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Rice Ratooning Management

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Abstract: The ratooning is the ability of the plant to regenerate new tillers from stubbles of the main crop. Though the crop thought to be the same, there may be variation in the physiological parameters between the main and ratoon crop. For example panicle development and heading are more uneven in ratoon than that of the main crop. The ratoons vary in their chemical composition according to the node number and position. The general low yield obtained from the ratoon crop is believed to be mainly due to the reduction in number of productive tillers and short growth duration. Although the yield contributing factors like plant height, leaf area, leaf canopy, panicle length, growth duration, cutting height of the stubble etc. are largely governed by the genetic make-up of the plant. Under various cultural practices cutting height of the main crop stubbles is correlated with yield of the ratoon crop, number of auxiliary buds and productive tillers. Also cutting height is correlated with regrowth potential or ratoon vigour, nodal and basal tillers, ratoon rating and ability, uniform growth and maturity, filled spikelets and missing hills. Application of nitrogen fertilizer is considered probably the most important single nutrient element in growth and yield of ratoons. The rice ratooning offers an opportunity to increase cropping intensity per unit of cultivated area because a ratoon crop has shorter growth duration than the main crop. In addition, ratoon crop may be grown with 50% less labour. Neither land preparation nor planting is needed and the crop uses 60% less water than the main crop. The yield of the ratoon crop may be achieved by 50% of the main crop, if crop management practices are used effeciently.

Keywords: Rice-Ratooning, Management

Morphology and physiology of rice ratoon: The morphology of the ratoon plant differs significantly from that of the main crop plant. Usually plant height (Balasubramanian *et al.*, 1970) is lower and effective tillers are fewer in the ratoon crop than the main crop (Bahar and De Datta, 1977). However, ratoon crop produce more total tillers than the main crop (Quddus, 1981; Samson, 1980). Stem thickness is correlated with higher carbohydrate content in the stubbles. This could have induced more vigorous regeneration of ratoon tillers, resulting in the production of a larger number of tillers and higher grain yield (Palchamy and Purushothaman, 1988). Ratoon growth of rice depends upon the amount of Total Carbohydrate Content (TAC) in the stem base, at least early growth. The large amount of TAC is required to produce many tillers, and it would be achieved by high cutting of main crop stubbles, because the amount of TAC in the stubbles increases with cutting height (Ichii and Ogaya, 1985). Ratoon growth after the early stage was affected not only by the amount of reserves in the stem base but also by photosynthetic products in foliage. However, the dependence of photosynthesis in foliage is far less important in determining tiller number than it is in determining foliage weight, because tiller number became constant far more rapidly than foliage weight after main crop harvest. Ratoon plants should have sufficient tillers in the early stage after the main crop harvest to achieve high yields. Cultivars and cultural practices, including cutting height and fertilizer management, which provide a large quantity of reserves at harvest, may be advantageous for rice ratooning (Ichii, 1984). Tillers that regenerated from higher nodes formed more quickly grew faster and matured earlier (Prashar, 1970). When the main crop was harvested late, ratoon tillers began to develop soon after the first crop ripened. In this situation, the culms of the growing ratoon tillers are damaged because they elongate within the old leaf sheaths (Szokolay, 1956). Several studies showed that ratoon tiller development depends upon the carbohydrates that remain in the stubbles and root after the main crop is harvested (Cuevas Perez, 1980; Ichii and Sumi, 1983; and Samson, 1980). Garcia (1981) reported that in cultivar BP176 carbohydrate content was correlated positively with main crop growth duration. However, ratooning ability was associated negatively with growth duration. Thick culms may store more carbohydrate than thin culms, which is probably reflected in the ratoon potential. In IR-44 the culm thickness varied from 2 to 5 mm; most were 3-5 mm thick. Ratoon tillers developed irrespective of culm thickness. Average tiller production varied from 1.33 to 2.90 (Chauhan *et al.*, 1985).

Ratoon Development: The ratoon tiller regeneration and growth depends on the buds that remained on the stubbles. The buds exist in various stages of development (Nair and Sahadevan, 1961). Auxiliary buds that develop at those nodes grow into ratoon tillers. In hybrid rice, most of the buds on the second, third and fourth nodes of the stubble are more viable compared to fifth node bud from the base (Sun Xiaohui *et al.*, 1988). The buds grew in different stages of development and no longer at the lowest nodes and were shorter at the upper nodes (Niar and Sahadevan, 1961). Chauhan *et al.* (1985) observed that IR-44's buds were similar in length irrespective of their position on the stubble. However, the length of buds was affected by nitrogen fertilizer application to the main crop as observed by Sun Xiaohui *et al.* (1988) in hybrid rice. Ratoon development began soon after the main crop ripened. In the case of delayed harvesting of the main crop, the culms of the growing tillers became damaged as they elongated under the old leaf sheaths (Szokolay, 1956). In a study on ratoon tiller development of IR-44, the length of the buds at the first, second and third nodes did not vary. Buds grew slowly 40 days after cutting of the main crop. After 5 days, the buds at the first node generally grew faster, followed by those from the second and third nodes. Maximum bud lengths were 235, 159 and 74 mm. The average bud lengths were 144.45 and 17 mm. Eight days after ratooning, the culms began to branch (Chauhan, 1988). Ratoon tillers are characterized by different C:N ratios according to their origin (Iso, 1954). In Kagi Ban2 cultivar, the C:N ratio was 17.0 in tillers from upper nodes, 13.88 in those from the base and 10.80 from those below the soil. Moreover, the tillers from the upper nodes with high C:N reached like old seedlings. They matured faster and were shorter in culm than those tillers emerging from the lower nodes, which behaved like young seedlings (Iso, 1954). Aubin (1979) observed in the D52-37 rice cultivar that the upper node tillers had fewer leaves than the lower node tillers. However, Volkova and Smetanin (1971) reported that different cultivars produced ratoon tillers differently. Ichii (1988) suggested that the large amount of total available carbohydrate (TAC) required to produce many tillers would be achieved by high cutting the main crop, because the amount of TAC in stubble increases with cutting height. Chauhan *et al.* (1985) assumed that thick culms would store more carbohydrate than thin culms and probably would be reflected in ratoon potential. In IR-44 they observed that the average tiller production was higher with thick culms. However, the origin and time of tiller development were not influenced by culm thickness (Chauhan *et al.*, 1985). Ratoon tillers that form early do not inhibit subsequent tiller production; therefore, plants with early regeneration ability produce more tillers. Early tiller regeneration may encourage tillering by providing nutrients to the developing buds (Chauhan *et al.*, 1985). In IR-44 the first tiller appeared 1 to 10 days after cutting, but the regeneration time was negatively and significantly correlated with the number of tillers at weeks after cutting and at ratoon harvest.

Varietal Potentiality: The prospect of successful ratoon cultivation depends largely on ratooning of a variety. Among the plant characteristics sought for high yield potential, plant type and nitrogen responsiveness have received extensive consideration (Poehlman, 1976). Lack of acceptance of rice ratooning by commercial farmers has been attributed to low yields, lack of good ratooning varieties, uneven maturity, disease and insect problem, lack of location-specific cultural practices, inferior grain quality and lack of assured return from investment (Chauhan *et al.*, 1985). Ratooning ability has been found to be a varietal character (Bahar, 1976; Balasubramanian *et al.*, 1970; Bahar and De Datta, 1977; Haque, 1975; Nadal and Carangal, 1979). Further, Nadal and Carangal (1979) identified three rice selections without standing tillering capacities and high ratoon yields under varying soil moisture regimes. Haque (1975) found out that IR2061- U23, IR2145-20-4 and IR1924-36-22 possessed high ratooning ability. In India, C3810, Ratna, CR20-66, and CR156-5021-207 showed superiority in ratooning and yield ability (Das and Ahmed, 1982). In China, some hybrid rices produced high grain yields and had high ratooning ability. The hybrid Zaishelgyou produced the highest main and ratoon crop yields resulting in a significantly higher total yield (11.0 t/ha). Despite the lower ratoon yield of Aiyou 1, Sun Xiaohui *et al.* (1988) considered it most suitable for ratooning than Aiyou 2, which yielded 2.6 t/ha. They observed that Aiyou 1 had wide adoptability and strong ratooning ability, while Aiyou 2 was susceptible to high temperature at flowering. A suitable ratoon variety for the area should have the following characteristics (Bardhan Roy *et al.*, 1982): Photoperiod sensitivity with high yielding background. Fertilizer responsiveness with main crop yield of 5t/ha in the dry season. Photoperiod-sensitive ratoon that remains in the vegetative stage from April-August. Good ratooning ability and vigorous growth during pre-monsoon rains. Some degree drought and sub-mergence tolerance or elongation ability for the ratoon, and Resistant to viral disease.

Tillering Capacity: Tillering ability is probably the most important genetic factor affecting ratoon performance of grasses. Because there are high and low tillering rice, ratoon depends to a large extent on the inherit tillering capacity of a cultivar (Plucknett *et al.*, 1984). Different varieties produce ratoon tillers differently (Volkova and Simetanin, 1971). Kuban grew tillers from all nodes of the stubble, whereas Klasnodarskii 424 developed tillers mainly from the third node. Findings indicated that the ratoon crop yields well if main crop stubble is left with 2-3 nodes. Elalaoui and Simons (1988) indicated that the initial tillering variety may be beneficial because it can transport photo assimilates from the non- surviving tillers before they die under dense plant community. In ratoon crop the effective tillers are fewer compared to the main crop. However, the actual number of tillers may be higher in the ratoon crop than in the main crop (Balasubramanian *et al.*, 1970); Bahar and De Datta (1977). Except for seed variability, all other characters (plant height, panicle length, spikelet size, number of productive tillers, and grain setting) were less pronounced in the ratoon crop than in the main crop (Reddy and Pawar, 1959).

Parago (1963a) obtained from Mulbiens similar number of tillers in the ratoon crop compared to the main crop. Bardhan Roy *et al.* (1988) compared photoperiod-sensitive ratoon crop with normal Aman rice crop. They found out that the same cultivars produced more tillers as ratoon crop than as Aman sown rice. Sun Xiaohui *et al*, (1988) obtained more tillers from the main crop with hybrid rice Zaishengyou. Varietal differences exist with respect to emergence of ratoon tillers from different nodes of the stubbles. The tillers may emerge from all nodes of the stubbles or from only the lower nodes or from any specific node number. Many finding suggested that ratoon crop is better if the main crop stubble is cut with 2-3 nodes left.

Tillers that form early do not inhibit subsequent tiller production. Infact, plants with early regeneration ability produced more tillers. Early tiller regeneration actually may encourage tillering by providing nutrients to developing buds. Appearance of first tiller varied from 1-10 days after cutting of the main crop. Regeneration time correlated negatively with number of tillers at three and six week after cutting and at ratoon harvest. Three weeks after cutting, tillers per plant varied substantially, although the correlation remained significant (Chauhan *et al.*, 1985).

Main Crop Growth Duration: Main crop growth duration has been reported to influence ratooning ability

(Bardhan Roy *et al.*, 1982); Cuevas Perez, 1980). Growth duration and grain yield was correlated strongly. Varieties with longer growth duration tended to have stronger ratooning ability. The ratoon crop production of later maturity Intan and Mingolo in Karanataka supported this finding. Good ratooning ability of short duration varieties CH45, PTB-10, N22, CT135, S705, Mangala and Intan mutant were reported (Basavaraju *et al.*, 1986). Very early maturing cultivars were recommended for ratoon crops in temperate areas, because they do not require early seeding and also allow a favourable growth period for the ratoon crop. Zandstra and Samson (1979) found significant correlation between ratoon crop yield and ratoon crop duration (r = 0.71) and between ratoon crop duration and main crop duration (r = 0.65). They stated that medium intermediate maturity cultivars (>135 days) produced higher yields than those with early maturity (<115 days). Further, they indicated that high ratoon yields might require by selecting varieties for a ratoon crop with duration longer than 70 days.

Ichii and Kuwada (1981) mentioned that early maturity did not affect ratoon weight, ratoon height and percentage of ratoon tillers. Early maturing cultivars do not produce a successful second crop unless the growing period is longer than 180 days (Hodges and Evatt, 1969). This was proven by Chatterjee *et al.* (1982), who harvested a satisfactory crop of an early maturing variety. However, Evatt (1958) and Parago (1963b) recommended early maturing cultivars for ratooning. Similarly, Shahi and Raharinirina (1988) quoting data from Arraudeau and Dechannet (1960-61, 1961-63 and 1963-64) reported that short duration (122-145 days) Taiwanese and Japonica cultivars produced higher ratoon yields than long duration check Chianang 8 9153 days) and No. 34 (176 days). In this case, low temperature inhibited ratoon growth in the late maturing cultivars. Tripathy and Pandya (1988) by testing ratooning ability of varieties reported that all the medium duration varieties had better ratooning ability while short duration had poor ability. Medium-late maturing rices will not produce a constant ratoon crop; although medium maturing cultivars sometimes have produced satisfactory ratoon crop yields (Hodges and Evatt, 1969). However, some cultivars with longer growth duration have better ratooning ability (Hsieh *et al.*, 1964). A ratoon crop of late maturing IR-42 yielded significantly more than early maturing IR-36. In IR-42, increased grain ratoon yield was due to higher panicle densities and filled spikelets per panicle (Sompaew, 1979). In another study, Ichii and Sumi (1983) reported that ratoon weight, ratoon height and percentage of ratoon tillers were unaffected by early maturity.

Plant Height: Per unit land area, taller plants intercept higher amounts of light and trap more CO2 for photosynthesis. The longer culms can accumulate more assimilates, which can be Tran located to the grain. However, taller plants indicate a higher proportion of non-photosynthetic plant parts. A major disadvantage of tall plants is their effect of lodging. Plant height therefore, should be maintained at optimum level (Kupkanchankul and Vergara, 1991). Harvest index is inversely correlated with plant height, and tall varieties usually have low harvest index. Usually, the height of the ratoon crop is shorter than that of the main crop (Hsieh *et al.*, 1964; Balasubramanian *et al.*, 1970; Andrade *et al.*, 1985; Chauhan, 1988). Bardhan Roy *et al.* (1988) evaluated the ratooning ability of three photoperiod-sensitive cultivars for deep water rice viz. FRI-13A, SR-26B, and Achral-081. They reported a range of plant height of 154 to 185 cm in the ratoon crop whereas the main crop's height ranged from 120-136 cm. The normal Aman rice crop of these cultivars was still shorter compared to their respective ratoon crop. Megalit and Serrano (1957) reported that ratoon crop recorded height as tall as the main crop.

Cultural Practices: To make rice ratooning productive and economical, a package of main and ratoon crop management practices is recommended (Zhang Jing-Guo, 1991). Chauhan *et al.* (1985) discussed the importance of management practices in the main crop and cultural practices at harvest, which influenced ratooning ability and ratoon yields. However, they and others have observed that ratoon yields vary substential between cultivars and within cultivars over space and time (Chauhan *et al.*, 1985; Mahadevappa, 1979).

Land Preparation: Success of the ratoon crop was dependent principally on the through preparation of land for the main crop (Parago, 1963b). Hsieh *et al.* (1968) described that an increase of the plowing depth tended to favour the elongation of the culm but decreased the viability of the ratoon. However, an increase of the number of panicles per plant was observed. Plowing 25 cm deep gave higher grain yield than shallow tillage. Plowing deeper than 25 cm tended to decrease ratoon crop viability (Hsieh *et al.*, 1968). Regular land preparation such as plowing followed by harrowing, in the main crop tended to produce more tillers in the ratoon crop compared to zero tillage (Bahar and De Datta, 1977). Plots with regular main cropland preparation tended to grow more ratoon tillers. However, tillage did not affect number of filed spikelets/panicle and number of missing hill (Samson, 1980).

Spacing: Spacing determines main crop plant population. A high main crop plant population increases the tiller number/unit area, and increasing potential ratoon tiller number/unit area. However, high main plant density increases the number of missing hill in the ratoon crop. The effect of spacing on grain yield of main ratoon crop was studied in IR-28. Different levels of spacing did not alter Main crop yield significantly. The optimum spacing for the best ratoon yield was 20 x 20 cm (Bahar and De Datta, 1977). Spacing significantly affected the yield of the main crop but had no significant influence on the ratoon yield. However, the productive ratoon dry matter production was significantly higher with close spacing (Srinivasan, 1988). In another report 10 x 10 plant spacing have significantly higher ratoon grain yield than 20 x 10, 30 x 30 and 40 x 40 cm spacings. Closer spacing however, required more main seed, time and labor during planting (Altamarino, 1959).

Seedling Age: Main crop seedling did not significantly affect grain yield or other ratoon crop characteristics. However, 20 day old seedlings tended to produce higher ratoon grain yield because they produced more panicles/unit area and filled spikelets/panicles, heavier grains and fewer un-filled spikelets (Sompaew, 1979).

Time of Main Crop Harvest: Cutting of the main crop is correlated with yield of main crop, number auxiliary buds sprouting, and number of productive panicles and yield of ratoon crop. The best time to harvest the main crop for raising a good ratoon crop is when culms are still green (Parago, 1963b). The best time to harvest the main crop for maximum ratoon yield is before the crop is fully matured (Nagai, 1958; Balsubramanian *et al.*, 1970). Cutting the main crop 34 days after heading, when maxillary buds began sprouting, resulted in the highest yields for both main and ratoon crop. The main crop is harvested when nearly mature and when ratoon shoots just began to grow (3-5 cm). Optimum cutting height should be 30-40 cm above grounds (Zhang Jing Guo, 1991). Szokolay (1956) suggested that harvest of the main crop be done when the main crop is fully ripened and the buds have just begun to grow. The number of maxillary buds is correlated with carbohydrate content and stem and sheath weight, which increased as cutting of main crop, was delayed. Cutting the main crop at 34 days after heading, when auxiliary buds began sprouting, gave highest yields for both main and ratoon crops. The increased yield of ratoon crop was attributed to higher number of productive panicles. laying main crop harvest to 44-56 days after flowering reduced ratoon crop growth duration (Votong, 1975). Haque, (1975) and Reddy *et al.*(1979) proposed that harvesting at 30, 35, 40, and 45 days after main crop flowering did not significantly affect ratoon yields. However, Mahadevppa *et al.* (1988) mentioned that because senescence is a varietal character, the time of main crop harvest might depend upon the variety and location.

Cutting Height: Cutting height determines the origin of the ratoon tiller and growth duration of ratoon crop (Sun Xiaohui *et al.*, 1988). It was reported that stubble height determines the number of buds available for re-growth. The effect of cutting height on ratoon vigor varied. Some cultivars ratooned from high node, others produced basal ratoon that are unaffected by cutting height (Volkova and Smetanin, 1971). Balasubramanian *et al.* (1970) reported that height of cutting had no effect on grain yield but greatly influenced the straw yield. An increase of the cutting height resulted in an increase of the ratoon straw yield. However, Bardhan Roy and Mondal (1982) reported that cutting height did not significantly affect ratooning ability, reproductive tillers and ratoon yields. In the Philippines ground level cutting was suggested to prevent growth of unproductive tillers (Parago, 1963b). It was reported that in the Philippines wet season rain fall is heavy, and cutting close to the ground level may risk a high tiller mortality rate and poor ratoon crop stand density (Zandstra and Samson, 1979; Samson, 1980; Chauhan *et al.*, 1985). Calendacion *et al.*(1991) reported that a lower cutting tended to increase grain yield but prolonged maturity. In Cambodia, plant cut at 15 cm gave higher yields than plants cut at ground level (Szokolay, 1956). However, Iso (1954) recommended that main crop cutting should leave 1.25 cm of the stubble above the water level. Submerged stubble may rot and tall stubbles may put forth vary weak tillers. Recommended cutting height of the main crop greatly varies and this is probably the result of cultivars and cultivation practices. Andrade *et al.* (1985) evaluated 10 irrigated rice cultivars at 10, 20 and 30 cm cutting heights. They observed that 30 cm cutting height gave the best results including plant height in all cultivars. Earlier, Hsieh *et al.* (1959) recorded a rate of tillering of 89.1, 80.6 and 71.9 % at 24, 15 and 6 cm cutting height respectively. In IR-8, Prashar (1970) reported that tillering increased with cutting height at 15 days after harvest, 0,4,8 and 12 cm cutting height resulted in 18, 19, 20 and 21 ratoon tillers respectively. These ratoon tillers represented 73-80% of the main crop tillers. At 75 days after harvest, tiller numbers were 28, 26, 27 and 23 at the four cutting heights respectively. Reddy and Pawar (1959) conducted studies at Karnataka and noted that cuttings 8,13, and 18 cm did not affect ratoon yields. In Japan ratoon stand varied with cutting height but these did not affect grain yield (Ishikawa, 1964). In India, Srinivasan (1988) reported that when Bhavani variety was cut at 15 cm height from ground level, it yielded 2.8 t/ha (50% of its main crop yield). Bahar and De Datta (1977) tested 5, 15 and 20 cm cutting heights with IR-28 and IR-2061-464-2. They observed that the tiller number of both cultivars decreased as the cutting increased. However, the ratoons had more tillers compared to the main crop. Because a low percentage of missing hills tend to offset the relatively low number of ratoon tillers per plant at high cutting height, 15 cm is considered as optimum for ratooning. In India Srinivasan (1988) reported that when Bhavani variety was cut at 15 cm height from ground level yielded 2.8 t/ha (50% of its main crop yield). In hybrid rice, Sun Xiaohui *et al.* (1988) reported that optimum cutting ranged from 30-40 cm above ground level in order to keep all buds with regrowth potential. Similar height of cutting was recommended by Ahmed and Das (1988) for the hilly regions in India. Ratoon produced more panicles/hill filled spikelets/panicle and higher 100 grain weight at 3 and 5 cm cutting heights than at 15 cm, but, grain yields were less because low cutting resulted in more missing hills (Chatterjee *et al.*, 1982; Quddus, 1981; Samson, 1980). As a general trend, the ratoon crop duration decreases as height of cutting increases (Evatt, 1958; Bahar and De Datta, 1977; Samson, 1980). For example, the growth duration of IR-8 increases from 73-86 days at 15 to 5 cm cutting height respectively (Bahar and De Datta, 1977). Lower cutting height delayed maturity but produced uniform growth and maturity (Quddus, 1981; Samson, 1980, Prashar, 1970). Vergara *et al.* (1988) recommended that under rain-fed conditions, where water needs to be retained in the field, the main crop should be cut at 15 cm or higher to minimize the number of missing hills in ratoon crop and to reduce weed growth. Ratoons from 10 cm high stubbles yielded 2t/ha, 0.54t/ha more than the yield of ratoons from 20 cm high stubbles.

Nitrogen Fertilizer Management: Soil fertility may directly or indirectly affect ratoon crop growth and yield (Plucknett *et al.*, 1978). Nitrogen is probably the most important single nutrient element in growth of ratoons, and the methods and rates of its application are major management factors. Fertilizer effects depend on inherent ratooning ability of the cultivar, its ratooning vigor, ratoon type and growth duration. As ratoon yields increase, N response also increases (Zandstra and Samson, 1979). Cultivars also differ in their response to N applied to ratoon crop (Balasubramanian *et al.*, 1970). Nitrogen has been observed to improve tillering and increase grain yield of the ratoon crop. However, responses of ratoon to N rate were not constant. Fertilized plots produced better ratoon yields than unfertilized plots (Reddy and Pawar, 1959; Yang, 1940). In some instances, N level did not affect tiller and panicle number, 100 grain weight, grain-straw ration and missing hills (Bahar, 1976). In other cases tiller number gradually increased with increasing N level, although ratoon weight was not significantly affected (Balasubramanian *et al.*, 1970). At IRRI, Philippines grain yield significantly increased as N rate increased. N level was optimal at 60 kg/ha (Bahar and De Datta, 1977). In China, as N increased from 0 to 69 kg/ha, ratoon tiller number of Aiyou 2 rice increased significantly (Sun *et al.*, 1988). In Cambodia, CICA-4 rice ratoon yielded 3.8 t/ha with the application of 25-50 kg

N (Sanches and Cheany, 1973). In Texas, only 50 or 70 kg additional N/ha (approximately 3/4 of the recommended N for the main crop) was required for ratoon crop (Evatt, 1966; Hodges and Evatt, 1969). Another study conducted by Turner and Mcilrath (1988) at Texas, reported that applying N to the main crop at heading 2 weeks after initial heading, or one half at panicle differentiation and on half at heading resulted in quicker tiller regeneration at ratoon crop that mature 7-10 days earlier. Post harvest nitrogen application to main crop consistently increased ratoon crop yield. Besides amount of applied N, application method in the main crops affects the ratoon crop (Quddus, 1981; Samson, 1980). Deep placement of nitrogen in the main crop significantly increased height of IR-36 ratoons, tiller number of IR-42 ratoons and yields of ratoon of both cultivars. Deep placement produced 15% high ratoon yield and high panicle density than split application. Split application in the main crop resulted in delayed maturity and lower leaf area index of the ratoon crop (Sompaew, 1979). However, Samson (1980) noted that deep nitrogen placement in the ratoon crop produced more panicles per plant, more spikelets/panicle and more vigorous ratoon plants, resulting in significantly high yield than did an equal amount of broadcast nitrogen. Fertilizer applied to the ratoon crop should be placed close to the stubble rows for rapid nutrient uptake and growth (Plucknett *et al.*, 1978). Complete fertilizer was needed not only for the main crop but also for the ratoon crop (Szokolay, 1956). Parago (1963b) recommended the application of ammonium sulphate fertilizer after cutting the straw followed by a gradual flow of the irrigation water. Four weeks after the first application of fertilizer the field should be applied with complete fertilizer (12-24-12) and a second application of complete fertilizer should be done before the booting stage. Applying P and K to the ratoon crop did not significantly affect ratoon grain yield (Chatterjee *et al.*, 1982). However, applying P to the main crop produced a highly significant increase in ratoon yield (Flinchum and Evatt, 1972). Quddus (1981) suggested that split application of 90 kgN/ha as a basal dose and at panicle initiation, early milk stage, late milk stage and 7-15 days before main crop harvest did not significantly affect tillers per m2 or ratoon crop grain yield. Applying high amounts of N fertilizer to the main crop reduced ratooning viability by encouraging excessive growth with weaker plants (Hsieh *et al.*, 1968). Applying N fertilizer two weeks before main crop harvest in hybrid rice ratooning increased the yield (Sun Xiaohui *et al.*, 1988). A successful ratoon crop in the United States (Mengel and Wilson, 1981) and in Karnataka, India (Prakash and Prakash, 1988) resulted N application immediately after main crop harvest. In the hilly regions of Karnataka, Gopala Reddy and Mahadevappa (1979) reported that 50 kgN/ha top dressing at 30 days after main crop harvest was best with long maturing Intan variety. Palchamy and Purushothaman (1988) reported that N split application at maximum tillering and at panicle initiation increased the ratoon crop grain yield upto 86.6% of the main crop. Seventy five percent of the recommended amount of N for the main crop should be applied immediately after harvest to achieve a good ratoon yield (Flinchum and Evatt, 1972). Some times second and third fertilizer application has been recommended (Parago, 1963b).

Water management: Water is critical major factor affecting ratooning (Plucknett *et al*, 1984). Water management before and after main crop harvest affected ratooning ability (Votong, 1975, Hague, 1975). To promote ratooning, the field should be moist but not flooded for weeks at the end of the main crop ripening. Draining the field several days after harvest also encourages ratooning. Irrigation water must be kept shallow in the early ratooning stages. It is essential to have irrigation immediately after the first fertilizer application. One week later, the field should be drained and weeded, followed by intermittent irrigation (Parago, 1963a). Fields drained during harvest of the main crop in order to promote tillering of ground level cuttings had more weeds. Furthermore, ground level cutting with continuous 5-7 cm flooding produced very few ratoons and increased percentage of missing hills. Such a problem was not observed with 15 cm or higher cutting height (Bahar and De Datta, 1977). Prashar (1970) observed that a significant interaction between height of cutting and first watering or tillering percentage with lower cut of stubble. Lower cut and delayed irrigation for 4 to 6 days was better than rewatering 1 day after cutting. Ichii (1983) reported that water management did not affect percentage of ratoon tillers or a ratoon height irrespective of height of cutting. However, Mengel and Wilson (1981) in their studies on the effect of irrigation and N requirement on the grain yield and milling quality of the ratoon crop of cultivar Labelle, observed that shallow irrigation given as continuous flooding immediately after main crop harvest gave better grain yields and plant characters than short-term delayed flooding. Draining the main crop at harvest is generally suggested to promote ratooning and prevent death of hills due to flooding. However, under rainfed situation where water has to be retained as much as possible, the main crop should be cut at 15 cm higher to reduce the number of missing hills in the ratoon crop (Zandstra and samson, 1979). However, draining the field during main crop harvest is not essential for good ratoon crop (Bahar, 1976). When the ratoon crop remained flooded, yield was 2.5 t/ha at 15 cm and at ground level cutting height (Bahar and De Datta, 1977). As soon as the main crop is harvested and fertilizer is applied, the field should be flooded 8-10 cm deep. If flooded water is not maintained, main crop grain that fell to the ground during mechanical harvest will germinate and compete with the ratoon crop for light and nutrients (Mengal and Wilson, 1981). Water management did not significantly affect percentage of ratoon tillers or ratoon height when the crop was cut at 5 or 20 cm, probably because ratooning ability depends on food reserves in the stem base and on temperature. Many hills died when the crop was cut at ground level and water remained 5 cm deep (Ichii and Ogaya, 1985).

External Environmental Factors: Environmental factors affecting plant growth and development are temperature and light. These factors greatly influence ratooning performance, particularly tiller production and yield.

Temperature: Ichii (1982) studied differences in ratoon height and percentage of ratoon tillers/cut plant exposed to high (30^oC) or low (20^oC) temperatures. He noted that the higher the temperature, the greater the ratoon plant height and percentage of tillers at early stages of development (5,10 and 20 days after cutting). Maximum tillering was 10 days at $30\,^oC$ and before 20 days at 20 ^oC. he concluded that higher the temperature, the higher the tiller number and the rate of increase. Photosynthetic products in the ratoon plant contribute to its growth as the ratoon plant consumes only small amount of reserves in the stem base for respiration (Ichii, 1982). However, Samson (1980) observed the effect of temperature on plant characters in later growth stages. Plants exposed to low temperature (20 °C) at booting formed three times more basal ratoon tillers than those exposed to high (35°C) temperature and two times more than those exposed to normal (29°C) temperature. Further more grain yield at 20°C was significantly lower than yields at high and normal temperatures because of high spikelets sterility. Temperature also affected ratoon growth duration. Crop maturity lengthens from 56 days at high temperature to 96 at low temperature.

Light Intensity: The increased light transmission in the canopy, increased panicles per unit area and grain yield (Kupkanchanakul and Vergara, 1991). Percentage of ratoon tillers, ratoon height and ratoon weight highest in full sunlight. This was followed by 50 and 75% shading two weeks before cutting. Stem base weight of stubble decreased as shading intensity increased, indicating that percentage of ratoon tillers, ratoon weight and height may be correlated with stem base traits (Ichii and Sumi, 1983). Shade duration influenced the ratoon growth. Quddus (1981) reported that shading the crop from flowering to 7 days after harvest (28 days) caused significantly lower ratoon yields than shading at late milk stage to seven days after harvest (24 days) or shading at harvest to seven days after harvest. Unshaded plant yielded 72% more than shaded plants. Applying an extra 30 kgN/ha at early and late milk stages and 15 days before harvest in combination with different periods of shading did not significantly affect ratoon grain yield. In respective of growth stage, shading produced a higher percentage of hills without ratoon tillers. Also, shading and nitrogen top dressing produced 22% fewer missing hills than shading without N topdressing (Quddus, 1981). Ichhi (1982) reported that ratoon weight and percentage of ratoon tiller were higher in light than in the dark, but ratoon grew taller in darkness than in light. Tiller regeneration ability was not affected by main crop shading. The number of ratoon tillers decreased as shading increased (Gracia, 1981). In general, no shading and 49% shading had similar effects on grain yield, spikelets/panicle, filled spikelets/panicle, 1000 grain weight, and percentage of sterile spikelets. However, 66% shading reduced ratoon grain yield, which was attributed to fewer spikelets/panicle, fewer filled spikelets/panicle, and increased spikelets sterility. Panicle per hill was not significantly affected by shading. More ratoon panicles tended to develop with less main crop shading (Gracia, 1981).

References

Ahmed, T. and G.R. Das, 1988. Scope for rice ratoon cropping in the Northern Hill Region of India. P 119. In: Rice Ratooning. IRRI, Philippines. 129p.

Altamarino, L.,1959.The influence of spacing on the development, yield and agronomic characters of rice ratoon crop. M.S Theisi, UPLB at Losbanos, Luguna, Philippines.

Andrade, W.E. de B.,S.Amorin Neto, A.B. de Olivera and M.B. Fernandez, 1985. Height of cutting the main crop influences ratoon yield (in Portuguese). Pp 173-178. In: Irrigated Rice Workshop, 14 Pelotas.

Aubin, J.P.,1979. Rice and its ratooning in Richard Toll, Senejal Montpellier. Intitut de Recherches Agronomiques Tropicales et des cutures Vivrieres 11p.

Bahar, F.A., 1976. prospects for raising productivity of rice by ratooning. Unpublished M.S. Theis, UPLB, Luguna, Philippines.102p.

Bahar, F.A. and S.K. De Datta, 1977. Prospects of increasing total rice production through ratooning. Agron. J. 69:536-540.

Balasubramanian, B., Y.B. Morachan and R.Kliappa, 1970. Studies on ratooning in rice. I.Growth attributes and yield. Madras Agric. J. 57(11)565-570.

Bardhan Roy, S.K., J.Mondal, B.N.Chattersee, S.Bhattacharya, P.Debnath, and B.Mondal, 1988. Potential for rice ratooning in Eastern India, with special reference to photoperiod-sensitive rice for deep water area. Pp 135-142. In: Rice ratooning. IRRI, Philippines.

Bardhan Roy, S.K. and J.Mondal, 1982. Ratooning ability of some photoperiod sensitive rice. IRRI Newsletter. 7(6):5.

Basavaraju, B., B.V. Jayakumar and N.Mahavevappa, 1986. ratoon crops performance of three rices. IRRI Newsletters. 2(1):27.

Calendacion, N.A., D.E.Garrity and K.T. Ingram, 1991. Locklodging: A new techonology for ratoon rice cropping. IRRI.

Chatterjee, B.N., S.Bhattacharya and P.Devnath, 1982. Ratooing of Rice. *Oryza*. 19:226-227.

Chuhan, J.S.,1988. Use of ratooning in hybrid rice.pp 151-154.In: Rice Ratooning. IRRI, Philippines.

Chuhan, J.S., B.S. Vergara and F.Ss. Lopez, 1985. Rice Ratooning. IRRI, Res. Pap. Ser. 102-119.

Cuevas Perez, F.E., 1980. Inheritance and associations of sis agronimic traits and stem-base carbohydrate concentrations on ratooning ability in rice *Oryza sativa* L. Ph.D Theisi, Oregon State University. 102p.

Das, G.R. and T.Ahmed, 1982. The performance of semi-dwarf varieties of ratoon crop after summer harvest. *Oryza*. 19(4/3):159-161.

Elalaoui, A.C. and S.R.Simons, 1988. Quantitative translocation of photo assimilates from non surviving tillers in barley. Crop Sci. 28(6):969-972.

Evatt, N.S.,1958. Stubble rice production tests. Rice J. 61(6):1819, 40.

Flinchum, W.T. and N.S. Evatt, 1972. The effect of 2,4-D and nitrogen on the stubble crop rice production in Texas. Rice Research in Texas. Consolidated pR 3105. Sep. 1972.

Gopala reddy, T. and M.Mahadevappa, 1988. rice ratoon crop management in Hilly Region of India of Karnataka. Pages 87-96. In: Rice Ratooning. IRRI, Philippines.

Gracia, R.N.,1981. The effects of growth duration and different levels of light intensity on the ratooning ability of rice. Unpublished undergraduate thesis. UPLB, Lasbanos, Philippines.

Haque, M.M., 1975. Varietal variations and evaluation procedures for ratooning in rice. Unpublished MS thesis, UPLB, Philippines. 110p.

Hodges, R.N. and N.S. Evatt, 1969. second rice production. Agron. Notes. 69:21-22.

Hsieh, C.F., S.Kao and C.Chiang, 1968. Studies on the cultivation of ratoon rice. III. Effect of plowing depth and amount of fertilizer on re-availability and yield of ratoon rice (in Chinese English summary). Agric. Res.(renamed as J. Taiwan Agric. Res.). 8(3/4):21-32.

Hsieh, C.F., S. Kao and C. Chiang, 1964. Studies on the cultivation of ratoon rice. Varietal variation on ratooning ability and yield (in Chinese English English summary). J. Taiwan Agric. Res. 17(4):14-21.

Hsieh, C.F., S. Kao and Young. 1959, Studies on the cultivation of ratoon rice (in Chinese English summary). J. Taiwan Agric. Res. 8(3/4):21-32.

Ichii, M.,1988. Some factors influencing the growth of rice ratoon. Pp41-46. In: Rice Ratooning. IRRI, Philippines.

Ichii, M., 1984. Studies on the utility of ratoon traits of rice as the indicator of agronomic characters in breeding. Mem. Fac. gric. Kagawa University, NO. 44.49p.

Ichii, M., 1982. The effect of light and temperature on rice plant rations. Jpn.J.Crop.Sci.51(3):281-285.

Ichii, M., and H.Kuwada, 1981. Application of ratoon to a test of agronomy characters in rice breeding. I. Variation in ratooning ability and its relation to agronomic characters of mother plant. Jpn.J.Breed. 31(3) 273-278.

Ichii, M. and N. Ogaya, 1985. Application of ratoon traits obtained by higher cutting for estimation of percentage of ripened grains in rice plants. Jpn.J.Breed. 35:311-316.

Ichii, M. and Sumi, 1983. Effect of food reserves on the ratoon regrowth of rice plant. Jpn.J.Crop Sci. 52(1):21-75.

Iso, E.,1954. Ratoon culture of Horai varieties. pp 197-200. In: Rice and Crops in its rotation in sub-tropical zones. Japan-FAO Association, Tokyo.

Ishikawa, T.1964. Studies on the ratoon of rice plant in early cultivation (in Japanese, English summary). Bull. Fac. Agric., Uni. Of Miyazai Japan.10(1):72-78.

Kupkanchanakul, T. and B.S. Vergara, 1991. Rice Ratooning. IRRI Re. Pap. Ser. 149.23p.

Magalit, N.R. and F.B.Serrano, 1957. A review of work on rice ratooning in the Philippines. Agric. Ind. Life. 15:8-9, 39.

Mahadevappa, M.,1979. Ratoon cropping to increase rice production. Univ. of Agril. Sci. Tech. Ser. 26. 23p.

Mahadevappa, M. and H.S. Yogeesha, 1988. Rice Ratooning. Breeding, agronomic practices and seed production potentials. P177-186. In: Rice Ratooning. IRRI. Philippines.

Mengel, D.B. and F.E. Wilson, 1981. Water management and nitrogen fertilization of ratoon crop rice. Agron. J. 73 (6):1008-1010.

Nadal, A.M. and V.R. Carangal, 1979. Performance of the main and ratoon crops of 13 advanced rice selections under dry seeded rainfed bunded conditions. Philipp. J. Crop. Sci. 4(2/3):95-101.

Nagai, I., 1958. Japonica rice, its breeding and culture. Yokendo Ltd., Tokyo. 834p.

Nair, N.R. and P.C. Sahadevan, 1961. A note on vegetative propagation of cultivated rice. Curr. Sci. 30:474-476.

Palchamy, A.and S.Purushothaman, 1988. grain yield and duration of ratoon rice varieties. AGril. College and Res. Inst. (ACRI), Tamil Naidu Agril. Uni. Madurai 625104, India. IRRN 13:5(Oct. 1988).9p.

Parago, J.F.,1963a. A review of work on rice ratooning in the Philippines. Agrics. Ind. Life. 25(7):8-9, 39.

Parago, J.F., 1963b. Rice ratooning culture. Agric. Ind. Life. 2598):15,45,47.

Prakash, K.S. and B.S.Prakash, 1988. screening rice genotypes for ratoon ability in the Tunga Bhadra River Project of Karanataka. P256-269.In: Rice Ratooning. IRRI, Philippines.

Plucknett, D.L., R.G.Escalada and Dela Pena, 1984. Crop ratooning pages 151-175. In: Crop Physiology Advancing Frontiers. U.S. Gupta Edit. Oxford and JBH Publishing Co.

Plucknett, D.L., R.G.Escalada and Dela Pena, 1978. Crop Ratooning. J.Ser. 2266 of the Hawaii Agril. Expt. Station, Honolulu, Hawaii, USA. 40p.

Poehlmana, J.M., 1976. Breeding Field Crops (Rice). 2nd Edition. Westcot, Connecticut: AVI Publishing Co.

Prashar, C.R.K., 1970. Paddy Ratoons. World Crops. 22(3):145-147.

Quddus, M.A., 1981. effect of several growth regulators, shading and cultural management practices on rice ratooning.

Reddy, T.G., M.Mahadevappa and K.R.Kulkarni, 1979. ratoon cropping of rainfed rice. IRRI Newsletter.4 (5):25-26.

Reddy, V.R. and M.S. Pawar, 1959. studies on ratooning in paddy. Andhra Agric. J.6(2):70-72.

Samson, B.T., 1980. Rice ratooning effects of varietal type and some cultural management practices. Unpublished MS Thesis, UPLB, Lasbonos, Philippines.166p.

Shahi, B.B. and J.Raharinirina, 1988. Potential of rice ratooning in Madagasrcar. P129-134. In: Rice Ratooning. IRRI, Philippines.

Sompaew, V., 1979.Stand establishment techniques in direct-seeded dry land rice. Unpublished Ph.D dissertation, UPLB, Philippines.

Srinivasan, K., 1988. Effect of N application timing of ratoon rice. IRRN. 14:6 (Dec. 1989). 16p.

Sun Xiaohui, zhang Jing guo and Liang Yujiu, 1988. Ratooning with rice hybrids. P155-161. In: Rice Ratooning. IRRI, Philippines.

Szokolay, G.,1956. ratooning of rice on the Swaziland Irrigation Schemes. World Crops. 8(2):71-73.

Tripathi, R.S. and R.Pandya, 1988. second crop rice in Rajasthan. Agril. Res. Station, banswara, India. IRRN. 13:3(June 1988).50p

Turner, F.T. and W.O.McIlrath, 1988. N fertilizer management for maximum ratoon crop yields. P187-194. In: Rice Ratooning. IRRI, Philippines.

Vergara, B.S., F.S.S. Lopez and J.S. Chauhan, 1988. Morphology and physiology of ratoon rice. Pp13-14. IRRI, Philippines.

Volkova, N.P. and A.P. Smetanin, 1971. On ratooning characters of rice Cv. Adopted to the Kuban region. Bulletin Nauchno-Tekchnicheskoi informatsii. Usisoyuznyi. Nauchro-issle. Dovatili Skii Inst. Risa. 3:21-24.

Votong, V., 1975. The effect of time of drainage anf time of rewatering on the yield of ratoon rice. Unpublished MS Thesis, Uni. Of Sydney, Australia.

Yang, S.J., 1940. The cultivation of regenerated rice and future in human and szechuan (in Chinese, English summary). Nung Pao 5:46 pages 1-10 in ratoon cropping in Swampy or wetland rice (from 1940-1965). Common Wealth Bureau of Pastures and Field Crops.

Zandstra, H.G. and B.T. Samson, 1979. Rice ratoon management. Paper presented at the Int. Rice. Res. Conf. 17-21 Apr. IRRI, Philippines. 10p.

Zhand Jing Guo, 1991. Hybrid rice ratoon exploited in Sichuan, China. IRRN 16: (5)(Oct., 1991).