaf in the control (no pruning) treatment is shown in Table 50. The mean length of the leaf blade after emergence and leaf sheath length is given in Table 50. The flag leaf (n th)

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was comparatively shorter than the leaf just below the flag leaf (n-1 th). The length of the n-2 leaf blade was comparatively longer than other leaves of the main culm. The full development and emergence of n-5 and n-4 leaf took place much earlier from the dates of PI in all the varieties (Table 50). The panicle initiation in the seedbed took place 114, 120 and 118 days in BR3, BR4 and Latisail varieties but delayed in the leaf pruning treatments. The morphological change at the panicle initiation stage was indicated by the elongation of n-1 th internode i.e., the internode between n-1 and n-2 leaves. Among the treatments PI took place just before the emergence of n-3 th leaf. The development of spikelets occurred simultaneously with the enlargement of n-1th and n th leaf and at that time the length of the panicle varied from 4-6 cm. The internode development was associated with the differentiation of panicle branches and spikelets. The emergence of n-1 th leaf and rapid development of n th leaf occurred at the same time. The n th leaf attained about 75% of its full length at the emergence of n-1 leaf. The panicle lengths in the varieties varied from 15-25.5 cm in BR3, 18-26.5 cm in BR4, and 16-22 cm in Latisail. At the time of emergence of n-1 leaf, the panicle attained nearly full size. Table 50 provides data on the development of internodal lengths at the ripening stage. Internodes n and n-1 elongated to a maximum along with the increase of panicle length. The length of the internodes at the panicle development stage

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increased significantly except the n-5 th and other basal internodes (Table 50).

The effect of the leaf pruning on the panicle developmental stages were recorded with reference to the heading time. Due to 100% pruning of n-4 th leaf, heading time was delayed by about 6-9 days from the control. The heading time in the control was 108, 118 and 113 days for BR3, BR4 and Latisail respectively (Table 49). However, the effect of 50% leaf pruning in the treatments indicated slight variation from the control treatment. The heading time also delayed numerically due to 100% pruning of the n th leaf. Variation of heading time was insignificant for the respective variety (Table 49). The period for anthesis varied from 3-6 days.

G1.2. Effect on the spikelets number. The effect of leaf pruning on the initiation of spikelets per panicle of the main culm is shown in Table 51. Variation was found among the varieties and treatments. The variation of spikelet number was highly significant for the varieties and treatments with interaction effect (Table 53). The number of spikelets per panicle were highest in BR4 and Lowest in Latisail. The effect of 100% pruning of n-4 th leaf differed significantly at 1% level from all other pruning treatments. The effect of 100% pruning of n-1 and n-4 leaves were statistically similar. However, 100% pruning of n-3 and n-4 leaves produced the

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lowest number of spikelets from other treatments. In BR3 100% pruning of n, n-1, n-2 and 50% pruning of n, n-1, n-2 leaves and control were statistically similar. The pruning effect of 100% n-1 and n-4 leaves of BR4 was different and significant. In Latisail the effect of 100% pruning of n, n-1, n-3 and 50% pruning of n, n-1 and n-2 leaves was similar. The pruning of 100% n-4 th leaf was significantly different from 100% pruning of n, n-1, n-3 and 50% pruning of n, n-1, n-2 and n-4. The number of spikelets per panicle was affected by 100% pruning of n-4 th leaf but less affected by 50% pruning. The effect of 100% pruning of n-4 leaf produced the lowest number of spikelets per panicle (Table 51). The interaction of variety x treatment was highly significant (Table 53).

G1.3. Effect on the spikelet degeneration. The percentage of degenerated spikelets is shown in Table 51. The percentage of spikelet degeneration was significant at 1% level for the varieties and treatments. The interaction of variety x treatment was also highly significant (Table 53).

Mean percentages of spikelet degeneration were statistically similar in BR4 and Latisail but significantly different from BR3 at 1% level. The variety BR3 had the highest percentage of spikelet degeneration (Plate 7, figures 9-10). The treatment of 100% pruning of n-3 th leaf differed significantly from all other treatments. The effect of 100%

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pruning of n-3 th leaf was significantly different from all other treatments of the three varieties. However, 100% pruning of n-2 th leaf of BR4 was also significantly different from all other treatments. The effect of 100% pruning of n-3 th leaf showed a significantly higher percentage of spikelet degeneration for the three varieties.

G1.4. Effect on spikelet sterility. Percentages of spikelet sterility is shown in Table 52. The interaction of variety x treatment was significant at 5% level. The effect of treatments showed significant differences between 100% leaf pruning of n and n-1 but these treatments were also differed significantly from other treatments. Irrespective of the variety, spikelet sterility percentage was found highest in 100% pruning of n th leaf.

G1.5. Effect on grain weight. Table 52 provides the effect of leaf pruning on grain weight (100-grain). Variation of grain weight in the different treatments was highly significant for the varieties and pruning treatments (Table 52). The interaction of variety x treatment was also highly significant (Table 53).

The varieties were significantly different for the grain weight. Heavier grains were found in BR3 and lighter in BR4. The effects of the treatments for pruning 100% of n-3, n-4 and 50% of n-3 and n-4 and control were statis-

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tically similar. The treatments of 100% and 50% leaf pruning of n-2 th leaf were similar but differed significantly from control and 100% pruning of n-3 th leaf. Irrespective of the variety the effect of 100% or 50% pruning of n or n-1 leaf was different and significant. The result indicated that the effect of 100% pruning of a leaf blade was most effective than 50% pruning.

Experiment G2. Effect of leaf pruning in the transplant Aman season 1979

Seeds were sown on 15 July 1979 in the seedbed. Thirty-day-old seedlings were transplanted in pots on 15 August. The experiment of Boro was repeated in transplant Aman season to evaluate the effect of seasonal variation on the development of panicle, spikelet degeneration and other characters related with panicle development. The results of the experiment are given in the following paragraphs.

G2.1. Effect on panicle development. The period for the development of the individual leaf and leaf-sheath is shown in Table 55. The PI of BR3, BR4 and Latisail was related with the emergence of n-3 th leaf. The elongation of n-1 internode occurred at the time of PI. In BR3, BR4 and Latisail PI took 40, 52 and 51 days respectively. The emergence of n-2 leaf took place at the end of spikelet differentiating stage and elongation of n-4 and n-3

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internodes. The emergence of n th (flag leaf) leaf took place 62, 76 and 73 days in BR3, BR4 and Latisail. Most of the anther cells completed meiotic division before the emergence of n th leaf. The pollen grains were found in tetrad condition just before emergence of n th leaf when the panicle reached its maximum length.

The effect of leaf blade pruning was relfected on the development of panicle in the varieties. Data are presented in Table 54. The heading time was comparatively earlier in the control treatment and was delayed in 100% pruning of n-4 th leaf. The pruning of other leaves also delayed the heading time. The developmental period for anthesis and ripening stages also showed numerical variation but due to 100% pruning of n and n-1 leaves emergence of panicles were found incomplete.

G2.2. Effect on the number of spikelets per panicle. The number of spikelets per panicle showed variation among the treatments (Table 57). Each of the varieties had statistically different number of spikelets per panicle. The variety BR4 produced the highest number and Latisail produced the lowest number of spikelets per panicle. By pruning 100% of n-4 th leaf, the spikelet number became significantly lowest among the treatments in the varieties. However, in BR4 100% and 50% pruning of n-4 th leaf had the similar

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effect. Statistically similar results were obtained from 100% pruning of n-1, n-2, n-3 and 50% pruning of n-1 and n-2 leaves but 100% pruning of n-2 th leaf was similar to 50% pruning of n-4 which differed significantly from other treatments. The number of spikelets developed per panicle was highest in the control.

G2.3. Effect on spikelet degeneration. The effect of leaf pruning treatments on the percentage of spikelet degeneration is shown in Table 57. Varietal differences were significant at 1% level (Table 58). The variety BR4 showed the lowest percentage of spikelet degeneration. Degeneration of spikelets due to 100% pruning of n-2 and n-3 leaves was different and significant from all other treatments. Irrespective of the varieties 100% pruning of n-3 th leaf degenerated the highest percentage of spikelets while control had the lowest percentage of spikelet degeneration. The interaction of variety x treatment was highly significant (Table 58).

G2.4. Efffect on plant height. The effect of pruning treatments on the development of main culm height is given in Table 57. Varieties were significantly different on the basis of main culm heights. Irrespective of the varieties 100% pruning of n-1 th leaf was significantly different from other treatments. Due to 100% pruning of n-1 th leaf, there

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was a reduction of the main culm height. The interaction of variety x treatment was highly significant (Table 58).

G2.5. Effect on spikelet sterility. The effect of leaf pruning showed variation on spikelet sterility (Table 57) among the treatments. The ANOVA is given in Table 58. Varieties also showed insignificant variation at 1% level. Irrespective of the variety, 100% pruning of n and n-1 th leaves developed significantly the highest percentage of spikelet sterility. The effect of 50% pruning of n, n-1, n-2, n-3 and 100% pruning of n-2 and n-3 leaves were statistically similar. However, in BR3 the effect of 50% pruning of n-4 th leaf on the spikelet sterility was similar with the control. In Latisail 50 and 100% pruning of n-4 th leaves showed statistically similar spikelet sterility with the control.

G2.6. Effect on grain weight. Variation among the treatments and varieties was highly significant along with interaction effect of variety x treatment (Table 58).

The grain weight differed significantly among the varieties at 1% level. The grain weight (100-grain) was found highest in BR3 and lowest in BR4. Irrespective of the variety, 100% pruning of n th and n-1 th leaf significantly reduced the grain weight among the treatments. The effect of 50% pruning of n-3, n-4 leaves and 100% pruning

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of n-3, n-4 leaves and control had statistically similar grain weight. However, 50% pruning of n th leaf and 100% pruning of n-2 th leaf was statistically similar but significantly different from all other treatments so far the grain weight was concerned. The interaction of variety x treatment was highly significant (Tables 57 and 58).

EXPERIMENT H : Effect of Variable Photoperiods on Panicle Development, Spikelet Degeneration and Other Yield Components

The object of the experiment was to find the effect of variable photoperiods on the panicle development and degeneration of spikelets of BR3, BR4 and Latisail. Seeds were sown on 01 April, 1980 in pots. Three healthy seedlings were selected for each pot and other seedlings were discarded. Twenty day old seedlings of each variety were exposed to four different photoperiods : full day length (12.70 - 13.70), 10, 8 and 6 hours for a period upto ripening of grains. The results of the experiment are given under following heads.

H.1. Panicle development

The effect of variable photoperiods on the development of panicle is given in the Table 59. Irrespective of the variety and photoperiod treatment, PI of the main culm occurred much earlier and almost at the same date in 8 and

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10 hours photoperiod treatments. However, Latisail did not initiate panicle in the treatment of full day length photoperiod. In BR3 and BR4 PI was delayed with full day length exposures. The photoperiod treatments of 6-hour also delayed the PI from 8 and 10 hours day length exposure. The chi-square-test for the age of PI among the photoperiods treatments was insignificant for BR3 and Latisail but significant for BR4. The mean ages for PI were 57.75, 70.25 and 48.67 days respectively for BR3, BR4 and Latisail. Irrespective of photoperiod treatments, the period PI to heading stages varied from 27-31 days. Heading date between the main culm and tillers per plant differed by 5-10 days. However, differences of heading dates between main culm and tillers per plant of BR4 were found 10-20 days in full day length treatment. Moreover, in BR4 only 3-4 tillers per plant developed panicles and the rest of the tillers did not initiate panicle.

H.2. Branches per panicle

The number of panicle primary branches developed in the main culm and first two tillers are given in the Table 59. The primary branches per panicle of BR3 and BR4 were comparatively higher in full-day length treatment but the lowest number was found with the 6-hour photoperiod exposure. In

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BR3 and BR4 the numbers of primary branches per panicle were found highly significant for varieties and photoperiod treatments. The interaction of variety x photoperiod treatments was significant only for the panicle of main culm but insignificant for the panicles of first two tillers (Table 61). In BR3 photoperiods of full day length, 10 and 6 hours were different and significant. However, in BR4, the photoperiod treatments of full day length, 10 and 8 hours were all insignificant but differed significantly from 6-hour photoperiod. The comparison between treatment mean level, the photoperiod treatments of full day length and 10 hours were insignificant but significantly different from 6 and 8 hours treatment. The variety means were significantly different.

The number of primary branches per panicle of the main culm and first two tillers increased in Latisail with the increase of photoperiod treatments from 6-10 hours. Variation in the number of primary branches of the panicles of main culm and first two tillers were found significantly different from 6-10 hours photoperiod treatments. The interaction of variety x treatment was insignificant (Table 61). The effect of various photoperiod on the variety BR4 was different and significant from BR3 and Latisail.

The number of secondary branches per panicle of main culm and first two tillers per plant decreased along with

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the decrease in day length exposure (Table 59). In BR3 and BR4, the highest and the lowest number of secondary branches developed with the full day length and 6 hours photoperiods respectively. Variation in the number of secondary branches in BR3 and BR4 was found highly significant for varieties and treatments. The interaction of variety x treatment was also highly significant (Table 61) for the panicle branches of main culm and first two tillers. The number of secondary branches developed per panicle of the main culm and first two tillers in Latisail increased with the increase in day length exposure from 6-10 hours. Variation of the number of secondary panicle branches among the photoperiods of 6, 8 and 10 hours for all the varieties differed significantly.

H.3. Effect on spikelet number

The effect of photoperiod treatments on the development of spikelet number per panicle of the main culm and first two tillers are given in the Table 60. Irrespective of the variety and photoperiod treatment, the number of spikelets per panicle of the main culm was higher than the first two tillers (Table 60). Moreover, the number of spikelets per panicle increased with the increase of photoperiod hours (Plate 6, figures 1-12). Variation of the number of spikelets per panicle was highly significant for the varieties and

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photoperiod treatments. The interaction of variety x photoperiod treatment was highly significant (Table 61). The photoperiod of 6-hour differed significantly from 8 and 10 hours which were insignificant between themselves. The spikelet number per panicle in BR4 was significantly different from BR3 and Latisail but difference between BR3 and Latisail was insignificant.

The number of spikelet formation in the photoperiod treatments (6, 8 and full day length) were significantly different from each other. Among the varieties, BR4 produced the highest number of spikelets per panicle for all the treatments (Table 60).

H.4. Effect on spikelet degeneration

Percentages of degenerated spikelets per panicle of the main culm and first two tillers per plant are given in the Table 60. Among the four photoperiod treatments, the percentage of spikelet degeneration of BR3 and BR4 had the lowest figure with full day length and highest with 6-hour photoperiod treatment. The difference of spikelet degeneration percentages between the main culm and first two tillers per plant was not significantly different for the respective photoperiod treatment. The spikelet degeneration percentages of BR3 and BR4 with the four photoperiod treatments were found highly significant along with the interaction of variety x treatment. The extent of spikelet degeneration in the

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varieties was insignificant for the main culm only but highly significant for first two tillers (Table 61).

The number of degenerated spikelets increased in BR3 with the decrease in day length exposure from full day length to 6 hours photoperiods (Plate 6, figures 1-5). In BR4, the effect of 6-hour photoperiod was highest among the other photoperiod and degenerated maximum panicle branches and spikelets (Plate 6, figures 6-10). In Latisail, 6-hour photoperiod enhanced spikelet degeneration (Plate 6, figure 11). The variation in the three treatments (6, 8 and 10 hours) was found highly significant for varieties and photoperiod treatments. The interaction of variety x treatment was highly significant for main culm and first two tillers per plant (Table 61). The percentage of degenerated spikelets of BR3 and Latisail was significantly different in each treatment (Table 60). Among the varieties, Latisail produced the lowest percentage of degenerated spikelets in all the photoperiod treatments.

H.5. Effect on panicle length

The panicle length increased with the increase in photoperiods from 6-hour to full day length (Table 60). The photoperiod treatment of full day length produced the largest panicles in BR3 and BR4 among the other photoperiod treatments. Similarly, photoperiod of 6-hour produced the

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smallest panicle among the other treatments. Variation of panicle lengths between the photoperiod treatments was highly significant for varieties, treatments and interaction of variety x treatment (Table 62).

H.6. Effect on plant height

The effect of the shortest photoperiod (6-hour) produced the shortest plant in all the varieties. The photoperiod of 10-hour produced the tallest plants among the other photoperiod treatments. Latisail in full day length treatment was comparatively taller but did not produce panicle. Variation of plant heights between the three photoperiod treatments (6, 8 and 10 hours) for all the varieties was highly significant for the treatment but insignificant for varieties. Variances of all photoperiod treatments of BR3 and BR4, were highly significant for varieties and photoperiod treatments. The interaction of variety x photoperiod treatments was also highly significant (Table 62).

H.7. Effect on tiller number

The number of tillers per plant increased with the increase in day length exposure (6-hour to full day length). Irrespective of the varieties, photoperiods of full day length produced the highest number of tillers per plant (Table 60). The lowest number of tillers per plant were found with the shortest photoperiod treatment of 6-hour.

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The analysis of variances for the tiller number were highly significant for photoperiod treatments but insignificant for varieties. The interaction of variety x photoperiod treatment was also insignificant (Table 62).

H.8. Effect on panicle number

The number of panicles per plant was lowest in the photoperiod of 6-hour in BR3 and Latisail. In BR4, the lowest number of panicles was produced in the treatment of full day length which was almost similar with 6-hour photoperiod treatment. The highest number of panicles per plant was produced in BR4 and Latisail by the photoperiod treatments of 10-hour. The highest number of panicles were produced in BR3 with full day length treatment. The variation of panicle number in the varieties for three treatments (6, 8 and 10 hours) was found highly significant for treatments but insignificant for varieties. The interaction of variety x treatment was also insignificant. The variation between four treatments of BR3 and BR4 was highly significant for varieties and treatments. The interaction of variety x treatment was highly significant (Table 62).

H.9. Effect on dry matter content

The dry weight of plants increased in all varieties with the increase of photoperiod from 6-hour to full day length. The plants developed in full day length were comparatively

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heavier among the other treatments. Plants developed in 6-hour photoperiod produced much lower dry weight per plant from other treatments. Variation of dry matter per plant was found highly significant (Table 62). In respect of dry matter content, BR3 and BR4 were insignificant but significantly different from Latisail.

EXPERIMENT I : Effect of Growing Rice Varieties Continuously under Seedbed Condition on the Panicle Development and Spikelet Degeneration

These experiments were undertaken to study the effect of keeping the seedlings in seedbed for the entire life cycle on the panicle development and degeneration of spikelets.

Seeds were sown on 15 July and 01 November 1978. Seedlings were kept in the seedbed for this study. Plant samples were randomly collected at an interval of three to five days for this study. The results of the two experiments (Aman and Boro) are given in the following paragraphs.

I.1. Vegetative phase of development

The rate of growth of seedlings were significantly faster in Aman season compared to Boro season (Table 69). The rate of growth of the seedling in Boro season from germination to 50th day of seedling age were insignificant for the varieties (BR3, BR4 and Latisail). However, in Aman season the growth rate of seedlings were relatively faster from 30-40 days

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before panicle initiation (Table 70). In general, seedlings which were sown on 1 November showed slow growth rate from the seedlings which were sown on 15 July. The growth rate in Boro season resulted into a longer vegetative phase for the varieties, BR3, BR4 and Latisail.

Tillering observed only in the border plants and the age at such tillering was significantly differeng in the two seasons. After seeding tillering started at about 25-30 days in Aman and 55-60 days in Boro seasons. Seedling in the central area produced no tillers. The sequence of changes in the vegetative shoot apex were similar in two seasons but differed in duration in the varieties. Tiller development was suppressed on the axils of the leaves and rudimentary tiller buds were observed in the axils of the 6th leaf. The total number of leaves developed in the varieties varied from 12-14, but were similar in two seasons.

1.2. Reproductive phase

The successive stages of panicle development were designated as the stages viz; premeiotic, meiotic, heading, anthesis, caryopsis development and ripening of grains. The premeiotic period included the successive stages from neck-node differentiating stage(Panicle initiation), branch development stage, spikelet development stage and formation of pollen mother cell in the spikelets. The sequence of development and the number of days passed from one stage to the other stage

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were taken from the 80 percent of the test materials.

The measurable changes in the growth apices from neck node differentiation to the stages after heading are presented in Table 64 and 65. Data in Table 64 represents the period for each developmental stage and relation with the development of panicle length in the transplant Aman season. The data in Table 65 shows the subsequent changes of the young panicle and relation with the plant age in Boro season. Data in Table 66 give a comparative effect of seasons on the age for panicle initiation and successive stages of panicle development. From the result it was apparent that the reproductive stage of development was almost similar but the time taken for the initiation of the stages were different among the varieties and seasons. In the pre-meiotic stage, the neck node initiated after 65, 80 and 88 days respectively for BR3, BR4 and Latisail when sown on 15 July (Aman season). The same stage was initiated in Boro season from 110 days in BR3, 115 days in BR4 and 110 days in Latisail when sown on 1 November (Table 66). In the transplant Aman season periods from neck node differentiation stage to heading stage were 30, 28 and 27 days in BR3, BR4 and Latisail respectively. However, in Boro season the periods between the same stage were 30, 30 and 25 days respectively in BR3, BR4 and Latisail. The period from meiotic stage to heading stage differed 10-13 days between the varieties and in two seasons (Table 66).

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The meiotic stage was designated for the period when most of the anthers entered into meiotic stages (Table 64). Table 67 indicates the relationship between the relative development of panicle length, spikelet dimensions and length of the anther lobes. Data in Table 68 represent the variation of spikelet sizes in the different positions of panicle branches. Variation of spikelet lengths within the panicle branches (primary and secondary) was significant 15-20 days from PI. The spikelet length of the primary branches gradually decreased from topmost branch to basal branches (Plate 8, figures 7-12). The variation between the spikelets of primary and secondary branches were significant only before heading and at 20 days after PI. Though, the differences between the spikelets borne on primary and secondary branches were significant at the pollen mother cell forming stage (Table 68), the differences were found insignificant at the time before panicle emergence.

There was a slight variation of seasonal effect on the development of spikelet dimensions and anther lobe lengths. The panicle attained nearly 50 percent of its full length when the topmost spikelets were nearly at the end of meiotic division. The increase of panicle and spikelet lengths were comparatively higher 12-15 days after panicle initiation. Just before heading most of the spikelets attained full

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length and the panicle reached its maximum length. The periods for anthesis and full development of caryopsis are shown in Tables 64, 65 and 66. The variation between the seasons and varieties was insignificant. In the transplant Aman season the life cycle of the varieties BR3, BR4 and Latisail were 130, 145 and 150 days respectively. However, in Boro season these were 180, 185 and 175 days respectively for the varieties BR3, BR4 and Latisail.

I. 3. Number of panicle branches

The data of Table 72 show the number of primary and secondary branches developed per panicle in two seasons. The number of panicle branches differed among the varieties and in two seasons. In Boro season the number of primary branches decreased but the number of secondary branches increased from transplant Aman season. Among the varieties BR4 produced significantly the highest number of secondary branches per panicle in both the seasons(Plate 8, figures 7-9).

I.4. Panicle branch degeneration

Percentages of panicle branch degeneration were significantly lowest for the primary branches and highest for the secondary branches. Percentages of primary branch degeneration differed among the varieties. Variations between the two seasons were insignificant only for BR4 but significantly different in BR3 and Latisail. The percentage of primary branch degeneration in BR3 was lowest in the transplant Aman

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season but highest for Latisail (Table 72). However, percentages of secondary branch degeneration differed slightly among the varieties. Variations between the two seasons were not significant.

I.5. Spikelet number

The number of spikelets developed per panicle differed among the varieties (Table 72). Irrespective of the varieties, the number of spikelets per panicle were significantly lowest in Aman season. The number of spikelets were highest in BR4 and lowest in Latisail for both the seasons.

I.6. Spikelet degeneration

In the various developmental stages after panicle initiations, some of the spikelets ceased to develop and mostly disappeared at the time of panicle emergence. After panicle emergence some of the degenerated spikelets could be found in few as rudimentary whitish spikelets or represented by scar on the panicle branches (Plate 8, figures 9-12). Just before heading most of the spikelets in the primary and secondary branches of the panicle attained nearly full length (7.5-8 mm). Tables 67 and 68 showed the variation of spikelet sizes in the respective panicle developmental stages. Some of the degenerated spikelets had a length of 0.5-3 mm and were found in any position of the panicle along with other developing spikelets. In the pre-meiotic stage some of the

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spikelets ceased to develop further. Such undeveloped spikelets could be distinguished from their respective size and position on the panicle branches about 15-20 days after PI. The data from Table 69 show relation between panicle developmental stages and percentages of spikelet degeneration under each developmental stage. Variations were significant among the varieties (Table 69). When the panicle length was about 15 mm, percentages of spikelet degeneration were found lowest for all the varieties. Percentages increased significantly from the pollen mother cell forming stage (about 15 days after panicle initiation). Irrespective of the varieties, percentages of spikelet degeneration were highest in the period when the spikelets on the primary branch entered into meiotic division stage (15-20 days after panicle initiation). Further degeneration of spikelets did not occur after panicle emergence and at the time of anthesis (Table 69).

The varieties showed variation in the amount of spikelet degeneration. Variations of spikelet degeneration percentages were significantly different for the two seasons (Table 72). Irrespective of the varieties, percentages of spikelet degeneration were highest in the plants which were sown on 1 November (Boro). Among the varieties, Latisail showed the highest percent of spikelet degeneration which significantly

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differed from the other varieties. BR3 had the lowest percentage of degenerated spikelets in two seasons and it differed significantly from BR4 and Latisail.

I.7. Plant height

The development of plant height at 10 days interval is shown in Table 70. The relative increase in plant heights in the varieties were significantly different for the seedlings of transplant Aman and Boro seasons. In transplant Aman season the growth rate was comparatively faster than Boro season. The increase of plant height was more at the seedling stage prior to PI and during panicle emergence. Table 70 shows the increase of plant height in the different developmental stages of the three varieties for both the seasons. There was a steady increase of plant height in the seedlings which were sown on 1 November.

I.8. Panicle length

The variation of panicle lengths in the two seasons differed significantly. Irrespective of the varieties panicles were shorter in Aman season than developed in Boro season (Table 73). Among the varieties BR4 produced the longest panicles in two seasons and Latisail the shortest panicles.

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I.9. Grain number per panicle

Irrespective of the varieties, the numbers of grains per panicle were highest in the plants which were sown on 1 November. Among the varieties BR4 produced significantly the highest number of grains per panicle. However, Latisail produced the lowest number of grains per panicle in both the seasons.

I.10. Spikelet sterility

The percentage of spikelet sterility between the two seasons was lowest in Boro season for all the varieties tested here. However, the percentage of spikelet sterility was highest in Latisail and lowest in BR4 in both seasons(Table 73).

I.11. Grain weight

The variation of 1000-grain weight among the varieties was significant. However, 1000-grain weight increased in Boro season for all the varieties (Table 73).

I.12. Panicle number

The number of panicles/m^2 was highest in the Boro between the two seasons. The percentage of panicle bearing plants differed significantly in the varieties (Table 73). It was highest in BR3 and lowest in BR4.

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I.13. Dry matter content

The variations of dry matter content in various developmental stages are shown in Table 71. The dry matter content of the plants increased at the time of panicle initiation. Subsequently during panicle emergence the dry matter content significantly increased. Variations between the two seasons were highly significant. However, at the panicle initiation stage, the highest dry matter content developed in Latisail and lowest in BR4 for both the seasons. Between the two seasons dry matter content in Boro was significantly lowest than produced in transplant Aman season.

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Chapter IV

DISCUSSION

1. Panicle Development and Spikelet Degeneration at Normal Planting and in Seedbeds

The rice plant passes through two major growth phases : vegetative and reproductive. At the end of the vegetative phase the conical shoot apex shows a flattening effect with the initiation of lateral dome-shaped projections (Plate 1, figures 1-7). These dome-shaped initials are the panicle branch primordia which develop in a basipetal order. These all develop after neck-node differentiation stage or panicle initiation stage (Plate 1, figures 1-2).

The vegetative phase increases or decreases depending upon the day length and temperature in which seeding is done. The low temperature in the Boro season increases the vegetative phase by 40-45 days compared to the time taken in the summer season (Table 1 and 66). Day length controls panicle initiation in the photoperiod-sensitive varieties while low temperature below 25°C delays panicle initiation and high temperature from 35 to 37°C induces earlier panicle initiation (Best 1959). Day length and temperature are often interrelated (Sircar and Sen 1950; Naguchi et al 1971).

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Irrespective of the variety and season the panicle initiation takes place earlier in the seedbed with higher density of plants and it is delayed in population with lower density (Tables 1 and 66). Chang and Yang (1966) and Shukla (1979) reported similar effect.

In the main culm panicle initiated earlier than in the tillers. The successive development stages of a panicle from neck-node development to heading stages have been divided into seven development stages, such as : neck-node, primary branch, secondary branch, spikelet initiation, pollen mother cell formation, meiotic and heading. The duration of each of the stages differs slightly due to variation in varieties, cultural conditions and time of seeding (Tables 1, 66 and 67). The development periods from panicle initiation to anthesis stages were divided by several workers (Terada 1923, Matsushima 1966, Saha 1969 and Ikeda 1970).

At the panicle initiation stage (neck-node development) the last three leaves (n, n-1 and n-2) remained inside and n-4 th leaf emerges completely (Plate 1, figure 2). Prior to PI the shoot apex is surrounded by developing leaves and leaf primordium. The shoot apex changed gradually into dome-shaped structure (Hasanuzzaman 1958, Nasiruddin 1963). The first order panicle branch primordium developed from lateral lobes spirally from the base of the main axis (Plate 1, figures 3-5). Saha (1969) also reported similar changes in the shoot apex at the PI stage. Variation in the number of

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branch primordia was observed from variety to variety, seasons and cultural practices. In the normal time of planting, the number of branch primordia was found to vary from 7-12, but it reduced to 4-6 in the panicles of plants left in the seedbed. These primordia are then transformed into primary branches and get arranged alternately either singly (BR3) or in pairs (BR4). The number of primordia might get reduced in the shoot apices of tillers. Multicellular hairs developed from the base in each of primary panicle primordium (Plate 1, figure 6) and at the later stages of panicle development also developed from each node. The hairs were seen to disintegrate from the early meiotic stage.

The secondary branches initiated alternately on the primary branches 8-10 days from the time of neck-node development (Plate 1, figures 5-7). The number of secondary branches per primary branch was found to vary from 0 to 5 in the panicles and the branches were found to increase from middle to basal primary branches. The number was significantly reduced in the panicles of the youngest tillers and in the panicles of the plants in seedbed.

The spikelets were found to be initiated 10 to 15 days after the neck-node development (Table 65). The number of spikelets per panicle branches was found to be 5-6 and in the secondary branches from 2-6. The number of spikelets

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was comparatively higher towards the sub-basal and basal branches (Plate 1, figure 12).With the emergence of n-2 th leaf the spikelet initiation was completed and at this stage panicle length was about 5 to 20 mm. The number of spikelets per panicle branches was different in the tillers, seasons and panicles from the seedbed.

The entire panicle with branches, spikelets developed more rapidly from 10 to 15 th day after neck-node development (Tables 2, 64 and 65). Some of the panicle branches and spikelets ceased to develop and degenerate. The degeneration occurred in the panicle branches with spikelets and spikelets itself (Plate 2, figures 7-9 and Plate 8, figures 1-3). The degenerated spikelets failed to attain pollen mother cell forming stage (Plate 8, figures 1-3). These branches and spikelets could be clearly recognized under binocular microscope 5 to 10 days before heading. The degeneration commenced from 5 to 10 days after spikelet initiation and the number of degenerated spikelets increased 10 days before heading. The basal primary and secondary branches degenerated higher number of spikelets than the upper panicle branches (Plate 8, figures 1-3). Similarly, the number of degenerated spikelets was higher in the basal secondary branches than other panicle branches. Spikelet growth proceeded from apical upper to basal direction (Arai *et al* 1978). This was evident from the dimension of the developing spikelets, sequence of flowering

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and of grain maturity.

The panicle branches, spikelets and panicle length developed rapidly in the pollen mother cell forming stage. The spikelet length increased 3.5 to 4.5 mm and panicle length increased 3.5 to 7.5 cm (Tables 2, 67 and 68). In the pollen mother cell forming stage the length of the spikelet differed slightly in the varieties and spikelet development in the seedbed condition. In the meiotic stage, spikelet length varied 5.5 to 7 mm and panicle length showed significant variation from 3.8 to 2.2 cm. At this time the flag leaf exerted from the boot to an approximate extent 3/5 to 4/5 th of its full length. At the final stage of pre-emergence of the panicle, the length of the panicle and of its leaf sheath were comparable and the crowded young branches and spikelets got spread out in the leaf sheath. The duration from neck-node development to heading stage varied from 28 to 32 days. (Table 1 and 66).

Development of rice panicle is different from that of spike and other cereals (Sircar and Sen 1953). Since rice inflorescence is a complex raceme or panicle, spikelets growth proceeded from upper to lower spikelets (Arai *et al* 1978). Although the lower branch primordia initiated earlier, their organization occurred towards the end (Noguchi 1929, Akimoto and Togari 1939, Hasanuzzaman 1958, Nasiruddin 1963,

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Saha 1969). The spikelet initiation was basipetal in development making it a determinate type of inflorescence. Because, all the branches are terminated by spikelets (Plate 1, figures 8-12). The inflorescence of wheat, barley and rye are spikes. The spike is unbranched and sessile and spikelets develop on the main axis (Arber 1926, Bonnett 1935, 1936 and 1937). On the contrary, rice inflorescence is branched and determinate with terminal single flowered spikelet which develop on a short pedicel.

Here one can see that degeneration of spikelets (failure to develop from early initial stage to fully formed spikelet) starts from a stage when the apical spikelet reaches meiotic stage. The degenerated spikelets thus can be easily identify at the late boot stage or panicle pre-emergence stage (5-6 days prior to heading). Degeneration of spikelets thus differs from sterility in spikelets where spikelet is fully formed. The spikelet sterility was due to degeneration of sex-organs or failure of pollination and fertilization or failure of grain development due to some other factors.

2. Factors affecting Panicle Development, Spikelet Degeneration and Grain Yield.

2.1 Seedling age

In the experiments (B_1 and B_2) three different rice varieties with three different reactions to photoperiod were

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used inorder to ascertain the effect of seedling ages on these varieties.

BR3,a rice variety being insensitive to photoperiod showed statistically significant variation on spikelet degeneration in the different seedling ages (Table 8). When seedling ages were 40 and 50 days old, the percentage of spikelet degeneration were 11.71 and 10.35 respectively. However, when the seedling ages were 60 to 80 days old there were not much variation of spikelet degeneration (9.74 to 9.94%). The difference was due to older seedlings which could tolerate better the effect of cold weather (Boro season) ultimately resulted in an insignificant yield difference.

In spite of higher degeneration percentages in the seedlings of 40 and 50 days old in Boro season, the yield difference was reduced because the younger seedlings got 10 to 20 days more field duration than those of older seedlings. As a result 40 and 50 days old seedlings had 22.36 and 20.23 panicles per plant respectively. These were higher and significantly different from 18.97, 18.54 and 18.23 panicles per plant produced by the seedlings of 60, 70 and 80 days old respectively (Table 8). Moreover, the number of spikelets per panicle were significantly higher in the lower seedling ages (40 and 50 days old) than other higher seedling ages (Table 8). Therefore, the higher spikelet degeneration

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in 40 and 50 days old seedlings was compensated by the extra panicles per plant and much higher number of spikelets per panicle. Furthermore, there were about 2% more spikelet sterility in the seedlings of 40 and 50 days old from other higher seedling ages (Table 9). A similar compensatory effect was also achieved by lower sterility in panicles with lower grain number than those with higher sterility with higher grain number. Therefore, though there was higher degeneration of spikelets in 40 and 50 days old seedlings, the more number of panicles and total grains per panicle assisted to equalize the yield with those of older seedlings with lesser degree of spikelet degeneration.

Similar results can be found for BR4 and Latisail. BR4 is slightly photoperiod sensitive and Latisail being a photoperiod-sensitive variety, received photoperiod induction during the months of December and January which assisted these varieties to produce flower along with BR3 in about mid of April. In each case the seedlings of 40 and 50 days old had higher spikelet degeneration like that of BR3. BR4 had numerically 3 to 4 less number of panicles from BR3 and Latisail. While, BR4 had maximum number of spikelets per panicle than BR3 and Latisail, the number of filled grains per panicle was also significantly higher than BR3 and Latisail. On the contrary, 1000-grain weight of BR4 was less than

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either BR3 or Latisail. But by virtue of higher number of filled grains per panicle, BR4 produced almost identical grain yield as in BR3 (Table 9). On the otherhand, Latisail had higher number of grains than BR3 but much lower than BR4. Moreover, Latisail had the higher percentage of spikelet degeneration than BR3 or BR4 (Table 8). In addition to spikelet degeneration it had much higher percentage of spikelet sterility. Therefore, both these two characters (spikelet degeneration and sterility) ultimately reduced the grain yield of Latisail per hectare. This was also corroborated in Latisail by highly significant negative correlation coefficient for the different yield component (Table 10). The total effects of these ultimately reduced the grain yield in Latisail. The correlation coefficient of grain yield with seedling ages was significant and negative. While, correlation for the grain yield was insignificant for BR3 and BR4 (Table 10). It may be noted here that when Latisail was seeded on 1 November, no matter of seedling ages (40-to 70-day-old) the grain yield was about 5 t/ha which was equivalent to the yield of high yielding variety. Similar results were obtained by Alim, Zaman and others (1962) by cultivating Latisail in the Boro season.

The length of the field duration had a significant effect on the yield components. In Boro, the field duration (transplanting to PI of the main culm) differed significantly in the different seedling ages (Table 7). Field durations

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of 40 and 80 days old seedlings were 80 and 50 days respectively. Field durations decreased with the corresponding increase in seedling age. However, when the field duration was 80 days there was higher number of panicles per plant, maximum spikelets per panicle and higher spikelet degeneration (Plate 4, figures 1-6). A minimum field duration of 50 days had the fewer panicles per plant, lower number of spikelets per panicle and lower percentage of spikelet degeneration. A similar effect of variation of field duration was also found for BR3, BR4 and Latisail when grown in the transplant Aman season.

In the experiment B_1, five seedling ages (30, 40, 50, 60 and 70 days old) were used for the three varieties. When BR3 was grown in T. Aman with 30 to 70 days old seedlings, there was spikelet degeneration unlike that of the Boro season. In this case the **per cent** of spikelet degeneration increased from 12.74 to 25.45 with the corresponding increase of seedling ages (Table 4). Seedling ages of 30 to 50 days had almost identical percentage of spikelet degeneration (12.25 to 12.74). On the contrary, when the seedling age was increased to 60-day, spikelet degeneration increased to 16.58%. The spikelet degeneration further increased to a maximum of 25-45% when seedling age was increased to 70-day before transplanting (Plate 3, figures 1-6).

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BR3 being a photo-insensitive variety usually took about 75 days for PI in the transplant Aman season. Hence, when seedling age was 70-day, the PI was supposed to occur only five days after transplanting. Due to the transplanting shock at this critical age of 70-day adversely affected the PI and spikelet production along with other characters of the panicle (Table 4). Due to this stage of transplanting, seedlings close to PI, there was a reduction of all important yield contributing characters like number of panicles per plant, spikelets per panicle, filled grains per panicle and 1000-grain weight. The higher percentage of spikelet sterility coupled with other reduced yield components combinedly reduced the grain yield from 5.13 to 1.5 t/ha (Table 5). Therefore, in BR3 seedling age beyond 50-day-old definitely increased significantly the percentages of spikelet degeneration and spikelet sterility. Moreover, the number of panicles per plant, panicle length, number of spikelets per panicle, filled grains per panicle and 1000-grain weight reduced significantly.

A similar trend was also found in BR4. In Latisail, however, the per cent of spikelet degeneration was maximum when seedling age was only 30-day-old. The higher vegetative phase induced maximum tillering with more unproductive tillers. When the seedling age was increased from 40 to 70 days, the spikelet degeneration reduced from 9.15 to 7.55% (Table 4).

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This can be explained that the longer vegetative phase in a photoperiod sensitive variety like Latisail when seeded in 15 July increased the degeneration percentage and also spikelet sterility. In spite of higher percentages of spikelet degeneration and sterility in 30-day-old seedlings, the grain yield increased from other higher seedling ages. In fact, all the important yield components were higher than other seedling ages. Subsequent older seedlings yielded lower because of reduction of yield components due to a shorter vegetative phase lower than the optimum number of days. In spite of lower percentages of spikelet degeneration and sterility in Latisail, the grain yield was adversely affected by the higher seedling ages.

Effects of seedling ages can be determined from the field duration for PI. Field duration for PI of the main culm decreased significantly with the corresponding increase in seedling ages from 30 to 70 days (Table 3). Field durations for 30 to 70 days old seedlings reduced from 45 to 05 days in BR3, 55 to 20 days in BR4 and 50 to 12 days in Latisail respectively. However, variation for the age of PI in the different seedling ages was insignificant for a variety.

Different panicle components along with other yield components decreased when seedling ages were increased from 40-day to other higher seedling ages. Variation in the

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varieties for the similar seedling ages was mainly due to the time taken for PI for each of the varieties. In BR3, BR4 and Latisail field durations for 40-day-old seedlings were 40, 50 and 43 days respectively. Hence, the reduction of field duration from 50 days affected the yield components. Similar result was found in the Boro experiments. Effect of various seedling ages on the panicle components and other yield components showed significant negative correlation with the seedling ages (Table 6).

The effect of field duration on spikelet number per panicle of the main culm showed significant variation. Regression coefficients were highly significant for the field duration (T. Aman). Results showed that for each day increase in seedling age for transplanting the number of spikelets per panicle reduced in the order of 3.69, 3.25 and 1.53 respectively in BR3, BR4 and Latisail. The result clearly indicated that the effect of field duration played a significant role for the initiation of spikelets per panicle and also spikelet degeneration.

Jennings *et al* (1979) showed that there was a compensatory association between panicle size and tiller number of rice crop. He showed, when the panicle size increased, the number of panicles per plant decreased. Thereby, the panicle character was not considered as an important criteria for

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yield determination. However, Padalia (1980) observed that seedlings of 20 to 60 days old when transplanted on August, decreased grain yield with the increase in seedling ages. Lin *et al* (1977) explained that delay in transplanting increased plant mineral content but produced fewer tillers and yielded lower. Murty and Sahu (1979) investigated four photoperiod insensitive varieties with seedling ages 20, 40 and 60 days old. The effect of higher seedling age (60-day-old) yielded much lower than 40-day-old seedlings but higher than 20-day-old seedlings. Higher seedling age is reported to reduce tiller production and grain yield of a short duration variety. Medium and long duration varieties at higher seedling age yielded higher (Singh *et al* 1975). Sharma *et al* (1979) while working on Pusa 2-21 and Joya rice varieties reported that 20-day-old seedlings yielded higher than 40 or 60-day-old seedlings.

The difference found herein that grain yield was not decreased when the seedlings of higher ages (40, 50, 60 and 70 days old) were transplanted in the Boro season. However, Padalia (1980) used short duration varieties for summer rice which were transplanted on August. In summer rice (T. Aman) the age for PI decreased resulting in lower yield from winter rice (Boro). On the contrary, the experiments (B2) were done in Boro. Therefore, the field duration increased with abundant sunshine with moderate temperature (particularly lower night temperature) and yielded higher in spite of higher

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seedling ages. According to Bardhan *et al* (1980) the effect of sowing in mid-November (Boro) gave the higher yield and decreased when sown on December. The yield was not decreased in the Boro, in spite of higher seedling ages (40, 50, 60 and 70 days old) as the seedings was done on 1 November.

When the same varieties were grown in T. Aman, grain yield decreased with the corresponding increase of seedling ages from 30 to 70 days. It has already been discussed that in the T. Aman (summer rice), yield decreased (Padalia,1980) when seedling ages were increased from 20 to 60 days. The age for PI was earlier in the T. Aman than the Boro. However, reduction of grain yield in the T. Aman season was significantly affected by lower field duration in the higher seedling ages. The minimum field duration for higher grain yield was found near about 50 days in T. Aman and Boro season for the three varieties. The grain yield decreased with the corresponding decrease of field duration from 50 days. Murty and Sahu(1979) obtained higher yield from 40-day-old seedlings than 20 or 60-day old seedlings. The experiments of T.Aman also showed significant increase of grain yield in the 30-day-old seedlings from other higher seedling ages. The effect of higher seedling ages (60 and 70 days) significantly decreased grain yield from other lower seedling ages.

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In conclusion, seedling ages for the same variety depended on the time of sowing. Effects of similar seedling ages differed in the varieties for the age of PI. The field duration for similar seedling ages was higher in the Boro than T. Aman season. Yield contributing characters decreased with the corresponding reduction of field duration from 50-day before panicle initiation. It has been shown that the yield of all the three varieties in the Boro season regard to the period at which the transplantation was made. In other words sowing on 1st November gave more or less the same yield for 40 to 70 days old seedlings. The result clearly indicates that the longer duration in the field beyond 70-day did not increase yield. It may be mentioned here that whatever loss was incured due to late transplanting was compensated by the yield contributing components.

The results obtained here have great economic importance when we consider that for no substantial gain in grain yield the crop is grown for one extra month in the field from December to January. From the economic point of view it is desirable to keep the seedlings for 70 days from 1 November in the seedbed in order to minimize the extra cost for field management.

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2.2. Time of transplanting

In BR3 early seeding on 30 June and transplanting 70-day-old seedlings on 9 September resulted in 13.26% spikelet degeneration. Same results were obtained with seeding upto 30 July and then transplantation of 40-day-old seedlings on 9 September (Table 12). As against this delayed seedings on 9 August and transplantation of 30-day-old seedlings reduced spikelet degeneration significantly to almost half (7.78%). On the other hand BR4 and Latisail (Table 12) showed a different trend possibly because of their photoperiod-sensitivity. BR4 being a weakly photoperiod sensitive variety it had a maximum amount of spikelet degeneration (10.63%) in early sowing (30 June). Shifting of seeding date of BR4 from 10 July to 9 August and the transplantation of the seedlings on 9 September did not enhance the amount of spikelet degeneration.

In Latisail spikelet degeneration was found to be maximum when seeding was done on 30 June and 10 July and transplantation of seedlings was done after 70 days(Table 12). Transplanting 30-50 days old seedings produced statistically similar amount of spikelet degeneration (12.59 - 12.89%). This variation in Latisail was different from both BR3 and BR4 because of the former's higher sensitivity to photoperiod.

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From the present investigation a few important facts seem to stand out clearly. Higher seedling age was one of the factor decreasing the spikelet number per panicle either by suppression or degeneration of panicle branches and spikelets. Due to lack of information on spikelet degeneration either in rice or other cereal crops the result cannot be compared with those of other authors.

The number of primary and secondary branches of the panicle of main culm decreased in higher seedling ages (Table 12). The number of spikelets per panicle also decreased due to lower number of panicle branches. Srivastava *et al* (1974) observed that the number of spikelets per panicle increased or decreased mainly by the number of panicle branches.

The number of panicle branches mainly secondary branches decreased either by suppression or degeneration or to both of panicle branches. The percentage of panicle branch degeneration increased with transplantaing seedlings of higher ages (Table 12). The number of panicle branch degeneration was higher in the secondary than primary branches per panicle.

Matsushima (1966) reported similar findings from his experimental observations conducted in 1953-54. According to him the percentage of spikelet degeneration increased by either degeneration of panicle branches or spikelets or to both. According to the same author main cause of panicle branch degeneration was the nutrient deficiency, especially

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nitrogen, at the meiotic stage of panicle development.

From the present findings it is evident that apart from nutrient deficiency, the effect of delayed transplantation is reflected in higher spikelet degeneration. The degeneration of spikelet was more pronounced in the panicles of the main culm than in the tillers by delayed transplantation. This was due to better nutritional status of the tillers in the field than the main culm. In BR3 the field duration was reduced from 35 to 0 days when the transplantation was delayed by 40 days (Table 11). The main culm had short field duration for nitrogen uptake, consequently degenerated higher percentage of spikelets and produced lower number of spikelets per panicle.

The lower number of spikelets per panicle of the main culm was the result of short field duration after transplanting.

In BR4 and Latisail spikelet degeneration was minimum when field duration was for a minimum period of 30 to 33 days. In general, the minimum 35 days favoured lower percentage of spikelet degeneration.

Thus, it was clear that in all the three varieties the minimum duration of 30-35 days in the field was essential for optimal development of spikelets.

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Transplanting of 70-day-old BR3 seedlings at the PI stage produced the highest number of panicles (18.8) compared to those transplanted earlier (Table 13). Seedlings transplanted at the PI stage tillering was prolonged,as a result a good deal of time difference was found between the main culm and those originated tillers. Hence, transplanting other seedlings increases the total length of the life cycle compared to those transplanted earlier. Murty and Sahu (1979) also made similar observation in older transplanted seedlings. Greater the field duration higher the total number of panicles per plant. However, the number of spikelets per panicle decreased when the tiller number increased. On the contrary, seedlings transplanted at lower ages, (30, 40 and 50 days old), the number of spikelets per panicle of the main culm was higher than in other tillers per plant. The contribution of the main culm to grain yield was higher than any other tillers of the plant. This is in close agreement with the results of the physiologists of BRRI (1982). Conversely, seedlings of BR3 transplanted at the higher ages (60 and 70 days), the contribution of the main culm to grain yield was lower than that of other tillers per plant. The result reported at BRRI (1982) differed only in the case of older seedlings.

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The greater period of tiller development after transplanting more was its beneficial effect on grain yield. The tillers which developed within 30 days after transplanting had significantly contributed to grain yield. As against this most of the tillers that developed afterwards produced no panicle. Similar results were reported by the physiologist of BRRI (1982). They observed that when the spacing was closer and greater, the contribution of tillers that developed within 21 and 35 days respectively was significant on grain yield. In the present investigation higher spacing (20 x 30 cm) of seedlings was allowed.

Transplanting of 70-day-old seedlings of BR3 at the PI stage, did not significantly reduce the grain yield compared to the seedlings transplanted earlier (Table 13). The contributions of tillers on grain yield was balanced by the other yield components. The negative effects of lower number of spikelets per panicle and a higher percentage of degenerated spikelets were offset by the positive effects of a higher number of panicles per plant and lower percentage of spikelet sterility.

Consequently, the sum total of positive and negative effect of the yield components produced an insignificant variation on grain yield with other lower seedling ages. Furthermore, when seedlings of different ages were trans-

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planted on the same date in the field, the field duration was found to be significantly different for different seedling ages. As a result, panicle bearing tillers produced a compensatory mechanism of other yield components such as panicle and grains per panicle i.e. one increases other decreases.

Apart from the positive and negative effects of the above yield components, the 1000-grain weight also decreased with the increase in panicle numbers per plant. Chaudhury *et al* (1973) also found a negative correlation between grain weight and number of panicles per plant.

In BR4 and Latisail, seedlings of older ages, when transplanted on the same date, showed delayed PI on the main culm (Table 11). However, field duration on the various seedling age groups was insignificantly different. The total durations from seeding to panicle initiation decreased by shifting of the seeding date from 30 June to 9 August. Kim *et al* (1980) also reported similar variation for heading time of certain rice varieties.

In BR4, the PI of the main culm took place earlier (72 days) when sown on 9 August. Similarly the PI of the early seeding (30 June) took place at a higher age (103 days). The early panicle initiation was the result of shorter day length from 13.7 hours in June to 11.6 hours in October.

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Ikeda (1970) reported similar variation in some rice varieties. He observed the flowering response in the photoperiod-sensitive varieties occurred earlier in a shorter day length (9-12 hours). Gangulee (1955) reported that flowering response of T. Aman varieties influenced by the critical day length not exceeding 13 hours. Sircar (1948), Sircar and Sen (1950 and 1955), Morinaga and Kuriyama (1954), and Matsushima (1966) reported early flowering under short day length and temperature.

Hence, the total duration from seeding to harvest decreased when seeded on 9 August and transplanted early. This was due to the decreasing day length. The effect of temperature in this respect cannot be ignored. June to October day temperature did not decrease appreciably (34.4-31.3^{o}C)but the night temperature decreased (26-22.8^{o}C). Ling and Chang (1976) observed that high night temperature delaying PI and flowering.

In the present investigation, the night temperature before PI was comparatively higher in early seeding and lower in late seeding. Yoshida (1973) reported that low temperature (28°C) at the maximum tillering stage inducing early flowering. Therefore, the effect of shorter day length and low night temperature either by itself in or combination, caused earlier PI. The field duration of both older and

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younger seedlings was more or less the same under combined effect of short day. Hence,the combination of day length and temperature resulted into an insignificant variation of field duration between higher and lower aged seedlings (Table 11). The effect of day length and temperature in Latisail also showed similar trend like BR4. The effect of day length was much higher in Latisail than BR4 (Table 11).

The number of spikelets per panicle of the main culm in BR4 and Latisail was significantly reduced when 70-day-old seedlings were transplanted (Table 12). The number of panicles per plant in the two varieties slightly increased when transplantation was delayed (Table 13). When the seedlings of different ages were transplanted in the same date, field durations for all the different aged seedlings showed insignificant variation, the grain yield did not differ significantly (Table 13). In case of Latisail, even though there was a significantly higher percentage of spikelet sterility in 50, 40 and 30 days old seedlings, the other yield components compensated grain yield differences (Table 13). Shamsuddin *et al* (1977) reported that lower grain yield in Latisail was mainly due to late planting (23 September). The effect of fertilizer had nothing to do on higher grain yield. The number of spikelets per panicle decreased when the planting date was delayed from 1 to 30 September. The

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present investigation showed that, the grain yield of Latisail was not significantly affected when transplanted on 9 September.

The above results demonstrate convincingly that in T. Aman season transplanting date in all the varieties is very important so far as the yield of these varieties is concerned.

In Boro the early vegetative phase passed through a cooler season which prolonged the vegetative phase. Kaneda and Beachell (1974) observed that low temperature causing slow growth and thereby increasing the vegetative phase. Bardhan (1980) also reported that low temperature in the Boro season inhibiting plant growth and leaf emergence. In the Boro, the PI was delayed by 35-40 days from those of the T. Aman season.

The effect of seeding dates (20 December to 29 January) showed a significant variation for the age of PI in the main culm except for Latisail which did not initiate panicle when seeded late from 30 December (Table 17). The age for PI decreased from early to late seeding significantly but the field duration after transplanting was insignificant in BR3 and BR4 (Table 17).

Irrespective of the seeding dates, panicles in the main culm initiated from mid-April in BR3 to early May in BR4.

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The effect of sowing dates from 20 December to 29 January decreased the age for PI 117 to 90 days in BR3 and 137 to 103 days in BR4 (Table 17). The temperature increased from December to April (maximum 26.1-33.5°C and minimum 12.2-22.5°C). In the PI stage day and night temperatures exceeded 33.5 and 22.5°C respectively. Conversely, in the early seeding (20 December) the age for PI increased due to low temperature, from December to February (maximum 26.1-27.2°C and minimum 12.3-13.5°C). A similar report came from Best (1959) who reported that high temperatures (35-37°C) inducing early PI but low temperature (25°C) delaying PI.

Hence the age for PI in the Boro season decreased with the increase in temperature. Seedlings transplanted on 10 March from five different sowing dates (seedlings were five different age groups). The effect of seedling age had no significant effect on PI but the age for PI mainly due to the variation of day length and temperature. The relative rate of growth was much lower than a higher temperature (35.5°C).

In BR3, the percentage of spikelet degeneration decreased significantly in early sowing (20 December) and increased in late seeding (29 January). Otherwise, the percentage of spikelet degeneration decreased significantly

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with transplanting higher aged (80-day-old) seedlings and increased in lower aged (40-day-old) seedlings (Table 18). The temperature prior to PI was lower for higher seedling ages and it subsequently increased for lower seedling ages. The temperature increased (27.8°C) from the later part of February and reached to a maximum of 33.50°C in April. The night temperature of May exceeded 24°C but in April it was below 23°C. Therefore, up to April, the night temperature remained very favourable for energy conservation of the rice plant. That is why, in a photoperiod-insensitive variety like BR3 when transplanted at the higher ages the percentage of spikelet degeneration remained at a lower level (Table 18). On the contrary, photoperiod-sensitive variety like BR4 and Latisail had a higher percentage of spikelet degeneration in older seedlings, because they received photoperiod-induction during the shorter days of December and January. The temperature also increased (32.4°C maximum and 23.7°C minimum). Yoshida (1973) reported that higher temperature increased the number of degenerated spikelets.

The day length increased (10.7-12.7 hours) in December-April. In BR4, the photoperiod-induction continued to occur up to the end of April. Tillers which originated from March to mid of April received photoperiod induction because of its lower degree of photoperiod sensitivity. Gangulee (1955) also reported as the critical day length of photoperiod-

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induction not exceeding 13 hours for the photoperiod sensitive varieties. In Latisail tillers which developed in the March received no photoperiod-induction due to longer day length (12-12.7 hours). On the other hand when sown earlier (20 December), only the main culm per plant initiated panicle because it received photoperiod-induction within January-February in a short day length (10.8-11.4 hours) of January and February. Similarly, in BR4, those tillers which developed in mid-April received photoperiod-induction in the day length not exceeding 13 hours. Ikeda (1975) also reported that photoperiod-induction required 20 short-day cycles on 10-to 30-day-old seedlings.

Hence, in BR4 and Latisail, the tillers which received necessary photoperiod-induction cycle in day lengths respectively for 12.7-13 and 10.7-11 hours only, developed panicles.

In BR3 the effect of lower seedling ages (40 and 50-day-old) in the Boro season increased the number of panicles per plant but decreased the number of spikelets per panicle (Tables 18 and 19). On the contrary, the older seedlings (80-day-old), the panicles per plant decreased but the spikelets per panicle increased. The percentage of spikelet sterility showed an insignificant variation in the seedling ages at transplanting (Table 19). In the lower

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seedling ages, the grain yield slightly increased from the seedlings of higher ages (Table 19). Hence, 80-day-old seedlings, when transplanted on 10 March, produced the negative effect of lower number of panicles per plant, and lower percentage of spikelet degeneration was offset by the positive effect of higher number of spikelets per panicle. Similarly, 40-day-old seedlings when transplanted on 10 March the negative effect of lower number of spikelets per panicle and higher percentage of spikelet degeneration was offset by the positive effect of higher number of panicles per plant.

Hence, the effect of different seedling ages in the Boro season had no significant effect on the grain yield (Table 17). The effect of late sowing (29 January) slightly increased the grain yield than early sowing (20 December). Khan and Swarnaker (1980) obtained higher yield in the first week of January seeding than the third week of December.

A different picture was revealed by BR4 as older or younger seedlings after transplanting did not show much variation in the number of panicles per plant (Table 19). Similarly, spikelet sterility was not affected by seedling ages (Table 19). Seedlings of 50-80 days old had statistically similar grain yield (4.06-5.26 t/ha) but significantly higher than 40-day-old seedlings (3.52 t/ha).

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The higher grain yield from older seedlings (50 to 80 days old) was attributed to the higher number of panicles per plant than younger seedlings (40-day-old). The grain yield was significantly reduced (0.03 t/ha) in Latisail and grain yield was practically nil when sown later than 20 December and transplanted on 10 March. The yield of Latisail significantly decreased because only the main culm per plant developed panicle and the number of spikelets per panicle was significantly reduced by a higher percentage of spikelet degeneration and spikelet sterility.

The results clearly indicate that the variation of day length and temperature significantly influence the grain yield of a photoperiod sensitive variety. In the Boro season the yield of BR3 was not affected in all the late sowing from 20 December to 29 January. This was no so in BR4 and Latisail whose photoperiod sensitivity to short day interferred with yield for the panicle production.

2.3. Fertilizers (NPK)

BR4 seedlings when transplanted at higher ages (60- and 70-day-old) irrespective of the fertilizer treatment, the percentage of spikelet degeneration increased significantly (Table 25). A higher percentage of spikelet degeneration was the result of long duration in the seedbed

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and short field duration after transplanting. The effective field duration of the main culm decreased with the increase in seedling age. The effective field duration for nutrient uptake significantly decreased when the seedlings were transplanted fewer than 20 days before PI and increased the percentage of spikelet degeneration. Similar effect was found in the experiments B1 and B2.

Irrespective of the seedling age, the percentage of spikelet degeneration significantly increased when fertilizers were not applied (Table 23 and Plate 5, figures 1-6).

Therefore, unless there is the requisite amount of nutrient in the soil, the percentage of spikelet degeneration will be higher regardless of seedling ages. Thus, two important facts are derived, viz :

1. Irrespective of the fertilizer treatment when the seedling age was delayed beyond 50 days for transplanting, the effective nutrient utilization period (ENUP) was reduced for the main culm. Therefore, the main culm received some benefits from such a low level of nutrient content of the soil.
2. Similarly, the total amount of fertilizer needed for an optimum growth of the main culm was not available for either lower or higher seedling

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ages in the control treatment. Therefore, the amount of fertilizer contained in the control treatment, failed to prevent the reduced growth and spikelet degeneration.

The effects of N, NP, NK or NPK fertilizer treatments were statistically similar for the percentage of spikelet degeneration. This was due to mainly the presence of different nutrients in the soil of the test plots (Table 27). However, the response of N alone was higher than P or K in minimizing the percentage of spikelet degeneration (Table 23). Nitrogen as topdressed at the PI stage decreased the percentage of spikelet degeneration over control treatment. Matsushima (1966) also found similar effect. He found that nitrogen, when applied at the meiotic stage prevented the higher percentage of spikelet degeneration.

Irrespective of fertilizer treatments, the number of spikelets per panicle significantly reduced with the increase in seedling ages (Table 25). Similar trend was found in the experiment B1. Enyi (1963) also reported similar results for higher seedling ages.

The main cause for the reduction of spikelet number per panicle was the suppression or degeneration of panicle branches, especially secondary branches which decreased significantly with the increase in seedling ages (Table 25). The

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decrease in the number of secondary branches was the result of panicle branch degeneration and suppression of the development of panicle branches.

The suppression or degeneration of panicle branches was accelerated by the reduction of effective field duration. The effective field duration from transplanting to panicle initiation was found 50 days for the optimum development of panicle branches and spikelets per panicle. Seedlings which were transplanted at higher ages (50, 60 and 70 days old), the effective field duration decreased (45, 40 and 10 days) below the optimum level (Table 22). As a result, the number of secondary branches per panicle decreased significantly along with the number of spikelets. Similar results were found in the experiments B1 and B2 as mentioned in Tables 4 and 12. The regression coefficient was highly significant for the number of spikelets per panicle in different field durations for different seedling ages. The result showed, for each day delay in transplanting after 15 August numerically 1.8 spikelets per panicle decreased.

Regardless of the seedling age, fertilizer treatments significantly increased the number of spikelets per panicle. (Table 23). The cumulative effect of NPK produced significantly the highest number of spikelets per panicle and decreased 6.45% over the control treatment (Plate 5, figures 1-6).

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Similarly the effect of NK treatment produced significantly the next highest (5.38%) of spikelets per panicle over the control treatment. The result showed that the contribution of N alone was higher than P or K in increasing the number of spikelets per panicle (Table 23).

Hence, nitrogen, other than the basal dose with PK, when applied at the PI stage, increased the number of spikelets per panicle. Similar result was reported by Matsushima(1966). He investigated that the number of spikelets per panicle increased when nitrogen was applied at the PI stage.

It was Probably, nitrogen requirement was higher in the PI stage for increasing the number of panicle branches and spikelets. On the other hand, because the amount of nitrogen contained in the control treatment produced significantly a lower number of spikelets per panicle than fertilizer treatments. Kumura (1956) observed a close correlation of the number of spikelets per panicle and nitrogen content at the PI stage. Takahasi *et al* (1976) also observed maximum nitrogen absorption just before the PI stage.

The response of K was also higher when combined with nitrogen and increased the number of spikelets per panicle. The response of P was also higher for increasing the number of spikelets per panicle. Similar observations were made

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by Rahman *et al* (1977). They found a higher response of P which increased the number of spikelets per ear in wheat.

The effect of fertilizers and seedling ages revealed two important facts regarding the factor influencing the number of spikelets per panicle.

1. The number of spikelets per panicle in higher seedling ages (60 and 70 days old) had no significant effect for fertilizer treatments, because the number of spikelets per panicle was statistically similar for the control and fertilizer treatments. That is, fertilizer applications at higher seedling ages were ineffective for the main culm; and
2. Regardless of the fertilizer treatment, seedling age was the most important factor for determining the number of spikelets per panicle.

Irrespective of the fertilizer treatments, the number of panicles per plant increased significantly in higher seedling ages (Table 25). Seedlings of 60 and 70 days old were transplanted respectively 5 and 15 days before the PI stage and produced a higher number of tillers as well as panicles per plant; whereas, seedlings of lower ages (30 to 50-day-old), when transplanted 25-45 days before PI, the number of panicles per plant were significantly lower than

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higher seedling ages (60 and 70 days old). Similar result was found in the experiment C1 (Table 13) in BR3 when seedlings were transplanted at the PI stage and 10 days before it (Table 13). Singh *et al* (1975) reported similar findings. They observed that seedlings, when transplanted 10-20 days before PI, produced a higher number of tillers. The result of the experiment B1 was different for higher seedling ages (Table 5) where the number of panicles per plant significantly decreased in higher seedling ages. The differences were mainly due to the presence of a lower amount of soil nutrients (Table 27).

The significant increase in tiller number per plant in higher seedling ages resulted from sufficient soil nutrients and additional fertilizer application at transplanting. Similarly a higher number of panicles per plant was produced due to nitrogen topdressing at the maximum tillering stage.

The effect of higher number of panicles per plant resulted from higher seedling ages (60 and 70 days old) produced short panicles, degenerated higher percentage of spikelet and lower number of spikelets per panicle. A compensatory mechanism seemed evident for a higher number of panicles developed a lower number of spikelets or shorter panicle. Jennings *et al* (1979) reported a compensatory association between panicle size and tiller number.

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Regardless of the seedling ages, the effect of fertilizers (N, NP, NK and NPK) significantly increased the number of panicles per plant (Table 24). A lower number of panicles per plant in the control treatment was due to an inadequate nitrogen level at the maximum tillering stage. Similar findings were reported by Lai *et al* (1977) and Dixit and Singh (1979).

Nitrogen, when applied basal, increased the tiller numbers. But nitrogen topdressed at the PI stage of the main culm, it increased the number of panicles per plant. Many similar results were earlier reported from Japan(Matsushima, 1965). De Datta (1978) also recognized the requirements of nitrogen and other elements at the maximum tillering stage, IRRI (1968), Chandler (1969) and Yoshida and Itayakawa (1970) observed that tillering of rice was strongly influenced by nitrogen application. Fagade and De Datta (1971) and Shiga *et al* (1977) found a strong positive correlation between nitrogen absorption and the number of panicles per plant. Bhuiyan (1980) also reported a strong correlation between tiller number at the maximum tillering stage and nitrogen content.

Hence, in lower seedling ages (30, 40 and 50 days old), nitrogen increased the number of spikelets per panicle but the number of panicles per plant was not increased signifi-

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cantly. On the contrary application of nitrogen on older seedlings (60 and 70 days old) resulted a significant increase in the number of tillers or panicles per plant.

When the seedling ages were either 60 or 70 days the effect of N was statistically similar to NP, NK or NPK combinations. Results indicated N alone needed for the development of panicle. In lower seedling ages (30, 40 and 50 days old) the effect of fertilizers was insignificant indicating that the soil had sufficient amount of NPK which produced on optimum number of panicles. Haque and Khan (1976) reported that the effect of P alone or PK significantly influenced the production of panicles per plant.

Irrespective of the fertilizer treatments the grain yield per plant significantly decreased in 70-day-old seedlings (Table 25), because the negative effect of a lower number of spikelet degeneration was not compensated by the positive effect of a higher number of panicles per plant but different for 60-day-old seedlings, the negative and positive effects combinedly produced an insignificant variation in grain yield with other lower seedling ages.

The result clearly indicated that 70-day-old seedlings, when transplanted five days before PI stage, the effect of short field duration significantly increased the negative effect and thereby reduced the grain yield. Furthermore, the percentage of spikelet sterility remained at a

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constant level and had no significant effect on yield difference (Table 25).

The grain yield difference of BR4 between 60 and 70 day old seedlings was 16.30%. Similarly yield difference with the lower seedling ages was 18.73%. Hence, 40 days delay in transplanting significantly increased the grain yield reduce to 18.73% in BR4. Enyi (1963) reported 28% reduction in grain -yield when transplanting was delayed for 30 days. The figure is therefore lower than that of Enyi (1963). Singh and Bhattacharya (1975) also reported 18% yield reduction in early varieties when 52-day-old seedlings were transplanted.

The yield reduction for the similar seedling ages was different in the varieties. This was due to mainly variation in the age for PI in the varieties and the field duration after transplanting. Furthermore, seedlings which received minimum field duration for 40-50 days from transplanting to panicle initiation, showed no significant reduction in grain yield. Results in the experiments B1, B2 and C1 (Tables 5, 9, 13) also showed similar effect.

The grain yield per plant was significantly the lowest in control irrespective of the seedling age (Table 24). The causes for yield reduction were the higher percentage of spikelet degeneration and a lower number of spikelets per panicle which significantly produced yield difference with the fertilizer treatments. The effect of treatment N, NP and

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NK on grain yield was statistically similar but significantly lower than NPK treatment. The cumulative effect of NPK application increased 12-21% grain yield per plant over the control. The result indicated that the effect N alone was significantly higher in increasing the grain yield per plant.

However, the combination of NK was higher than NP. Similar insignificant effect of P on the grain yield was also reported by Agarwala (1978). BRRI soil chemists(1977-78), Sadaki and Wada (1975) also found significant effect of N and P on the grain yield. Similar results were reported by Rahman (1981). The grain yield was increased over control only by nitrogen as topdressing in the PI stage. Abichandani and Patnaik (1963), and IRRI (1978) also reported positive response of nitrogen on grain yield.

The findings lead to the fact that older seedlings when transplanted 10-20 days before PI significantly decreased grain yield. The reduction was due to the higher percentage of spikelet degeneration and a lower number of spikelets per panicle. Fertilizer application produced little effect for panicle development of the main culm. It increased the number of panicles but each panicle produced a lower number of spikelets. Moreover, the harvesting period increased because of a prolonged flowering of tillers.

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Irrespective of the fertilizer doses, the seedling age determined the number of spikelets per panicle. The effective field duration when decreased beyond 50 days reduced the number of spikelets per panicle. Evidently that, with an adequate level of NPK in the soil, additional fertilization may show a little or no response on yield.

2.4. Seed rate

Plant population density in different seeding rates (6.25-200 g/m^2) was increased with the corresponding increase in seeding rates. Since 1000-grain weight was different in the varieties, the population density ratio of BR3, Latisail, and BR4 was respectively 1:1.08 :1.42. That is, per unit of BR4 seed weight had 0.42 times more plants than BR3.

From 20 December seeding, the vegetative growth phase increased 50 days for BR3 and 40 days for BR4 from 20 July seeding (Table 28 and 34). Latisail did not produce flowers in Boro because of late seeding in December which did not allow sufficient photoperiod-induction. The vegetative growth phase increased due to low temperature, night temperature especially (12.14^{o}C) in December-February.

The effect of a higher seeding rate (200 g/m^2), irrespective of variety and season, decreased the days to PI and flowering (Tables 28 and 34). Similar effect for a higher

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density was earlier reported by Chang and Yang (1966). Shukla (1979) also reported early flowering in higher seeding rates.

The percentage of spikelet degeneration in different seeding rates showed significant variation in BR3 and BR4 (Table 29). Correlations between the percentage of spikelet degeneration and seeding rate were significant and negative in BR3 and BR4. Spikelet degeneration increased from 16.75 to 50.75% in BR3 and 37.02 to 52.07% in BR4 when seeding rates were increased from 6.25 to 200 g/m^2. A similar trend was found in the transplant Aman season. Spikelet degeneration increased from 21.77 to 55.60% in BR3, 5.70 to 62.84% in BR4 and 14.39 - 49.95% in Latisail (Table 35).

In a higher density plants competed for nutrients, light and space as a result of which their growth was stunted, tillers decreased or was suppressed, they developed short panicles and produced fewer spikelets per panicle (Table 29 and 30). Furthermore, spikelets after initiation decreased by a higher percentage of degeneration. The percentage of spikelet degeneration in the panicles of tillers were higher than the panicles of the main culm per plant (Table 6.2). Similar trends were found in transplant Aman for BR3, BR4 and Latisail (Tables 35 and 36).

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A higher percentage of spikelet degeneration was due to a shortage of nutrients in a higher density of plant population. Tanaka and Garcia (1965) investigated retarded assimilation and restricted absorption of roots due to a higher density of plants. Matsushima (1966) also concluded that the number of degenerated spikelets increased due to nutritional deficiency. On the contrary, a lesser number of plants resulting from a lower seeding rate (6.25 g/m^2) naturally had more space per plant which assisted in more nutrient absorption and nutrition.

Lower seeding rates (6.25-25 g/m^2) had more panicles per plant than higher seeding rates from 50 to 200 g/m^2 (Table 30). Similar effect was found in transplant Aman (Table 36). In wider spacings plants encountered less competition and received more nutrients, moisture, and light. Consequently, they produced more productive tillers. This observation is in close agreement with Safi(1956), Qudus and Huda (1965), Nagi (1959) and Ghosh (1960). With a higher density tiller production decreased and practically produced no tillers when seeding rate was increased to 200 g/m^2. Kakizaki (1965) also reported that higher seeding rates suppressed tillering.

Higher seeding rates (50-200 g/m^2), produced a higher percentage of mortality of plants and tillers mainly before the PI stage, because, in a higher density, the absorption

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of nitrogen before PI seemed to be inadequate (Shukla 1974).

So far as the production of panicles per plant was concerned, the mean number of panicles was significantly reduced with each increment of seeding rates from 50 to 200 g/m^2 (Table 30). It was also true for the transplant Aman season (Table 36). Similar result was reported by Lee (1965) and Chang and Yang (1966). The effect of seeding rates on the production of total panicles per plant showed significant negative correlation with seeding rates. Similar correlations were found in transplant Aman for BR3, BR4 and Latisail. That is, the harmful effect of higher seeding rate was independent of seasonal variation.

The length of the panicle decreased with the increase in the seeding rate accompanying the number of spikelets per panicle (Plate 7, figures 1-8). It was also true for the transplant Aman season (Tables 35 and 36). Similar observation was reported by Lee(1965)and others. The effect of seeding rates on panicle length and spikelets per panicle showed a higher negative correlation. Similar correlations were found in transplant Aman for BR3, BR4 and Latisail. Srivastara *et al* (1974) also found a significant association between panicle length and spikelets per panicle.

Hence, the seeding rate was one of the important factor on the spikelet degeneration and determing the number of panicles per plant, panicle length, and number of

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spikelets per panicle.

The percentage of spikelet sterility significantly increased with each increment of seeding rate (Table 30). Correlations were found significant and positive for BR3 and BR4 (Table 36). Similar trends were found in the transplant Aman season (Table 30 and 36). There are many reports that the percentage of spikelet sterility increased in lower (15-21°C) and higher temperatures (35-41°C). The effect of such temperatures was detrimental to anthesis (Yoshida 1977a,b, 1978). The effect of higher temperatures (33°C maximum and 24°C minimum) at the time of anthesis also increased the percentage of spikelet sterility. However, the effect of a higher density increased further the percentage of spikelet sterility. Tanaka and Garcia (1965) investigated that a lower amount of assimilatory production was the result of a restricted nutrient supply that increased in a higher plant density.

The grain yield/m^2 decreased in higher seeding rates (100 and 200 g/m^2). The correlation between grain yields, and seeding rate was significant and was negative for the varieties. Similar significant and negative correlations were found in transplant Aman (Table 38). The grain yield in different seeding rates (6.25-100 g/m^2) was statistically similar but significantly reduced in a higher seeding rate (200 g/m^2).

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The grain yields in lower and higher seeding rates were compensated by a higher number of panicles/m^2. The density of plants higher in the seed rate of 200 g/m^2. In a higher seeding rate the negative effect of the following offset the positive effect of the total number of panicles /m^2.

- a lower number of spikelets per panicle;
- a higher percentage of spikelet degeneration;
- a higher percentage of spikelet sterility; and
- a reduced grain weight.

Therefore, the grain yield in a higher density was produced mainly by the total number of panicles per unit area (Hesieh *et al*, 1966). Similar results at a variable density was reported by Mehrotra *et al* (1979). In wheat, they used six different densities (100-600 plants/m^2).

The grain yield in different seeding rates in transplant Aman was not similar with Boro. Except for BR3, it significantly decreased with higher seeding rates (25-200/ g/m^2). In BR3, 6.25-25 g/m^2 seeding rate were statistically similar (Table 36). De Datta (1978) reported similar effect of a higher density from IRRI experiments with plant density and nitrogen. According to De Datta (1978) yields up to a certain level was dependent on the rate of fertilizer application or by increasing plant density or the combination of both.

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Since panicles/m^2 did not compensate Boro yields in higher seeding rates,the transplant Aman results differed from Boro. This was because in Boro, a lower number of spikelets per panicle and a higher percentage of spikelet degeneration produced lower grain yield which was not compensated by the higher number of panicles/m^2. This was due to mainly a better growth period in Boro. In the transplant Aman season environmental conditions after October were not at all conducive for better vegetative growth.

Thus it appears that in rice, there exists a maximum limit of panicle number per unit area and this remains, by and large, unaffected under varying population density. The increase of panicle numbers observed under a higher plant density appeared to reflect in a consistently large biological yield but the advantage was offset by a corresponding lowering of harvest index.

Among the characters directly concerned with the grain yield, spikelet number per panicle of the main culm appeared to be most sensitive to variation of plant density.

All these compensating characters resulted in a statistically similar grain yield in the different seeding rates in Boro, except the highest one (200 g/m^2) which gave significantly lower value, a higher value being obtained in a lower

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seeding rate (6.25 g/m^2). Thus, it may be worthwhile to have the maximum yield from the seeding rates of 6.25-25 g/m^2 in transplant Aman and 6.25-50 g/m^2 in Boro.

2.5. Tiller pruning

In order to study the effect of numbers of tillers per plant on the degeneration of spikelets, the restricted tillering was made by tiller pruning. The treatments consisted of the main culm (T) alone or with the number of tillers per plant as one (T_1), two (T_2), three (T_3), four (T_4), and unpruned as control treatment (T_n). This experiment was done in pots in the transplant Aman and Boro seasons.

As the tiller number increased, irrespective of the variety, panicles became smaller with a lesser number of spikelets resulting from a higher percentage of spikelet degeneration of the panicles. In the treatments, the upper limit of spikelet number per panicle was found in a lower number of tillers per plant (Table 40). When, one or two tillers (T_1 or T_2) per plant were kept, in addition to main culm , spikelets per panicle increased in the varieties. Moreover, the percentage of spikelet degeneration also decreased. Similar effect was also found in the Boro season (Table 45). It can be deduced that plants in a lower population level received a comparatively higher

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amount of nutrients, light and space than plants in a higher population level.

On the contrary, when only the main culm was kept alone by pruning the other tillers, the number of spikelets on its panicle did not increase significantly but the percentage of spikelet degeneration increased. Here, in spite of more nutrients, the main culm did not produce the maximum number of spikelets perhaps due to some injurious effect of tiller pruning. That is, the uniculm condition by tiller pruning had a lower number of spikelets by higher spikelet degeneration. This was true for both the seasons. Similar observations were reported from wheat by Saini and Nanda (1979).

Regardless of the variety and season, the percentage of spikelet degeneration significantly increased . . . tiller number was kept intact (T_n). The result showed that 12-17% spikelets degenerated in transplant Aman and 15-21% in Boro. Evidently, this loss to grain yield could be overcome if there was no spikelet degeneration. What is of interest to us is this amount of degenerated spikelets that caused the same amount of loss in grain yield which, in fact, remain unnoticed.

As the number of panicles increased, the higher number of spikelets per panicle failed to attain the grain filling

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stage and increased the percentage of spikelet sterility (Table 41). Nevertheless, there were clearly many spikelets per panicle which reached anthesis but failed to do so by a compensatory mechanism either by the number of panicles or spikelets per panicle.

The percentage of spikelet sterility increased when the main culm was kept alone (T) by pruning other tillers and in the unrestricted tillering treatment (T_n). Similar results were obtained in Boro (Table 46).

The grain yield per plant was significantly higher in the unrestricted tillering than the restricted tillering treatments (Table 41). All the negative effect of a higher tiller number per plant such as the higher percentages of spikelet degeneration and spikelet sterility was compensated by the positive effect of the number of panicles per plant. Similar trend was found in Boro (Table 46). When spikelets per panicle was higher than transplant Aman. The number of tillers per plant in T_n also increased, but the grain yield per plant did not increase significantly, because the values of the yield components in Boro were comparatively lower than transplant Aman for the higher number of panicles. Here, again, it is proved that a higher number of panicles in Boro increased the percentage of spikelet degeneration and spikelet sterility.

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Although the grain yield per plant was significantly higher in T_n, the grain yield per tiller decreased with the increase in tiller numbers. Saini and Nanda (1979) showed an inverse relation of a total ear number in wheat in relation to grain yield. They observed that the grain yield in the uniculm was much less at a lower density and was not better than either unrestricted or restricted tillering at a higher density.

Although plant density is an important yield determinant, (Chandler 1968), at a certain level, the plant growth decreased with the resultant yield reduction (Matsuo 1965). BRRI scientists (1978-79) also reported that the number of grains per panicle had a reverse relation with spacings.

The grain yield per panicle decreased when tiller number per plant increased. However, the higher grain yield per panicle was attributed to one or two tillers kept with the main culm per plant. Similar result was found in the Boro. A linear trend of reduction in the grain weight per panicle was evident from the regression equations of the varieties.

	T. Aman	Boro
BR3	$\hat{Y} = 5.48-0.227x$	$\hat{Y} = 4.11-0.148x$
BR4	$\hat{Y} = 4.67-0.201x$	$\hat{Y} = 5.56-0.227x$
Latisail	$\hat{Y} = 5.10-0.224x$	$\hat{Y} = 2.36-0.068x$

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Regression coefficients were significant at the 1% level. The result clearly indicated that, with every increase of one panicle, the grain weight decreased in the order of 2.27, 2.01 and 2.24 g in transplant Aman and 1.48, 2.27 and 0.68 g in Boro respectively in BR3, BR4 and, Latisail. The decrease of regression coefficients in Boro indicated a higher number of tillers in T_n.

Plants in the unrestricted tillering, though the yield was higher due to compensatory effect of higher number of panicles but the following disadvantages were there :

a. Due to increase in flowering duration for so many panicles, the maturity period also increased and harvesting become difficult.

b. When 80% of the spikelets mature and at this stage harvesting is done to get the maximum benefit but fair amount of spikelets are found either as over matured or less matured. Such a rice mixed with one to under matured grains fetches a lower market price and there is higher percentage of breakage in the milled rice. That is the head rice out turn is always lower which decreases the total value of the crop.

Therefore, the ultimate market value of the crops depends on the quality of head rice production. Profuse tillering

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therefore, is not a desirable thing for the farmer. To avoid this the advanced countries use the higher seed rate in such a way so that the number of panicle bearing tillers per plant may not increase more than three. The grains of the panicle mature at the same time which increase the market value of the crop by reducing breakage in rice milling.

2.6. Leaf pruning

The individual effect of leaf loss by pruning 50% or 100% of the leaf blade was investigated. The emergence of a leaf and its subsequent developmental periods are shown in Tables 50 and 55.

It was observed that complete emergence and full development of n-5 and n-4 leaves took place much earlier before panicle initiation. The plant at that time actually remained in the vegetative phase. The PI took place just before the complete emergence of the n-3 th leaf. The n-3 th leaf emerged 7-10 days after the complete emergence of n-4 th leaf. Since, the panicle was initiated with the emergence of n-3 th leaf. Complete removal of n-4 th leaf blade by pruning before PI adversely affected the normal development of the panicle and spikelets contained therein. However, 50% pruning of the n-4 th leaf, had no significant effect on

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the panicle development. It was also observed that regardless of the variety and the season, the effect of 100% pruning of n-4 th leaf delayed heading by 6-9 days (Tables 49 and 54). Whereas, Rahman *et al* (1977) studied the effect of defoliation in wheat. Defoliation increased the length of the vegetative and spikelet initiation phases.

The effect of total removal (100% pruning) of n-4 th leaf also showed reduction of spikelets per panicle (Tables 51 and 56). The effect of total removal of n-4 th leaf was higher than n-3 th leaf. Rahman *et al* (1977) also observed that defoliation before floral initiation and at floral initiation affected the number of spikelets per spike in wheat.

Regardless of the variety and season, removal of either (100% pruning) n-2 or n-3 th leaf increased significantly the percentage of spikelet degeneration (Tables 51 and 56). Between the leaves n to n-3, the older the leaf, greater was the chance for higher percentage of spikelet degeneration. Partial pruning of n-3 or n-2 th leaf showed no significant effect on the extent of spikelet degeneration.

At the time of PI, it was observed that last three leaves (n, n-1 and n-2) remained inside and n-3 th leaf emerged partly from the leaf sheath. The initiation of spikelets occurred simultaneously with the rapid enlargement

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of n, n-1 and n-2 leaves. The emergence of n-2 th leaf took place at the time of spikelet initiation stage. Spikelets developed rapidly with the enlargement of n-1 and n th leaves. The rate of development of panicle length and spikelets were comparatively higher with the emergence of n-2 th leaf. The complete emergence of n-2 th leaf occurred 8-11 days after full emergence of n-3 th leaf. Hence, regarding spikelet development, the contribution of n-3 th leaf was higher than n-2 leaf. The development of a leaf also showed a relation between spikelet development and spikelet degeneration in the panicle developmental stages (Tables 50 and 55).

This result indicated that the contribution of n-3 th leaf was higher for reducing spikelet degeneration. Hence, 100% loss of n-3 th leaf was not compensated by other leaves. Similarly 100% pruning of n-2 th leaf was not compensated by n-3 th leaf or other leaves. On the contrary, the partial (50% pruning) leaf loss was compensated by the remaining portion of the leaf blade.

It was evident from the observation that n-1 th leaf emerged completely when the panicle attained nearly full size and spikelets were found nearly its full length. Therefore, the spikelet degeneration took place before the complete emergence of n-1 th leaf. Irrespective of the

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variety and season, the effect of 100% pruning of n or n-1 th leaf significantly increased the percentage of spikelet sterility pruning of the leaf blade. The effect of 50% pruning of n or n-1 th leaf was statistically similar with 100% pruning of n-2 or n-3 or n-4 th leaf (Tables 52 and 57). The effect of 100% pruning of n th leaf significantly produced higher spikelet sterility and lower grain weight than 100% pruning of n-1 th leaf.

The emergence of n th leaf (flag leaf) occurred with the complete development of spikelets and at that time most of the anthers had pollen tetrad stage. The result also indicated that effects of 100% pruning of n-2, n-3 and n-4 th leaves increased the percentage of spikelet sterility. The contribution of n th leaf was not compensated by n-1 or other leaves. It was higher than n-1 th leaf.

Mallick and Ghosh Hazra (1977) observed more detrimental effect of both partial and complete defoliation of leaf blades at the reproductive stage decreased the grain yield. The effect of complete defoliation was higher than partial. The present investigation also found a similar effect by pruning 100% of n th leaf (flag leaf) which decreased the number of filled grains per panicle and grain weight.

The result is close agreement with the result of Mitra and Biswas (1976). They observed the effects of 100% pruning

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of n and n-1 leaves. The grain yield per panicle was reduced significantly. The flag leaf is the primary supplier of photosynthate directly to the panicle (Tripathi 1971).

BRRI entomologists (1981) studied the extent of yield loss caused by rice hispa (Dicladispa armigera, oliv.) at the early tillering to maximum tillering stage. They estimated yield loss 30% at the early tillering to mid-tillering stages and 36% at the maximum tillering stage. The grain yield is the product of the yield components. Any decrease of spikelet number per panicle or filled grains per panicle or grain weight ultimately reduced the grain yield. Hence, the function of the leaves when obliterated by 100% pruning or damaged by insects or pests have significant effect on grain yield particularly just before the panicle initiation stage.

Murugesan and Chelliah (1983) studied the effect of leaf-folder (Cnaphalocrocis medinalis, Guen.) on IR20. They reported that 10% increase in flag leaf damage increased the percentage of unfilled grains to 45%. The present investigation showed lower than reported by Murugesan and Chelliah (1983).

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2.7. Photoperiod

The time taken from seeding to PI and flowering (April-June) showed variation under different photoperiod treatments on BR3, BR4 and Latisail (Table 49). From April-June, the normal day length increased (12.7-13.7 hours) and from July-August decreased (13.5-13.0 hours). The three varieties showed different degrees of photoperiod sensitivity.

Though BR3 is insensitive to photoperiod, the PI or flowering was significantly earlier in 10 and 8 hours photoperiod treatments than normal day length exposure. The result indicated that the long-day treatment significantly increased the vegetative growth phase, from short day treatments (10 and 8 hours). In BR3 similar effect for short-day for early flowering was reported by Haque (1977). He observed significant decrease in flowering duration from seeding on 30 July or 15 August for short-day. However, the duration was found to be increased when seeded on 15 February for long-day. Ikeda (1972) also reported early flowering by short-day treatment (9-12 hours) in a photoperiod insensitive variety (Todorokiwase).

The degree of photoperiod sensitivity was measured from the time taken between planting and flowering in long day (13.5-13.7 hours) and short-day (8-hour) treatments. The degree of photoperiod-sensitivity was found 14.29%. Similar result was reported by Haque (1977). The degree of

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photoperiod-sensitivity in BR3 was 19.50% which was higher from this result. The optimum period for early flowering was in between 8 to 10 hours.

BR4, also showed similar trend for short-day photoperiod (10 and 8 hours) treatments. BR4 is slightly sensitive to photoperiod, the normal day length produced flowers only in few tillers per plant. The tillers which received necessary photoperiod induction between the day length 12.7-13.3 hours, produced flowers. Hence, in a long day, the flowering was delayed and PI was suppressed in tillers. Similar conclusion was made by Vergara and Chang (1976). The degree of photoperiod-sensitivity was measured (24.19%) which was higher than BR3. The optimum photoperiod for early flowering was found 8 and 10 hours. The critical photoperiod was around 12.7-13.7 hours. The result of the experiment C2 also showed similar critical photoperioa range for BR4.

Latisail is a photoperiod-sensitive variety the effect of long-day (12.7-13.7 hours) did not initiate panicle in the normal day length treatment (Table 59). Similar result was found in the experiment C2 where the PI was suppressed when day length exceeded 12 hours. Whereas, in short-day (8 and 10 hours) treatment, the PI or flowering was earlier than other two varieties. Similar result was reported by Ikeda (1971 and 1972). He observed early heading in Norin 18

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in short-day (9-12 hours) treatment. The optimum photoperiod for early flowering was found 8-10 hours. The critical photoperiod of Latisail was found 12 hours. The result of the experiment C2 also showed similar day length for critical photoperiod of Latisail. Vergara and Haque (1977) observed the critical range of photoperiod of Latisail was in between 12 and 14 hours.

Irrespective of the photoperiod-sensitive and photoperiod-insensitive varieties, the photoperiod treatment of 6-hour increased the duration to flowering from 8 and 10 hours photoperiod treatments. Similar observations were reported earlier by Morinaga and Kuriyama (1954). They investigated that the vegetative growth phase of Peta rice variety increased in 6-hour photoperiod treatment but decreased in 7 and 8 hours photoperiod treatments. Whereas, the vegetative growth phase again increased with higher photoperiods. Similar observations were reported by Vergara and Haque (1977). They used IR5, IR20, DA31 and Latisail varieties. They showed that the vegetative growth phases of IR5, IR20 and DA31 increased in higher photoperiods more than 12 hours.

The effect of normal day length treatment produced significantly highest number of panicles per plant in BR3, lowest in BR4 and practically zero in Latisail. The effect

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of long-day length exceeding 13 hours suppressed the panicle development in the tillers of BR4, because it is slightly photoperiod-sensitive variety. In BR4 and Latisail 10-hour photoperiod treatment produced significantly highest number of panicles per plant. Irrespective of the variety panicles per plant significantly decreased in 8 and 6 hours photoperiod treatments.

Similarly the number of spikelets per panicle decreased with the decrease in photoperiod duration (Table 60, Plate 6 and figures 1-12). Since spikelet number is one of the major yield components. Hence any increase or decrease in the number of spikelets per panicle influenced the grain yield. The number of spikelets per panicle reduced in two ways viz :

a) lower number of spikelets per panicle and

b) degeneration of spikelets.

The effect of short-photoperiods (8 and 6 hours) significantly decreased the number of spikelets per panicle and increased significantly the percentage of spikelet degeneration (Plate 6, figures 1-12). Consequently the number of potential spikelets per panicle significantly reduced. Percentages of spikelet sterility increased significantly in the lowest photoperiod (6-hour) treatment. On the contrary, 100-grain weight also decreased in lower photoperiods (8 and 6 hours). The grain yield significantly

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decreased in 8 and 6 hours photoperiods because all the yield components showed negative effects. In BR3 the normal day length treatment produced significantly highest grain yield from other lower photoperiod treatments. The effect of 10-hour photoperiod treatment decreased grain yield in BR3 but increased in BR4 and Latisail. Hence 10-hour photoperiod was the critical level in decreasing the grain yield in BR3. Similarly 8-hour photoperiod was critical level for BR4 and Latisail.

Hence, the length of the photoperiods had profound influence on the development of yield components. All the yield components showed significant negative effects when the length of the photoperiods were reduced from 10-hour. The effect of short day length 6-hour decreased significantly the grain yield. There was no compensatory mechanism, because all the yield components showed negative effects in lower photoperiods (8 and 6 hours).

The compensatory mechanism of the yield components were found in the different seedling ages, different seeding dates and fertilizer treatments. However, irrespective of the variety the effect of the day length less than 10-hour, showed significant decrease in the panicle components.

Hence early flowering in lower photoperiod (8-hour), decreased the vegetative growth phase and also decreased significantly the grain yield for all the varieties.

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Chapter V

SUMMARY AND CONCLUSIONS

SUMMARY

A study on spikelet degeneration in rice at different stages of panicle development was undertaken. The experiments were conducted at the Bangladesh Rice Research Institute, Joydebpur, Dhaka. This study included 16 experiments (9 in field and 7 in greenhouse). The objective of the experiments was to study spikelet degeneration in rice at different stages of panicle development and the factors that affect spikelet degeneration. The consequence of spikelet degeneration on the rice yield was also studied.

The following factors were incorporated in this study to determine their effect on panicle development, spikelet degeneration and on yield components.

- Varieties : BR3, BR4 and Latisail.
- Seasons : Transplant Aman (July-December) and Boro (November-April).
- Seedling age : Seedlings of 30, 40, 50, 60 and 70 days old at transplanting from sowing on 15 July (T. Aman) and 40, 50, 60, 70 and 80 days old at transplanting from sowing on 1 November (Boro) 1978.

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- Time of transplanting : Seedlings transplanted on 9 September and 10 March from five different sowing dates (30 June - 9 August 1979) in T. Aman and (20 December - 29 January 1980) in Boro respectively.
- Fertilizer (NPK) Fertilizer N, NP, NK and NPK treatments at 60-60-40 kg $N-P_2O_5-K_2O$/ha.
- Seed rate : Seedling spacings of six different seeding rates (6.25-200 g/m^2) in T. Aman and Boro seasons.
- Tiller pruning : Controlled tiller number by tiller pruning
  T, T+1 = T_1, T+2 = T_2, T+3 = T_3, T+4 = T_4 and T+n = T_n, where T = main culm.1, 2, 3, 4 ..... n = number of tillers with the main culm per plant.
- Leaf pruning : Pruning 50% or 100% of the individual leaf blade per plant of n, n-1, n-2, n-3 and n-4 where, n = flag leaf ,n-1 = leaf below the flag leaf.
- Photoperiod : Normal day length and controlled day length treatments of 10, 8 and 6 hours.
- Seedbed : Continuous growing seedlings under seedbed condition where density of plant population was higher.

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Effects of the factors like varieties, season, seedling ages, time of transplanting, fertilizer (NPK) and seed rate were studied under usual field condition. To study the normal development of panicle and spikelet degeneration, the plants were grown in pots in the greenhouse. Experiments on tiller pruning, leaf pruning and photoperiods were studied in the greenhouse. The seedbed experiments studied the morphological development of panicle and spikelet degeneration.

Three rice varieties, BR3, BR4 and Latisail were used for this study. BR3 (Biplab) was developed at BRRI from a cross of IR506-I-133 x Latisail (DA17). BR3 is a photoperiod insensitive variety and grown in T. Aman, Boro and Aus seasons. BR4 (Brrisail), was also evolved at BRRI from a cross IR20 x IR5-114-3-1 and was recommended for the T. Aman season. It is slightly photoperiod-sensitive. Latisail (DA17) is a local improved variety and sensitive to photoperiod. The three varieties with different degrees of photoperiod-sensitivity were used as a factor to study the effects on the varieties on panicle development, spikelet degeneration and other yield components.

The experiments were conducted in two seasons : Transplant Aman (T. Aman) and Boro seasons. The day length decreases in T. Aman and increases in Boro. The temperature decreases in T. Aman and increases in Boro. Seasonal factors like length of the day, intensity of light and temperature exert

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profound influence on the growth and development of rice plant. The experiments were conducted with different degrees of photoperiod-sensitive varieties to find the effects of seasons on the varieties.

In the field experiments, seedlings were grown in the well prepared seedbeds. Seedbeds were fertilized with 80-60-40 kg $N-P_2O_5-K_2O$/ha, one day before seeding. Seeds were surface sterilized by using 0.01% mercuric chloride solution. Pre-germinated seeds were sown at 150 g/m^2. Seedbeds were properly managed to provide healthy seedlings. The transplanting field was thoroughly prepared. The individual sub-plots were fertilized one day before transplanting at 60-60-40 kg $N-P_2O_5-K_2O$/ha in the T. Aman and 80-60-40 kg $N-P_2O_5-K_2O$/ha in the Boro. Nitrogen was applied in two equal splits according to the treatments of the experiment. The experiments on seedling ages, the experimental plot was laid out in split plot design, varieties were placed in the main plot and seedling ages in the sub-plots with four replications. In the rest of the experiments, the treatments were in the main plot and varieties were in the sub-plots. Standard cultivation practices as recommended in "Adhunik Dhaner Chash" published by BRRI were used for all the experimental works.

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Bottom-sealed earthen pots of equal size were used for the greenhouse experiments. Soil collected from the experimental plots was air dried and then pulverized. The pulverized soil was passed through a 5 mm sieve and mixed several times before potting. A 5 kg of the soil was used for each potting. For the tiller and leaf pruning experiments 1 kg of well rotten powdered cowdungs was used as manure. In the rest of the greenhouse experiments 5 g each urea and triple superphosphate and 3 g of muriate of potash were mixed thoroughly with 5 kg pulverized soil for each pot. The experiments were set up in a completely randomized design. The potted plants were kept weed free and irrigated to maintain the water level 2-3 cm throughout the growing season. The seedbed experiments were conducted in well prepared seedbed. The seedbed was fertilised at 80-60-40 kg N-P_2O_5 and/K_2O/ha. The seed rate used was 150 g/m^2. Seedbeds were properly irrigated and weeded as and when necessary.

The plants were randomly selected from the effective area for sampling. In order to keep the identity of the main culm plant, this was labelled by replaceable wire ring. In the subsequent developmental stages, tillers which emerged from the leaf sheath were kept free out of the wire ring. This process continued for the entire tillering period. The main culms were collected from 60 and 100 days after sowing at three days interval in T. Aman and Boro seasons respectively.

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The shoot apices were dissected under binocular microscope using sharp bow needles. Miscroscopic observations were recorded for each developmental stages of the panicle. The shoot apices also preserved in formaline, acetic acid and ethyl alcohol (FAA) solution (Johansen 1940) for further microscopic observation. Macro-photographs of the panicle developmental stages were made by Nikkon camera using close-up lenses. Similarly, coloured slides were prepared by using Kodak Ektachrome films. The slides and prints were processed at BRRI.

Observations on the following were made :

- Dates of panicle initiation, periods for the development stages of the panicle.
- The number of primary and secondary branches per panicle.
- The number of degenerated panicle branches and spikelets per panicle.
- The number of developing and degenerated spikelets per panicle.
- The number of tillers and panicles per plant.
- The number of filled and unfilled grains per panicle.
- Plant heights at different developmental stages.
- Grain weight and grain yield.

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All the data were taken from 50 samples in each treatment and in each replication. The data were statistically analysed following Little and Hills (1972); and Zaman, Rahim and Howlader (1982).

Panicle Development and Spikelet Degeneration

The morphological development of rice panicle was made from the greenhouse and seedbed experiments in T. Aman and Boro seasons 1978-79.

Rice panicle passes through two major growth phases : Vegetative and reproductive. The vegetative growth phase duration differed in the varieties irrespective of season and cultural practice. Panicle initiation (PI) occurred earlier in the seedbed where the density of plants were higher than normal planting. In transplant Aman(summer rice) PI was found 40-45 days earlier than Boro (winter rice), regardless of variety and cultural practices. In the PI stage of the main culm, there was a gap of 10-15 days between maximum tillering and young panicle formation. Tillers which developed after PI of the main culm had 3 to 4 leaves and degenerated. The main culm of each plant initiated panicle earlier than other tillers of a plant.

The development of panicle from neck-node development to heading stages could be divided into seven stages based on the developing structures and period for each developmental

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stages. The successive developmental stages were; neck-node, primary branch, secondary branch, spikelet, pollen mother cell, meiosis in anther cell and heading. The total duration for the developmental stages from neck-node to heading varied from 28 to 32 days, regardless of the variety, seasons and cultural practices.

The panicle branch primordia developed basipetally in succession into primary branch and on the primary branches developed secondary branch primordia in the same manner. Spikelets developed at the tip of each of the panicle branches. The panicle is branched and terminated by spikelets. The panicle is a complex racemose inflorescence. Spikelets growth proceeded from upper to lower panicle branches. Number of primary, secondary branches and spikelets per panicle were significantly different in the varieties, seasons and cultural practices.

Shortly after spikelet initiation, spikelets developed rapidly accompanying the panicle branches. When the top spiklets of the primary branch reached pollen mother cell forming stage, some of the panicle branches and spikelets ceased to develop and degenerated 5 to 10 days before heading. The number of secondary panicle branches degenerated more than those of the primary branches. The number of panicle branches were higher in the sub-basal and basal part of the panicle. The degeneration of panicle branches were higher in the basal part of the panicle. Percentages of panicle branch and

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spikelets degeneration were significantly different in the varieties, seasons and cultural practices. Irrespective of the variety and season, the plants in the seedbed produced short panicles, few spikelets per panicle and degenerated higher percentage of spikelets than normal planting condition.

In the meiotic stage the spikelet dimensions were 5.5-7 mm in length, 1.3-1.8 mm in breadth and the anther lobes varied from 0.6-1.2 mm in length. The panicle size increased from 3.8 to 21.5 cm during the meiosis. In the seedbed the panicle size was 2.5-8.5 cm in the meiotic stage. In the meiotic stage the nth leaf (flag leaf) exerted from the boot to an approximate extent of 3/5 to 4/5 th of its full length. In the heading stage the panicle emerged from the leaf sheath in between 28 to 32 days after neck-node development stage.

The heading stage was followed by anthesis. Some of the spikelets failed to attain anthesis and these spikelets became sterile. The percentage of spikelet sterility were significantly different in the varieties, seasons and cultural practices.

Plant height development was significantly reduced in the Boro than T.Aman. In the seedbed plants were short.

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The dry matter content significantly increased in the panicle initiation stage and significantly different in the varieties, season and cultural practices.

Seedling Age

Field experiments were conducted in T. Aman and Boro seasons to findout the effects of various seedling ages on panicle development, spikelet degeneration and yield components.

Seeds were sown on 15 July 1978 and seedlings of 30, 40, 50, 60 and 70 days old were transplanted. Regardless of the seedling ages the mean time taken for PI in the main culm from seedling were 80, 60, 90 and 83 days respectively in BR3, BR4 and Latisail. Seedling ages showed no significant variation on the age for PI. Field duration (days after transplanting) for PI in the main culm in the seedling ages from 30 to 70 days old significantly decreased from 45 to 05 days in BR3, 55 to 20 days in BR4 and 50 to 12 days in Latisail. Regardless of the variety and seedling age duration between neck-node development and heading stage had a range of 28 to 32 days.

Correlation between the number of primary and secondary branches per panicle with the seedling ages was negative and significant for the varieties (BR3, BR4 and Latisail). The percentage of panicle branch degeneration also showed positive and significant correlation with the seedling ages of the

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varieties. Regarding spikelets per panicle, the regression coefficients were highly significant for the varieties.For each day delay in transplanting, the number of developing spikelets per panicle decreased in the order of 3.69, 3.25 and 1.53 respectively in BR3, BR4 and Latisail.

The percentage of spikelet degeneration in higher seedling ages (60 and 70 days old) increased in BR3 and BR4 but decreased in Latisail. The spikelet degeneration in the seedling ages from 30 to 70 days old were 12.25 to 25.45% in BR3, 6.10 to 10.92% in BR4 and 13.45 to 8.01% in Latisail. Correlation between seedling ages and percentages of spikelet degeneration was significant for the varieties. The correlations were positive for BR3 and BR4 but negative for Latisail.

Plant heights, number of panicles per plant, panicle length and grains per panicle showed significant negative correlation with the seedling ages for the varieties. The percentage of spikelet sterility increased in higher seedling ages of BR3 and BR4 but decreased in Latisail. The correlation between seedling ages and percentages of spikelet sterility was significant for the varieties. Correlation were positive in BR3 and BR4 but negative in Latisail.

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Transplanting 30 to 50 days old seedlings, the grain yield decreased from 5.13 to 4.47 t/ha in BR3, 6.94 to 5.55 t/ha in BR4 and 4.90 to 4.25 t/ha in Latisail. The grain yield reduced from 3.56 to 1.15 t/ha in BR3, 5.35-5.26 t/ha in BR4 and 4.01 to 2.81 t/ha in Latisail when 60 and 70 days old seedlings were used for transplanting. The grain yields showed significant and negative correlation with seedling ages for the test-varieties. The grain yields in higher seedling ages were decreased because all the yield components had negative effect in higher seedling ages. In Latisail the grain yields in higher seedling ages were not compensated by the lower percentages of spikelet degeneration.

Seedlings of 40, 50, 60, 70 and 80 days old were transplanted for the Boro experiments. Transplanting seedlings of 40 to 80 days old, the field duration between transplanting and panicle initiation (main culm) significantly decreased from 80 to 50 days in BR3, 82 to 52 days in BR4 and 80 to 50 days in Latisail. Irrespective of the variety and seedling age the period from neck-node development to heading had a range of 29-33 days and from anthesis to development of caryopsis took another 30-33 days.

The number of panicle branches (primary or secondary) and percentages of panicle branch degeneration showed no significant difference in the seedling ages. Correlation between seedling ages and number of panicle branches or

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percentages of panicle branch degeneration was not significant. This was quite opposite to the results of the T.Aman season. Transplanting 40 to 60 days old seedlings, the number of spikelets per panicle of the main culm showed no significant variation. Regardless of the variety 80-day-old seedlings produced significantly lowest number of spikelets per panicle. Correlation between spikelets per panicle and seedling ages was significant and negative for BR3, BR4 and Latisail.

Spikelet degeneration decreased 11.71 to 9.44% in BR3, 17.23 to 13.01% in BR4 and 2.11 to 16.94% in Latisail with the increase in transplanting age of seedlings from 40 to 80 days. The correlation between seedling ages and percentages of spikelet degeneration were significant and negative for the varieties. The results were quite opposite from transplant Aman season.

The number of panicles per plant decreased in higher seedling age. The correlation between seedling ages and number of panicles per plant were significant and negative for the varieties. Percentages of unproductive tillers showed significant and positive correlation in the varieties. Latisail produced maximum unproductive tillers with higher seedling ages as the later developed tillers did not get photoperiod induction to produce panicle.

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The percentage of spikelet sterility decreased in higher seedling ages, and significant only for BR3. The correlation between seedling ages and percentages of spikelet sterility was significant and negative for BR3 but insignificant for BR4 and Latisail.

Transplanting seedlings from 40 to 80 days old grain yields were 6.04-5.97 t/ha in BR3, 7.35-6.55 t/ha in BR4 and 5.58-4.69 t/ha in Latisail. In Boro grain yields in the higher seedling ages were not decreased significantly, because grain yields were compensated by the positive effect of lower percentage of spikelet degeneration.

Time of Transplanting

Five different seeding dates at 10 days intervals were used to produce seedlings and were transplanted on the same date. This provided variability in the seedling age at the time of transplanting. The experiments were done in T. Aman and Boro seasons to determine the effects of seeding dates and seedling ages on panicle development, spikelet degeneration and other yield components.

Seeds were sown from 30 June to 9 August and seedlings were transplanted on 9 September 1979. Date of seeding and seedling ages showed insignificant variation on the age for PI of the main culm in BR3 but significant in BR4 and Latisail. Field durations (transplanting to PI of the mean

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culm was found to decrease in early seedings for BR3, because of higher seedling ages. On the contrary, BR4 and Latisail being sensitive to photoperiod took more or less identical period for various seedling ages for the initiation of panicle. This was the result of photoperiod-induction in a particular day length.

Number of primary and secondary branches per panicle showed a significant and negative correlation with the seedling ages in BR3, BR4 and Latisail. Regardless of the variety, the percentage of panicle branch degeneration had also significant and positive correlation with the seedling ages for the varieties.

The number of spikelets per panicle significantly decreased in higher seedling age (70-day-old seedlings). The correlation between seedling ages and number of spikelets per panicle of the main culm was significant and negative for the three varieties.

Regardless of the variety, the percentage of spikelet degeneration significantly increased in higher seedling age (70-day-old seedlings). Transplanting 30-day-old seedlings, irrespective of the variety the percentage of spikelet degeneration decreased from higher seedling ages. Percentages of spikelet degeneration in the varieties showed significant and positive correlations with the seedling ages.

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Regardless of the variety, the number of per panicle per plant increased in higher seedling ages. The correlation between seedling ages and the number of panicles per plant was significant and positive for the varieties. The result was just opposite to the result of T. Aman. The difference was the time of transplanting.

In Boro, grain yields in higher seedling ages although decreased but showed insignificant variation between the seedling ages. Grain yields in higher seedling ages were compensated by the positive effect of panicles per plant which offset the negative effects of higher percentage of spikelet degeneration and lower number of spikelets per panicle.

In the Boro field experiment seedlings from five different seeding dates (20 December-29 January) were transplanted on 10 March 1980. Age for PI of the main culm decreased in late seedlings from 20 December. Latisail did not initiate panicle when seeded from 30 December to 29 January and transplanted on 10 March. Furthermore, seedlings transplanted from 20 December, produced panicle only in the main culm per plants, because the daylength was critical to Latisail.

Number of secondary branches and spikelets per panicle significantly decreased in late seeding (29 January) than from early seeding (20 December). Correlations between seedling ages and number of secondary branches per panicle and spikelets per panicle were significant and positive for BR3 and BR4.

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The percentage of panicle branch degeneration and spikelet degeneration showed significant correlations with the seedling ages; negative for BR3 but positive for BR4.

Number of panicles per plant in late seeding (29 January) increased in BR3 but decreased in BR4. The correlation between seedling ages and number of panicles per plant was significant and negative for BR3 but significant and positive for BR4. Percentages of non-effective tillers showed significant correlation with the seedling ages; positive for BR3 but negative for BR4. BR4 being a weakly photoperiod sensitive variety produced lower number of panicles in late seeding for critical day length exceeding 13 hours.

Grain yields of BR3 in different seedling ages (40 to 80 days old) were not decreased in higher seedling ages. Because the yield difference was compensated by the positive and negative effects of the yield components. The grain yield in BR4 significantly reduced in late seeding (29 January) in spite of a lower seedling age (40-day-old). The grain yield was not compensated by the yield components, because the lower number of panicles per plant.

The practical significance of these findings are following :

Seedings from 30 June to 9 August (T. Aman) and transplanted on 9 September had similar effect on grain yield in BR3, BR4 and Latisail.

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Similarly seedings from 20 December to 29 January and transplanted on 10 March had similar effects on grain yield in BR3 but decreased in BR4 and practically nil in Latisail.

Hence, early seeding in transplant Aman and late seeding in Boro for a photoperiod-sensitive variety have no economic benefit.

Fertilizers (NPK)

Field experiment was designed to evaluate the effects of fertilizers N, NP, NK and NPK at different seedling ages on spikelet degeneration and other yield components.

Seeds were sown on 15 July 1979 and seedlings were transplanted after 30, 40, 50, 60 and 70 days from sowing date. Effects of fertilizer treatments on seedling ages at transplanting showed no significant variation on panicle developmental stages. Transplanting 70-day-old seedlings irrespective of the fertilizer treatment PI took place earlier among the seedling ages. Regardless of the fertilizer treatment, field duration significantly decreased with the increase in seedling age.

Irrespective of the seedling ages, effects of fertilizers significantly increased the number of secondary branches per panicle and spikelets per panicle over control treatment (0-0-0). Regardless of the fertilizer treatments, the number of secondary branches per panicle and spikelets per panicle

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significantly decreased in higher seedling ages (50, 60 and 70 days old). The effect of N and NPK increased the number of secondary branches per panicle.

Regardless of the fertilizer treatments, the percentage of spikelet degeneration significantly increased in higher seedling ages (60 and 70 days old). Effects of fertilizers significantly decreased the percentage of spikelet degeneration. Irrespective of the seedling ages effect of N alone significantly decreased the percentage of spikelet degeneration.

The effect of N and NPK increased the number of effective tillers per plant. Seedlings transplanted 20-10 days before panicle initiation (60-70 days old seedlings), the field duration for the main culm significantly decreased but the field duration of tillers significantly increased. As a result, plants produced higher number of tillers, lower number of spikelets per panicle and different maturity period.

Irrespective of seedling ages effect of fertilizers significantly increased grain yield over control treatment. Irrespective of fertilizer treatments grain yield per plant significantly decreased in higher seedling age (70-day-old). Higher percentage of spikelet degeneration and lower number of spikelets/panicle produced lower grain yield. Grain yield difference between 30 to 60 days old seedlings were compensated by the positive and negative effects of yield components.

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Seed Rate

The field experiments were conducted in T. Aman and Boro seasons 1980-81 with six different seeding rates (6.25-200 g/m^2). Higher seeding rates increased plant density and decreased plant spacings. The different seeding rates were used to determine the effects on panicle development, spikelet degeneration and on other yield components.

Regardless of the variety and season plants with higher density (200 g/m^2) initiated panicles earlier but in late seeding (20 December), Latisail did not produce panicle.

The effect of higher seeding rates (100-200 g/m^2), irrespective of the variety and season decreased significantly panicle length, spikelets per panicle, panicles per plant and plant height. The correlation of the above components with the seeding rates was also significant and negative.

Irrespective of the variety and season, the percentage of spikelet degeneration significantly increased with higher seeding rates (100-200 g/m^2). The correlation between seeding rate and percentage of spikelet degeneration was significant and positive for the three varieties.

The percentage of spikelet sterility significantly increased with each increment of higher seeding rate. The correlation between seeding rate and the percentage of spikelet sterility was significant and positive for all the varieties.

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Grain weight and grain yield decreased in the Boro with higher seeding rate (200 g/m^2). Although grain yields obtained with other higher seeding rates did not decrease significantly. Because the higher number of panicles per m^2 compensated all negative effects of the yield components. The effect of higher seeding rates (50 to 200 g/m^2) in transplant Aman showed significant decrease in grain yield, because the grain yields were not compensated by the higher number of panicles per m^2.

Tiller Pruning

The effect of tiller number per plant on spikelets degeneration and other yield components were studied in greenhouse, T. Aman and Boro seasons.

Regardless of the variety and season, the number of primary and secondary branches per panicle significantly decreased in the control treatment. The number of spikelets per panicle also decreased with the increase in tiller number per plant.

The percentage of spikelet degeneration significantly increased in the control treatment. Irrespective of the varieties and seasons percentages of spikelet degeneration were significantly lowest when the main culm was kept along with one or two tillers per plant. The percentage of spikelet degeneration also increased in the main culm when kept alone per plant. Regardless of the varieties and treatments, the

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percentage of spikelet degeneration was significantly the highest in the Boro season than that of transplant Aman season. The percentages of spikelet sterility also significantly increased in the control treatment and increased in the main culm when kept alone.

Regardless of the variety and season, the grain yield per panicle decreased with the increase of tiller or panicle number per plant. For every increase in tiller number the grain weight per panicle decreased in the order of 2.27, 2.01 and 2.24 mg in the transplant Aman and 1.48, 2.27 and 0.68 mg in the Boro respectively in BR3, BR4 and Latisail. The grain yield per panicle was the highest when the main culm was kept along with one or two tillers per plant. When the main culm was kept alone (uniculm) grain yield per panicle was not better than the main culm along with three or four tillers per plant. The grain yield per panicle of the main culm alone decreased for higher percentages of spikelet degeneration and sterility. Regardless of the variety and season the grain yield per plant significantly the highest in the control treatment, because the grain yield was compensated by the higher number of panicles per plant.

Leaf pruning

The greenhouse experiments were conducted in transplant Aman and Boro seasons to evaluate the effects of leaf loss

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(by leaf pruning) on panicle development, spikelet degeneration and spikelet sterility.

Forty and 30 days old seedlings were transplanted on 10 December 1978 and 15 August 1979 respectively. The leaf pruning treatments consisted of pruning of specific leaf per plant (main culm) either 50% or 100% of the leaf blade after complete emergence. The number of degenerated and developing spikelets per panicle were studied three to five days before heading.

The effect of 100% pruning of n or n-4 th leaf increased the days to heading. The effect of 100% pruning of n-2 or n-3 th leaf increased significantly the percentage of spikelet degeneration irrespective of the varieties and seasons. Moreover, of 100% pruning of n-3 th leaf produced significantly the highest percentage of spikelet degeneration. The effect of 50% pruning of n-2 or n-3 or 100% pruning of n-4 th leaf slightly increased the percentage of spikelet degeneration.

Irrespective of the varieties and seasons 100% pruning of n or n-1 th leaf significantly increased the percentage of unfilled grain or spikelet sterility and 100% pruning of n th leaf produced significantly the highest percentage of spikelet sterility. Effect of 50% pruning of n or n-1 th leaf or 100% pruning of n-2 or n-3 th leaf slightly increased

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the percentage of spikelet sterility. Regardless of the variety and season 100-grain weight significantly decreased by 100% pruning of n or n-1 th leaf.

Photoperiods

Effects of different photoperiod treatments on panicle developments, spikelet degeneration and other yield components were studied under greenhouse condition. Seeds were sown on 1 April 1979. The photoperiod treatments consisted of normal daylength, 10, 8 and 6 hours day length from 20th day of seedling age.

Irrespective of the varieties, PI took place earlier in 10 and 8 hours day length treatments but the effect of 6-hour treatment delayed PI. The normal day length treatment, suppressed PI of Latisail and delayed in PI of BR3 and BR4. In normal day length treatment, BR4 produced average of 3.92 panicles per plant and the PI in other tillers was suppressed.

In April to June, the normal day length increased 12.7-13.7 hours and from July to August slightly decreased (13.5-13.0 hours). Latisail being a photoperiod-sensitive variety, the long-day-length prevented panicle initiation. BR4 being a weakly photoperiod sensitive variety, the tillers which received photoperiod induction between the day length 12.7-13.3 hours produced flowers. BR3, is insensitive to photoperiod, the long day length increased the duration to panicle initiation.

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Regardless of the variety, number of panicle branches, panicle length, plant height and spikelets per panicle significantly decreased in 6-hour day length treatment.

Spikelet degeneration increased 18.47 to 45.65% in BR3 and 25.96 to 40.78% in BR4 between normal day length and 6 hours treatments. In Latisail spikelet degeneration increased 16.57 to 37.30% in 10 to 6 hours day length treatments. Regardless of the variety the percentage of spikelet degeneration significantly increased in 8 to 6 hours day length treatments.

The number of tillers per plant decreased shorter day length. The number of panicles per plant in BR3 significantly decreased with the decrease in day length from 10 to 6 hours. The number of panicles per plant in BR4 significantly lowest in normal day length treatment. Effects of 8 and 6 hours day length significantly decreased the number of panicles per plant in BR4 and Latisail.

Effect of 8 and 6 hours day length treatments significantly reduced the grain yield per plant in BR4 and Latisail. The grain yield per plant in BR3 significantly decreased in 10 to 6 hours day length treatment than normal day length treatment. The grain yields in short day length treatments (8 to 6 hours) were not compensated by other yield components, because the number of grains per panicle significantly decreased by higher percentages of spikelet degeneration and sterility. The dry matter contents decreased significantly in all the three varieties in short day length (6-8 hours).

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CONCLUSIONS

Panicle Development and Spikelet Degeneration Under Normal and Seedbed Conditions

- The low temperature in the beginning of the Boro season increased the vegetative phase by 40-45 days more when the same variety is grown in transplant Aman.
- Panicle initiation occurs earlier in seedbed population with higher density.
- The period of panicle development from neck-node to heading stages has been divided into seven different stages, the stages are related with the periods of development and developing structure.
- The development period from neck-node to heading stages does not significantly vary from variety to variety or season to season or normal planting to seedbed condition.
- The process of degeneration found to start during the period when the terminal spikelets get ready for meiosis. Degeneration of a panicle branches and spikelets occurred 10 to 15 days after the development of neck-node.

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- Degeneration continued 5 to 10 days until heading.
- The degeneration is not confined to the basal spikelet region but spreads throughout the panicle branches.
- Degeneration of spikelets was more pronounced than panicle branch degeneration. Secondary branches degenerated more frequently than primary branches. The lower secondary branches degenerated more than the upper secondary branches.
- Number of spikelets in the main culm was higher compared to the tillers but percentage-wise the extent of degeneration was same.
- The plants in the seedbed developed short panicle, few spikelets per panicle and degenerated lower number of spikelets than normal planting condition.
- The panicle branch gap or rudimentary panicle branches was the result of suppression of panicle branch primordia.
- The spikelet degeneration in BR3, BR4 and Latisail differed significantly and the varietal differences were maintained under different seasons and cultural condition showed different amount of spikelet degeneration.

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- The dry matter content significantly increased in the PI stage and significantly different in the varieties, season and cultural practices.

Seedling Age

- Irrespective of seedling ages, seasons and varieties, the duration from neck-node development to heading showed insignificant variation.
- Seedling age at the time of transplantation was found to be one of the most important factor in determining the extent of spikelet degeneration.
- Seedlings transplanted less than 20 days before panicle initiation, percentages of spikelet degeneration increased significantly.
- Older the seedlings ages at the seedbed the greater is the degeneration of spikelet irrespective of the variety and season. The same was found to be true for grain yield.
- Seedling age was the determining factor for grain yield. The threshold value for effective field duration was found to be 50 days and found critical for economic yield regardless of the variety and season.

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- Thirty-day-old seedlings of BR3, BR4 and Latisail in transplant Aman performed better when transplanted on 15 July. In Boro, seedlings transplanted 40 to 70 days after 1 November produced similar effect on grain yield.

Time of Transplanting

- Regardless of sowing dates, panicle initiation was observed within the fixed period after transplantation in the photoperiod-sensitive variety (Latisail). In the photoperiod-insensitive variety BR3, panicle initiation was dependent on the total period of its growth from sowing.
- When day length exceeded 12 hours, Latisail did not produce panicle, when day length exceeded 13 hours, panicle formation in tillers was suppressed in BR4.
- Irrespective of varieties, when higher aged seedlings were transplanted in less than 20 days before panicle initiation the percentage of spikelet degeneration increased.
- Late seeding (9 September and 29 January) of BR3 produced a higher number of panicles per plant at the same time enhanced the amount of spikelet. In a weakly photoperiod-sensitive variety (BR4) panicle

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number showed reduction under long-day length (12.7 hr) and reduced the percentage of spikelet degeneration.

- In Boro irrespective of sowing dates (20 December to 29 January) and seedling ages, the photoperiod-insensitive variety (BR3) produced similar grain yield. The grain yield significantly decreased in the weakly photoperiod sensitive variety (BR4) when younger seedlings were transplanted (10 March) in the long-day.

- The variation of grain yield of photoperiod-sensitive varieties irrespective of the seedling ages were insignificant for similar field durations when transplanted on 9 September. Reverse was the case for a photoperiod-insensitive variety (BR3).

  In other words sowing dates (20 December to 29 January) and seedling ages(80 to 40) at transplanting (10 March) had no influence on the grain yield of photoperiod-insensitive variety in the Boro season but this is no so in the T. Aman season because of short field duration.

Seed Rate

- Higher seeding rates exceeding 50 g/m^2 increased significantly a higher percentage of spikelet degeneration and sterility, irrespective of seasons.

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- The grain yield in Boro season had similar effect for the seeding rates from 6.25 to 100 g/m^2. In transplant Aman, seeding rates of 6.25 to 12.50 g/m^2 increased grain yield. With the seed rate (100-200 g/m^2) the population density increased which in turn reduced the number of grains per panicle, thereby reducing the overall yield inspite of the increased number of panicle. Grain yield upto a certain seed rate increased proportionately, beyond this level increase in seed rate did not influence the higher grain yield.

Fertilizers

- Application of NPK at 60-60-40 kg N-P_2O_5-K_2O/ha increased significantly the percentage of spikelet degeneration. The effect of N was higher than P or K in reducing spikelet degeneration.
- Regardless of fertilizer treatments, spikelet degeneration in older seedlings was higher when they were transplanted less than 20 days before panicle initiation. Grain yield was also significantly reduced in such situation.
- Addition of N or NPK increased the number of panicle branches.

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- Fertilizer treatments had no effect in influencing the number of spikelet degeneration when the field duration was less than 50 days.
- Application of N, NK, and NPK increased the number of spikelets per panicle when applied at the panicle initiation stage.
- Nitrogen when topdressed at the time of panicle initiation of the main culm, increased the number of panicles per plant.
- Cumulative effect of NPK was higher than individual effects of N, P or K in increasing the grain yield. Addition of fertilizers extended the period of tillering in T. Aman seedlings transplanted after 20 days but reduced grain yield.

Tiller Pruning

- The number of spikelets per panicle decreased with the increase of tiller number per plant.
- Spikelet degeneration increased significantly with a higher number of tillers per plant.
- In the main culm with one or two tillers produced higher spikelets per panicle and lower percentage of spikelet degeneration.

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- Irrespective of the variety and tiller number per plant spikelet degeneration increased significantly in the Boro season compared to T. Aman season.
- Higher the number of tillers per plant, the greater was spikelets sterility.
- Higher the number of tillers per plant, the lower was the grain yield per panicle.
- Grain yield per panicle was significantly higher when one or two tillers per plant were associated with the main culm.

Leaf Pruning

- Heading time was delayed by complete removal of n or n-4th leaf blade.
- The percentage of spikelet degeneration significantly increased by 100% pruning of n-2 or n-3th leaf. Effect of 100% pruning of n-3th leaf was higher than n-2th leaf on the degeneration of spikelets. Pruning of 50% of the leaf blade did neither significantly affect the spikelet number nor did it enhance the spikelet degeneration.
- The percentage of spikelet sterility and grain weight significantly decreased by 100% pruning of n or n-1th leaf. This effect was higher for nth leaf.

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Variable Photoperiods

- Optimum photoperiod for induction of flowering in the varieties (BR3, BR4 and Latisail) was 8 and 10 hours.
- Short-day length below 8 hours delayed panicle initiation in all the varieties.
- Regardless of the varieties, 6 and 8 hours exposure of day light increased significantly the percentage of spikelet degeneration, the highest percentage of spikelet degeneration being found at the latter day length. Under 6 and 8 hours day light exposure, the percentage of spikelet degeneration remained unaltered in application of various doses of fertilizers.
- All the yield components decreased significantly with short-day length (6 hours).
- Grain yield in BR3 was significantly higher in normal day length treatment (12.7-13.7 hours). Effect of normal day length prevented panicle initiation in Latisail and suppressed it in BR4.
- Dry matter content decreased significantly in plants of all the three varieties exposed to 6 and 8 hours day length.

Table 1. Development of shoot apices of BR3, BR4 and Latisail as influenced by transplant Aman and Boro seasons.

Sowing date	Vegetative shoot apex with bract	Development of panicle						
		Age of plant (DS)[a]						
		Panicle initiation (neck-node)	Spikelet	PMC[b]	Active reduction division	Heading	Anthesis	Ripening
				BR3				
15 Jul	68-70	70-75	80-85	85	90-95	98	100-105	130-135
01 Nov	108	110-115	120	125	135	142	145-150	175-180
				BR4				
15 Jul	75	80-85	90	95	105	110	112-115	145-150
01 Nov	118	120-125	130	138	144	152	155-157	185-190
				Latisail				
15 Jul	82	85-90	90-95	100	110	115	117-120	150-155
01 Nov	110	115-120	125	130	138	145	148-150	180-182

[a]DS Days after sowing.

[b]PMC Pollen mother cell.

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Table 2. Relative development of panicle length, spikelet and anther lobe length at the panicle development stages of BR3, BR4 and Latisail, transplant Aman. (1978)

Developing structures	Panicle developmental stages[a]		
	PMC forming stage[b]	Meiotic stage	Heading stage
		BR3	
Panicle length (cm)	3.5-4.0	3.8-18.5	24.5
Spikelet length (mm)	3.5-4.5	6.4- 6.5	7.5-8.0
Spikelet breadth (mm)	0.9-1.2	1.3- 1.5	1.8-2.1
Anther lobe length (mm)	0.3-0.5	0.6- 1.1	1.5-1.8
		BR4	
Panicle length (cm)	4.0-9.5	8.5-21.5	27.3
Spikelet length (mm)	3.6-4.1	5.6-7.0	8.0-8.2
Spikelet breadth (mm)	1.0-1.3	1.5-1.8	2.3-2.5
Anther lobe length (mm)	0.6-0.7	0.8-1.2	1.6-2.0
		Latisail	
Panicle length (cm)	3.5-7.5	6.5-20.5	26.5
Spikelet length (mm)	3.4-4.0	5.5- 6.5	8.0-8.2
Spikelet breadth (mm)	0.8-1.0	1.3- 1.6	2.2-2.6
Anther lobe length (mm)	0.5-0.7	0.8- 1.0	1.6-2.0

[a] Development measured from the topmost spikelet.

[b] PMC Pollen mother cell.

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Table 3. Developmental stages of panicles of BR3, BR4 and Latisail as influenced by seedling ages, transplant Aman, 1978.

Transplanting date	Seedling age at transplanting (DS)[a]	Maximum tillering period (DT)	Total age for panicle initiation (DS)	Panicle developmental stages (DT)[b]				
				Panicle initiation	Meiotic	Heading	Anthesis	Ripening
				BR3				
15 Aug	30	42	75	45	64	74	77	108
25 Aug	40	40	80	40	58	68	70	102
04 Sep	50	35	86	36	55	64	67	98
14 Sep	60	25	87	27	46	64	57	88
24 Sep	70	24	75	05	23	33	36	69
				BR4				
15 Aug	30	50	85	55	74	85	88	118
25 Aug	40	45	90	50	68	78	80	110
04 Sep	50	40	90	40	59	68	72	103
14 Sep	60	35	95	35	33	62	65	95
24 Sep	70	35	90	20	39	47	50	85
				Latisail				
15 Aug	30	48	80	50	70	80	83	115
25 Aug	40	50	83	43	63	72	75	105
04 Sep	50	35	85	35	53	62	64	97
14 Sep	60	24	85	25	42	52	54	84
24 Sep	70	28	82	12	30	39	43	76

[a]DS Days after sowing. [b]DT Days after transplanting.

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Table 4. Effect of seedling ages on the degeneration of spikelets and development of panicle components of BR3, BR4 and Latisail, transplant Aman, 1978 (av.of four replications).

Seedling age at trans-planting (days)	Branches (no./panicle)		Spikelets (no./panicle	% Degeneration		Panicle length (cm)	Plant ht (cm)	% spikelet reduction from 30-day-old seedlings
	Primary	Secon-dary		Panicle branches	Spikelet (no./panicle			
				BR3				
30	11.43	40.44	190.76	13.01	12.74	25.17	82.89	-
40	10.06	32.53	175.19	12.96	12.25	24.76	81.24	8.16
50	9.62	29.73	163.64	13.47	12.66	23.18	76.09	14.21
60	8.01	20.32	117.80	17.71	16.58	20.89	62.73	38.24
70	5.40	10.39	44.34	18.37	25.45	18.38	51.08	76.76
				BR4				
30	12.41	60.63	286.47	7.35	6.50	27.56	115.35	-
40	12.01	51.49	276.14	6.57	6.10	27.46	103.86	3.61
50	11.53	49.44	249.57	7.07	6.75	26.07	97.48	12.88
60	11.20	44.38	211.12	8.50	7.76	25.84	95.56	26.30
70	9.68	32.27	169.10	10.22	10.92	22.37	78.80	40.97
				Latisail				
30	11.75	35.41	177.29	14.76	13.45	26.07	119.01	-
40	9.71	32.04	157.84	9.25	9.15	25.79	114.80	10.97
50	9.12	24.38	118.67	7.39	8.08	24.38	103.81	33.06
60	9.07	23.85	118.11	7.47	7.55	22.87	89.29	33.38
70	9.01	22.50	116.31	7.48	8.01	20.24	79.63	34.40
F. test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Sig Significant.

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Table 5. Grain yield and other quantitative characters of BR3, BR4 and Latisail as influenced by seedling age, transplant Aman 1978 (av. of four replications).

Seedling age at transplanting (days)	Panicle (no./plant)	Filled grains (no./panicle)		% spikelet sterility	1000-grain wt (g)	Grain yield (g/plant)	Grain yield (kg/ha)
		Main culm	Tillers				
			BR3				
30	13.93	135.39	84.70	15.03	28.30	30.78	5129
40	13.22	126.67	77.42	16.53	28.25	28.95	4807
50	11.88	115.85	73.60	17.78	28.30	26.80	4468
60	10.68	72.38	43.68	24.41	27.45	21.34	3556
70	6.68	20.26	20.89	33.97	23.26	6.94	1154
			BR4				
30	14.63	214.05	172.45	18.01	21.06	43.67	6941
40	13.78	205.92	168.02	19.03	21.10	39.97	6662
50	12.58	181.80	152.87	21.99	20.90	35.08	5550
60	10.90	145.91	133.93	26.65	20.76	32.13	5354
70	8.22	103.76	116.63	31.14	18.92	19.53	5256
			Latisail				
30	14.78	146.97	132.38	12.09	24.48	29.41	4903
40	14.68	144.84	120.41	11.54	24.50	27.74	4623
50	13.58	111.19	104.82	11.13	24.46	25.49	4250
60	13.65	107.72	91.43	8.12	24.02	24.02	4007
70	12.34	105.40	67.84	7.59	23.80	16.88	2812
F-test	Sig.	Sig.	Sig.	Sig.	ns.	Sig.	Sig.

Sig Significant. ns nonsignificant.

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Table 6. Correlations between seedling ages and related characters of BR3, BR4 and Latisail transplant Aman season.

Correlated characters	Correlation coefficients (r^2 and R^2)		
	BR3	BR4	Latisail
Primary branches (no./panicle)	0.933**	0.892**	0.699*
Secondary branches (no./panicle)	0.971**	0.939**	0.884**
% branch degeneration	0.823*	0.694*	0.665*
Spikelet (no./panicle)	0.880**	0.932**	0.823*
% spikelet degeneration	0.705*	0.772*	0.666*
Panicle length (cm)	0.944**	0.815*	0.926**
Plant ht (cm)	0.910**	0.949**	0.974**
Panicle (no./plant)	0.889**	0.951**	0.887**
Filled grain (no./panicle)	0.884**	0.944**	0.834*
% spikelet sterility	0.857**	0.952**	0.891**
Grain yield (g/plant)	0.824*	0.917**	0.884**
Grain yield (kg/ha)	0.822*	0.889**	0.882**

* Significant at the 5% level.

** Significant at the 1% level.

Table 7. Effect of seedling age on the developmental stages of BR3, BR4 and Latisail, Boro 1978-79.

Transplanting date	Seedling age at transplanting (days)	Maximum tillering period (DT)[a]	Total age for panicle initiation (DS)[b]	Panicle developmental stages (DT)[a]			
				Panicle initiation	Heading	Anthesis	Ripening
				BR3			
10 Dec	40	65	120	80	110	115	145
20 Dec	50	60	125	75	105	108	140
30 Dec	60	52	128	68	97	102	132
09 Jan	70	43	128	58	87	92	124
19 Jan	80	34	130	50	83	87	119
				BR4			
10 Dec	40	70	122	82	115	120	153
20 Dec	50	63	125	75	105	110	142
30 Dec	60	56	130	70	101	104	136
09 Jan	70	48	132	62	92	96	126
19 Jan	80	35	132	52	82	85	115
				Latisail			
10 Dec	40	70	120	80	109	112	145
20 Dec	50	50	122	72	104	106	136
30 Dec	60	54	128	68	97	100	130
09 Jan	70	47	131	61	90	92	123
19 Jan	80	35	130	50	80	84	116

[a]DT Days after transplanting. [b]DS Days from sowing.

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Table 8. Effect of seedling age on degeneration of panicle branches, spikelets and other quantitative characters of BR3, BR4 and Latisail, Boro season (av. of four replications).

Seedling Age at transplanting	Branches (no./panicle)		Spikelet (no./panicle	% degeneration		Panicle length (cm)	Plant ht (cm)	Panicle (no./plant	% unproductive tillers/plant
	Primary	Secondary		Panicle branches	Spikelets panicle				
				BR3					
40	8.81	22.58	142.01	11.48	11.71	23.55	67.40	22.36	19.63
50	8.80	21.95	136.30	10.51	10.35	23.47	71.40	20.23	25.16
60	8.87	20.78	136.79	9.91	9.94	23.20	73.83	18.97	25.91
70	9.03	21.75	132.67	10.52	9.86	23.27	76.25	18.54	27.63
80	9.03	21.80	131.32	11.62	9.74	23.16	75.68	18.27	27.07
				BR4					
40	10.72	54.80	272.62	15.61	17.23	26.78	99.31	18.38	19.27
50	10.86	49.28	261.65	12.26	14.21	26.34	105.38	15.82	23.94
60	10.84	47.79	254.74	13.01	13.55	26.83	105.92	15.35	25.38
70	10.93	46.10	244.27	12.35	13.10	26.67	109.41	15.07	26.59
80	10.83	46.72	242.87	11.71	13.01	27.18	109.59	14.37	30.11
				Latisail					
40	8.65	30.68	175.36	21.01	20.11	25.30	97.92	23.95	17.64
50	8.83	30.17	173.91	19.11	19.90	25.07	107.11	23.60	24.40
60	8.87	31.82	170.42	18.59	18.88	26.02	112.74	21.67	30.70
70	8.84	28.99	162.09	20.07	18.59	26.64	114.26	21.23	39.03
80	8.13	26.70	148.15	16.52	16.94	25.59	113.98	19.02	41.48
F-test	ns	ns	sig.	ns	sig.	ns	sig.	sig.	sig.

sig Significant. ns nonsignificant.

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Table 9. Effect of seedling age on the grain yield and other quantitative characters of BR3, BR4 and Latisail, Boro season.

Seedling age at trans-planting	Filled grains (no./ panicle)	1000-grain wt(g)	1000-unfilled grain wt (g)	% spikelet sterility	Grain yield (g/ plant	Grain yield (t/ha)
			BR3			
40	109.98	26.65	5.78	11.97	36.19	6.04
50	108.84	27.24	5.90	11.51	36.76	6.13
60	110.89	28.48	5.24	10.01	37.51	6.25
70	107.57	28.99	5.70	9.52	38.62	6.64
80	106.93	28.22	5.20	9.12	37.04	5.97
			BR4			
40	192.98	19.29	4.50	14.35	37.39	6.25
50	190.10	19.06	4.47	15.73	38.47	6.41
60	180.49	20.35	4.36	17.62	39.74	6.62
70	177.92	20.92	4.27	16.68	44.12	7.35
80	177.61	19.63	4.62	15.95	39.29	6.55
			Latisail			
40	115.40	24.58	5.35	17.25	33.46	5.58
50	114.31	25.28	5.39	17.33	34.38	5.73
60	114.17	26.09	5.10	17.52	33.20	5.64
70	104.10	25.73	5.30	18.96	30.22	5.14
80	99.97	26.92	4.82	17.97	28.11	4.69

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Table 10. Correlation between seedling ages and related characters of BR3, BR4 and Latisail, Boro season.

Correlated characters	Correlation coefficients (r^2 and R^2)		
	BR3	BR4	Latisail
Spikelet (no./panicle)	0.898**	0.958**	0.933**
% branch degeneration	0.402ns	0.630ns	0.559ns
% spikelet degeneration	0.732*	0.746*	0.916**
Panicle (no./plant)	0.864**	0.807*	0.942**
% unproductive tillers/ plant	0.737*	0.944**	0.983**
Plant ht (cm)	0.876**	0.800*	0.801*
Filled grains (no./panicle)	0.399ns	0.886**	0.845**
% spikelet sterility	0.946**	0.294ns	0.126ns
Grain yield (g/plant)	0.291ns	0.337ns	0.804*
Yield	0.489ns	0.339ns	0.739*

* Significant at the 5% level.

** Significant at the 1% level.

ns Nonsignificant.

Table 11. Developmental stages of BR3, BR4 and Latisail as influenced by sowing dates and seedling ages, transplant Aman, 1979.

Date of sowing	Seedling age (DS)[a] (9 Sep)	Period for panicle developmental stages								
		Age for panicle initiation (DS)	Panicle initiation (DT)[b]	Heading (DT)	Age for panicle initiation (DS)	Panicle initiation (DT)	Heading (DT)	Age for panicle initiation (DS)	Panicle initiation (DT)	Heading (DT)
			BR3			BR4			Latisail	
30 Jun	70	70	0	27	103	33	61	97	27	55
10 Jul	60	70	10	38	95	35	63	87	27	55
20 Jul	50	70	20	46	85	35	63	80	30	58
30 Jul	40	68	28	46	77	37	64	72	32	60
09 Aug	30	65	35	52	72	42	69	64	34	61
Chi-square test										
Mean		68.60	18.60	48.20	86.40	36.40	64.00	80.00	30.00	57.80
X^2		0.28	41.89	10.56	7.49	1.29	0.56	8.23	1.27	0.53
P		0.990	.005	0.025	0.100	0.750	0.950	0.250	0.750	0.950
		0.995		0.050	0.250	0.900	0.975	0.100	0.900	0.975

[a]DS Days after sowing,

[b]DT Days after transplanting.

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Table 12. Effect of seedling age at different sowing dates on the degeneration of spikelets and development of panicle components, transplant Aman 1979.

Sowing date	Seedling age (DS)[a] (9 Sep)	Branches (no./panicle)		Spikelets (no./panicle)	% degeneration		Panicle length (cm)
		Primary	Secondary		Panicle branches	Spikelets /panicle	
				BR3			
30 Jun	70	7.67 e	20.58 e	88.98 g	12.01 c	13.26 a	19.42 e
10 Jul	60	9.25 d	34.05 cd	160.80 f	11.67 c	11.95 a	23.33 cd
20 Jul	50	10.50 d	35.01 c	178.75 d	11.24 c	11.56 a	23.88 cd
30 Jul	40	10.80 bc	37.03 c	184.51 c	11.13 c	11.18 ab	23.70 cd
09 Aug	30	11.01 b	37.00 c	187.93 c	7.94 d	7.78 c	23.71 cd
				BR4			
30 Jun	70	10.89 b	44.78 b	228.96 b	11.19 c	10.63 a	25.00 b
10 Jul	60	11.02 b	50.65 a	238.90 a	8.27 d	7.84 b	25.33 b
20 Jul	50	11.01 b	51.47 a	238.93 a	7.63 d	7.80 b	24.64 bc
30 Jul	40	11.33 a	52.14 a	239.15 a	7.41 d	7.76 b	24.64 bc
09 Aug	30	11.43 a	52.10 a	243.19 a	7.39 d	6.71 b	24.38 bc
				Latisail			
30 Jun	70	11.00 b	35.50 c	170.79 e	15.57 a	16.71 a	24.98 b
10 Jul	60	11.40 a	37.40 c	175.84 d	13.28 b	14.66 b	26.65 a
20 Jul	50	11.40 a	37.31 c	176.05 d	11.79 c	12.89 c	26.78 a
30 Jul	40	11.50 a	38.17 c	180.24 d	11.68 c	12.75 c	26.25 a
09 Aug	30	11.15 ab	38.83 c	187.75 c	11.62 c	12.59 c	25.80 ab

Means in a column followed by the same letter are not statistically different at the 1% level.

[a]DS Days after sowing.

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Table 13. Grain yield and other quantitative characters of BR3, BR4 and Latisail as influenced by seedling ages of different sowing dates, transplant Aman, 1979.

Sowing date	Seedling age (DS)[a] (9 Sep)	Plant ht (cm)	Panicle (no./plant)	% spikelet sterility	Grain yield (g/plant)	Grain yield /plot (kg/ha)
			BR3			
30 Jun	70	71.31	18.88	24.48	24.21	3368 ab
10 Jul	60	74.45	16.18	24.45	25.79	3757 a
20 Jul	50	75.55	13.75	24.75	26.99	3999 a
30 Jul	40	76.09	13.63	25.53	24.98	3664 a
09 Aug	30	76.23	13.58	26.56	24.37	3553 a
			BR4			
30 Jun	70	110.03	12.48	24.03	27.33	4098 a
10 Jul	60	110.35	11.75	24.65	28.34	4260 a
20 Jul	50	111.10	11.01	24.75	28.33	4224 a
30 Jul	40	111.28	10.55	25.45	28.09	4201 a
09 Aug	30	111.04	10.50	26.40	28.01	4181 a
			Latisail			
30 Jun	70	113.21	15.53	35.40	21.37	2896 ab
10 Jul	60	114.97	15.54	37.59	23.45	3218 ab
20 Jul	50	116.32	15.41	39.32	24.19	3366 ab
30 Jul	40	116.62	14.86	40.80	22.95	3110 ab
09 Aug	30	118.50	14.83	42.57	22.81	3112 ab

Means in a column followed by the same letter are not statistically different at 5% level.

[a]DS Days after sowing.

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Table 14. Analysis of variance for the development and degeneration of panicle components as affected by seedling ages at different sowing dates on BR3, BR4 and Latisail, transplant Aman, 1979.

Source of variation	DF	Mean squares				
		Branches (no./panicle)		Spikelets (no./panicle)	% degeneration	
		Primary	Secondary		Panicle branches	Spikelets/ panicle
Total	59					
Replication	3	0.01ns	0.67ns	2.10ns	0.39ns	0.31ns
Seedling age (P)	4	3.90**	167.01**	3446.01**	25.88**	32.37**
Error (A)	12	0.05	2.44	8.94	0.34	0.64
Variety (V)	2	12.68**	1640.66**	32.29	97.55**	166.90**
V X P	8	2.13**	34.32**	1798.13**	3.38**	2.70ns
Error (B)	30	0.02	1.43	7.29	0.27	2.35
CV (A)%		2.17	3.89	1.56	5.45	7.24
CV (B)%		1.39	2.98	1.41	4.88	6.84

* Significant at the 5% level.

** Significant at the 1% level.

ns nonsignificant.

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Table 15. Analysis of variance for grain yield and other quantitative characters as affected by seedling ages and sowing dates, transplant Aman, 1979.

Source of variation	DF	Mean squares				
		Panicle length (cm)	Panicles (no./plant)	% spikelet sterility	Grain yield (g/plant)	Grain yield /plot (t/ha)
Total	59					
Replication	3	0.19ns	0.37ns	0.12ns	0.46ns	0.02ns
Seedling age (P)	4	8.15**	15.48**	27.11**	7.81**	0.19**
Error (A)	12	0.21	0.54	0.75	0.64	0.01
Variety (V)	2	54.97**	105.83**	1308.45**	195.89**	5.51**
V X P	8	4.49**	4.50**	5.18**	0.60ns	0.01ns
Error (B)	30	0.22	0.39	0.57	0.83	0.01
CV (A) %		1.85	5.32	2.92	3.62	3.04
CV (B) %		1.90	4.51	2.54	4.12	3.27

* Significant at the 5% level.

** Significant at the 1% level.

ns nonsignificant .

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Table 16. Correlations between seedling ages of different sowing dates and related characters of BR3, BR4 and Latisail, transplant Aman, 1979.

Characters	Correlation coefficients (r^2 and R^2)		
	BR3	BR4	Latisail
Primary branches (no./panicle)	0.869**	0.904**	0.712*
Secondary branches (no./panicle)	0.673*	0.675*	0.901**
% panicle branch degeneration	0.702*	0.688*	0.781*
Spikelets (no./panicle)	0.725*	0.739*	0.915**
% spikelet degeneration	0.837*	0.730*	0.822*
Panicles (no./plant)	0.798*	0.837*	0.848**
Plant ht (cm)	0.796*	0.915**	0.963**
% spikelet sterility	0.853**	0.941**	0.995**
Grain yield (kg/ha)	0.341ns	0.501ns	0.801*

* Significant at 5% level.

** Significant at 1% level.

ns nonsignificant.

Table 17. Developmental stages of panicles of BR3, BR4 and Latisail as influenced by sowing dates and seedling ages, Boro, 1979-80.

Date of sowing	Seedling ages (DS)[a] (10 Mar)	Age for panicle initiation (DS)	Panicle initiation (DT)[b]	Heading (DT)	Age for panicle initiation (DS)	Panicle initiation (DT)	Heading (DT)	Age for panicle initiation (DS)	Panicle initiation (DT)	Heading (DT)
			BR3			BR4			Latisail	
20 Dec	80	117	37	65	137	57	86	120	40	68
30 Dec	70	110	40	68	131	61	90	NPI[c]	-	-
09 Jan	60	108	48	75	121	61	89	NPI	-	-
19 Jan	50	98	48	73	113	63	91	NPI	-	-
29 Jan	40	90	50	75	103	63	92	NPI	-	-
Chi-square test										
Mean		104.60	44.6	71.20	121.00	61.00	89.60			
x^2		4.314	2.942	1.135	6.149	0.393	0.237			
P		0.25	0.50	0.750	0.10	0.975	0.990			
		0.50	0.75	0.990	0.25	0.090	0.995			

[a]DS Days after sowing.

[b]DT Days after transplanting.

[c]NPI No panicle initiation.

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Table 18. Effect of seedling ages at different sowing dates on the degeneration of spikelets and development of panicle components, Boro, 1979-80.

Sowing date	Seedling age (DS)[a] (10 Mar)	Branches (no./panicle) Primary	Branches (no./panicle) Decondary	Spikelets (no./panicle)	% degeneration Panicle branches	% degeneration Spikelets /panicle	Panicle length (cm)
			BR3				
20 Dec	80	10.35	32.22 c	166.24 d	13.52 de	11.88 cd	22.85
30 Dec	70	10.13	27.74 d	160.45 e	13.68 de	11.89 cd	22.92
09 Jan	60	9.87	27.70 d	159.72 e	16.16 d	14.58 c	22.97
19 Jan	50	9.53	27.40 d	157.20 e	16.80 d	15.02 c	23.34
29 Jan	40	9.66	26.10 d	152.09 f	17.56 d	16.50 c	23.75
			BR4				
20 Dec	80	13.25	72.01 a	334.82 a	29.58 a	33.79 a	33.25
30 Dec	70	13.20	70.90 a	330.82 a	28.67 a	32.93 a	33.32
09 Jan	60	13.01	69.77 a	319.83 b	28.56 a	31.55 a	33.41
19 Jan	40	12.96	67.79 a	316.94 b	26.24 ab	29.08 a	33.63
29 Jan	30	11.85	62.94 b	302.83 c	22.94 c	24.72 ab	34.38
			Latisail				
20 Dec	80	11.35	48.25	191.12	16.92	41.40	26.60
30 Dec	70	NPI[b]	-	-	-	-	-

[a]DS Days after sowing.

[b]NPI No panicle initiation in the seedlings which were sown on 30 Dec,09, 19 and 29 January.

Means in a column followed by same letter are not statistically different at the 1% level.

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Table 19. Grain yields and other quantitative characters of BR3, BR4 and Latisail as influenced by seedling ages of different sowing dates, Boro, 1979-80.

Sowing date	Seedling age (DS)[a] (10 Mar)	Plant ht (cm)	Panicle (no./plant)	% non-effective tillers	Filled grains (no./panicle)	% spikelet sterility	Grain yield (g/plant)	Grain yield/plot (kg/ha)
				BR3				
20 Dec	80	81.88	10.58	31.10	118.80	19.16	28.35	4802 a
30 Dec	70	81.56	11.45	26.25	114.77	18.93	28.34	4871 a
09 Jan	60	81.35	11.47	24.10	108.54	20.04	20.11	4879 a
19 Jan	50	81.59	12.11	24.01	105.78	20.64	29.42	4978 a
29 Jan	40	81.86	12.42	16.35	102.25	21.24	29.84	4992 a
				BR4				
20 Dec	80	111.30	9.97	38.27	164.90	25.48	32.85	5263 a
30 Dec	70	110.84	8.96	36.45	165.33	25.47	29.17	4941 a
09 Jan	60	111.12	8.47	34.85	166.86	25.35	25.72	4251 a
19 Jan	50	111.30	8.46	29.20	169.10	24.85	24.12	4058 a
29 Jan	40	111.47	8.01	25.36	170.94	24.79	21.05	3520 b
				Latisail				
20 Dec	80	102.52	1.00	91.43	75.53	34.35	1.92	321
30 Dec	70	NPI	NPI	NPI	NPI	NPI	NPI	NPI

[a]DS Days after sowing. [b]NPI No panicle initiation.

Means in a column followed by the same letter are not statistically different at the 5% level.

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Table 20. Analysis of variance for the development and degeneration of panicle components and other quantitative characters as affected by seedling ages and sowing dates, Boro, 1979-80.

Source of variation	DF	Mean squares						
		Panicle branches (no./panicle)		Spikelets (no./panicle)	% degeneration		Panicle (no./plant)	Grain yield (t/ha)
		Primary	Secondary		Panicle branches	Spikelets /panicle		
Total	39							
Replication	3	0.01ns	0.20ns	17.47ns	0.26ns	0.16ns	0.05ns	1.02ns
Seedling age (P)	4	1.33**	60.61**	617.25**	4.66**	7.50**	0.15ns	77.73**
Error (A)	12	0.007	0.69	6.51	0.46	1.38	0.11	0.97
Variety (V)	1	86.62**	16380.64**	262145.20**	1358.15**	2702.90**	78.06**	249.60**
V X P	4	0.43ns	11.72**	124.38**	37.68**	62.34**	3.81**	118.31**
Error (B)	15	0.65	1.19	4.03	1.88	5.99	0.03	0.93

* Significant at the 5% level. ** Significant at the 1% level. ns nonsignificant.

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Table 21. Collerations between seedling ages of different sowing dates and related characters of BR3, BR4 and Latisail, Boro, 1979-80.

	Correlation coefficients (r^2 and R^2)	
	BR3	BR4
Secondary branches (no./panicle)	0.730*	0.886**
% panicle branch degeneration	0.924**	0.859**
Spikelets (no./panicle) (main culm)	0.940**	0.954**
% spikelet degeneration	0.923**	0.909**
Panicle (no./plant)	0.937**	0.876**
% noneffective tillers	0.889**	0.945**
Panicle length (cm)	0.865**	0.786**
Filled grains(no./panicle)	0.983**	0.957**
% spikelet sterility	0.907**	0.889**
Grain yield (kg/ha)	0.934**	0.992**

* Significant at the 5% level.

** Significant at the 1% level.

ns Nonsignificant.

Table 22. Effect of seedling age and fertilizer (NPK) on the development of panicles on BR4, transplant Aman season, 1979.

Transplanting date	Seedling age (DS)[a]	Total age for panicle initiation (DS)	Panicle development stages (DT)[b]			
			Panicle initiation	Heading	Anthesis	Ripening
15 Aug	30	90	60	86	90	122
25 Aug	40	90	50	76	79	112
04 Sep	50	95	45	70	73	106
14 Sep	60	100	50	65	70/80[c]	100/110
24 Sep	70	80	10	36	40/85[d]	70/115
Chi-square test						
Mean		91	41	66.4	70.4	103.6
X^2		1.413	34.63	22.24	19.73	12.46
P		0.50	0.005	0.005	0.005	0.010
		0.75	-	-	-	0.025

[a]DS Days after sowing. [b]DT Days after transplanting.

c,d Anthesis stage of the main culm and tillers per plant.

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Table 23. Mean effects of fertilizer (NPK) on seedling ages for the development of panicle branches, spikelets per panicle and degeneration of panicle branches and spikelets of BR4, transplant Aman, 1979.

Treatment	Fertilizer rate (kg/ha)			Panicle branches (no./panicle)		Spikelets (no./panicle)	% degeneration /panicle	
	N	P_2O_5	K_2O	Primary	Secondary		Branches	Spikelets
Control	0	0	0	11.25	45.37 b	222.02 d	8.08	9.65 a
N	60	0	0	11.95	46.68 a	230.49 c	7.35	8.63 b
NP	60	60	0	11.64	46.36 a	230.62 c	7.49	8.25 b
NK	60	0	40	11.78	46.63 a	234.64 b	7.82	8.76 b
NPK	60	60	40	11.82	47.40 a	237.34 a	8.16	8.96 b
Main effect over control								
N				0.70	1.31	8.47	0.73	1.02
NP				0.39	0.99	8.60	0.59	1.40
NK				0.53	1.26	12.62	0.26	0.79
NPK				0.55	2.03	15.32	-0.08	0.69
Mean effect over control				0.53	1.40	11.25	0.42	0.98

In a column the figures followed by a common letter do not differ significantly at the 5% level.

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Table 24. Mean effects of fertilizer (NPK) on seedling ages for the development of some quantitative characters of BR4, transplant Aman,1979.

Treatment	Fertilizer rate (kg/ha)			Panicle length (cm)	Plant ht (cm)	Panicle (no./plant)	% spikelet sterility	Grain yield (g/plant)
	N	P_2O_5	K_2O					
Control	0	0	0	25.15 ab	107.36 c	10.71	28.80	22.71 c
N	60	0	0	26.05 a	110.64 b	12.01	28.39	24.09 b
NP	60	60	0	26.06 a	110.16 b	12.11	27.91	24.21 b
NK	60	0	40	25.73 a	111.68 a	12.40	27.67	24.85 b
NPK	60	60	40	26.37 a	111.96 a	13.11	27.52	25.87 a
Main effect over control								
N				0.90	3.28	1.30	0.41	1.38
NP				0.91	2.80	1.40	0.89	1.50
NK				0.58	4.32	1.69	1.13	2.14
NPK				1.22	4.60	2.40	1.28	3.16
Mean effect over control				0.93	3.25	1.70	0.93	2.05

In a column the figures followed by a common letter do not differ significantly at the 5% level.

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Table 25. Mean effects of seedling age and fertilizer (NPK) on the number of spikelets developed per panicle, the percentage of spikelet degeneration and some quantitative characters of BR4, transplant Aman, 1979.

Seedling age (DS)[a]	Panicle branches (no./panicle)		Spikelets (no./panicle)	% degeneration /panicle		Panicle length (cm)	Plant ht (cm)	Panicle (no./plant)	% spikelet sterility	Grain yield (g/plant)
	Primary	Secondary		Branches	Spikelets					
30	12.98	51.54 a	261.51 a	7.90 ab	8.72 ab	27.48 a	115.76 a	10.92 b	26.99	24.2[illegible] a
40	12.15	51.95 a	253.05 b	6.95 d	7.77 c	26.13 b	115.29 a	11.43 b	28.60	25.5[illegible] a
50	12.16	49.70 c	247.43 c	8.06 a	8.86 ab	26.73 b	113.99 b	11.59 b	28.21	25.4[illegible] a
60	11.36	44.54 d	219.01 d	8.16 a	9.34 a	25.27 c	107.67 c	13.15 a	28.18	25.7[illegible] ab
70	9.93	34.74 c	174.02 e	7.84 bc	9.87 a	23.75 d	99.09 d	13.24 a	28.31	20.7[illegible] c
Seedbed	6.10	8.06	74.85	40.88	45.86	12.67	61.22	1.00	28.55	-

In a column the figures followed by a common letter do not differ significantly at the 5% level.

[a]DS Days after sowing.

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Table 26. Analysis of variance for some quantitative characters as influenced by fertilizer (NPK) and seedling age on BR4, transplant Aman, 1979.

Source of variation	DF	Secondary branches (no./ panicle)	Spikelets (no./ panicle)	% degeneration/panicle Branches	% degeneration/panicle Spikelets	Plant ht (cm)	Panicle (no./ plant)	% spikelet sterility	Grain yield (g/ plant)
Total	99								
Replication	3	0.50ns	0.73ns	0.13ns	0.23ns	2.73ns	0.37ns	0.65ns	1.91ns
Seedling age (P)	4	1036.65**	25389.15**	4.64**	13.10**	1004.88**	22.41**	7.18ns	87.12**
Fertilizer treatment (T)	4	1091.00**	666.45**	2.54**	5.35**	66.98**	15.16**	4.93ns	26.14**
P X T	16	10.11**	39.61**	1.44**	1.48ns	3.13ns	1.41**	0.79ns	4.32ns
Error	72	1.24	11.95	0.18	1.04	2.35	0.40	4.11	3.33
CV (%)		5.08	1.49	5.39	11.54	1.39	5.25	7.23	7.50

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 27. Physico-chemical characteristics of soils of the experimental plots and pots.

Constituent	Expt.plot T.Aman 1978 Expt. B_1	Expt.plot seedbed Expt. B_1	Expt.plot Boro 1978 Expt.B_2	Expt.plot T.Aman 1979 Expt. C	Pot soil 1980-81 Expt. H	Methods used for soil analysis
Texture	Clay	Clay	Silty clay	Silty clay	Clay	Hydrometer
pH	7.1	7.2	6.5	6.7	7.0	
CEC m.eq/100g soil	11.3	10.8	10.2	14.3	10.6	Ammonium saluration
OM(%)	1.45	1.21	1.14	1.57	1.39	Wet oxidation
N (%)	0.125	0.101	0.098	0.131	0.108	Micro - Kjeldahldigestion
P_2O_5 (ppm)	17.42	15.00	18.64	20.94	15.25	Ison's
K_2O (ppm)	158.20	94.50	92.10	48.7	93.75	Flame photometer
Mn (ppm)	27.40	20.00	32.10	13.0	23.15	Mn, Cu, Zn - 0.05 N Hcl extraction
Sulphate sulphur (ppm)	11.06	11.04	10.15	12.03	11.05	
Cu (ppm)	0.60	0.37	1.25	0.99	0.40	
Zn (ppm)	1.01	1.80	3.52	2.42	2.10	

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Table 28. Effect of seeding rates on the panicle developmental stages of BR3, BR4 and Latisail, Boro season, 1980-81.

Treat-ments	Seeding rate (g/m^2)	Panicle developmental stages (DS)[a]								
		Panicle initia-tion	Head-ing	Anthe-sis	Ripe-ning	Panicle initia-tion	Head-ing	Anthe-sis	Ripe-ning	Panicle initia-tion
			BR3				BR4			Latisail
T_1	6.25	124	152	156	188	130	157	160	192	NPI[b]
T_2	12.50	124	152	156	188	130	157	160	192	NPI
T_3	25.00	124	152	156	188	130	157	160	192	NPI
T_4	50.00	124	152	156	186	125	152	155	188	NPI
T_5	100.00	120	149	154	185	122	148	152	186	NPI
T_6	200.00	115	143	148	182	122	150	153	186	NPI
Chi-square test										
Mean		121.83				126.50				
χ^2		0.565				0.629				
P		0.975-0.990				0.975-0.990				

[a]DS Days after sowing.

[b]NPI No panicle initiation.

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Table 29. Effect of seeding rate on the development of spikelet number per panicle, percentage of spikelet degeneration panicle length and plant height in the varieties, Boro season, 1980-81.

Seeding rate (g/m^2)	Spikelet (no./panicle)		% spikelet degeneration		Panicle length (cm)	Plant ht (cm)
	Main culm	Tillers	Main culm	Tillers		
			BR3			
6.25	113.42 d	91.70 d	16.75 f	31.66 ef	21.75 c	57.77 a
12.50	103.39 de	87.16 de	17.06 f	32.36 de	20.32 d	55.45 a
25.00	94.12 de	83.12 def	22.74 e	32.12 de	20.29 d	54.25 a
50.00	87.08 ef	79.94 def	25.02 de	33.30 de	19.59 e	51.52 a
100.00	82.37 efg	71.31 efg	27.80 d	36.32 cd	16.47 f	47.65 a
200.00	61.50 g	61.50 g	50.75 a	50.75 a	11.43 h	38.04 ab
			BR4			
6.25	266.33 a	251.83 a	37.02 c	42.42 b	25.59 a	71.73 a
12.50	263.61 a	256.69 a	38.80 bc	42.57 b	25.01 a	67.56 a
25.00	230.83 b	209.87 b	36.66 c	41.31 b	24.03 b	66.97 a
50.00	224.89 bc	201.19 b	40.80 bc	40.66 bc	23.42 b	56.34 ab
100.00	203.14 e	165.40 c	43.10 b	42.20 b	21.06 c	54.51 ab
200.00	67.28 fg	67.28 fg	52.07 a	52.07 a	12.56 g	40.61 c

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Table 30. Effect of seeding rates on some quantitative characters of BR3 and BR4, Boro season, 1980-81.

Seeding rate (g/m^2)	Panicle (no./plant)	Panicle (no./m^2)	Grains (no./panicle)	% spikelet sterility	1000-grain wt (g)	Grain yield (kg/ha)
			BR3			
6.25	5.70 a	281 f	89.82 a	24.69 g	28.08 c	5331 a
12.50	5.17 a	325 e	78.30 b	25.53 f	27.94 d	5301 a
25.00	4.73 ab	395 d	67.40 c	28.48 d	27.86 d	5298 a
50.00	3.95 c	459 c	59.99 c	31.10 c	27.38 e	5195 a
100.00	3.33 c	533 b	49.37 d	37.25 b	25.05 f	4135 a
200.00	1.00 d	970 a	30.25 e	44.60 a	24.56 h	3994 ab
			BR4			
6.25	5.50 a	208 d	144.87 a	19.80 j	19.22 a	4681 a
12.50	4.83 a	209 d	147.32 a	20.35 i	19.14 a	4686 a
25.00	4.40 ab	254 c	121.89 b	21.62 h	18.98 b	4592 a
50.00	4.25 ab	270 c	117.90 b	24.27 g	18.67 b	4487 a
100.00	3.38 c	325 b	91.09 c	27.17 e	18.07 c	3927 a
200.00	1.00 d	648 a	37.26 d	29.46 d	16.96 g	2885 b

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Table 31. Analysis of variance for spikelet numbers per panicle and percentages of spikelet degeneration in BR3 and BR4 as influenced by seeding rates, Boro season, 1980-81.

Source of variation	DF	Mean squares			
		Spikelets (no./panicle)		% spikelet degeneration	
		Main culm	Tillers	Main culm	Tillers
Total	47				
Replication	3	166.33ns	11.02ns	4.41ns	6.94ns
Seedling rate (T)	5	16464.84**	13022.43**	198.56**	15.05**
Error (A)	15	218.79	129.88	3.67	3.27
Variety (V)	1	170050.20**	153014.50**	4123.11**	1527.65**
V X T	5	6520.26**	7010.71**	33.95**	86.70**
Error (B)	18	107.29	69.07	3.61	3.81
CV (A) %		9.87	8.41	5.96	4.76
CV (B) %		6.91	6.43	5.91	5.15

* Significant at the 5% level.

** Significant at the 1% level.

ns Nonsignificant.

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Table 32. Analysis of variance of some quantitative characters of BR3 and BR4 as influenced by seeding rates, Boro season, 1980-81.

Source of variation	DF	Mean squares				
		Panicle length (cm)	Plant ht (cm)	Panicle (no./plant)	% spikelet sterility	Grain yield (t/ha)
Total	47					
Replication	3	0.20ns	0.74ns	0.28ns	0.14ns	0.84ns
Seeding rate (T)	5	148.77**	660.10**	19.99**	266.68**	343.61**
Error (A)	15	0.21	3.37	0.26	0.23	0.64
Variety (V)	1	158.56**	1009.80**	0.35ns	799.68**	532.26**
V X T	5	3.39**	54.94ns	0.25ns	10.06**	17.09**
Error (B)	18	0.16	39.38	0.23	0.26	0.75
CV (A) %		2.94	3.34	13.18	1.73	1.76
CV (B) %		11.99	11.40	12.25	1.82	1.91

* Significant at the 5% level.

** Significant at the 1% level.

ns Nonsignificant.

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Table 33. Correlation coefficients between different seeding rates and some characters of BR3 and BR4, Boro season, 1980-81.

Characters	Correlation coefficients (r^2 and R^2)	
Spikelets (no./panicle) (main culm)	0.894**	0.956**
Spikelets (no./panicle) (tillers)	0.946**	0.971**
% spikelet degeneration /panicle (main culm)	0.958**	0.963**
Panicle length (cm)	0.988**	0.975**
Plant ht (cm)	0.990**	0.932**
Panicles (no./plant)	0.976**	0.974**
Panicles (no./m^2)	0.973**	0.948**
Grain (no./panicle)	0.892**	0.979**
% sterility	0.974**	0.893**
1000-grain wt (g)	0.885**	0.989**
Yield (kg/ha)	0.789**	0.996**

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

ns Nonsignificant.

Table 34. Effect of seeding rates on the panicle developmental stages of BR3, BR4 and Latisail, transplant Aman season, 1981.

Seeding rate (g/m^2)	Panicle developmental stages (DS)[a]											
	Panicle initiation	Heading	Anthesis	Ricening	Panicle initiation	Heading	Anthesis	Ripening	Panicle initiation	Heading	Anthesis	Ripening
		BR3				BR4				Latisail		
6.25	75	102	106	140	87	115	120	153	85	110	113	145
12.50	75	102	106	140	87	115	120	153	85	110	113	145
25.00	70	96	100	132	87	115	120	153	80	105	108	140
50.00	70	96	99	131	87	115	120	153	80	105	108	140
100.00	70	96	99	131	85	110	115	147	77	105	108	140
200.00	70	96	99	131	85	110	115	147	77	105	108	140
Chi-square test												
Mean	71.67				86.33				80.66			
χ^2	0.465				0.062				0.810			
P	0.990				0.995				0.975			
	0.995				1				0.990			

[a]DS Days after sowing.

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Table 35. Effect of seeding rate on the development of spikelet number per panicle and percentage of spikelet degeneration in the varieties BR3, BR4 and Latisail, transplant Aman season, 1981.

Seeding rate (g/m^2)	Spikelet (no./panicle) (main culm)			% spikelet degeneration/panicle		
	BR3	BR4	Latisail	BR3	BR4	Latisail
6.25	99.75 d	158.10 a	88.93 e	21.77 hi	5.70 k	14.39 j
12.50	93.25 de	136.40 b	80.20 fg	22.50 hi	6.88 k	19.77 i
25.00	86.75 ef	117.70 c	67.85 hi	29.53 g	11.20 j	21.36 hi
50.00	78.48 fg	92.80 de	67.45 i	32.65 efg	34.14 ef	24.31 h
100.00	73.80 gh	75.93 gh	52.60 j	35.80 e	45.58 d	31.49 fg
200.00	23.85 k	14.65 k	18.68 kl	55.60 b	62.84 d	49.95 c

In a colum figures followed by a common letter do not differ significantly at the 1% level.

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Table 36. Effect of seedling rates on the quantitative characters of BR3, BR4 and Latisail transplant Aman season, 1981.

Seedling rate (g/m^2)	Panicle length (cm)	Plant ht (cm)	Panicles (no./plant)	Panicles (no./m^2)	Grain (no./ panicle)	% sterility	1000-grain wt (g)	Grain yield (kg/ha)
				BR3				
6.25	19.16	57.41	5.00	255	60.18	10.39	28.04 a	4331 a
12.50	18.85	56.42	4.70	262	59.50	10.87	28.01 a	4329 a
25.00	18.60	56.73	3.50	266	59.10	14.85	27.76 a	4310 a
50.00	17.78	56.10	3.20	309	50.17	16.44	27.00 b	4131 b
100.00	16.89	47.90	2.80	395	40.04	20.50	24.84 de	2928 f
200.00	10.16	30.80	1.00	687	10.58	25.91	24.68 e	1795 i
				BR4				
6.25	21.12	74.67	4.85	164	118.27	21.92	19.42 g	3697 c
12.50	20.57	74.80	4.15	182	108.07	24.88	19.17 gh	3695 c
25.00	18.51	74.92	3.60	211	89.73	29.13	19.01 gh	3572 d
50.00	17.09	62.15	3.15	287	60.20	32.27	18.87 gh	3235 e
100.00	15.46	53.97	2.85	394	28.55	37.41	18.71 h	2051 gh
200.00	10.29	30.37	1.00	844	7.43	42.85	17.49 i	1092 j
				Latisail				
6.25	18.83	78.18	4.75	188	68.84	13.77	25.71 c	3291 e
12.50	18.81	79.31	4.55	201	64.92	14.82	25.53 c	3257 e
25.00	17.48	80.12	4.25	224	50.07	16.82	25.44 cd	2839 f
50.00	16.64	76.17	3.55	246	36.86	20.46	25.12 cde	2262 g
100.00	15.30	75.56	2.80	351	24.35	26.30	24.86 de	2135 g
200.00	10.10	50.93	1.00	696	10.33	32.22	23.47 f	1686 i

In a column figures followed by a common letter do not differ significantly at the 1% level.

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Table 37. Analysis of variance for spikelet numbers per panicle, percentages of spikelet degeneration and some quantitative characters in BR3, BR4 and Latisail as influenced by seeding rates transplant Aman season, 1981.

Source of variation	DF	Spikelet (no./ panicle)	% spikelet degenera- tion	Panicle length (cm)	Plant ht(cm)	Panicle (no./ plant)	% spikelet sterility	1000- grain wt(g)	Grain yield (t/ha)
Total	71								
Replication	3	11.67ns	4.58ns	0.09	0.04ns	0.02ns	0.21ns	0.08ns	0.00ns
Seeding rate (T)	5	13905.07**	3037.96**	148.65**	1989.30**	22.90**	582.81**	11.55**	9.86**
Error (A)	15	47.65	4.55	0.21	0.52	0.02	0.99	0.13	0.00
Variety (V)	2	8456.39**	261.64**	6.17**	3034.28**	0.28**	1417.99**	419.75**	7.10**
V X T	10	925.94**	220.83**	1.99*	94.69**	0.19**	6.03ns	1.41**	0.44**
Error (B)	36	14.49	3.56	0.13	0.26	0.03	11.38	0.08	0.00
CV (A) %		8.72	7.31	2.76	1.16	4.63	4.36	1.53	1.10
CV (B) %		4.81	6.46	2.12	0.81	4.87	14.75	1.12	2.39

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 38. Correlation coefficients between different seeding rates and some quantitative characters of BR3, BR4 and Latisail, transplant Aman season, 1981.

Characters	Correlation coefficients (r^2 and R^2)		
	BR3	BR4	Latisail
Spikelets (no./panicle)	0.959**	0.941**	0.960**
% spikelet degeneration	0.932**	0.904**	0.986**
Panicle length (cm)	0.944*	0.966**	0.949**
Plant ht (cm)	0.962**	0.977**	0.874**
Panicle (no./plant)	0.908**	0.929**	0.993**
Panicle (no./m^2)	0.881**	0.913**	0.858**
Grain (no./panicle)	0.992**	0.901**	0.978**
% sterility	0.938**	0.800**	0.950**
1000-grain wt (g)	0.841**	0.951**	0.984**
Grain yield (kg/ha)	0.963**	0.968**	0.821**

* Significant at the 5% level. ** Significant at the 1% level.
ns Nonsignificant.

Table 39. Effect of tiller numbers (by tiller pruning) on the development of panicles in BR3, BR4 and Latisail, transplant Aman season, 1978.

Treatment[a]	Panicle developmental stages (DT)[b]											
	Panicle initiation	Heading	Anthesis	Ripening	Panicle initiation	Heading	Anthesis	Ripening	Panicle initiation	Heading	Anthesis	Ripening
	BR3				BR4				Latisail			
T	43	71	75	105	47	75	80	113	40	68	71	100
T_1	40	68	72	102	44	74	77	110	35	64	68	97
T_2	38	68	72	102	44	73	77	110	35	64	68	96
T_3	38	65	70	102	45	73	77	110	35	64	67	96
T_4	36	64	68	98	42	70	74	110	34	64	68	96
T_n	36	64	68	98	40	68	72	105	34	64	68	96
Chi-square test												
Mean	38.50	66.66	70.83	101.17	43.67	72.17	76.17	109.67	35.50	64.67	68.33	96.83
X^2	0.610	0.590	0.520	0.364	0.672	0.483	0.510	0.304	0.606	0.206	0.137	0.162
P	0.975	0.975	0.990	0.995	0.975	0.990	0.990	0.995	0.975	0.995	0.995	0.995
	0.990	0.990	0.995	1	0.990	0.995	0.995	1	0.990	1	1	1

[a]T Main culm; 1,2,3,4,5.....n signify tiller numbers. [b]DT Days after transplanting.

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Table 40. Effect of tiller number (by tiller pruning) on the development of the number of panicle branches, spikelets and percentage of spikelet degeneration, transplant Aman, 1978.

Treatment[a]	Panicle branches (no./main culm)		Spikelets (no./panicle)		% spikelet degeneration (no./panicle)	
	Primary	Secondary	Main culm	Tillers	Main culm	Tillers
			BR3			
T	12.50 d	46.60 c	236.00 f	236.00 ef	12.25 b	12.25 c
T_1	12.00 e	46.50 c	281.80 cd	249.10 e	9.62 bc	11.60 cd
T_2	11.77 f	43.83 cd	272.80 d	245.25 e	11.39 b	10.77 cd
T_3	11.75 f	42.10 cd	268.75 de	236.33 ef	12.77 b	11.52 cd
T_4	11.60 f	42.03 od	262.21 de	231.40 f	12.74 b	12.33 c
T_n	11.00 g	39.10 de	247.00 ef	195.60 g	14.03 b	15.33 b
			BR4			
T	13.15 bc	66.95 a	340.25 a	340.25 a	8.29 cd	8.29 ef
T_1	13.00 bc	62.50 a	350.20 a	315.25 b	6.66 d	6.25 g
T_2	12.25 d	58.25 ab	336.22 ab	292.15 c	7.15 cd	8.90 de
T_3	12.25 d	56.38 b	301.20 c	269.33 d	8.05 cd	10.67 cd
T_4	12.10 d	56.06 b	283.60 cd	255.50 e	8.46 cd	9.96 de
T_n	11.25 g	47.35 c	240.40 f	185.25 g	11.89 b	11.60 cd
			Latisail			
T	14.75 a	64.58 a	277.80 cd	277.80 d	12.48 b	12.48 c
T_1	13.67 b	55.66 b	291.21 c	280.50 d	7.85 cd	10.63 cd
T_2	13.50 b	54.25 b	291.00 c	273.15 d	9.73 bc	12.65 c
T_3	13.45 b	50.70 bc	269.00 de	270.40 d	11.19 bc	12.10 c
T_4	13.00 bc	48.10 c	265.40 de	249.75 e	11.30 b	14.65 b
T_n	12.50 d	37.85 ef	223.80 g	175.50 gh	17.44 a	20.60 a

In a column the figures followed by a common letter do not differ significantly at the 1% level.

[a]T Main culm; 1,2,3,4,5 ..... n signify tiller numbers.

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Table 41. Effect of tiller number (by tiller pruning) on some quantitative characters of BR3, BR4 and Latisail, transplant Aman season, 1978.

Treatment[a]	Plant ht (cm)	Panicle length (cm)	Panicle (no./plant)	% spikelet sterility	Filled grains (no./panicle)	Grain yield (g/plant)
			BR3			
T	74.62 g	27.25 a	1	18.55 ef	168.15 cd	4.50 k
T_1	75.73 g	26.10 a	2	11.85 h	194.11 c	10.35 j
T_2	76.15 g	25.25 ab	3	11.36 h	193.25 c	15.51 g
T_3	73.12 gh	25.10 ab	4	14.20 g	176.41 c	19.13 e
T_4	74.24 g	24.15 b	5	14.14 g	172.18 cd	23.21 d
T_n	70.10 i	23.76 b	11.65	20.15 e	133.24 e	30.04 a
			BR4			
T	98.65 c	28.10 a	1	32.65 a	212.15 b	4.13 k
T_1	104.13 ab	26.90 a	2	20.60 e	234.67 a	9.21 j
T_2	106.93 a	26.10 ab	3	19.86 e	213.29 b	12.56 i
T_3	103.27 b	26.25 ab	4	20.20 e	191.99 c	15.08 g
T_4	106.22 a	26.01 ab	5	20.15 e	183.69 c	18.03 ef
T_n	92.46 d	25.25 b	10.55	25.86 c	121.41 e	27.14 b
			Latisail			
T	89.15 de	27.25 a	1	32.10 a	165.09 cd	3.95 k
T_1	90.65 de	25.10 b	2	26.15 c	185.13 c	9.66 j
T_2	92.55 d	25.25 b	3	24.63 c	179.83 c	14.08 gh
T_3	94.10 d	25.06 b	4	23.50 cd	181.83 c	18.98 e
T_4	93.63 d	25.10 b	5	24.53 c	160.87 cd	20.99 e
T_n	86.50 ef	24.06 b	11.10	28.10 b	100.19 f	26.01 c

In a column the figures followed by a common letter do not differ significantly at the 1% level.

[a]T Main culm; 1,2,3,4,5..... n signify tiller numbers.

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Table 42. Analysis of variances for panicle branches, spikelets per panicle and spikelet degeneration of the tested varieties as affected by tiller number (by tiller pruning), transplant Aman, 1978.

Source of variation	DF	Mean squares					
		Panicle branches (no./main culm)		Spikelet (no./panicle)		% spikelet degeneration/panicle	
		Primary	Secondary	Main culm	Tillers	Main culm	Tillers
Total	71						
Variety (V)	2	18.19**	1284.08**	19059.95**	11620.75**	123.01**	129.81**
Treatment (T)	5	4.78**	443.35**	9379.24**	16218.48**	68.66**	57.01**
V X T	10	0.17**	40.66**	2002.01**	1706.68**	4.10*	8.96**
Error	54	0.05	4.01	53.67	38.26	1.76	0.57
CV (%)		1.78	3.92	2.61	2.43	10.35	6.39

* Significant at the 5% level. ** Significant at the 1% level.

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Table 43. Analysis of variances for some quantitative characters of the test varieties as affected by tiller number (by tiller pruning), transplant Aman, 1978.

Source of variation	DF	Mean squares				
		Plant ht(cm)	Panicle length (cm)	% spikelet sterility	Filled grains (no./panicle)	Grain yield (g/plant)
Total	71					
Variety (V)	2	4769.98**	10.58**	835.95**	5829.45**	46.01**
Treatment (T)	5	129.85**	13.74**	168.22**	11118.82**	827.82**
V X T	10	20.99**	0.48ns	14.56**	551.53**	5.95**
Error	54	1.81	0.54	1.58	75.23	0.34
CV (%)		1.51	2.86	5.82	4.93	3.72

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 44. Effect of tiller number (by tiller pruning) on the development of panicles of BR3, BR4 and Latisail, Boro season, 1978-79.

Treatment[a]	Panicle developmental stages (DT)[b]											
	Panicle initiation	Heading	Anthesis	Ripening	Panicle initiation	Heading	Anthesis	Ripening	Panicle initiation	Heading	Anthesis	Ripening
	BR3				BR4				Latisail			
T	80	108	111	140	86	116	120	150	84	112	115	145
T_1	75	104	108	140	84	114	118	146	80	108	112	140
T_2	75	102	106	137	84	114	118	148	80	108	112	140
T_3	75	102	106	137	84	114	118	148	80	108	112	140
T_4	75	102	106	137	84	114	117	148	80	108	112	140
T_n	70	97	100	130	80	110	113	144	76	103	107	137
Chi-square test												
Mean	75	102.50	106.17	136.83	83.67	113.67	117.33	147.33	80	107.83	111.67	140.33
X^2	0.667	0.619	0.611	0.488	0.231	0.170	0.233	0.145	0.400	0.379	0.299	0.23[illegible]
P	0.975	0.975	0.975	0.990	0.995	0.995	0.995	0.994	0.995	0.995	0.995	0.99[illegible]
	0.990	0.990	0.990	0.995	1	1	1	1	1	1	1	1

[a]T Main culm; 1,2,3,4, ... n signify tiller numbers. [b]DT Days after transplanting.

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Table 45. Effect of tiller number (by tiller pruning) on the development of the number of panicle branches, spikelets and percentages of spikelet degeneration, Boro season, 1978-79.

Treatment [a]	Panicle branches (no./main culm)		Spikelet (no./panicle)		% spikelet degeneration/panicle	
	Primary	Secondary	Main culm	Tillers	Main culm	Tillers
			BR3			
T	12.10 a	35.26 a	201.00 a	201.00 a	19.91 a	19.91 ab
T_1	11.90 a	37.50 a	207.25 a	198.75 a	17.36 ab	18.27 b
T_2	11.80 a	35.80 a	199.50 a	203.50 a	16.83 ab	18.95 ab
T_3	11.25 a	32.65 b	195.00 a	186.15 a	19.01 a	20.62 a
T_4	11.10 ab	30.90 ab	193.50 ab	166.50 b	19.23 a	20.53 a
T_n	10.05 c	28.75 bc	172.00 c	117.22 c	20.84 a	22.40 a
			BR4			
T	14.00 a	48.65 c	358.75 b	358.75 a	18.18 a	18.18 a
T_1	12.88 b	54.10 a	380.00 a	360.30 a	11.21 c	12.97 b
T_2	12.72 b	54.08 a	376.50 a	348.55 a	10.92 c	11.70 b
T_3	12.54 b	55.45 a	365.75 ab	336.86 ab	12.24 c	12.34 b
T_4	11.40 c	51.30 b	365.25 ab	330.20 ab	12.18 c	12.15 b
T_n	10.45 d	42.45 d	315.00 c	203.02 c	15.71 b	16.42 a
			Latisail			
T	11.25 a	30.50 a	147.35 b	147.25 a	16.12 b	16.12 bc
T_1	11.05 b	34.24 a	159.25 a	154.75 a	16.12 b	16.12 bc
T_2	10.25 ab	34.50 c	156.25 a	145.60 a	12.85 c	16.55 b
T_3	10.25 ab	33.25 a	155.50 a	138.38 a	17.17 b	18.39 b
T_4	10.05 bc	33.00 ab	152.75 a	130.25 ab	17.39 b	17.97 b
T_n	9.10 d	30.10 c	140.50 ab	101.50 c	20.72 a	24.15 a

In a column the figures followed by a common letter do not differ significantly at the 1% level.

[a] T Main culm; 1,2,3,4,5 ..... n signify tiller numbers.

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Table 46. Effect of tiller number (by tiller pruning) on some quantitative characters of BR3, BR4 and Latisail, Boro season, 1978-79.

Treatment[a]	Plant ht (cm)	Panicle length (cm)	Panicle (no./plant)	% spikelet sterility	Field grains (no./panicle)	Grain yield (g/plant)
			BR3			
T	65.25 ab	25.11 a	1	21.20 a	125.26 a	3.48 e
T_1	68.36 a	25.05 a	2	14.19 b	140.41 a	8.65 d
T_2	66.77 a	26.51 a	3	13.26 b	141.55 a	11.78 c
T_3	67.25 a	25.32 a	4	14.33 b	125.59 a	13.90 b
T_4	66.50 a	25.83 a	5	14.79 b	112.11 ab	15.47 b
T_n	64.15 b	24.66 a	14.20	19.32 a	71.50 c	28.61 a
			BR4			
T	70.25 b	28.33 a	1	24.25 b	220.35 ab	4.67 f
T_1	73.63 a	28.25 a	2	22.10 b	240.52 a	10.26 e
T_2	74.26 a	28.45 a	3	23.25 b	233.21 a	14.88 d
T_3	74.89 a	27.83 a	4	21.52 bc	231.75 a	19.47 c
T_4	73.64 a	26.14 ab	5	22.20 b	227.68 a	23.70 b
T_n	69.80 b	26.63 a	12.55	28.51 a	123.30 c	31.96 a
			Latisail			
T	82.15 b	28.70 a	1	26.50 b	91.50 a	2.18 cd
T_1	86.53 a	27.62 a	2	24.25 b	105.25 a	4.82 c
T_2	81.50 b	25.25 b	3	23.27 bc	94.24 a	6.71 bc
T_3	83.55 b	25.50 b	4	25.86 b	85.75 ab	8.03 b
T_4	83.26 b	25.15 b	5	24.50 b	80.68 ab	9.68 b
T_n	80.10 bc	25.12 b	16.10	30.10 a	55.82 c	20.81 a

Means in a culm followed by a common letter do not differ significantly at the 5% level.

[a]T Main culm;1,2,3,4,5 ..... n signify tiller numbers.

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Table 47. Analysis of variances for panicle branches, spikelets per panicle and spikelet degeneration of the test varieties as affected by tiller number (by tiller pruning), Boro season, 1978-79.

Source of variation	DF	Mean squares					
		Panicle branches (no./main culm)		Spikelet (no./panicle)		% spikelet degeneration/panicle	
		Primary	Secondary	Main culm	Tillers	Main culm	Tillers
Total	71						
Variety (V)	2	24.18**	2587.02**	290427.15**	229663.95**	178.69**	233.49**
Treatment (T)	5	9.97**	108.83**	2299.62**	16400.60**	58.36**	51.16**
V X T	10	0.41ns	21.43**	343.96**	1903.03**	9.71**	15.68**
Error	54	0.21	1.57	44.24	94.85	1.46	1.09
CV (%)		4.04	3.21	2.82	4.58	7.48	6.02

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 48. Analysis of variances for some quantitative characters of the test varieties as affected by tiller number (by tiller pruning), Boro season, 1978-79.

Sources of variation	DF	Mean squares				
		Plant ht (cm)	Panicle length (cm)	% spikelet sterility	Filled grains (no./panicle)	Grain yield (g/plant)
Total	71					
Variety (V)	2	1655.18**	29.48**	606.15**	104262.55**	464.24**
Treatment (T)	5	37.46**	6.67**	75.69**	9669.22**	790.30**
V X T	10	4.66**	4.23*	8.37**	1001.18**	21.32**
Error	54	1.62	1.78	1.53	76.91	1.18
CV (%)		1.72	5.05	5.66	6.30	8.21

* Significant at the 5% level. ** Significant at the 1% level.

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Table 49. Effect of leaf pruning on the panicle developmental stages of BR3, BR4 and Latisail, Boro 1978-79.

Treatment (n flag — leaf)	% leaf blade pruning	Panicle developmental period (DT)[a]					
		Heading	Anthesis	Heading	Anthesis	Heading	Anthesis
		BR3		BR4		Latisail	
n	100	112	117	123	129	119	123
n	50	110	114	120	125	114	119
n-1	100	110	114	119	124	115	118
n-1	50	108	113	118	122	113	117
n-2	100	109	113	118	122	115	118
n-2	50	108	112	118	122	114	118
n-3	100	110	115	121	126	117	120
n-3	50	108	112	118	122	113	116
n-4	100	114	118	126	130	121	125
n-4	50	110	115	121	125	115	119
Control		108	112	118	122	113	116
Chi-square test							
Mean		109.73	114.09	120.00	124.45	115.36	119.00
Chi-square value		0.328	0.358	0.567	0.681	0.559	0.655

[a]DT Days after transplanting.

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Table 50. Periods for the development of leaf blade, leaf sheath, -panicle length and internode length (av. of four replications).

Leaf no. (n flag leaf)	Leaf blade length (cm)	Leaf sheath length (cm)	Panicle length (cm)	Developmental period (DT)[a]	Internode no. n = upper internode[b]	Internode length (cm)
			BR3			
n-5	23.15	16.53	0	65.16	n-5	0.55
n-4	36.36	18.32	0	75.22	n-4	1.62
n-3	38.85	20.92	.01- 0.80	85.16	n-3	3.14
n-2	43.41	21.41	3-10.00	95.36	n-2	6.65
n-1	41.16	21.07	15-25.50	103.52	n-1	10.76
n	20.52	27.36	25.52[c]	108.86	n	24.25
			BR4			
n-5	49.20	20.52	0	77.26	n-5	0.65
n-4	50.51	21.65	0	85.10	n-4	1.61
n-3	46.96	22.85	0.01-0.41	94.86	n-3	3.81
n-2	50.77	23.12	2-5.00	102.35	n-2	7.28
n-1	44.29	25.51	18-26.50	110.14	n-1	16.98
n	29.97	31.53	28.50[c]	115.36	n	33.53
			Latisail			
n-5	32.16	16.52	0	74.28	n-5	0.51
n-4	32.25	18.41	0	81.35	n-4	1.53
n-3	30.21	18.39	0-01	88.74	n-3	4.76
n-2	42.56	20.96	4-10	98.10	n-2	13.56
n-1	42.41	23.46	16-22.00	106.25	n-1	21.62
n	33.52	32.04	27.25[c]	110.52	n	33.29

[a]DT Days after transplanting. [b]Internode between panicle base and flag leaf node.
[c]Full length.

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Table 51. Effect of leaf pruning on the development of spikelet number and degeneration of spikelets of BR3, BR4 and Latisail, (av. of four replications), Boro, 1978-79.

Leaf no. (n flag leaf)	% leaf blade pruning	Spikelets (no./panicle)			% spikelet degeneration		
		BR3	BR4	Latisail	BR3	BR4	Latisail
n	100	230.52 a	345.63 a	176.63 a	14.25 c	10.84 bc	10.95 d
n	50	226.89 a	340.15 ab	174.83 a	15.06 bc	11.65 bc	10.83 d
n-1	100	228.40 a	338.65 ab	170.25 a	16.82 b	12.83 b	14.23 bc
n-1	50	228.63 a	336.63 ab	175.25 a	14.54 c	10.69 c	11.13 cd
n-2	100	230.65 a	338.16 ab	168.46 ab	17.26 b	16.64 a	16.26 b
n-2	50	228.89 a	341.25 ab	172.63 a	14.80 c	12.15 bc	13.16 c
n-3	100	219.63 ab	340.25 ab	171.26 a	20.18 a	18.49 a	18.80 a
n-3	50	224.48 a	338.16 ab	167.38 ab	16.85 b	13.90 b	12.41 c
n-4	100	217.33 ab	342.82 a	162.62 b	15.25 bc	14.25 b	15.63 b
n-4	50	220.65 ab	340.62 ab	168.68 ab	13.83 c	12.12 bc	11.75 cd
Control		228.85 a	349.89 a	175.82 a	14.31 c	10.95 bc	10.13 d

In a column the figures followed by a common letter do not differ significantly at the 1% level.

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Table 52. Effect of leaf pruning on spikelet sterility and grain weight of BR3, BR4 and Latisail, Boro,1978-79.

Leaf no. (n flag leaf)	% leaf blade pruning	% spikelet sterility			100-grain wt (g)		
		BR3	BR4	Latisail	BR3	BR4	Latisail
n	100	16.28 a	18.62 a	17.38 a	2.38 f	1.77 e	2.22 f
n	50	12.95 c	12.16 c	13.65 b	2.78 d	1.98 c	2.51 d
n-1	100	14.63 b	16.54 b	15.86 a	2.42 e	1.93 d	2.42 e
n-1	50	12.64 c	11.95 c	12.63 b	2.80 c	2.08 ab	2.64 c
n-2	100	11.95 c	12.15 c	11.86 bc	2.85 b	2.09 a	2.68 ab
n-2	50	11.62 c	12.96 c	11.92 bc	2.86 ab	2.09 a	2.67 b
n-3	100	11.15 cd	11.89 c	11.65 bc	2.89 a	2.10 a	2.70 a
n-3	50	11.20 cd	12.10 c	12.14 b	2.88 a	2.10 a	2.68 ab
n-4	100	10.95 cd	11.64 c	11.85 bc	2.86 ab	2.09 a	2.70 a
n-4	50	11.18 cd	11.86 c	11.64 bc	2.87 ab	2.09 a	2.69 a
Control	-	10.85 cd	10.68 cd	11.03 bc	2.89 a	2.10 a	2.70 a

In a column the figures followed by a common letter do not differ significantly at the 1% level.

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Table 53. Analysis of variance for spikelets number per panicle, percentages of spikelet degeneration and sterility on rice varieties as affected by leaf pruning, Boro, 1978-79.

Source of variation	DF	Mean squares			
		Spikelets (no./panicle)	% spikelet degeneration	% spikelet sterility	100-grain wt (g)
Total	131				
Variety (V)	2	330807.40**	97.42**	5.38**	6.47**
Treatment (T)	10	125.92**	63.05**	48.63**	0.26**
V X T	20	46.99**	3.07**	1.21*	0.01**
Error	99	8.18	1.03	0.73	0.0002

* Significant at the 5% level. ** Significant at the 1% level.

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Table 54. Effect of leaf pruning on the panicle developmental stages of the test varieties, transplant Aman, 1979.

Treatment (n flag leaf)	% leaf blade pruning	Panicle developmental period (DT)[a]					
		Heading	Anthesis	Heading	Anthesis	Heading	Anthesis
		BR3		BR4		Latisail	
n	100	66	72	80	85	78	84
n	50	65	70	78	84	76	80
n-1	100	64	68	78	84	75	80
n-1	50	64	68	78	84	75	80
n-2	100	64	68	79	84	75	80
n-2	50	65	70	78	84	75	80
n-3	100	64	68	79	85	77	80
n-3	50	66	68	77	82	75	80
n-4	100	69	72	84	88	82	87
n-4	50	66	70	80	85	78	82
Control	-	64	68	78	84	75	78

[a]DT Days after transplanting.

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Table 55. Period for the development of leaf blade, leaf sheath, panicle length and internode length at the ripening stage of BR3, BR4 and Latisail.

Leaf no. (n flag leaf)	Leaf blade length (cm)	Leaf sheath length (cm)	Panicle length	Development periods (DT)[a]	Internode no. (n upper internode)	Internode length (cm)
			BR3			
n-5	39.91	20.36	0	22	n-5	0.91
n-4	45.47	21.53	0	30	n-4	1.24
n-3	50.27	22.35	0	37	n-3	3.52
n-2	50.09	21.97	0.9	48	n-2	7.34
n-1	42.28	22.09	2-10.0	58	n-1	16.11
n	28.15	31.80	15-24.25[c]	62	n	32.98
			BR4			
n-5	49.63	23.63	0	35	n-5	0.82
n-4	50.28	22.57	0	43	n-4	2.51
n-3	52.57	20.78	0.01	52	n-3	6.59
n-2	45.01	20.40	0.8- -1.50	60	n-2	10.61
n-1	39.25	22.84	4.0-11.00	70	n-1	19.04
n	24.83	33.28	16.0-26.47[c]	76	n	34.55
			Latisail			
n-5	51.62	26.67	0	33	n-5	1.04
n-4	54.59	24.76	0	43	n-4	2.82
n-3	57.55	22.62	0- 0.04	51	n-3	6.01
n-2	52.96	22.60	1- 3.00	60	n-2	11.34
n-1	43.97	23.75	5-12.00	68	n-1	21.48
n	30.34	34.23	14-26.75[c]	73	n	36.56

[a]DT Days after transplanting. [b]Internode between panicle base and flag leaf node.
[c]Full length.

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Table 56. Effect of leaf pruning on the development of spikelet number and degeneration of spikelets, of BR3, BR4 and Latisail, transplant Aman, 1979.

Leaf no. (n flag leaf)	% leaf blade pruning	Spikelets (no./panicle)			% spikelet degeneration		
		BR3	BR4	Latisail	BR3	BR4	Latisail
n	100	210.67 a	295.82 ab	196.63 a	9.19 de	6.51 de	10.36 c
n	50	204.23 a	310.12 a	198.73 a	9.28 d	5.98 de	9.78 c
n-1	100	208.32 a	292.36 b	189.10 ab	12.26 c	8.82 d	11.25 c
n-1	50	197.57 ab	289.72 b	201.63 a	10.86 cd	7.25 d	9.96 c
n-2	100	196.26 ab	294.63 b	192.65 a	16.12 b	12.33 b	14.26 b
n-2	50	198.37 ab	298.15 ab	198.15 a	13.18 c	10.92 b	11.37 c
n-3	100	201.31 ab	296.90 ab	190.21 ab	18.12 a	15.69 a	15.84 a
n-3	50	203.63 a	298.10 ab	196.13 a	12.12 c	10.51 bc	10.63 c
n-4	100	180.63 c	281.60 bc	176.25 c	11.78 c	10.83 b	11.89 c
n-4	50	194.54 b	285.35 bc	188.10 ab	10.07 d	11.15 b	10.10 c
Control -no pruning		208.83 a	304.32 a	198.76 a	8.72 de	5.95 de	9.95 c

In a column the figures followed by a common letter do not differ significantly at the 1% level.

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Table 57. Effect of leaf pruning on the development of plant height, spikelet sterility and grain weight of BR3, BR4 and Latisail, transplant Aman, 1979.

Leaf no. (n flag leaf)	% leaf blade pruning	Main culm ht (cm)			% spikelet sterility			100-grain wt (g)		
		BR3	BR4	Latisail	BR3	BR4	Latisail	BR3	BR4	Latisail
n	100	86.25	106.33	104.04	20.62 a	17.33 a	18.95 a	2.64 e	1.81 c	2.45 d
n	50	88.26	108.45	106.04	13.10 c	12.65 b	13.88 c	2.71 d	1.88 b	2.57 bc
n-1	100	84.15	103.46	100.62	18.62 b	16.15 a	16.62 b	2.68 d	1.84 bc	2.58 bc
n-1	50	89.26	109.10	104.67	13.25 c	12.90 b	13.26 c	2.81 ab	1.94 a	2.62 ab
n-2	100	85.19	106.38	105.25	12.86 c	13.25 b	12.28 c	2.77 bc	1.87 b	2.60 ab
n-2	50	89.88	108.36	105.80	12.95 c	13.36 b	12.65 c	2.79 ab	1.94 a	2.62 ab
n-3	100	89.27	108.95	106.10	11.90 c	12.86 b	12.80 c	2.83 a	1.95 a	2.63 a
n-3	50	88.63	108.88	105.35	12.86 c	11.67 b	12.36 c	2.84 a	1.94 a	2.64 a
n-4	100	90.25	109.63	106.07	12.10 c	12.15 b	11.69 cd	2.82 a	1.94 a	2.64 a
n-4	50	89.16	108.72	105.89	11.30 cd	10.15 bc	10.80 cd	2.84 a	1.96 a	2.66 a
Control	no pruning	90.17	109.45	106.04	11.48 cd	12.65 b	11.30 cd	2.83 a	1.96 a	2.65 a

In a column the figures followed by a common letter do not differ significantly at the 1% level.

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Table 58. Analysis of variance for spikelet number, percentage of spikelet degeneration and grain weight of the test varieties, transplant Aman, 1979.

Source of variation	DF	Mean squares			
		Spikelets (no./panicle)	% spikelet degeneration	% spikelet sterility	100-grain wt (g)
Total	131				
Variety (V)	2	142399.05**	65.56**	4.43**	9.24**
Treatment (T)	10	591.97**	78.57**	71.98**	0.04**
V X T	20	80.58**	4.41**	2.50**	0.001**
Error	99	23.33	0.70	0.90	0.0003
CV(%)		2.10	7.61	7.09	1.03

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Table 59. Effect of variable photoperiods on the development of panicle and number of panicle branches of the varieties sown on 01 April, 1980.

Photoperiod treatment	Panicle developmental stages (DS)[a]				Panicle branches (no.)			
					Main culm		First two tillers	
	Panicle initiation	Heading	Anthesis	Ripening	Primary	Secondary	Primary	Secondary
					BR3			
Full day-length	65	96	98	127	10.17 c	41.75	9.54	33.54
10 h	52	80	84	115	9.00 d	34.92	8.46	32.29
08 h	52	80	84	115	8.25 de	30.42	9.04	28.87
06 h	62	91	94	124	7.58 e	23.58	7.21	20.77
					BR4			
Full day-length	81	109	111	140	12.75 a	69.27	12.25	62.17
10 h	63	91	94	125	12.67 a	69.20	11.92	61.86
08 h	63	91	95	127	12.58 a	64.68	11.88	59.42
06 h	74	102	105	135	11.08 b	46.92	10.93	47.34
					Latisail			
Full day-length	NPI[b]	NPI	NPI	NPI	NPI	NPI	NPI	NPI
10 h	46	73	77	105	9.17	39.50	8.21	34.29
08 h	48	76	80	108	9.13	35.00	7.96	30.29
06 h	62	80	83	114	8.04	27.83	6.93	24.23

The letters followed by the same letter are not statistically different at the 5% level.

[a]DS Days after sowing. [b]NPI No panicle initiation.

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Table 60. Effect of variable photoperiods on the development of spikelet number per panicle, degeneration and some quantitative characters of BR3, BR4 and Latisail, 1980.

Photoperiod treatment	Spikelets (no./panicle)		% spikelet degeneration/panicle		Panicle length (cm)	Plant ht (cm)	Tiller (no./plant)	Panicle (no./plant)	Dry straw wt (g)/plant
	Main culm	First two tillers	Main culm	First two tillers					
BR3									
Full day length	163.08 b	140.82	18.47	18.64	24.79	92.02	19.25	14.58	25.04
10 h	139.58 c	130.75	32.69 e	30.35	23.98	94.17	13.25	11.01	12.57
08 h	122.92 c	111.96	39.28 cd	41.57	22.38	84.98	11.42	9.50	9.69
06 h	96.50 d	86.75	45.65 a	50.37	17.81	67.81	6.92	5.59	2.60
BR4									
Full day length	271.25 a	256.34	25.96	27.39	26.24	109.42	15.34	3.92	21.36
10 h	268.79 a	239.67	30.62 e	30.15	25.50	111.44	13.25	11.67	18.45
08 h	256.67 a	226.51	34.99 cde	30.21	24.43	110.44	11.83	9.29	9.34
06 h	185.00 b	171.28	40.78 bc	39.04	22.81	95.59	6.58	5.02	4.96
Latisail									
Full day length	NPI [a]	-	-	-	-	115.50 [b]	17.33	Nil	14.80
10 h	140.83	120.05	16.57	15.60	27.27	113.32	15.34	12.75	12.27
08 h	128.34	114.50	22.62 f	25.83	24.52	106.17	11.33	8.50	7.74
06 h	94.58	80.06	37.30 cd	41.26	20.50	95.15	6.92	5.58	4.05

In a column figures followed by a common letter do not differ significantly at the 5% level.

[a] NPI No panicle initiation. [b] Plant height measured from leaf tip.

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Table 61. Analysis of variance for the number of panicle branches, spikelets per panicle and spikelet degeneration in the panicles of the main culm and first two tillers of BR3, BR4 and Latisail as affected by variable photoperiods.

Source of variation	DF	Main squares							
		Branches (no./panicle				Spikelet (no./panicle)		% spikelet degeneration	
		Main culm		First two tillers					
		Primary	Secondary	Primary	Secondary	Main culm	First two tillers	Main culm	First two tillers
Total (a)	35								
Variety	2	52.11**	3284.30**	57.13**	3096.03**	44293.28**	602.63	602.63**	527.09**
Treatment	2	6.31**	720.74**	4.62**	464.22**	10901.55**	8404.75**	652.03**	1007.65**
Variety x treatment (interaction)	4	0.26ns	51.55**	0.06ns	10.12**	739.25**	344.80**	37.32**	83.71**
Error	27	0.23	0.904	0.036	0.89	162.12	15.31	5.27	4.70
CV (%)		4.89	2.30	2.09	2.50	8	2.75	6.88	6.4[illegible]
Total (b)	31								
Variety	1	99.23**	7125.19**	94.25**	6649.35**	105626.40**	89684.60**	6.97ns	99.97**
Treatment	3	6.40**	627.15**	4.53**	323.15**	8928.97**	7273.07**	635.82**	671.67**
Variety x treatment (interaction)	3	1.04*	58.01**	0.52ns	5.77**	668.20*	422.30**	66.09**	189.33**
Error	24	0.27	0.714	0.16	1.23	184.02	18.11	5.68	5.47
CV (%)		4.96	1.78	3.93	2.56	7.22	2.50	7.10	6.99

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 62. Analysis of variance for some quantitative characters of the test varieties as affected by variable photoperiods.

Source of variation	DF	Mean squares				
		Panicle length (cm)	Plant ht(cm)	Panicle (no./panicle)	Tillers (no./plant)	Dry straw wt(g/plant)
Total (a)	35					
Variety	2	31.02**	2096.13**	0.30ns	5.01ns	62.00**
Treatment	2	83.98**	1254.54**	124.53**	234.04**	607.78**
Variety x treatment (interaction)	4	5.37**	39.71**	2.20ns	5.52ns	34.74**
Error	27	0.36	2.92	1.03	3.81	2.67
CV (%)		2.68	1.75	11.58	14.75	13.73
Total (b)	31					
Variety	1	49.50**	3864.07**	58.22**		
Treatment	3	42.09**	735.25**	51.41**		
Variety x treatment (interaction)	3	5.91**	59.27**	56.94**		
Error	24	0.41	3.07	1.09		
CV (%)		2.73	1.83	11.84		

* Significant at the 5% level. ** Significant at the 1% level. ns Nonsignificant.

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Table 63. Climatic environment at BRRI farm, Joydebpur, April - August, 1980.

Month	Day length (hr)	Air temperature (°C)		Solar radiation K-cal/cm^2 (total)	Bright sunshine (hr)	Total rainfall (mm)	Total evaporation (mm)	Relative humidity (%)	
		Max.	Min.					6 a m	12 noon
Apr	12.7	35.0	24.3	14.9	8.9	110.0	243.0	89.2	57.0
May	13.3	31.2	22.5	14.4	7.6	410.5	207.8	90.7	73.5
Jun	13.7	31.2	26.0	11.8	5.8	311.7	167.9	90.4	79.7
Jul	13.5	31.1	25.9	11.0	4.8	357.1	167.3	92.5	82.9
Aug	13.0	31.3	25.9	12.4	6.3	344.4	139.5	91.2	77.6
Sep	12.3	31.8	25.8	11.4	6.6	238.0	162.0	92.4	78.3

[a]The values in these columns are averages. Solar radiation has been calculated from bright sunshine hours.

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Table 64. Panicle developmental stages in relation to the panicle length in the seedbed, transplant Aman season.

Panicle developmental stages	Panicle length (mm)	Plant age (DS)[a]		
		BR3	BR4	Latisail
Panicle initiation	0	65-70	80-85	88-92
Branch development	0.1- 1	70-75	85-88	92-95
Spikelet development	1-15	75-80	90-95	95-100
Pollen mother cell formation	20-60	80-82	95-98	100-105
Active reduction division	100-115	85-90	100-108	110-115
Heading	110-140	95-100	108-110	115-120
Anthesis	110-140	100-105	110-115	120-125
Ripening	110-140	130-135	145-150	150-155

[a]DS Days after seeding.

Table 65. Panicle developmental stages in seedbed as influenced by Boro season.

Plant age (DS)[a]	Panicle developmental stages		
	BR3	BR4	Latisail
105	Bract development	Vegetative shoot apex	Vegetative shoot apex
110	Panicle initiatioin	Bract development	Panicle initiation
115	Primary branch development	Panicle initiation	Development of spikelet primordium
120	Spikelet development	Primary branch development	Development of spikelets
125	Pollen mother cell development	Spikelet development	Pollen mother cell development
130	Meiosis in anthers	Pollen mother cell development	Meiosis in most of the anthers and panicle enlargement
135	Early stage of tetrad formation	Meiosis in anthers	Heading
140	Heading	Pollen grain development	Anthesis
145	Anthesis	Heading	Milk
150	Grain filling	Anthesis	Grain filling
170	Grain filling	Grain filling	Grain development
175	Dough	Grain development	Full development of caryopsis
180	Full development of caryopsis	Grain development	-
185		Full development of caryopsis	

[a]DS Days after seeding (1 November, 1978).

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Table 66. Seasonal effect on the developmental stages of panicles in seedbeds.

Season	Sowing date	Panicle developmental stages (DS)[a]							
		Pre-meiotic				Meiotic	Head-ing	Anthe-sis	Ripe-ning
		Panicle initia-tion	Branch develop-ment	Spikelet develop-ment	Pollen mother cell				
					BR3				
Aman	15 Jul	65	70	75	80	82	95	100	132
Boro	01 Nov	110	115	120	125	130	140	145	175
					BR4				
Aman	15 Jul	80	85	90	95	98	108	115	145
Boro	01 Nov	115	120	125	132	135	145	150	185
					Latisail				
Aman	15 Jul	88	92	95	100	105	115	120	150
Boro	01 Nov	110	112	115	122	125	135	140	175

[a]DS Days after seeding.

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Table 67. Relative length of the panicle, spikelet and anther lobe in the stages of panicle development in seedbed of rice varieties BR3, BR4 and Latisail sown on 01 November, 1978.

Developing structures (mm)	Panicle developmental stages[a]						
	Spikelet development			Meiotic stages			
	Primary branch	Secondary branch	Pollen mother cell formation	Active division	Tetrad formation	Heading	Anthesis
			BR3				
Panicle length	3-10	15-30	40-65	70-100	100-110	110-130	110-130
Spikelet length	0.3-0.6	1-3.2	3.5-5.1	5.5-7.1	7.1-7.5	7.5-7.8	7.5-8.0
Spikelet branch	0.1-0.3	0.4-1.0	1.0-1.2	1.3-1.7	1.7-1.8	1.8-2.0	2.0-2.2
Anther lobe length	-	0.1	0.1-0.4	0.5-1.0	1.0-1.2	1.2-1.4	1.5-1.8
			BR4				
Panicle length	4-20	25-30	35-50	55-100	100-110	110-140	120-140
Spikelet length	0.4-1.3	1.5-2.0	2.5-3.5	4.5-7.0	7.0-7.5	7.5-8.0	8.0-8.2
Spikelet breadth	0.1-0.3	0.5-0.8	0.9-1.0	1.2-2.1	2.1-2.4	2.4-2.5	2.4-2.6
Anther lobe length	0.1-0.4	0.6-0.7	0.7-0.9	1.0-1.2	1.2-1.5	1.5-1.7	1.7-2.0
			Latisail				
Panicle length	1.5-15	20-25	30-35	40-100	100-110	110-130	120-130
Spikelet length	0.2-1.8	1.8-2.5	3.5-4.5	4.8-7.0	7.0-7.5	7.5-8.0	7.5-8.2
Spikelet breadth	0.1-0.6	0.6-1.0	1.1-1.3	1.5-1.8	1.8-2.0	2.0-2.6	2.4-2.6
Anther lobe length	0.1-0.2	0.2-0.3	0.4-0.6	0.7-1.0	1.1-1.2	1.2-1.3	1.8-2.0

[a]Top spikelets were considered for each developmental stages (averages from 100 samples).

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Table 68. Relative development of primary and secondary branched spikelets in the panicle developmental stages, Boro seedbed, 1978.

Spikelet length (mm)/ panicle branches [a]	Panicle developmental stages			
	Early spikelet development	Pollen mother cell formation	Meiotic division	Heading
		BR3		
Primary branch	1.0-3.0	3.5-5.0	5.5-7.5	7.5-8.0
Secondary branch	0.1-0.8	0.4-2.5	3.5-7.5	7.0-7.5
		BR4		
Primary branch	1.5-2.5	2.5-3.5	4.5-7.5	7.5-8.2
Secondary branch	0.2-0.8	0.5-2.0	3.5-7.5	6.5-8.0
		Latisail		
Primary branch	1.5-2.5	3.5-4.5	4.8-7.5	7.5-8.0
Secondary branch	0.2-1.2	0.8-2.5	3.5-7.0	7.0-8.0

[a]Top spikelets from primary branches and basal spikelets from secondary branches.

Table 69. Relation between panicle developmental stages and percentages of spikelet degeneration as influenced by Aman and Boro seasons.

Characters	Season[a]	Panicle developmental stages							
		Spikelet development		Pollen mother cell formation		Meiotic		Heading	Anthesis
				BR3					
Panicle length (mm)		3-10	15-20	30-40	40-65	70-80	80-100	110-130	110-130
% spikelet degeneration	Aman	0	0	10.63	24.67	28.02	30.51	15.64	10.25
	Boro	0	5.63	12.82	20.55	27.13	33.09	15.64	14.15
				BR4					
Panicle length (mm)		4-20	25-30	35-40	40-55	55-85	85-100	110-150	110-150
% spikelet degeneration	Aman	0	6.14	15.16	28.14	30.15	32.96	10.64	8.73
	Boro	0	8.21	18.25	26.42	33.64	38.29	11.86	10.59
				Latisail					
Panicle length (mm)		1.5-15	20-25	25-30	30-40	40-70	70-90	100-130	100-130
% spikelet degeneration	Aman	0	5.21	14.62	30.15	35.63	38.79	14.59	10.25
	Boro	0	3.65	18.15	37.21	40.78	42.92	16.26	11.59

[a]Aman seeds were sown on 15 July and Boro seeds on 1 November.

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Table 70. Seasonal effect on plant height development in the seedbed of BR3, BR4 and Latisail.

Seedling age (days)	Plant ht development (cm)					
	Sowing date					
	15 Jul (Aman)			1 Nov (Boro)		
	BR3	BR4	Latisail	BR3	BR4	Latisail
10	10.11	7.11	7.93	1.98	2.98	2.62
20	13.96	15.92	20.25	3.62	5.74	4.72
30	14.41	22.25	28.33	4.51	7.92	6.12
40	20.31	23.80	32.46	6.33	8.10	8.31
50	25.25	27.15	45.23	8.84	8.69	10.11
60	29.48	31.65	49.15	9.79	9.75	13.20
70	32.70[a]	33.87	59.19	12.95	15.42	17.72
80	32.84	34.25[a]	61.72	12.89	15.53	18.03
90	37.25	38.32	62.92[a]	13.60	16.61	18.18
100	41.76[b]	39.97	67.50	16.17	21.16	21.20
110	47.51	48.23[b]	68.22	16.71[a]	22.76	24.28[a]
120		60.20	68.25[b]	18.73	22.78[a]	24.55
130				19.25	23.95	25.62
140				26.24[b]	25.98	32.99[b]
150				35.25	36.98[b]	44.15
160				40.35	48.26	53.20

[a]Panicle initiation stage. [b]Heading stage.

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Table 71. Seasonal effect on the development of dry matter contents of BR3, BR4 and Latisail in their growth stages in the seedbed.

Seedling age (days)	Dry matter content (g/20 plants)					
	Sowing date					
	15 Jul (Aman)			1 Nov (Boro)		
	BR3	BR4	Latisail	BR3	BR4	Latisail
10	0.24	0.15	0.19	0.10	0.09	0.11
20	1.07	1.01	0.94	0.19	0.18	0.16
30	1.58	1.68	1.92	0.29	0.37	0.28
40	2.32	1.92	2.10	0.62	0.56	0.65
50	3.96	2.71	3.55	0.92	0.61	0.82
60	4.92	2.98	4.86	1.01	0.69	0.94
70	5.15[a]	3.66	5.65	1.59	0.97	1.52
80	7.31	4.25[a]	7.11	1.65	1.20	1.88
90	9.21	6.70	8.35[a]	1.84	1.36	2.02
100	10.52[b]	8.85	10.36	1.89	1.45	2.11
110	12.86	11.38[b]	12.35	1.92[a]	1.69	2.17[a]
120	13.89	13.26	14.80[b]	2.01	1.73[a]	2.29
130		16.38	20.82	2.89	2.11	4.12
140				4.36[b]	3.30	5.42[b]
150				7.82	3.72[b]	7.49
160				9.20	5.91	8.42
170				10.15	7.20	9.49
				10.25	10.45	9.51

[a]Panicle initiation stage. [b]Heading stage.

Table 72. Seasonal effect of the development and degeneratioin of panicle branches and spikelets in the seedbed.

Season	Sowing date	Panicle branches no.		% panicle degeneration		Spikelet no./panicle	% spikelet degeneration
		Primary	Secondary	Primary	Secondary		
				BR3			
Aman	15 Jul	5.45[a] ± 0.37[b]	4.81 ± 0.55	11.19 ± 1.62	70.24 ± 1.01	37.25 ± 2.29	30.51 ± 0.4[illegible]
Boro	01 Nov	4.67 ± 0.07	5.01 ± 0.29	16.08 ± 1.83	70.50 ± 1.25	41.68 ± 1.50	33.09 ± 1.6[illegible]
				BR4			
Aman	15 Jul	6.10 ± 0.21	8.06 ± 0.88	19.51 ± 1.21	73.94 ± 2.05	40.87 ± 3.22	32.96 ± 2.1[illegible]
Boro	01 Nov	5.37 ± 0.08	9.99 ± 0.38	19.18 ± 1.32	71.47 ± 1.85	55.80 ± 2.60	38.29 ± 1.4[illegible]
				Latisail			
Aman	15 Jul	4.97 ± 0.14	4.30 ± 0.36	30.17 ± 1.75	72.79 ± 1.98	25.24 ± 0.77	38.79 ± 2.46
Boro	01 Nov	4.70 ± 0.27	5.74 ± 0.93	10.65 ± 1.86	74.03 ± 1.70	38.25 ± 1.05	42.92 ± 2.65

[a]Mean value . [b]Standard error.

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Table 73. Seasonal effect on the development of some quantitative characters of BR3, BR4 and Latisail.

Season	Sowing date	Plant ht(cm)	Panicle length (cm)	Grain (no./ panicle	% spikelet sterility	1000-grain wt(g)	% panicle bearing plants	% seed germi-nation
				BR3				
Aman	15 Jul	48.61	11.39	26.85	29.75	25.11	74.47	85
Boro	01 Nov	41.56	12.45	28.51	25.67	24.08	81.76	88
				BR4				
Aman	15 Jul	64.43	12.74	27.39	27.31	18.25	61.61	96
Boro	01 Nov	50.55	14.07	34.43	22.97	19.28	71.43	97
				Latisail				
Aman	15 Jul	68.38	10.67	15.44	32.35	24.01	65.33	95
Boro	01 Nov	54.25	12.35	21.83	29.65	23.88	72.41	94

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PLATE I

Different stages of the development of a normal panicle.

Figure 1. The shoot apex in the late vegetative phase. The lateral bulges (A) indicating panicle branch primordium.

Figure 2. Shoot apex enclosed by leaves (L) showing the flag leaf (n th) and leaf below the flag leaf (n-1).

Figures 3-4. Panicle initiation stage. Lateral domes are primordia of panicle branches (PB). Neck-node is prominent (NN).

Figures 5-7. Development of secondary branch primordia (SBP) and hairs (H) in the node (Fig.6). Figure 7 shows tHe magnified view of SBP.

Figures 8-11. Development of spikelets on the primary and secondary panicle branches. Note basipetal sequence of spikelet formation. The panicle branch is terminated by a spikelet (TS), lemma (L), palea (P) and two lower sterile glumes (SI and S2) are shown in figures 9-11.

Figure 12. A normal panicle of BR4 showing the terminal spikelet (TS), and primary (PB) and secondary (SB) branches on the peduncle. The terminal spikelets and those on the basal secondary branches (BB) follow the basipetal development.

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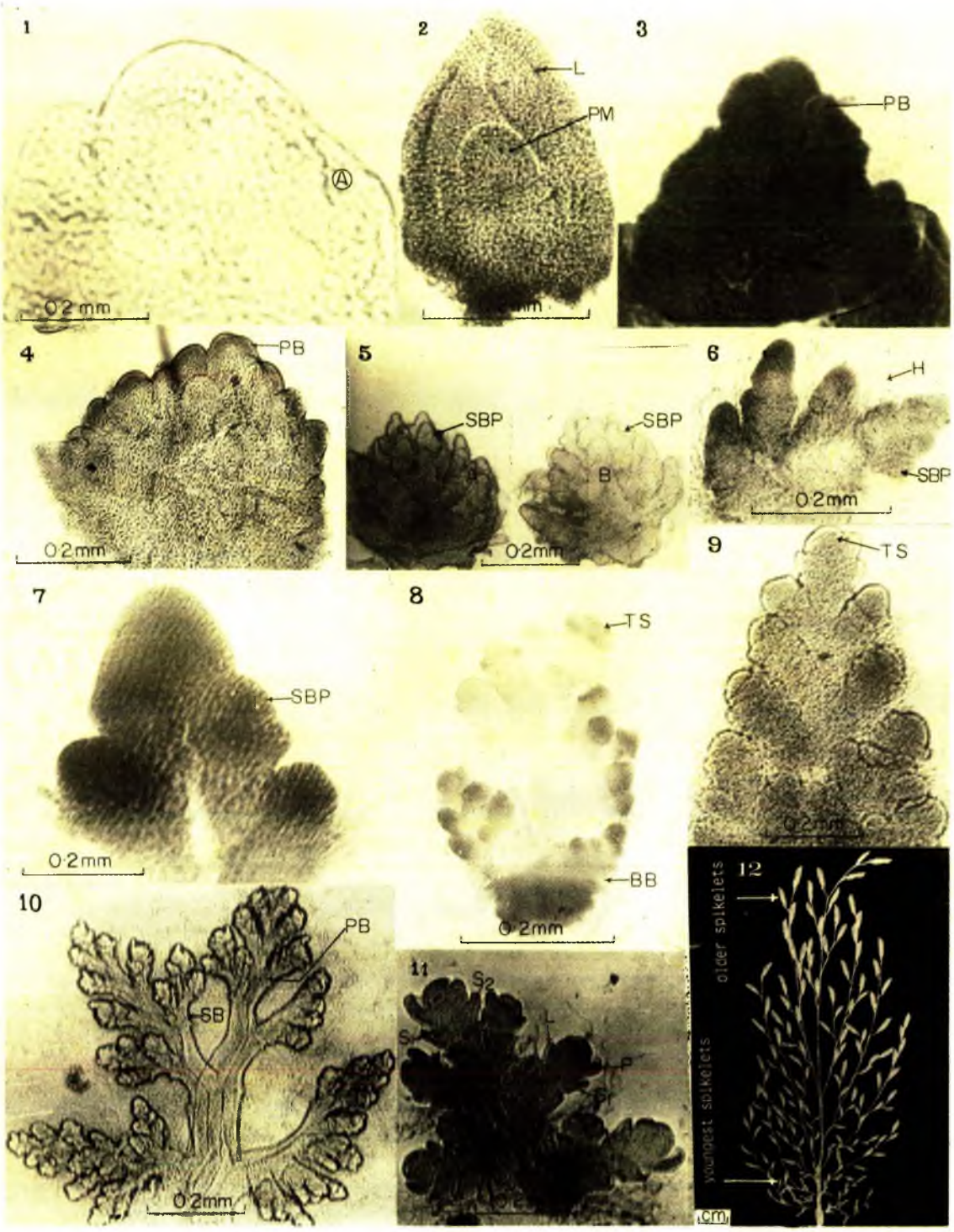

PLATE 1

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PLATE 2

Normal spikelet development

Figure 1. Successive stages of panicle development of BR3.

- o a - the late PI stage;
- o b - spikelet developing stage;
- o c - all components of panicle have formed; and
- o d,e and (f - i) further development of panicle and spikelet is continued.

Figure 2. Development of spikelet at different stages of panicle development of BR4 (a-c).

Figure 3. Two later stages of panicle development in Latisail (a and b).

Figures 4-6. The early meiotic stage of spikelet development (T. Aman) in BR3 (Fig.4), BR4 (Fig. 5), and Latisail (Fig. 6) showing spikelet dimension in different panicle branches. Note some of the degenerated spikelets.

Figures 7-9. The early meiotic stage of spikelet development (Boro) in BR3 (Fig. 7), BR4 (Fig. 8) and Latisail (Fig. 9).

Note : Degenerated spikelets are marked with arrows.

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PLATE 2

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PLATE 3

The spikelet number and degeneration of spikelets as obtained from transplanted seedlings at a higher age (70-day-old), T. Aman season.

Figure 1. Normal and degenerated spikelets of BR3.

Figure 2. The magnified view of the box shown in Fig.1; the degenerated panicle branches and spikelets are now easily seen under higher magnification.

Figure 3. Developing and degenerated spikelets of BR4.

Figure 4. The magnified view of the box shown in Fig. 3; showing the degenerated branches and spikelets.

Figure 5. Developing and degenerated spikelets of Latisail.

Figure 6. The magnified view of the box of Fig. 5 showing the number of developing and degenerated spikelets.

Note of number of spikelets per panicle of the plants obtained from 30-day-old seedlings (Plate 2) and transplanted older seedlings (70-day).

Note Degenerated spikelets are marked with arrows.

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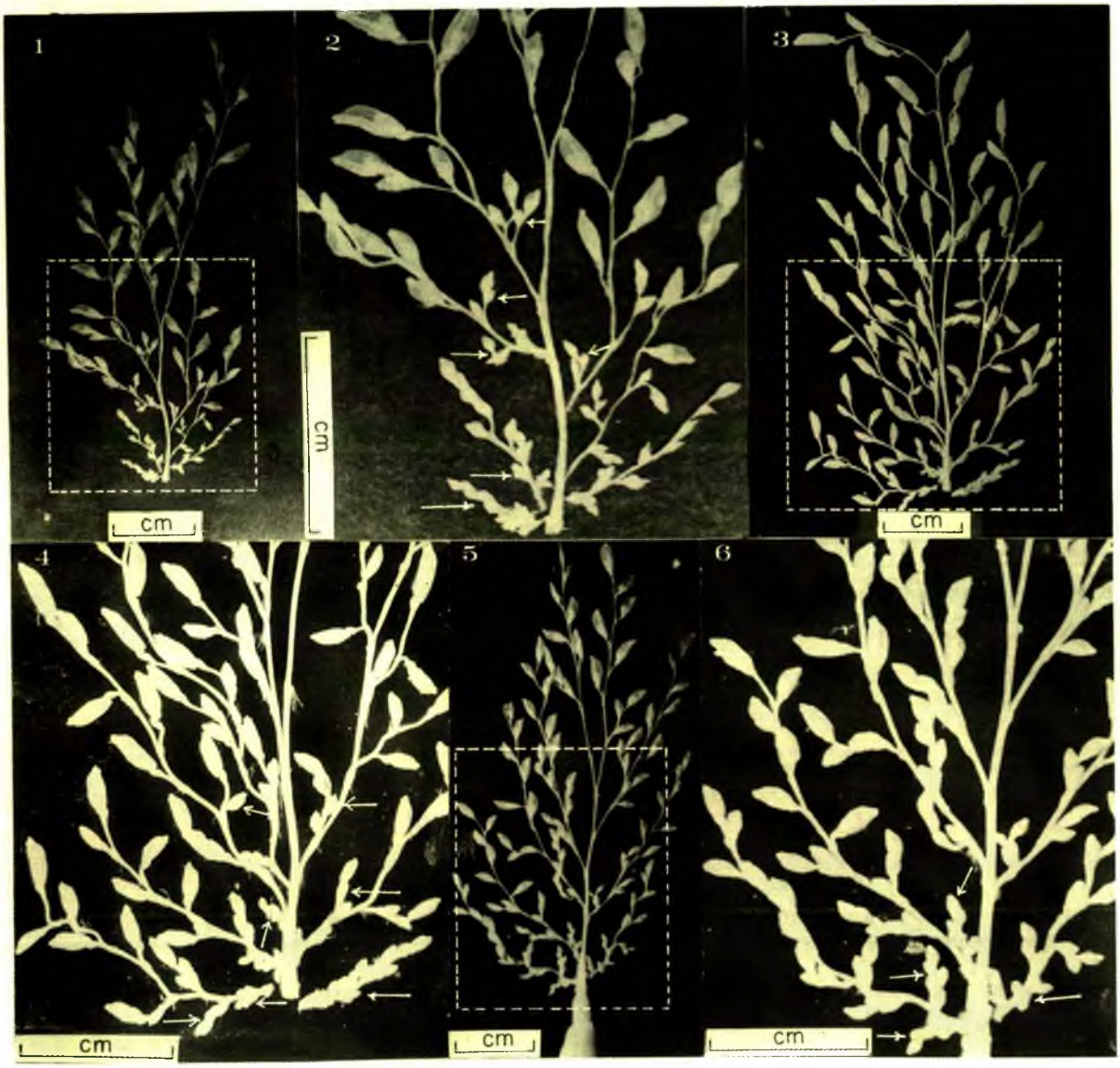

PLATE 3

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PLATE 4

Degeneration of developing spikelets in the panicles of the 80-day old transplanted seedlings at the Boro season.

Figure 1. Normal and degenerated spikelets of BR3.

Figure 2. The magnified view of the box shown in Fig. 1 showing the spikelet dimension in the different panicle branches. Note that the degeneration of a spikelet occurred before the meiotic stage of development.

Figure 3. Developing and degenerated spikelets of BR4.

Figure 4. The magnified view of the box shown in Fig. 3 showing the dimension of developing and degenerated spikelets.

Figure 5. Developing and degenerated spikelets of Latisail.

Figure 6. The magnified view of the box shown in Fig. 5 showing the developing and degenerated spikelets.

Note The number of spikelets that developed per panicle from plants obtained from seedlings of higher ages in the T. Aman and Boro season (Plates 3 and 4). Spikelet degeneration occurred at different panicle branches. Degenerated spikelets are marked with an arrows.

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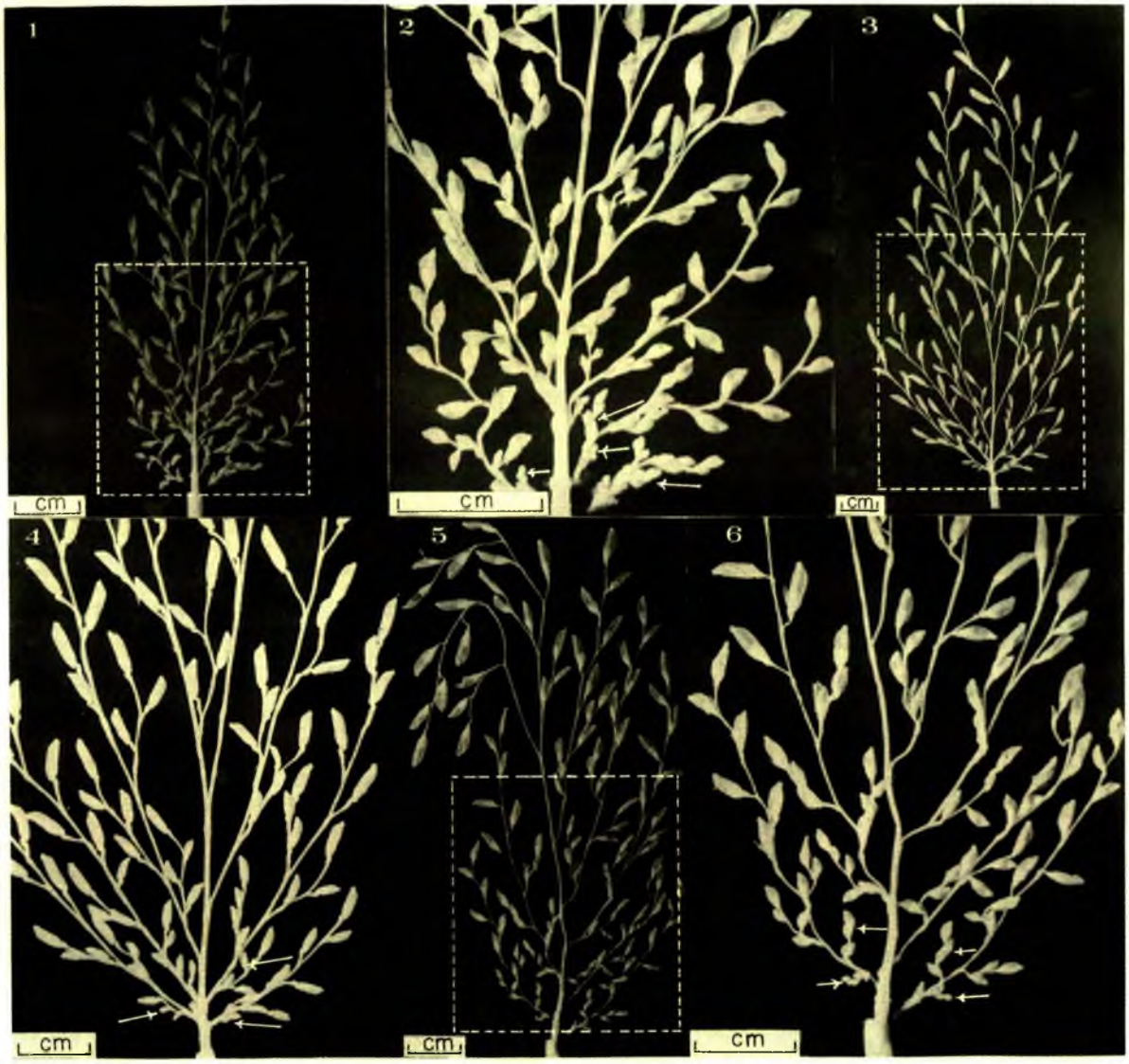

PLATE 4

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PLATE 5

Fertilizer effect on the number of spikelets and spikelet degeneration in BR4.

Figure 1. Effect of fertilizer treatment on spikelet number and degeneration.

Figure 2. The magnified view of the box shown in Fig. 1, showing the spikelet dimension in the different panicle branches and spikelet degeneration.

Figure 3. Effect of nitrogen treatment on spikelet number and degeneration.

Figure 4. The magnified view of the box shown in Fig. 3, showing the spikelet degeneration.

Figure 5. Zero fertilizer treatment on the number of spikelets per panicle.

Figure 6. The magnified view of the box shown in Fig. 5 showing the degenerated spikelets.

Note Degenerated spikelets are arrow marked.

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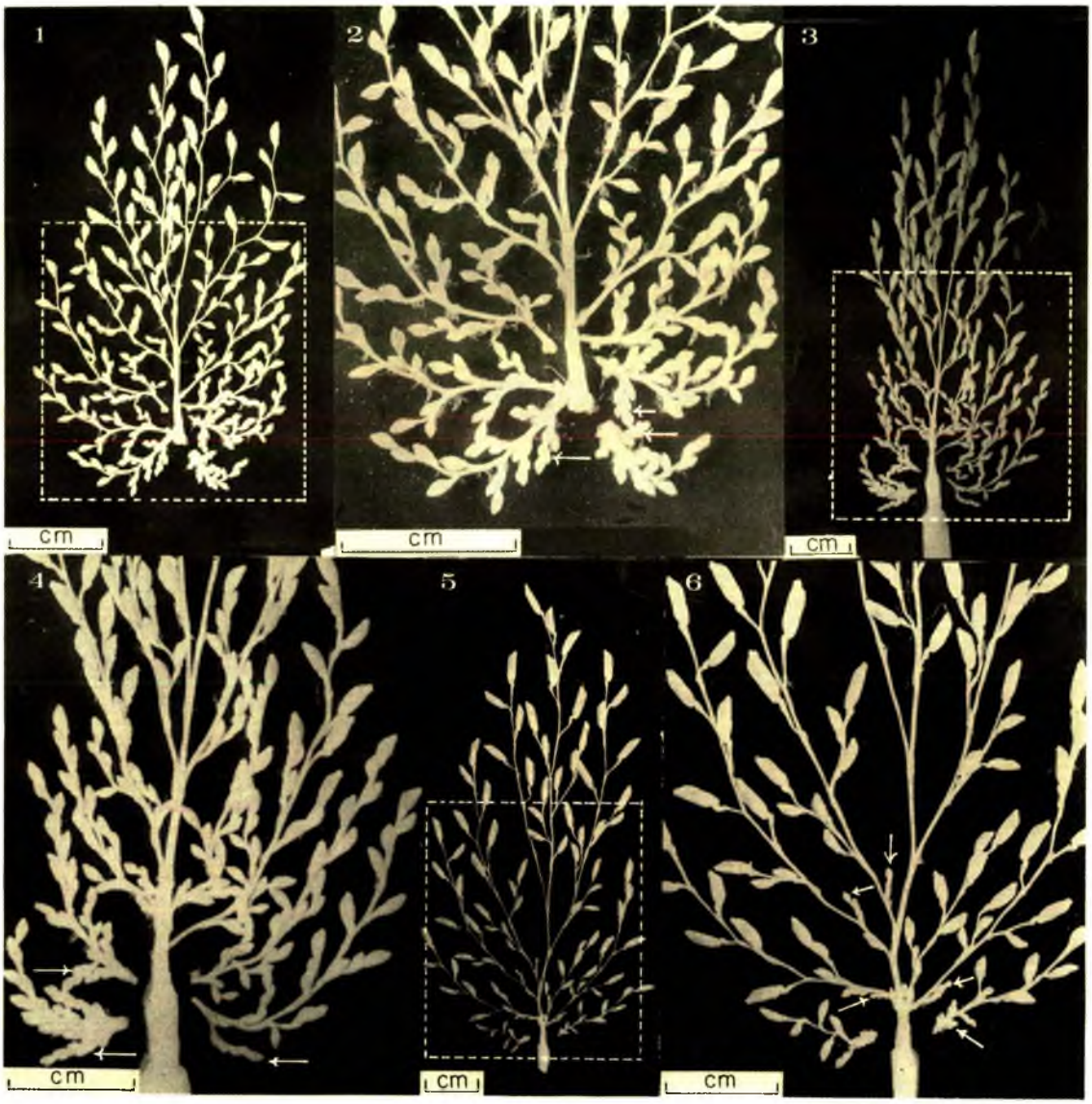

PLATE 5

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PLATE 6

Effect of photoperiods on spikelet number per panicle and spikelet degeneration of BR3, BR4 and Latisail.

Figure 1. Photoperiod treatments on BR3. Normal day length (Fig.1); 10-hr (Fig.2); 8-hr (Fig.3) and 6-hr (Fig. 4).

Figure 5. The magnified view of the box shown in Fig. 4, showing degenerated branches and spikelets.

Note The reduction of spikelet number and spikelet degeneration from normal day length to 6 hrs.

Figure 6. 10-hr day length treatment on BR4.

Figure 7. The magnified view of the box shown in Fig. 6 showing the degenerated branches and spikelets.

Figure 8. 10-hr day length treatment on Latisail.

Figure 9. The magnified view of the box shown in Fig. 8, the degenerated spikelets are now easily seen under higher magnification.

Figure 10. 6-hr day length treatment on BR4 showing the degenerated branches and spikelets.

Figure 11. 6-hr day length treatment on Latisail showing the degenerated branches and spikelets.

Figure 12. The magnified view of the box (Fig.4), showing the degenerated branches and spikelets.

Note Degenerated spikelets are arrow marked.

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PLATE 6

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PLATE 7

A. Effect of seeding rates on spikelet number and degeneration in the panicle of the main culm of transplanted Aman.

Figure 1-4. Panicles of BR3 (Fig. 1), BR4 (Fig. 2), Latisail (Fig.3), and magnified view of the box of figure 3 (Fig. 4) of a lower seeding rate (6.25 g/m^2),

Figure 5-8. Panicles of BR4 (Fig. 5) and Latisail (Fig. 7) and their magnified portions in figures 6 and 8, respectively in a higher seeding rate (100 g/m^2).

Note The reduction of spikelet number per panicle, panicle length and the number of degenerated spikelets in a higher seeding rate.

B. Effect of 100% pruning of n-2 or n-3 leaf on spikelet degeneration,,Boro.

Figure 9. Effect of 100% pruning of n-3 th leaf of BR4 showing spikelet degeneration.

Figure 10. The magnified view of the box of Fig. 9 showing the degenerated panicle branches and spikelets.

Figure 11.12. Panicle branches of BR4 (Fig. 11) and BR3 (Fig. 12) showing spikelet degeneration.

Note Degenerated spikelets are marked with an arrow.

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PLATE 7

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PLATE 8

A. Developing and degenerated spikelets in panicle branches.

Figure 1-3. Development of spikelet and spikelet degeneration in panicle branches at normal transplanting BR3 (Fig. 1), BR4 (Fig. 2) and Latisail (Fig. 3).

Figures 4-6. Developing and degenerated spikelets in panicle branches from seedlings transplanted at higher ages (Boro), BR3 (Fig.4), BR4 (Fig. 5) and Latisail (Fig. 6).

Note: Degenerated spikelets were higher in the lower secondary branches. Moreover, spikelets degenerated before the meiotic stage.

B. Panicle development and spikelet degeneration in plants grown in the seedbed.

Figures 7-9. Panicle development in the seedbed of BR3 (Fig. 7), BR4 (Fig. 8) and Latisail (Fig. 9).

Note: Panicles had fewer primary and secondary branches.

Figures 10-12. Development and degeneration of spikelets in BR3 (Fig. 10), BR4 (Fig. 11) and Latisail (Fig. 12).

Note: In the seedbed, only few spikelets developed per panicle followed by degenerated basal branch spikelets. Degenerated spikelets are marked with an arrow.

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PLATE 8

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APPENDIX

BR3

BR3, BR27-10-1 (Biplab) was developed at Bangladesh Rice Research Institute in November 1969 from a cross IR506-1-113 x Latisail (DA17). Latisail is a local improved variety of transplant Aman season. IR506-1-133 is a progeny of IR8 x (B589A4-18/2 x TN1). The new rice variety released in 1973, meets a long-expressed demand of farmers, scientists and planners. It was named Biplab in Bengali. BR3 is a semidwarf (85-100 cm), photoperiod-insensitive variety with erect growth habit and late maturity. This variety is rapidly replacing IR8 for its wide spectrum of disease and insect resistance and adaptation in Aus, T. Aman and Boro seasons. Life cycle varies (133-170 days) from season to season and method of cultivation.

It has medium-coarse grain with abdominal white, a seed dormancy of about one month, and a uniform kernel consistency. Under optimum conditions, yield potential may vary from 5.5 to 7.4 t/ha. The highest yield is obtained in Boro and lowest in Aus. Under upland rainfed conditions, a broadcast crop may not yield more than 3.7 t/ha. Under present average farming conditions, about 60% of yield potential is obtained. The grain sterility may range from 5 to 15%.

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BR4

BR4 (Brrisail) BR51-91-6 was developed at BRRI in 1969 from a cross IR20 x IR5-114-3-1. It is weakly photoperiod-sensitive and was recommended for the transplant Aman season. Plants are erect, attain a height of 120-125 cm with a life cycle of 140-145 days. The variety is resistant to bacterial leaf blight. The mature caryopsis are medium, straw coloured with an abdominal white spot. The yield at field level may vary from 5 to 7 t/ha.

Latisail

Latisail (DA17) is a local improved photoperiod-sensitive variety originally collected from Sylhet area. The plants are medium tall with a mean height of 125-130 cm and a life cycle of 150-160 days. It is recommended and widely grown as transplant Aman. Latisail is resistant to rice tungro virus and susceptible to bacterial leaf streak. It has light straw coloured medium caryopsis with abdominal white kernel. The yield at a field level ranges 3-4 t/ha.