EVALUATION OF LOWCOST AGRONOMIC TECHNIQUES FOR SUSTAINED RICE PRODUCTION

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "EVALUATION OF LOW COST AGRONOMIC TECHNIQUES FOR SUSTAINED RICE PRODUCTION" is a bonafide record of research work done by me during the course of the research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "EVALUATION OF LOW COST AGRONOMIC TECHNIQUES FOR SUSTAINED RICE PRODUCTION" is a record of research work done independently by Smt.P.Sreedevi under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Population growth and food deficit would still be the greatest challenges for humanity in the decades to come. Even today more than half a billion people suffer chronic malnutrition and hunger for shortage of food. By the turn of this century, it is projected that the world population will be around six billion and for more than half of them, rice forms the staple food.

Rice production will have to be doubled to keep pace with the increasing population in Asia by 2000 A.D. It is estimated that an annual increase of 1.3 million tons of rice is necessary to meet the needs of the teeming rice eating millions. The sky rocketing prices of fossil fuel dependent inputs is the major constraint to increased rice production. Therefore it is urgent to explore possibilities of employing various technological alternatives to substitute the expensive energy intensive food production technologies. Development of agronomic techniques to help economize the use of chemical fertilizers - the most expensive energy input in food production especially in developing countries, is highly welcome.

The selection of proper variety suited to a particular situation is of prime importance. Most of the modern varieties give high yields only when they are grown under ideal conditions of soil, water supply and nutrients and well protected from their natural enemies. These varieties also possess the advantage of high fertilizer responsiveness. But the farmers often cannot afford the amount of fertilizers required by the modern varieties to express their full yield potential. They need a variety that will give a fairly good yield with a moderate amount of fertilizer application, which can exploit and utilize both soil and fertilizer nutrients efficiently. IR 42 is such a variety which combines high yield potential with the capacity to yield well at low nutrient levels (IRRI, 1978). It has good agronomic characteristics as well as moderath drought and submergence tolerance and resistance to major pests and diseases.

The important low cost factor next to varietal selection is plant population. With the same level of nutrition and water higher plant population gives higher yield in many crops. The modern varieties of rice with dwarf stature are more responsive to high plant population per unit area. However, overcrowding of plants is also not desirable as it invites tremendous competition among the crop plants and incidence of pests and diseases. This inturn necessitates, the maintenance of an increased optimum plant population to utilize the high cost inputs efficiently.

Seedling age and number of seedlings per hill are two other important non-monetary/lowcost inputs in transplanted rice crop. Seedlings of proper age must be planted in right number to utilize the expensive energy inputs with utmost efficiency.

Nitrogen though most abundant in the atmosphere is the king pin in fertilization limiting the yield of wet land rice. Nitrogen fertilizer being a high fossil fuel dependent input, the use of any supplemental organic source will cut down the cultivation expenses of the farmer. Recently great attention is being given to the Azolla-anabaena associations as a potential nitrogen source in rice culture. The incorporation of azolla has reported to increase rice yields from 13-54%. Compared to other organic manures, this biofertilizer mineralises more rapidly and nitrogen made available to plants early.

Three seperate field experiments were conducted with low fertilizer dose, in combination with organic matter application through azolla and with high density of plant population. The approach made is to optimise the yield with minimal costly inputs and increasing non-monetary and low cost inputs.

In a developing country like ours the agricultural scientists are thus facing a tremendous challenge to devise most appropriate and economically feasible rice production techniques to achieve sustained high yields. Hence the present investigation was undertaken with the following objectives.

1. To assess the performance of IR 42 - a low fertilizer responsive variety, under different fertilizer management situations.

2. To evaluate the effect of age of seedlings and plant population through spacing and number of seedlings and to arrive at an optimum combination of both in the above variety.

3. To estimate the extent of economy of fertilisation by the integrated use of Azolla.

Review of Literature

REVIEW OF LITERATURE

With the advent of the modern era of high yielding rice varieties there was a spurt in nutritional studies on rice in 1960's, most of them being oriented towards the response of these varieties to higher levels of N, P and K. Such trials have been confined to the short and medium duration varieties. In recent years, however, the escalating prices of fertilizers and a fear of shortage of fossil fuel dependent inputs have made many to take up work on the possibility of reducing the use of fertiliser inputs. There is also a need to make the technology more suitable for the small and marginal farmers. Hence it was proposed to investigate the possibilities of economising the fertilizer dose in a low fertilizer responsive modern variety by using suitable non-monetary and low cost inputs. The review pertaining to the different aspects of the investigations are given below.

1. IR-42 - A low fertilizer responsive variety

Cultivation of the right type of variety is essentially a non monetary input and it is the first step in production technology (Pillai and Katyal, 1977). Each variety of a crop represents different genetic constitution of a varying potentialities of yield and other economic characters. Under the present day situation of continued price rise of fossil fuel dependent inputs, IR 42 appears to be a good choice of modern rice variety for small farmers to date because it has the capacity to extract and utilise both soil and fertilizer nitrogen efficiently. The consistency of IR 42's relatively high yield without nitrogen fertilizer makes it a suitable variety for low fertility conditions (IRRI, 1978). It greatly outyielded two earlier modern varieties, IR8 and IR 26, at 0 and 60 kg N/ha^{-1} in the dry and wet seasons of 1977 at IRRI. It also gave high yields in farmers fields at 0 and 16 kg N/ha^{-1}. The average yields of IR 42 without nitrogen fertilizer at three sites in Laguna Province in 1978 were 5.1 t ha^{-1} in the dry season and 5.8 t/ha^{-1} in the wet season compared with IR-8's 4.7 t/ha^{-1} and 4.8 t/ha^{-1} (IRRI 1978, Khush *et al.*, 1979).

In a trial with five varieties of Maahas clay with no N, P, K fertilizers IR 42 gave the highest yield of 4.6 t/ha^{-1} (Ponnamperuma, 1979).

Thus nitrogen use efficiency of IR 42 will be a great boon to the small farmers of South and South east Asia where most rice lands are nitrogen deficient and rice producers cannot afford large amounts of fertilizers. Hence rice types such as IR 42 will enable small farmers to obtain stable yields in unfavourable environments also (Mahadevappa et al., 1979).

2. Rice nutrition

Among the various nutritional elements needed by rice nitrogen is the most important one limiting the yield of wet land crop. Most rice lands in South and South East Asia except those of Malaysia are deficient in nitrogen (Kawaguchi and Kyuma, 1977).

Considering the cost of manufacture, production of one kg of urea requires 14,300 K cal (including mining and transport). Thus nitrogen fertilizer applied as urea at the rate of 120 kg ha^{-1} consumes an energy of 1.7 million K cal ha^{-1} the equivalent of 160 litres or ten barrels of petroleum ha^{-1} (FFTC, 1984). Hence any amount of saving in terms of nitrogen fertilizer alone will definitely cut down the cost of cultivation.

2.1 Nitrogen fertilization in rice

Universal response for nitrogen is observed in wet land rice culture.

The favourable response to nitrogen is achieved through its influence on growth and development of morphological characters, yield components and the metabolic functions in rice plant (Murata, 1969).

2.1.a. Effect on growth characters

A linear increase in plant height was observed by several investigators due to the application of graded levels of nitrogen (Balasubramanian, 1980; Sathasivan, 1980 and Padalia, 1981). But Sunus and Sadeque (1974) reported that plant height was unaffected by applied nitrogen.

Kumura (1956) observed a positive correlation between the number of tillers and the nitrogen content during the tillering stage. An increase in the number of tillers with increase in the amount of applied N was reported by Oshima (1962). Kalyanikutty et al. (1968) found a positive correlation between the number of tillers and N levels. Chandler (1969) is also of the opinion that tillering in rice is highly influenced by the nitrogen level in the soil. However, Rao (1963) and Nair (1968) could not obtain a significant increase in tiller number with increasing rates of nitrogen application.

Murata (1969) observed higher leaf area index (LAI) with increase in nitrogen levels especially before panicle initiation. According to Fagade and De Datta (1971) and Tanaka (1972) higher LAI values can be obtained by increasing the nitrogen application and plant density. The LAI of rice plants was more at higher levels of nitrogen (Tanaka, 1972 Yogeswara Rao et al., 1972; Ramaswamy, 1975; Raju, 1979; and Sathasivan, 1980).

2.1.b Effect on yield and yield attributes

Ramanujam and Sakharam Rao (1971) concluded that number of panicles per hill was increased by higher levels of nitrogen. Eunus and Sadeque (1974) and Sreekumaran (1981) could also observe a similar trend.

Kumura (1956) observed a close correlation between the number of spikelets panicle^{-1} and average N content of leaf blades one to four weeks before heading. Shimizu (1967) found a close relationship between number of spikelets per unit area and the amount of N uptake by the plant upto heading. Dayanand et al. (1972) and Verma and Srivastava (1972) reported that the number of grains per panicle increased with increase in nitrogen level. Balasubramanian (1980) also obtained similar results. According to Eunus and Sadeque (1974) number of filled grains per panicle was unaffected by nitrogen levels. Ramaswamy (1975), Seshadri et al. (1976), Natarajan and Arunachalam (1979) and Sathasivan (1980) also could observe similar trend.

Thousand grain weight was more at higher levels of nitrogen (Ahmed and Faiz, 1969 and Lenka, 1969). On the other hand, Eunus and Sadeque (1974) concluded that thousand grain weight was unaffected by nitrogen levels.

Kalyanikutty et al. (1968) reported an increase in the sterility percentage with higher doses of nitrogen. Similar results were also reported by Mukherji et al.(1968), Nair (1968), Muthuswamy et al. (1972), Eunus and Sadeque (1974).

2. Yield

According to Yamada (1959) the tall hybrid culture H_4 responded poorly to low levels of soil fertility, but expressed high yield potential at higher levels of fertilization. Potty (1964) obtained significant increase in grain yield with increase in dose of nitrogen. Subramaniam (1965) recorded yield response to nitrogen upto 27 kg ha^{-1} in a tall long duration variety. Lenka and Behera (1967) observed significant increase in yield upto 120 kg nitrogen ha^{-1} in dwarf types and upto 80 kg ha^{-1} in local varieties. Sood and Singh (1972) recorded higher grain yield in tall indica rice with an increase in the level of N from 0 to 90 kg ha^{-1}.

Tanaka (1958) could not observe any apparent increase in grain yield with higher levels of applied nitrogen in both indica and japanica varieties. Similar results were reported by Nair (1968).

Straw yield was found to be increased by higher rates of nitrogen application (Potty, 1964, Sahu and Lenka, 1967, Lenka and Behera, 1967). Nair (1968) and Place et al. (1970) also observed similar results. But Gopalakrishnan et al. (1970) and Daniel (1971) could not notice any significant effect of nitrogen levels on the yield of straw.

Thus from the above review it is seen that N fertilization had a positive influence on growth characters, yield attributes such as number of panicles m^{-2}, thousand grain weight and yield of grain and straw whereas number of filled grains $panicle^{-1}$ was not much influenced. Higher sterility percentage was also associated with higher N levels.

2.2 Phosphorus fertilization in rice

Phosphorus has a key role in rice nutrition. Rice plant needs a continuous supply of phosphorus throughout the growth period, especially before and during tillering and before formation of the flower primordia. An adequate supply of phosphorus at the beginning of growth promotes root development and thus tolerance to possible dry spells. Apart from this, it encourages active tillering, early flowering and ripening with higher thousand grain weight (Atanasiu and Samy, 1983). By increasing the phosphorus content of grains through phosphorus application the quality of grain will be improved.

2.2.a. Effect on growth and growth characters

Tanaka et al. (1960) observed taller plants with increasing levels of phosphorus upto ten ppm. According to Potty (1964) application of phosphorus influenced the height of plants only in the vegetative stage. Place et al. (1970) and Rao et al. (1974) also obtained similar results.

Enyi (1964) reported an increase in the number of tillers with higher levels of phosphorus application. According to Potty (1964) increase in tiller production with increasing levels of phosphorus was observed only in the vegetative stage. Lusanandana and Suwanawaong (1967) also noticed higher tiller number with higher doses of phosphorus application.

2.2.b. Effect on yield and yield attributes

(i) Yield attributes

Sreenivasulu and Pawar (1965) could not observe any significant effect of levels of applied phosphorus on panicle production. Place et al. (1970) also observed similar results.

A marked increase in the number of grains per panicle due to phosphorus application upto 14 kg ha^{-1} was recorded by Potty (1964). On the other hand, Gately (1968) and Rao et al. (1974) could not observe any influence of phosphorus application on the number of filled grains.

Thousand grain weight was seen to be unaffected by applied phosphorus (Potty, 1964 and Rao et al., 1974). But, Place et al. (1970) registered a decrease in thousand grain weight with increase in levels of phosphorus.

According to Potty (1964) varying levels of phosphorus had no influence on sterility percentage.

(2) Yield

Increased grain yields with increasing levels of phosphorus was reported by Enyi (1964). Subramanian (1965) recorded response to phosphorus application upto 20 kg ha^{-1} in long duration varieties. Sahu (1965) also observed increased grain yields with higher levels of phosphorus application upto 45 kg ha^{1}. On the other hand Vijayan and Menon (1965) did not notice any significant effect of phosphorus on grain yield in two tall varieties.

Straw yield was found to be increased with the application of phosphorus upto 20 kg ha^{-1} (Krishna Rao et al., 1962). Sahu (1965) concluded that application of higher rates of phosphorus had little influence on straw yield. From the above review, it is seen that phosphorus fertilization had a favourable effect on the growth attributes and yield of grain and straw while little effect was noticed on the yield attributes.

2.3 Potassium fertilization in rice

Potassium plays an important role in the nutrition of rice. It has a positive influence on tillering and on the size and weight of grains. It is associated with the synthesis and translocation of carbohydrates and grain development. Further, it renders resistance to pests, diseases and to adverse climatic conditions by strengthening and stiffening of plant cells.

2.3.a. Effect on growth and growth characters

According to Bavappa and Rao (1956) plant height was increased with increase in potassium application. Similar results were reported by Mukherji et al. (1968). But Potty (1964) could not notice any influence of potassium levels on the height of plants while Sahu and Manoranjan Ray (1976) recorded a reduction in plant height with potassium application.

Increase in tiller number with increase in levels of potassium was observed by Bavappa and Rao (1956) whereas Potty (1964) and Mukherji et al. (1968) could not obtain any favourable effect of potassium on tillering.

2.3.b. Effect on yield and yield attributes

1. Yield attributes

Panicle number was found to be increased with potassium application (Bavappa and Rao, 1956). Sahu and Manoranjan Ray (1976) also reported similar results.

According to Bavappa and Rao (1956) potassium application increased the number of filled grains $panicle^{-1}$

and thousand grain weight. Sreekumaran (1981) recorded more number of filled grains panicle^{-1} at the highest dose of potassium tried (90 kg/ha). He observed maximum thousand grain weight at 70 kg ha^{-1} of potassium. But Potty (1964) did not find any positive influence of potassium on the above characters.

(2) Yield

In pot culture trials, Tanaka (1966) recorded increase in yield with potassium levels upto 200 ppm in the tall indica variety Peta. Kanwar and Grewal (1966) and Sahu and Roy (1976) also obtained similar results. Mahapatra and Prasad (1970) recorded an average response of 472 to 1353 kg grain ha^{-1} with potassium application in modern varieties. Sreekumaran (1981) obtained highest grain yield at 45 kg potassium ha^{-1} whereas Guar and Singh (1982) noticed a reduction in grain yield with higher levels of potassium tried.

Esakimuthu et al. (1975) observed an increase in straw yield with increase in levels of applied potassium. According to Sreekumaran (1981) highest straw yield was at 60 kg potassium ha^{-1}. But, Potty (1964) could not get any response in straw yield due to the application of higher doses of potassium. Potassium fertilization also possesses a favourable effect on the growth, yield attributes and yield of rice.

3. Rice nutrition in relation with cultural and management practices

3.1 Spacing

According to Yamada (1961) higher planting density within limits produced more total biomass and grain per unit area when rice was grown on less fertilized soil. Under fully fertilized condition, the growth of plant was accelerated, the space was covered with leaves, and the total biomass production per unit area at harvest became constant regardless of its density (Kira et al., 1959).

3.1.a. Effect on growth and growth characters

Increased plant height was observed with wider spacing (Ramiah, 1937; Vachhani et al., 1961; Mishra, 1976; Ibrahim et al., 1980). Lei and Xi (1967) reported higher plant height with closer spacings. Taller plants were observed under dense stands in the initial stages whereas the same was observed under low density at maturity (Nishiyama, 1977). Chang and Su (1977) obtained increase in plant height with decrease in spacing in the semidwarf indica rice cv. Cauvery and the tall local indica cv. Hesur in Saudi Arabia. But Subramanian (1965) and Shahi et al. (1976) concluded that plant height was unaffected by plant population.

Bhaktal (1960) observed increased tiller number m^{-2} with wider spacing. Similar results were reported by Vachhani et al. (1961) also. But Mishra (1976) obtained increased tiller number m^{-2} with narrow spacings of 20 x 5 and 10 x 5 cm.

Murata et al. (1957) found that narrower the spacing, greater the photosynthetic ability at early to middle stage of growth. However, the relationship was reverse in the later stages. Mehrothra et al. (1975) reported an increase in LAI with a spacing of 10 x 10 cm and a decrease in LAI with wider spacing. Mishra (1976) observed an increase in LAI with narrow spacings of 20 x 5 and 10 x 5 cm. Several investigators like Chang and Su (1977), Palanichamy (1978) and Ghosh et al. (1979) also found an increase in LAI with closer spacings.

3.1.b. Effect on yield and yield attributes

(1) Yield attributes

Vachhani et al. (1961) obtained higher number of panicles m^{-2} under wider spacing whereas Mahapatra (1969) and

Mohapatra et al. (1971) recorded more number of panicles with closer spacing. Kurup and Sreedharan (1971) reported an increase in the panicle number m^{-2} with a spacing of 15 x 10 cm at 120 kg N ha^{-1} in the varieties Karuna and Annapoorna. Nair and George (1973) also found an increase in the number of panicles m^{-2} with a spacing of 10 x 10 cm at 120 kg N ha^{-1}.

A reduction in the number of filled grains $panicle^{-1}$ was reported by Nair and George (1973) in culture 12035 with a closer spacing of 10 x 10 cm at 120 kg N ha^{-1}. Raj et al. (1974) observed higher number of filled grains per panicle in IR 20 with a spacing of 15 x 5 cm at 200 kg N ha^{-1}. Mishra (1976) reported that the number of filled grains per panicle was reduced by closer spacings of 20 x 5 and 10 x 5 cm. Palanichamy (1978) found more number of filled grains $panicle^{-1}$ with wider spacing at 140 kg N ha^{-1}.

Sewaram et al. (1973) observed an increase in thousand grain weight with closer spacing at 200 kg N ha^{-1} whereas Nair and George (1973) found a decrease in thousand grain weight with a closer spacing of 10 x 10 cm at 120 kg N ha^{-1}. Mishra (1976) recorded a decrease in thousand grain weight under nitrogen constraint with closer spacings of 20 x 5 and 10 x 5 cm. According to Palanichamy (1978) closer spacing recorded more thousand grain weight. Higher thousand grain weight was observed in wider spacings at 140 kg N ha^{-1} and in closer spacings at 100 kg N ha^{-1}.

(2) Yield

Under low fertility status highest grain yields were obtained with closer spacings of 10 x 10 cm in varieties Padma, Jaya and BC 6. At 100 kg N ha^{-1} Padma gave the highest yield at a spacing of 15 x 10 cm while Jaya and BC 6 gave the same at a closer spacing of 10 x 10 cm at IARI (IARI, 1969), Mishra (1976) observed higher paddy yields at spacings of 20 x 5 and 10 x 5 cm than at wider spacings under nitrogen constraint. Parashar (1976) found that highest paddy yields of 6.46 t ha^{-1} was obtained at 7.5 x 7.5 cm and the lowest yields of 3.8 t ha^{-1} at 30 x 15 cm in the variety IR 8. Highest yields were reported at 15 x 15 cm and 22.5 x 15 cm compared to seven other spacings tried in the variety SR 26 B (Bhattacharya,1977). Cheng and Su (1977) reported increased grain yield with wider spacing in varieties, Cauvery and Hasawi. Ghosh et al. (1979) observed highest yield at a spacing of 15 x 15 cm with 50 kg N ha^{-1} and at a spacing of 20 x 20 cm with 100 kg N ha^{-1} in the variety Pankaj. Chandraker and

Khan (1981) found that optimum grain yields of medium and late maturing varieties were obtained at a spacing of 15 x 10 cm or 20 x 10 cm and early varieties at 10 x 10 cm. In Manipur, highest grain yield was obtained at 15 x 15 cm spacing compared to 20 x 20 and 30 x 30 cm (Singh et al., 1982). In Kharuhan rice, yields increased with increase in N rates and crops grown at a spacing of 10 x 10 cm gave highest yield than those grown at wider spacings (Singh et al., 1982). Singh et al. (1982a) recorded highest yields in narrow spacing of 10 x 10 cm compared to 15 x 15 and 20 x 20 cm. Thangamuthu and Subramaniam (1983) reported that a spacing of 20 x 15 cm (33 plants m^{-2}) gave significant increase in grain yield in wet and dry seasons. Theotharappan and Palaniappan (1984) concluded that a spacing of 20 x 10 cm was best regardless of seedling age in the short duration variety Rasi. According to Majid et al. (1976) rice yield decreased with increased spacing. But this effect was found to be reduced under higher fertility levels and the highest mean yield was obtained at a spacing of 15 x 15 cm. Shahi et al. (1976) observed no significant difference in grain yields at various spacings tried in the variety Jaya. Singh et al. (1982) concluded that for early transplanting, spacing did not affect grain yield in the rice variety Ngoba in Meghalaya. Singh (1982) could not observe any significant effect of spacing on yield in well reclaimed soil. Raju and Rao (1983) also observed no significant difference in grain yield due to various spacings.

Sahu et al. (1980) reported that harvest index was reduced significantly under high Nitrogen rates and high plant density with a spacing of 20 x 20 cm compared to 60 x 60 cm.

Subramanian et al. (1974) found that the protein content of rice was unaffected by levels of nitrogen or spacing. However Mishra (1976) reported that closer specings decreased the nitrogen content of grain and straw.

From the above review it is evident that the effect of spacing on growth, yield attributes and yield of rice depend mainly on the duration of the variety. In general, short duration varieties require closer spacings while medium and late duration varieties prefer wider spacings for optimum performance.

3.2 Age of seedlings

Age of seedling is one of the important non-monetary input which can influence the production considerably. As the purchasing power of inputs of farmers is low, there is need to make up this deficiency of inputs by emphasising the adoption of non-monetary inputs (Chhillar et al., 1984).

Seedling age and number of seedlings $hill^{-1}$ to be transplanted at each hill are two non-monetary/low cost inputs in transplanted rice. The age and number of seedlings should be optimum to derive the maximum benefit from the high cost inputs. The optimum age of seedlings used for transplanting in rice also varies with the duration of varieties, season and management practices (Mahapatra and Leelavathy, 1971).

The age of seedlings used for transplanting varies with countries. Trijillo (1961) reported that transplanting is done at 40 to 60 days after sowing in Korea. In the lower plains of Indonesia 35 to 55 days old seedlings are planted while 70 to 100 days old seedlings are planted in the mountainous regions (VandeGoor, 1953). According to Brown (1958) rice is transplanted 45 to 65 days after sowing in Malayasia, whereas Cada and Taleon (1963) reported the use of 25 to 45 days old seedlings in Philippines. Under 'Peru' condition, even 75 days old seedlings of the local variety 'Minabir' can be planted (Sanchez and Larrea, 1972) whereas in Kerala 18 days old seedlings of short duration varieties and 20-25 days old seedlings of medium duration varieties are recommended. Under ill drained conditions, the long duration varieties like Pankaj, Jaganath, and IR 5 are to be planted 30 days after sowing. However, during *virippu* season, age of seedlings can go upto 35 days in the case of medium duration varieties and 25 days for short duration varieties (KAU 1981).

Barthakur and Gogoi (1974) found that 30 days old seedlings are good for transplanting in Jaya and IR 8. According to Balasubramonian et al. (1977) for late planting older seedlings of 35-45 days may be used for the varieties IR 8 and IR 20.

It is seen from the above review that the optimum seedling age in transplanted rice appears to depend upon the variety, season and management practices followed.

3.2.a. Effect on growth and growth characters

With different ages of seedlings, increase in N application was seen to increase the height of plants. According to Palanichamy (1978) at higher levels of N application younger seedlings were found to record more plant height. Similarly, Venkataraman (1981) reported a reduction in plant height with aged seedlings. On the other hand Sundararajan (1978) concluded that the plant height was unaltered by N at any of the age levels tried.

Singh and Bhattacharyya (1975) observed a reduction in tiller production with aged seedlings. On the contrary, Sundararajan (1978) concluded that increased N levels increased the tiller number even in 40 days old seedlings. But Saerai (1972) could not notice any significant effect of age on tillering.

In medium duration varieties the leaf area index increases with the use of older seedlings. Sundararajan (1978) recorded higher leaf area index values in 30 days old seedlings followed by 40, 50 and 20 days old seedlings. Murty and Sahu (1979) could observe a reduction in leaf area index at flowering by nine per cent when 60 days old seedlings were transplanted in the short duration variety Rasi. They also reported that significant reduction in leaf area index at flowering was not evident in medium and late maturing varieties. Theetharappan (1983) observed that leaf area index was not adversely affected upto 40 days in the early maturing variety, Rasi and 45 days in the late maturing variety Co-40.

3.2.b Effect on yield and yield attributes

(1) Yield attributes

According to Sanchez and Larrea (1972) delay in transplanting from 30 to 60 days was associated with a decrease in the panicle number $hill^{-1}$. Singh and Bhattacharyya (1975) also recorded a reduction in the number of panicles with increase in age of seedlings. Sundararajan (1978) observed highest number of panicles $hill^{-1}$ with 39 days old seedlings. But Seerai (1972) could not get any significant influence of age on panicle number. Theetharappan (1983) concluded that the number of panicles $hill^{-1}$ was not adversely affected upto 40 days in the early maturing variety Rasi and 45 days in the late maturing variety Co-40.

Less number of grains was associated with older seedlings (Sanchez and Larrea, 1972). Reduction in the number of filled grains per panicle was observed in the case of overaged as well as very young seedlings (Sundararajan, 1978) whereas Murty and Sahu (1979) obtained 15-20 per cent increase in filled grains with aged seedlings.

Sanchez and Larrea (1972) observed slight decrease in thousand grain weight with aged seedlings when planted in the second crop season. Decrease in thousand grain weight with older seedlings in the second crop season was reported by Seshadri et al.(1976) and Anon (1981) under Kerala conditions. However, Sundararajan (1978) and Manoharan (1981) could not observe any significant effect of age on thousand grain weight. Thus the results do not reveal a constant trend and is found to vary according to the situation.

(2) Yield

Narayanaswamy and Nagarathinam (1966) recorded highest grain yields in varieties ASD 5 and ASD 11 with 35 days than with 25 and 45 days old seedlings. Seerai (1972) obtained highest grain yield with 40 days old seedlings in the variety Peta. According to Sanchez and Larrea (1972) yield reduction due to planting of aged seedlings is more pronounced in early maturing than in late maturing varieties. Annappan et al.(1973) observed that 25, 30, 35 and 50 days old seedlings were comparable with regard to grain yield in the variety 'Ponni'. An increase in the grain yield of rice variety IR 8 was observed with 36 days old seedlings (Dargan and Gaul, 1974). Shahi and Gill (1978) reported that seedling age showed positive correlation with paddy yield and yield components in variety Palman 579 and Jaya. Singh and Tarat (1978) reported that 34 days for early maturing and 40 days for late maturing varieties are good. Sharma et al. (1979) observed consistency in yield reduction due to planting of aged seedlings regardless of seedling number in rice variety Pusa 2-21, whereas in the medium duration variety Jaya, the magnitude of yield reduction due to overaged seedlings was low. In the case of rice variety Rasi, grain yield was higher in 40 and 60 days when compared with 20 days old seedlings (Murty and Sahu, 1979). Singh et al. (1980) reported that Ratna and Sona gave the highest grain yield with 35 days old seedlings in saline alkali soils. Natarajan et al. (1980a) observed that at Tirur, the best age of TKM 9 and ADT 31 was 40 days to produce significantly higher yields than 25 and 30 days old seedlings. Khan and Swarnkar (1980) found that seven week old seedlings were superior to six week old seedlings in respect of yield under Madhya Pradesh condition. Navakodi et al. (1981) reported that for both short and medium duration varieties upto 40 days old seedlings can be planted without significant yield reduction in sandy loam soils in valley land under mid altitude condition of Meghalaya. Panda and Das (1978) could not observe any yield reduction by planting 50 days old seedlings in four high yielding varieties under Sambalpur condition. Pyarelal et al. (1981) also noticed a similar trend. Ghosh (1982) observed that paddy yield decreased with increase in seedling age from 40 to 50 and 60 days on late planting in kharif and with older seedlings yields were significantly higher at closer spacings. Islam and Ahmed (1983) reported an yield increase upto 50 days beyond which the yield decreased. Murthy et al. (1983) observed significant increase in paddy yield when older seedlings (45 and 60 days old seedlings) were planted in the variety IET 7251 and had the lowest spikelet sterility. Patel et al. (1983) obtained higher paddy yields by planting 24 days old seedlings to a depth of 3-4 cm in puddled soil. Patel and Patel (1983) recorded maximum grain and straw yield in the variety Ratna with 35 days old seedlings while Raju and Rao (1983) observed highest grain yield in Jaya with 25 days old seedlings. Chandrasekharan et al. (1984) could not notice any reduction in yield due to planting of older seedlings. Chillar et al. (1984) observed higher yields in 36 days old seedlings than in younger seedlings. According to Reddy and Mitra (1984) highest grain yields were recorded with 55 days in the variety CR-1016. According to Ramaswamy et al. (1985) under low nitrogen levels, 40 days old seedlings yielded better than other age levels tried. Singh et al. (1982b) observed no significant effect of age of seedling on late planted rice yield. Shahani et al.(1984) concluded that grain yield was unaffected by seedling age at transplanting but increased with increasing fertilizer levels.

Palanichamy (1978) observed a significant increase in protein content of rice and N content of straw with increase in the age of seedlings. Theetharappan (1983) reported that NPK uptake of rice plants was not considerably reduced upto 45 days. Manoharan (1981) found that there was significant influence of age of seedling on the N uptake. The uptake by the crop was higher in 25 and 35 than with 45 days old seedlings. He also observed that P uptake was higher in younger seedlings than older seedlings whereas K uptake was unaffected by age. Sundararajan (1978) also reported similar results.

The above review reveals that short duration varieties require younger seedlings while medium and long duration varieties require older seedlings for their optimum performance with regard to growth, yield attributes and yield of rice.

3.3 Number of seedlings $hill^{-1}$

Higher N rates are needed to obtain an yield response of low tillering varieties to increased seedling number (IARI, 1971). At 100 kg N, the grain yield of the variety IR 127-80-1 increased from 2.5 to 4.4 tha^{-1} when the number of seedlings was increased from one to six.

3.3.a. Effect on growth and growth characters

Rumiati and Oldeman (1974) reported a decrease in the tiller number $hill^{-1}$ with increase in plant population. Pothiraj et al. (1977) observed that maximum leaf area index at flowering was obtained by planting one seedling per hill and 100 hills m^{-2}. Reduction in the hill number m^{-2} reduced leaf area index at all stages.

3.3.b. Effect on yield and yield attributes

(1) Yield attributes

Rumiati and Oldeman (1974) recorded a decrease in the number of panicles $hill^{-1}$ and number of filled grains $panicle^{-1}$ while an increase was noticed in the thousand grain weight. With variety Pelita I/1, a grain yield of 660 gm m^{-2} was obtained at the highest density compared to 502 gm m^{-2} at the lowest density. Natarajan (1982) observed an increase in panicle number $hill^{-1}$ by 15.5 per cent in Ponni and 11.6 per cent in ASD 15 by increasing the number of seedlings $hill^{-1}$ from two to six. He also reported that all other panicle characters were reduced by increasing the seedling number $hill^{-1}$.

(2) Yield

Kang and Choi (1976) reported that increasing the number of seedlings per hill increased grain yields in the rice variety Tongil especially for late season planting. Sharma et al. (1979) found an increase in yield when the number of seedlings from the same age group rose from two to six $hill^{-1}$. According to Nair et al. (1981) doubling plant density and shallow planting (3 cm) at the same N level resulted in only moderate yield increases in the early maturing variety Jyothi. Gautam and Sharma (1982) reported increased grain yields due to high planting density (400 hills m^{-2} against 25 hills m^{-2}) by 10 per cent in Ratna 14 per cent in Rasi and 24 per cent in Cauvery. Lal et al. (1982) found that increasing plant density increased the yield of the fertilized crop. The response to higher plant density was greater with 50 kg N ha^{-1} than with 100 kg N ha^{-1} indicating that the higher N rate compensated for low plant population. Gautam and Sharma (1983) reported that early maturing varieties like Ratna, Rasi and Cauvery almost equalled Jaya in yield at high plant density provided the environmental conditions were the same for all varieties during the reproductive and ripening period. Ngnu and Alluri (1983) observed an increase in grain yields in varieties FARO 27, ITA 117, ITA 235 as the plant density was increased from 28 x 10^3 to 217 x 10^3 hills ha^{-1} in upland rice. Wasano (1983) also found significant increase in yield as the plant density was increased from two to three seedlings $hill^{-1}$ in low land rice. Shahi et al.(1976) could not notice any significant difference in grain yield when the seedling number was increased from one to four $hill^{-1}$. Singh (1982) also observed no significant effect of plant population on yield in well reclaimed soil.

It is evident from the above review that increasing the plant density by increasing the seedling number from two to six $hill^{-1}$ was found to be beneficial to obtain higher yields. The tiller number and LAI were also influenced favourably by higher plant densities especially in the vegetative growth stage.

3.4 Azolla - a low cost biofertilizer for rice

Recently more and more attention is being given to the Azolla - Anabaena associations as a potential nutrient source in rice culture. The symbiosis between Azolla and Anabaena is most efficient in nitrogen fixation.

Various reports revealed that under favourable conditions upto 900 kg N ha^{-1} $year^{-1}$ could be fixed by azolla (Singh 1977 a, b and c and Singh et al., 1982 a). On dry weight basis it contains 3 to 6 per cent N, 0.5 to 0.9 per cent P, 2 to 4 per cent K, 0.8 to 1 per cent Ca and traces of other micronutrients. It can fix as much as 1.5 kg N ha^{-1} day^{-1} or 500 kg N ha^{-1} $year^{-1}$ (Watanabe et al., 1980). Incorporation of one layer of azolla into soil before transplanting rice seedlings increased growth and paddy yields by 12 to 30 per cent depending on the cultivar and season (Singh, 1977 a). Besides substituting the chemical nutrient requirement, azolla has the effect of green manuring also. Azolla was used as green manure in Japan as early as in 1947 (Fujiwara et al., 1947). Moore (1969) and Thuyet and Tuan (1973) reported the value of azolla as a potential N supplying green manure.

3.4.a. Effect of azolla on growth and growth characters

Singh (1977 b, d) reported an increase in plant height and tiller number with the incorporation of Azolla @ 10 t ha^{-1}. Similar results have been obtained by Subudhi and Singh (1980), Jaikumaran (1981) and Mathewkutty (1982). Seventy five per cent N with Azolla produced the same LAI as that of 100 per cent N applied either alone or with

Azolla or farm yard manure (Jaikumaran, 1981). Mathewkutty (1982) concluded that utilization of azolla in combination with 30 kg fertilizer N at active tillering stage gave higher LAI.

3.4.b. Effect on yield and yield attributes

(1) Yield attributes

An increase in filled grains panicle^{-1} was observed with azolla application along with urea than with urea alone (Kulasoorya and Desilva, 1977 b). According to Singh (1977 c) azolla incorporation at the rate of 10 t ha^{-1} increased the number of panicles m^{-2} in varieties IR-8 and Supriya. Maximum number of panicles, filled grains and percentage of filling was observed with incorporation of azolla at the rate of 5 t ha^{-1} with 75 per cent of the recommended dose of N (Jaikumaran, 1981). He also reported that the test weight of grains with 75 per cent N along with Azolla was comparable with 100 per cent N application alone. Mathewkutty (1982) also could register higher panicle number, number of filled grains panicle^{-1} and thousand grain weight with the application of azolla along with fertilizer N. The above review reveals the favourable effect of Azolla application on the yield attributes.

(2) Yield

Studies at CRRI, Cuttack revealed that azolla incorporation at the rate 10 to 12 t ha^{-1} gave significant increase in rice yields (Singh 1977 b, d and e). Azolla incorporation resulted in increased grain yields of 12 to 25 per cent in rice varieties IR-8 Supriya, Vani and CR 1005 in kharif and an increase of 38 to 41 per cent in rabi (Singh, 1977 b). He found that combined application of azolla at the rate of 10 t ha^{-1} with 30 or 50 kg fertiliser N ha^{-1} gave yields equivalent to that produced by 60 or 80 kg N applied alone. Srinivasan (1977) reported an increase of about 19 per cent and Watanabe (1977), 13 per cent increase in grain yield through Azolla incorporation whereas Singh (1979 b) obtained 54 per cent increase over control. Sundaram et al. (1979) reported that azolla incorporation at the time of transplanting or first weeding along with 75 per cent of the recommended dose of N recorded higher grain yield than application of full recommended dose of N. Arunachalam (1980) obtained increased grain and straw yield with azolla application. Natarajan et al. (1980b) also reported similar results in all seasons. Sreenivasan (1980) concluded that yield increases in the short duration variety ADT 31 were significant for azolla application upto 60 t ha^{-1} at the paddy experiment station, Aduthurai. According to Jaikumaran (1981) azolla incorporation along with 75 per cent of the recommended dose of N gave rice yields equivalent to that obtained with full recommended dose of N alone or in combination with farm yard manure or azolla. Kaushik and Venkataraman (1981) found that in pot trials with 'Basmathi', grain yields increased from 3.58 in control to 5.6 g pot^{-1} with azolla application alone. Mathur et al. (1981) observed an increase in grain yield of rabi rice by 4.4 per cent with azolla alone, 17.8 per cent with 100 kg N ha^{-1} and by 22.2 per cent with a combination of azolla and N. Kannaiyan et al. (1983) found that plots treated with 30 kg N ha^{-1} as fertilizer and 30 kg N as azolla at 40 x 10 cm spacing gave the highest yield. Krishnarajan and Balasubramanian (1983) reported that grain yield increased from 5.2 t ha^{-1} in control to 6.2 t ha^{-1} with incorporation of azolla @ 6 t ha^{-1}. Mathewkutty and Sreedharan (1983) recorded highest grain and straw yields in treatments having basal incorporation of azolla combined with inoculation. Sreenivasan (1983) observed increase in grain yields with all levels of N and azolla application in 'ADT 31' under Aduthurai condition. Tahmida and Abdul Kader (1983) concluded that azolla incorporation alone or in combination with urea stimulated rice growth and increased both grain and straw yield. Kannaiyan et al. (1984) reported that highest grain yield of 5.08 t ha^{-1} was obtained with 60 kg N ha^{-1} plus azolla compared with 4.33 t ha^{-1} with 60 kg N alone while straw yields were highest with 90 kg N plus azolla in IR-20 during the samba season. Thus it is evident that the extent of increase in grain and straw yield varies with the varieties, method of application of azolla plus the soil and climatic condition of each place.

3.4.c. Effect on fertilizer substitution

Several workers have reported about the N economy through the incorporation of azolla (Singh, 1977 b,c,d,e; Singh, 1978; Watanabe, 1978; Arunachalam, 1980; Subudhi and Singh, 1980 and Subbarao, 1981). Singh (1977 a) estimated that a layer of azolla covering one ha of rice field produces 10 t of green matter containing about 30 kg N ha^{-1}. According to Sawatdee et al. (1978) and Sawatdee and Seetanum (1979), azolla incorporation registered rice yields equivalent to that obtained through the application of 37.5 kg inorganic N ha^{-1}. Studies by Govindarajan et al. (1980) revealed that plots treated with 75: 50: 50 kg NPK plus azolla yielded as good as those with 100: 50: 50 kg NPK alone in IR 20 at Tirur. In 'ADT 31', incorporation of

Azolla along with 50 kg N ha^{-1} gave yields equal to those with 75 kg N ha^{-1} alone at Ambasamudram. Natarajan et al. (1980b) also obtained about 25 per cent saving in inorganic nitrogen when azolla was applied along with graded levels of N. Azolla incorporation @ 6 t ha^{-1} at transplanting was found to be comparable with 35 and 17 kg ha^{-1} of urea in <u>kharif</u> and <u>rabi</u> seasons, respectively. According to Swatdee et al. (1980) one azolla layer, whether incorporated into soil or not increased rice yield to the same level as would 30 kg N ha^{-1}. Under Kerala conditions, Jaikumaran (1981) observed a saving of 28 and 44 kg N ha^{-1} in the <u>virippu</u> and <u>mundakan</u> seasons, respectively, with azolla incorporation at the rate of 5 t ha^{-1}. Guar and Singh (1982) reported a saving of 25 to 30 kg N ha^{-1} through azolla incorporation. Kannaiyan and Govindarajan (1982) Mathewkutty (1982) and Mandal and Bharathi (1983) also observed similar results. Haq et al. (1984) obtained yield with azolla culture similar to that with 60 kg applied N. The yield response to azolla application @ 6 t ha^{-1} was found to be equivalent to 36 kg N and the response to one t Azolla inoculated, grown insitu and incorporated was equivalent to 24 kg N ha^{-1} in 'Sita' (Roy, 1984). Kikuchi et al. (1984) concluded that under favourable conditions, a layer of azolla covering one ha of rice field releases 20-30 kg

0

organic N which can increase rice yield by 0.4 to 1.5 t ha^{-1}.

From the above review it is seen that the quantity of N substitution with azolla application varied with soil types and an average quantity of 25-30 kg fertiliser N could be substituted with the application of azolla @ 5 t ha^{-1}.

3.4.d. Effect on uptake and soil status of nutrients

Rice showed a linear increase in N uptake with increase in azolla application from 5 to 20 t ha^{-1}. The effect of N uptake was more pronounced in the dry season (Subudhi and Singh 1980; Singh, 1979 a). Jaikumaran (1981) recorded maximum uptake of N, P and K when azolla was incorporated with 100 per cent N in virippu and 75 per cent N in mundakan season. Mathewkutty (1982) also obtained maximum uptake of N and P with incorporation and dual culturing of azolla followed by in situ incorporation of azolla with 30 kg N application at panicle initiation stage. Thus from the above review the NPK uptake of rice is enhanced by the combined application of fertiliser and Azolla.

Reports from China revealed that azolla incorporation in rice fields improved the organic matter content and soil aggregation (Anon, 1975-77). Analysis of soils after harvest of the crop indicated that in Azolla treated plots there was a gradual increase in organic carbon, total nitrogen and available phosphorus (Singh, 1979 a and Arunachalam, 1980). According to Subudhi and Singh (1980) only marginal increase in organic carbon content was recorded with Azolla application. Venkitaraman (1980) found an increase from 1.54 to 1.59 per cent in organic carbon content, a slight decrease in P content and no change in K content due to the incorporation of azolla. Subramanian (1981) found a build up in total N content with azolla application along with 30 kg fertilizer N. Lizhuo-xin (1982) also reported improvement in the chemical characteristics of the soil by the application of azolla. Singh et al. (1982 a) obtained similar results.

Thus it is clear from the above review that the nutrient status of the soil will be improved by the application of azolla with or without fertilizer.

Materials and Methods

MATERIALS AND METHODS

A series of experiments to evaluate low cost agronomic techniques in rice production were conducted in Kerala, India during the period from 1982 to 1985. The project consisted of three separate field trials, viz.

1. Performance of IR 42 under different levels of fertilizer and spacing.
2. Effect of age of seedling and planting density in rice variety IR 42.
3. Evaluation of Azolla as a low cost biofertilizer in rice variety IR 42.

The materials used and methods adopted in the course of these investigations are described below.

1. Location of the trial

The trials were conducted at the Regional Agricultural Research Station of the Kerala Agricultural University, Pattambi in Pálghat district. The research station is situated at 10° 48' N latitude and 76° 12'E longitude and at an altitude of 25.359 meters above mean sea level.

1.1 Soil

The blocks in which the trials were conducted are A 12 a and b, B 1a and b, IV 1a, 3a, V 1a, 1g, h, 2 f, g, h V 5a and 6a. The physio-chemical characteristics of the soil of the experimental field are given below. Pooled samples from block A, B, IV and V were used for mechanical analysis while soils of each block were used separately for chemical analysis.

A. Physical properties of the soil

Average mechanical composition of the soil (International pipette method).

Sand	..	52.55 per cent
Silt	..	20.14 per cent
Clay	..	25.00 per cent
Loss on ignition	..	2.31 per cent

Textural class - Sandy clay loam

Field capacity (0.3 bar) = 22.11 per cent

(Pressure plate apparatus, Richards, 1948).

B. Chemical properties of the soil

The chemical properties of the soil are given in Table 1.

Table 1 Chemical properties of soil

Particulars	A (East)	B(West)	IV	V
1. pH (1:2.5 soil : solution ratio Elico pH meter Piper, 1942)	5.5	5.6	5.5	5.4
2. Organic carbon (%) (Walkley and Black method - Piper, 1942)	1.5	1.6	1.4	1.3
3. Total nitrogen (%) (Microkjeldahl method Jackson, 1958)	0.16	0.18	0.15	0.15
4. Available P_2O_5 (kg ha^{-1}) (Bray and Kurtz method, Jackson, 1958)	21.8	21.2	20.8	21.3
5. Exchangeable K_2O (kg ha^{-1}) (Neutral normal Ammonium acetate method - Jackson, 1958)	248.3	242.8	236.5	231.8
6. C.E.C.(me/100 g of soil)	14.2	14.2	13.5	14.1

2. Cropping history of the experimental field

Every year a bulk crop of rice was raised before the conduct of the experiment.

3. Season

Trial I and II were conducted for two virippu and two mundakan seasons of 1982 and 1983 while trial III was conducted during two mundakan seasons of 1982 and 1984. Virippu season corresponds to first crop (April-May to September-October) and mundakan season corresponds to second crop (September-October to December-January) in Kerala.

4. Climate

The weekly averages of temperature, relative humidity, sunshine hours, evaporation and total rainfall during the cropping period were collected from the meteorological observatory of the Research Station and are presented in Appendix-I. These data correspond to standard weeks starting from 14th July 1982 to first week of March, 1985, the period during which the trials were conducted.

In general the seasons were favourable for the satisfactory growth of the crop.

5. Materials

5.1 Variety

IR-42 - a medium duration (145 days), semi dwarf variety introduced by IRRI in 1981 was used for the investigation. It appears to be a good modern variety of rice for small farmers because of its capacity to extract and utilize both soil and fertilizer nutrients efficiently. The consistency of IR 42's relatively high yield without N fertilizer makes it a valuable variety under low fertility conditions (IRRI, 1978).

5.2 Manures and fertilizers

Farm yard manure @ 5 t ha^{-1} was incorporated in trials I & II.

Urea, superphosphate and muriate of potash analysing 46 per cent N, 16 per cent P_2O_5 and 60 per cent K_2O, respectively were used for the trials.

With regard to the application of fertilizers the package of practices recommendations (KAU, 1981) were followed.

5.3 Azolla

Azolla pinnata was used for incorporation as per treatments in the Azolla trials. It contained 91.50 per cent moisture, 2.75 per cent total nitrogen, 0.24 per cent total phosphorus and 2.01 per cent total K on dry weight basis.

6. Methods

6.1 Trial I. Performance of IR 42 under different levels of fertilizer and spacing

The trial consisted of four levels of fertilizer as main plot and six spacing as sub plot treatments.

Main plot treatments - Fertilizer levels (Four)

1. F_0 = 0 (Control)
2. F_1 = 50% of the recommended dose of 90: 45: 45 kg NPK* ha^{-1}
3. F_2 = 75% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}
4. F_3 = 100% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

Sub plot treatments - Spacing levels (six)

1. S_1 - 20 x 20 cm (25 hills m^{-2})
2. S_2 - 20 x 15 cm (33 hills m^{-2})
3. S_3 - 20 x 10 cm (50 hills m^{-2})
4. S_4 - 20 x 5 cm (100 hills m^{-2})
5. S_5 - 15 x 15 cm (44 hills m^{-2})
6. S_6 - 15 x 10 cm (66 hills m^{-2})

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*The notations N, P and K used in the text, represent N, P_2O_5 and K_2O, respectively.

Treatments	-	24
Replications	-	5
Design	-	Split plot
Gross plot size	-	6 x 3 m^2
Net plot size	-	Varied with spacing

Trial II. Effect of age of seedling and planting density on rice variety IR 42

The trial consisted of three levels each of age and number of seedlings hill^{-1} and two levels of fertilizer as given below.

A. Age groups (three)

1. A_1 = 25 days old seedlings
2. A_2 = 30 days old seedlings
3. A_3 = 35 days old seedlings

B. Number of seedlings hill^{-1} (three levels)

1. N_1 = 2 seedlings hill^{-1}
2. N_2 = 4 seedlings hill^{-1}
3. N_3 = 6 seedlings hill^{-1}

C. Fertilizer (Two levels)

1. F_1 - 50% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}
2. F_2 - 75% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

For the first year of the experiment

3. F_1 - 75% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

4. F_2 - 100% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

For the second year of the experiment

Treatment combinations	-	18
Replications	-	3
Design	-	Factorial RBD
Spacing	:	20 x 15 cm for <u>virippu</u>
	:	20 x 10 cm for <u>mundakan</u>
Gross plot size	:	5 x 4.05 M^2 for <u>virippu</u>
	:	5 x 4 M^2 for <u>mundakan</u>
Net plot size	:	3.8 x 3.45 M^2 for <u>virippu</u>
	:	3.8 x 3.6 M^2 for <u>mundakan</u>

Trial III. Evaluation of Azolla as a low cost bio-fertiliser

The trial consisted of four levels each of fertilizer and azolla as given below.

1. Main plot treatments

Fertilizer levels (four)

1. F_0 - Control (without fertilizer)
2. F_1 - 50% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

3. F_2 - 75% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

4. F_3 - 100% of the recommended dose of 90: 45: 45 kg NPK ha^{-1}

2. Sub plot treatments

Azolla levels (four)

1. A_1 - 5 t ha^{-1}
2. A_2 - 10 t ha^{-1}
3. A_3 - 15 t ha^{-1}
4. A_4 - 20 t ha^{-1}

Treatment combinations	-	16
Replications	-	5
Design	-	Split plot
Spacing	-	20 x 10 cm
Gross plot size	-	5 x 4 m^2
Net plot size	-	3.8 x 3.6 m^2

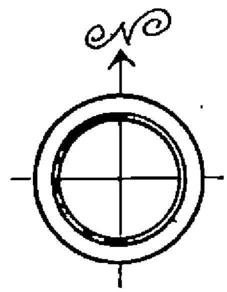
Azolla was incorporated in each plot as per treatments before transplanting the seedlings.

6.2 Field culture

The package of practices recommendations of Kerala Agricultural University for cultivation of medium duration rice varieties ((KAU 1981)) were followed during the cropping period.

The general performance of the crop was good and there was no severe attack of pests and diseases during the course of this study. The layout plans of the experiments are illustrated in Fig., a, b and c. The time of sowing and harvest of each experiment are given in Table 2.

RV	$F_1 S_2$	$F_2 S_6$	$F_0 S_3$	$F_3 S_4$
	$F_1 S_3$	$F_2 S_5$	$F_0 S_1$	$F_3 S_1$
	$F_1 S_1$	$F_2 S_4$	$F_0 S_4$	$F_3 S_6$
	$F_1 S_4$	$F_2 S_2$	$F_0 S_2$	$F_3 S_5$
	$F_1 S_5$	$F_2 S_3$	$F_0 S_6$	$F_3 S_3$
	$F_1 S_6$	$F_2 S_1$	$F_0 S_5$	$F_3 S_2$
RIV	$F_2 S_5$	$F_1 S_2$	$F_3 S_3$	$F_0 S_6$
	$F_2 S_3$	$F_1 S_1$	$F_3 S_1$	$F_0 S_2$
	$F_2 S_4$	$F_1 S_3$	$F_3 S_2$	$F_0 S_3$
	$F_2 S_1$	$F_1 S_4$	$F_3 S_6$	$F_0 S_4$
	$F_2 S_2$	$F_1 S_6$	$F_3 S_4$	$F_0 S_5$
	$F_2 S_6$	$F_1 S_5$	$F_3 S_5$	$F_0 S_1$
RIII	$F_0 S_1$	$F_1 S_2$	$F_3 S_3$	$F_2 S_4$
	$F_0 S_5$	$F_1 S_1$	$F_3 S_2$	$F_2 S_1$
	$F_0 S_3$	$F_1 S_3$	$F_3 S_4$	$F_2 S_2$
	$F_0 S_4$	$F_1 S_5$	$F_3 S_6$	$F_2 S_6$
	$F_0 S_2$	$F_1 S_6$	$F_3 S_1$	$F_2 S_3$
	$F_0 S_6$	$F_1 S_4$	$F_3 S_5$	$F_2 S_5$
RII	$F_3 S_2$	$F_2 S_3$	$F_0 S_1$	$F_1 S_2$
	$F_3 S_1$	$F_2 S_2$	$F_0 S_2$	$F_1 S_4$
	$F_3 S_5$	$F_2 S_6$	$F_0 S_6$	$F_1 S_3$
	$F_3 S_3$	$F_2 S_1$	$F_0 S_4$	$F_1 S_6$
	$F_3 S_6$	$F_2 S_4$	$F_0 S_5$	$F_1 S_1$
	$F_3 S_4$	$F_2 S_5$	$F_0 S_3$	$F_1 S_5$
RI	$F_1 S_3$	$F_0 S_4$	$F_2 S_6$	$F_3 S_1$
	$F_1 S_4$	$F_0 S_2$	$F_2 S_1$	$F_3 S_4$
	$F_1 S_6$	$F_0 S_6$	$F_2 S_4$	$F_3 S_2$
	$F_1 S_1$	$F_0 S_5$	$F_2 S_5$	$F_3 S_5$
	$F_1 S_5$	$F_0 S_3$	$F_2 S_5$	$F_3 S_3$
	$F_1 S_2$	$F_0 S_1$	$F_2 S_3$	$F_3 S_6$



MAIN PLOT TREAMENTS. — FERTILIZER LEVELS.

F_0 - CONTROL (WITHOUT FERTILIZER)

F_1 - 50% OF THE RECOMMENDED DOSE OF 90:45:45 kg NPK ha^{-1}

F_2 - 75% -DO-

F_3 - 100% -DO-

SUB PLOT TREATMENTS — SPACING LEVELS

S_1 - 20×20 cm (25 HILLS m^{-2})

S_2 - 20×15 cm (33 HILLS m^{-2})

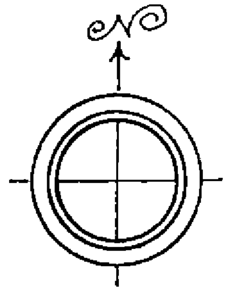
S_3 - 20×10 cm (50 HILLS m^{-2})

S_4 - 20× 5 cm (100 HILLS m^{-2})

S_5 - 15×15 cm (44 HILLS m^{-2})

S_6 - 15×10 cm (66 HILLS m^{-2})

FIG. I(a). LAY OUT PLAN OF TRIAL No. I.
DESIGN - SPLIT PLOT.



	$F_1A_2N_3$	$F_2A_2N_1$	$F_1A_3N_1$	$F_1A_3N_2$	$F_1A_2N_1$	$F_2A_1N_1$
R III	$F_2A_3N_2$	$F_1A_3N_3$	$F_2A_3N_3$	$F_1A_1N_2$	$F_2A_1N_2$	$F_2A_2N_3$
	$F_2A_3N_1$	$F_1A_1N_3$	$F_1A_2N_2$	$F_2A_1N_3$	$F_2A_2N_2$	$F_1A_1N_1$
	$F_2A_1N_3$	$F_1A_2N_1$	$F_2A_1N_1$	$F_1A_2N_3$	$F_2A_2N_2$	$F_2A_3N_3$
R II	$F_2A_2N_3$	$F_2A_2N_1$	$F_1A_3N_1$	$F_2A_1N_2$	$F_1A_3N_3$	$F_1A_1N_3$
	$F_1A_2N_2$	$F_1A_1N_2$	$F_1A_1N_1$	$F_1A_3N_2$	$F_2A_3N_2$	$F_2A_3N_1$
	$F_1A_1N_3$	$F_2A_2N_1$	$F_1A_1N_2$	$F_2A_2N_3$	$F_1A_3N_2$	$F_2A_1N_1$
R I	$F_2A_2N_2$	$F_1A_3N_3$	$F_1A_2N_1$	$F_2A_3N_2$	$F_2A_2N_1$	$F_1A_3N_3$
	$F_1A_1N_1$	$F_2A_2N_2$	$F_2A_3N_3$	$F_1A_1N_1$	$F_1A_3N_2$	$F_2A_1N_3$

TRETMENTS

1. FERTILIZER LEVELS

FIRST YEAR
- F_1 - 50% OF THE RECOMMENDED DOSE OF 90:45:45 kg NPK ha^{-1}
- F_2 - 75% - DO -

SECOND YEAR
- F_1 - 75% - DO -
- F_2 - 100% - DO -

2. AGE OF SEEDLINGS

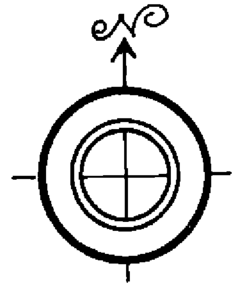
- A_1 - 25 DAYS AFTER SOWING.
- A_2 - 30 "
- A_3 - 35 "

3. NUMBER OF SEEDLINGS $HILL^{-1}$

- N_1 - 2 SEEDLINGS $HILL^{-1}$
- N_2 - 4 "
- N_3 - 6 "

FIG.I.b. LAY OUT PLAN OF TRIAL No. II.
DESIGN - FACTORIAL RBD.

R V	F_0A_2	F_2A_1	F_1A_4	F_3A_3
	F_0A_1	F_2A_4	F_1A_2	F_3A_1
	F_0A_4	F_2A_2	F_1A_3	F_3A_2
	F_0A_3	F_2A_3	F_1A_1	F_3A_4
R IV	F_1A_1	F_3A_4	F_0A_4	F_2A_1
	F_1A_3	F_3A_1	F_0A_1	F_2A_3
	F_1A_2	F_3A_3	F_0A_2	F_2A_4
	F_1A_4	F_3A_2	F_0A_3	F_2A_2
R III	F_2A_1	F_0A_4	F_1A_3	F_3A_1
	F_2A_3	F_0A_1	F_1A_2	F_3A_4
	F_2A_2	F_0A_2	F_1A_4	F_3A_2
	F_2A_4	F_0A_3	F_1A_1	F_3A_3
R II	F_3A_2	F_2A_1	F_0A_4	F_1A_3
	F_3A_4	F_2A_3	F_0A_1	F_1A_4
	F_3A_1	F_2A_4	F_0A_3	F_1A_1
	F_3A_3	F_2A_2	F_0A_2	F_1A_2
R I	F_1A_4	F_0A_3	F_3A_1	F_2A_4
	F_1A_2	F_0A_1	F_3A_4	F_2A_3
	F_1A_3	F_0A_4	F_3A_2	F_2A_1
	F_1A_1	F_0A_2	F_3A_3	F_2A_2



MAIN PLOT TREATMENTS	FERTILIZER LEVELS
F_0	CONTROL (WITH OUT FERTILIZER)
F_1	50 % OF THE RECOMMENDED DOSE OF 90:45:45 kg NPK ha^{-1}
F_2	75 % -DO-
F_3	100 % -DO-

SUB PLOT TREATMENTS	AZOLLA LEVELS
A_1	5 tha^{-1}
A_2	10 tha^{-1}
A_3	15 tha^{-1}
A_4	20 tha^{-1}

FIG.I.C. LAY OUT PLAN OF TRIAL No. III.
DESIGN - SPLIT PLOT.

Table 2. Duration of the crop in different seasons

Year	Trial No.	VIRIPPU SEASON			MUNDAKAN SEASON		
		Date of sowing	Date of harvest	Duration (days)	Date of sowing	Date of harvest	Duration
I year	I	19.6.1982	14.11.1982	145	20.10.1982	2.3.1983	132
	II	9.6.1982	11.11.1982	152	22.9.1982	2.2.1983	129
		14.6.1982		147	27.9.1982		124
		19.6.1982		142	2.10.1982		119
	III	-	-	-	7.11.1982	9.3.1983	122
II Year	I	29.6.1983	24.11.1983	145	8.10.1983	16.2.1984	128
	II	25.6.1983	17.11.1983	142	9.9. 1983	19.1.1984	130
		30.6.1983		137	14.9.1983		125
		5.7.1983		132	19.9.1983		120
	III	-	-	-	15.10.1984	4.3.1985	139

6.3 Observations

Sampling unit

A sampling unit consisting of ten plants was selected randomly in each plot and was demarcated for taking pre harvest and post harvest observations.

6.3.1 Preharvest observations

(a) Height of plants

The height of plants was recorded at active tillering, panicle initiation, flowering and at harvest. However, the data on the height of plants at panicle initiation and at harvest are given. Height was measured from the bottom of the culm to the tip of the longest leaf or earhead which ever was taller.

(b) Number of tillers m^{-2}

Total number of tillers of the plants in the sampling unit was counted and recorded per m^2 in all the above four stages, though only the data at panicle initiation and harvest stage are given.

Hills were selected at random, from the row meant for destructive sampling after making sure that the hills were surrounded by living hills at each stage of observation. The number of tillers was counted from each selected hill. The length and maximum width of each of the leaves on the middle tiller was measured and the leaf area was computed using the length width method. Leaf area = K x length x width where K is the adjustment factor. The value used for K was 0.75 during all stages except harvest where the value was 0.67 (IRRI, 1972). The LAI was then derived by dividing leaf area by the corresponding land area.

(d) Dry matter production (DMP) at harvest

Dry weight of all the plant parts except roots from the sample hills used for LAI measurement was taken and expressed as kg ha^{-1}.

(e) Number of panicles m^{-2}

Number of panicles from each sampling unit was counted and the values m^{-2} were computed.

6.3.2 Post harvest observations

(a) Number of filled grains $panicle^{-1}$

Number of fully filled grains in each panicle was counted and recorded.

(b) Sterility percentage

Number of filled grains and chaff of each panicle was counted separately and recorded and sterility percentage worked out.

(c) Thousand grain weight

Thousand filled grains of the panicles from the sampling unit were collected, counted separately and their weight recorded.

(d) Grain yield

Plot wise final grain yield was taken after cleaning and drying in the sun for 3 to 4 days. The yield data were computed at 14 per cent moisture and expressed as kg ha^{-1}.

(e) Straw yield

The straw weight was recorded after complete drying. It was dried till two consecutive weights agreed. The yield of straw was expressed as kg ha^{-1}.

(f) Harvest index

This is the percentage of grain weight to total plant weight (Donald, 1962). This was calculated from the grain and straw weight as indicated below.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

$$= \frac{\text{Grain yield}}{\text{Grain + straw yield}} \times 100$$

6.3.3 Chemical analysis

1. Soil analysis

Composite soil samples collected from each block prior to the commencement of the experiment were analysed for organic carbon content, total N, available P_2O_5 and exchangeable K_2O. The pH and cation exchange capacity of the soils of the respective blocks were found out. The physical properties of the soil were also determined. After the harvest of the crop, soil samples from individual plots were collected and analysed for residual organic carbon content, available P_2O_5 and exchangeable K_2O.

2. Plant analysis

NPK content of rice plants at harvest were estimated and the uptakes were calculated by multiplying the same with DMP at harvest and expressed as kg ha^{-1}.

3. Protein content of grains

The nitrogen content of whole grains was estimated by the Microkjeldahl digestion method and the protein content was computed by multiplying the nitrogen content by a factor 6.25 (Simpson et al., 1965).

4. Fertilizer response and per cent recovery of applied fertilizer

The fertilizer response and per cent recovery of applied fertilizer were calculated in trial I using the following formula.

$$\text{Fertilizer response} = \frac{(yt - yo)}{At}$$

Yt = Yield of treatment

Yo = Yield of control

At = Fertilizer applied in treatment

(Patnaik et al., 1971).

$$\%\ \text{Nutrient recovery} = \frac{\text{Nutrient uptake from fertilizer treatment} - \text{Nutrient uptake from control}}{\text{Nutrient applied}} \times 100$$

(Bartholomew and Clark, 1965).

The fertilizer response and response per 100 kg of azolla applied were calculated in trial III.

6.3.4 Statistical analysis

The data relating to experiments were analysed by applying the analysis of variance technique as suggested by Panse and Sukhatme (1978) for split plot design and factorial RBD. Correlation coefficients between plant growth, yield attributes, grain and straw yields were worked out and presented for the first trial. The path analysis was also carried out to study the direct and indirect effects of different factors on grain yield in trial I.

Economics

Gross and net income per ha, benefit-cost ratio, and rupee invested per kg of nutrient applied were calculated based on the cost of cultivation, cost of input and produce for three spacings and their combination with fertilizer levels in first trial and for all combinations in third trial.

Results and Discussion

RESULTS AND DISCUSSION

Rice culture in Kerala is a low profit agri business. Continued efforts are made to cultivate rice more out of the gratification and cultural satisfaction than out of profits. But tailoring the variety with low cost inputs like Azolla with minimal fertilizer inputs and high plant population is likely to optimise the yields as against a minimal inputs. This was attempted in a series of experiments where each aspect was tested out. Results of such a series of trials are presented in this chapter.

The main effects of the treatments alone are discussed wherever there is no significant and consistent interactions.

Trial I. Performance of IR-42 under different levels of fertilizer and spacing

1. Growth and growth characters

1.1 Plant height

During both the years in virippu season tallest plants were produced with full dose of fertilizer (Table 3 a, b, c & d and 4 a, b, c & d). It was similar to 75 per cent of the recommended dose of fertilizer from panicle initiation

Table 3 a. Height of plants (cm) at panicle initiation stage as influenced by fertilizer and spacing levels. _Virippu_ 1982

Fertilizer levels (% of reccommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	67.1	59.3	58.9	57.3	59.0	57.9	59.9	C.D.(0.05) for F	4.28 (1.96)
F_1 - 50	68.0	66.8	65.7	63.2	67.4	64.4	65.9	C.D.(0.05) for S	2.45 (1.23)
F_2 - 75	70.9	68.4	66.0	64.2	67.7	65.8	67.1	C.D.(0.05) for S within same F levels	NS (2.46)
F_3 - 100	73.5	69.8	72.7	70.9	70.9	69.4	71.2		
Mean	69.9	66.1	65.8	63.9	66.2	64.4		C.D.(0.05) for S between F levels	NS (3.21)

Table 3 b. _Virippu_ 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	73.4	76.5	75.3	71.3	77.8	75.2	74.9	C.D.(0.05) for F	1.32 (0.60)
F_1 - 50	81.8	81.7	79.9	75.5	78.9	78.8	79.4	C.D.(0.05) for S	1.75 (0.87)
F_2 - 75	82.1	81.9	82.6	78.3	83.8	83.0	81.9	C.D.(0.05) for S within same F levels	NS (1.75)
F_3 - 100	83.1	82.2	84.6	82.8	83.5	84.8	83.1		
Mean	80.1	80.6	80.6	77.0	81.0	80.4		C.D.(0.05) for S between F levels	NS (2.03)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S Em +/-

Table 3 c. Height of plants (cm) at panicle initiation stages as influenced by fertilizer and spacing levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm) S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean
F_0 - 0	42.1	41.9	41.0	39.4	41.5	38.4	40.7
F_1 - 50	46.9	48.3	46.6	43.7	43.4	44.2	45.5
F_2 - 75	50.7	49.7	46.6	45.5	47.2	47.9	47.9
F_3 - 100	50.9	48.6	48.8	46.3	47.4	47.3	48.2
Mean	47.7	47.1	45.8	43.7	44.9	44.4	

C.D.(0.05) for F	2.39	(1.09)
C.D.(0.05) for S	1.71	(0.85)
C.D.(0.05) for S within the same F levels	NS	(1.36)
C.D.(0.05) for S between F levels	NS	(1.56)

Table 3 d. <u>Mundakan</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm) S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean
F_0 - 0	54.4	53.3	52.6	49.3	52.8	50.7	52.2
F_1 - 50	60.6	58.0	55.6	55.4	58.7	56.6	57.5
F_2 - 75	61.9	58.9	57.9	58.1	59.0	57.5	58.9
F_3 - 100	63.9	62.6	58.6	57.6	61.9	57.4	60.3
Mean	60.2	58.2	56.2	55.1	58.1	55.5	

C.D.(0.05) for F	2.23	(1.028)
C.D.(0.05) for S	2.12	(1.066)
C.D.(0.05) for S within the same F levels	NS	(2.133)
C.D.(0.05) for S between F levels	NS	(2.235)

* 90: 45: 45 kg. NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 4 a. Height of plants (cm) at harvest as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	83.0	78.4	78.0	75.0	80.2	77.4	78.7	C.D.(0.05) for F	2.06 (0.94)
F_1 - 50	88.8	84.2	84.8	80.8	85.6	83.0	84.5	C.D.(0.05) for S	1.99 (1.00)
F_2 - 75	90.8	88.8	82.2	82.8	83.8	84.2	85.4	C.D.(0.05) for S within same F levels	NS (2.00)
F_3 - 100	91.0	88.4	88.2	85.6	86.4	84.6	87.4		
Mean	88.4	85.0	83.3	81.1	84.0	82.3		C.D.(0.05) for S between F levels	NS (2.38)

Table 4 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	95.0	94.2	95.0	92.8	97.0	94.2	94.7	C.D.(0.05) for F	3.02 (1.39)
F_1 - 50	100.8	100.8	97.6	96.8	96.8	96.0	98.1	C.D.(0.05) for S	2.02 (1.01)
F_2 - 75	102.4	101.2	100.4	94.6	102.6	99.4	100.1	C.D.(0.05) for S within same F levels	NS (2.03)
F_3 - 100	105.2	100.8	101.6	95.8	103.2	102.2	101.5		
Mean	100.9	99.3	98.7	95.0	99.9	98.0		C.D.(0.05) for S between F levels	NS (2.44)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 4 c. Height of plants (cm) at harvest as influenced by fertilizer and spacing levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	62.8	61.4	58.4	56.8	57.6	56.0	58.8
F_1 - 50	65.8	65.4	65.4	60.8	62.0	62.0	63.6
F_2 - 75	68.4	68.0	65.2	62.6	65.6	64.2	65.7
F_3 - 100	69.8	68.8	67.2	63.8	65.6	64.0	66.5
Mean	66.7	65.9	64.1	61.0	62.7	61.6	

C.D.(0.05) for F 2.02 (0.92)
C.D.(0.05) for S 1.36 (0.68)
C.D.(0.05) for S within same F levels NS (1.07)
C.D.(0.05) for S between F levels NS (1.35)

Table 4 d. <u>Mundakan</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	66.0	64.6	61.8	58.4	62.8	61.2	62.5
F_1 - 50	73.4	75.0	66.8	64.0	67.0	65.0	68.5
F_2 - 75	73.0	70.4	68.2	66.6	68.8	66.4	68.9
F_3 - 100	75.4	73.2	68.0	65.6	72.2	66.8	70.2
Mean	72.0	70.8	66.2	63.7	67.7	64.9	

C.D.(0.05) for F 2.57 (1.18)
C.D.(0.05) for S 2.16 (1.08)
C.D.(0.05) for S within same F levels NS (2.17)
C.D.(0.05) for S between F levels NS (2.37)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

to harvest. The same trend was observed in the mundakan season as well. Full dose and 75 per cent of the recommended dose of fertilizer were comparable in most of the stages.

Irrespective of year and season, the widest spacing (20 x 20 cm) with a plant population of 25 hills m^{-2} has produced the tallest plants while the closest spacing (20 x 5 cm) with a plant population of 100 hills m^{-2} recorded the shortest plants in most of the stages. Combination effect was not significant at all stages of growth.

Inspite of the fact that the variety (IR 42) tried is a dwarf indica, the tremendous impact of N in increasing the plant height is quite evident from the results. The physiological role of N in increasing the height is well known. Several investigators have reported increased plant height with higher levels of fertilizer N (Balasubramanian, 1980; Sathasivan, 1980; Padalia, 1981).

The widest spacing with the lowest plant population of 25 hills m^{-2} produced the tallest plants. Lack of competition for the nutrients, space and light in this treatmen may be attributed as the reasons for the increase in the height of plants. In contrast the shortest plants are obtained in the closest spacing (20 x 5 cm) with the highest plant population of 100 hills m^{-2} throughout the crop growth stages in both the years. This is in conformity with the findings of Ramiah (1973); Vachhani et al. (1961), Mishra (1976) and Ibrahim et al.(1980).

1.2 Tiller number m^{-2}

Full dose of fertilizer has resulted in the highest number of tillers followed by 75 and 50 per cent of the recommended dose in both seasons of two years (Table 5 a, b, c & d and 6 a, b, c & d).

At panicle initiation and at harvest stages, the spacing, 20 x 5 cm with a plant population of 100 hills m^{-2} has recorded the maximum tiller number in virippu and mundakan seasons of both years. The lowest number of tillers was observed in the spacing 20 x 20 cm with a plant population of 25 hills m^{-2}, in three out of four seasons at the same stage. The spacing 20 x 15 cm with a plant population of 33 hills m^{-2} was recording invariably the next higher number than the former spacing m^{-2}.

Full dose of fertilizer in combination with a spacing of 20 x 5 cm having a plant population of 100 hills m^{-2} recorded significantly more number of tillers than many other combinations throughout the growth stages in both years.

Table 5 a. Number of tillers m^{-2} at panicle initiation stage as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	313	314	343	474	352	413	368	C.D.(0.05) for F	19.5 (8.9)
F_1 - 50	381	410	399	548	446	449	439	C.D.(0.05) for S	18.2 (9.1)
F_2 - 75	425	458	449	592	466	459	475	C.D.(0.05) for S within same F levels	36.5 (18.3)
F_3 - 100	461	478	473	624	557	606	533		
Mean	395	415	416	560	455	482		C.D.(0.05) for S between F levels	44.5 (21.9)

Table 5 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	343	345	423	550	373	442	413	C.D.(0.05) for F	18.7 (8.6)
F_1 - 50	436	449	441	632	440	485	481	C.D.(0.05) for S	22.4 (11.2)
F_2 - 75	469	475	472	677	443	523	518	C.D.(0.05) for S within same F levels	44.8 (22.5)
F_3 - 100	419	484	496	861	537	618	569		
Mean	417	438	458	680	448	517		C.D.(0.05) for S between F levels	53.0 (26.3)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 5 c. Number of tillers m^{-2} at panicle initiation stage as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	538	563	580	760	524	538	584	C.D.(0.05) for F	23.3 (10.6)
F_1 - 50	595	577	568	720	652	697	635	C.D.(0.05) for S	26.1 (13.1)
F_2 - 75	642	611	677	684	721	702	673	C.D.(0.05) for S within same F levels	52.1 (26.1)
F_3 - 100	656	671	713	864	722	747	729		
Mean	608	605	635	757	655	671		C.D.(0.05) for S between F levels	62.1 (30.7)

Table 5 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	427	432	487	650	465	529	498	C.D.(0.05) for F	22.9 (10.5)
F_1 - 50	496	500	628	752	548	583	585	C.D.(0.05) for S	25.2 (12.6)
F_2 - 75	536	551	643	774	619	687	635	C.D.(0.05) for S within same F levels	NS (25.3)
F_3 - 100	545	597	686	868	628	670	666		
Mean	501	520	611	761	565	617		C.D.(0.05) for S between F levels	NS (29.7)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 6 a. Number of tillers m^{-2} at harvest as influenced by fertilizer and spacing levels. <u>Virippu</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	271	300	289	390	307	322	313	C.D.(0.05) for F	17.5 (8.0)
F_1 - 50	340	271	340	444	354	382	355	C.D.(0.05) for S	16.4 (8.2)
F_2 - 75	339	356	332	436	347	379	365	C.D.(0.05) for S within same F levels	32.9 (16.5)
F_3 - 100	318	369	405	524	361	369	391		
Mean	317	324	342	449	342	363		C.D.(0.05) for S between F levels	40.1 (20.2)

Table 6 b. <u>Virippu</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	237	280	370	480	330	389	348	C.D.(0.05) for F	16.5 (7.6)
F_1 - 50	265	312	385	600	352	435	392	C.D.(0.05) for S	28.3 (14.2)
F_2 - 75	310	347	405	620	369	468	420	C.D.(0.05) for S within same F levels	56.6 (28.5)
F_3 - 100	325	351	420	830	382	495	467		
Mean	284	323	395	633	358	447		C.D.(0.05) for S between F levels	65.2 (32.5)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 6 c. Number of tillers m^{-2} at harvest as influenced by fertiliser and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean		
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0	- 0	390	422	450	540	405	475	447	C.D.(0.05) for F	33.6 (15.4)
F_1	- 50	455	455	470	620	475	534	502	C.D.(0.05) for S	37.5 (18.8)
F_2	- 75	460	508	540	620	519	581	538	C.D.(0.05) for S within same F levels	NS (37.7)
F_3	- 100	485	528	590	660	554	581	566		
Mean		448	479	513	610	488	543		C.D.(0.05) for S between F levels	NS (44.2)

Table 6 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean		
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0	- 0	355	393	410	560	374	482	429	C.D.(0.05) for F	29.5 (13.4)
F_1	- 50	380	403	522	640	462	516	487	C.D.(0.05) for S	22.4 (11.2)
F_2	- 75	430	430	530	670	492	521	512	C.D.(0.05) for S within same F levels	44.8 (22.5)
F_3	- 100	460	475	545	740	473	514	535		
Mean		406	425	502	653	450	508		C.D.(0.05) for S between F levels	56.8 (27.7)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Irrespective of the number of plants per unit area, the highest dose of fertilizer has resulted in highest tiller production. The influence of N in increasing the vegetative tiller production is well known. The increased tiller number observed at panicle initiation stage was maintained upto the harvest stage though there was a reduction in the number of tiller at harvest. Many of the previous workers on rice crop like Kumura (1956), and Kalyanikutty et al. (1969) have stressed the importance of N in increasing the tiller production.

The spacing likewise had a drastic impact on the tiller production. The closer spacings with more plant population recorded the maximum tiller number while the wider two spacings (20 x 20 and 20 x 15 cm) with a plant population of 25 and 33 hills m^{-2} produced the minimum number of tillers. Mishra (1976) could also observe the same trend. Many of the tillers associated with closer spacing and higher plant population did not contribute to the yield and is made clear from the yield data recorded elsewhere. Eventhough a plant facing least competition for light, nutrient and space produces lesser number of tillers m^{-2} under wider spacing compared to closer spacings, the contribution towards yield will be much more under former situations. IR 42 being a high tillering variety, increasing the plant population per unit area by closer spacing beyond a particular level is detrimental inspite of the fact that higher number of vegetative tillers can be produced.

1.3 Leaf area index (LAI)

LAI is found to be significantly influenced by the fertilizer application (Table 7 a, b, c & d). The highest LAI was observed in treatments which received full dose of fertilizer and the lowest in zero level. It could also be observed that the full dose of fertilizer recorded maximum LAI in most of the stages and seasons and at certain stages it was similar with 75 per cent of the recommended fertilizer dose especially at harvest. The LAI was highest with the spacing, 20 x 5 cm in most of the stages particularly at harvest. It was lowest during panicle initiation and harvest stages in the widest spacing 20 x 20 cm in all the seasons. No definite trend could be observed in the behaviour of other spacings. The combination effect was not significant at most of the stages.

The above results reveal that the fertilizer dose has influenced the LAI tremendously. The treatments receiving the maximum fertilizer has obviously recorded higher LAI at all stages. The lowest LAI was noticed at zero level.

Table 7 a. Leaf area index (LAI) at panicle initiation stages as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)								
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean		
F_0 - 0	4.27	4.62	4.63	5.30	4.24	4.36	4.57	C.D.(0.05) for F	0.83 (0.38)
F_1 - 50	5.30	5.12	5.22	4.67	5.68	5.12	5.18	C.D.(0.05) for S	NS (0.34)
F_2 - 75	5.06	5.33	5.37	5.39	5.43	4.64	5.20	C.D.(0.05) for S within same F levels	NS (0.69)
F_3 - 100	7.21	7.41	6.47	7.17	6.91	6.35	6.92		
Mean	5.46	5.62	5.42	5.63	5.57	5.12		C.D.(0.05) for S between F levels	NS (0.76)

Table 7 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)								
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	4.80	5.20	4.55	6.20	4.61	5.05	5.07	C.D.(0.05) for F	0.615 (0.282)
F_1 - 50	5.16	5.19	5.36	6.62	4.94	6.50	5.63	C.D.(0.05) for S	0.697 (0.351)
F_2 - 75	4.70	5.86	6.08	6.40	5.23	6.10	5.73	C.D.(0.05) for S within same F levels	NS (0.701)
F_3 - 100	6.37	5.92	6.23	7.38	6.30	6.05	6.37		
Mean	5.26	5.54	5.55	6.65	5.27	5.93		C.D.(0.05) for S between F levels	NS (0.698)

* 80: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 7 c. Leaf area index (LAI) at panicle initiation stage as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	3.24	4.24	3.90	3.66	3.72	4.33	3.85
F_1 -- 50	4.37	5.80	5.75	6.20	5.27	5.99	5.56
F_2 - 75	5.77	6.13	6.87	7.90	7.17	7.35	6.86
F_3 - 100	5.59	6.77	6.38	7.75	7.89	6.46	6.81
Mean	4.74	5.73	5.73	6.38	6.01	6.03	

C.D. (0.05) for F	1.M4 (0.525)
C.D. (0.05) for S	0.978 (0.492)
C.D. (0.05) for S within same F levels	NS (0.984)
C.D. (0.05) for S between F levels	NS (1.067)

Table 7 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	3.51	4.72	4.40	3.57	3.87	3.99	4.01
F_1 - 50	4.84	6.16	5.92	4.75	5.68	5.17	5.42
F_2 - 75	5.54	6.00	6.24	6.47	6.10	5.89	6.04
F_3 - 100	5.61	6.41	6.05	6.28	6.43	6.13	6.15
Mean	4.88	5.82	5.65	5.27	5.52	5.30	

C.D. (0.05) for F	0.387 (0.177)
C.D. (0.05) for S	0.426 (0.214)
C.D. (0.05) for S within same F levels	NS (0.428)
C.D. (0.05) for S between F levels	NS (0.430)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Full dose of fertilizer supplies 90: 45: 45 kg NPK ha^{-1} to the plant, the major contribution being from N. The influence of this nutrient in increasing the vegetative growth is well known. Leaf area is determined by the height of the plants and the number of tillers (Yoshida, 1981). It may be seen from the data on these two characters (Table 3 a, b, c & d, 4 a, b, c & d, 5 a, b, c & d and 6 a, b, c & d) that the full dose of fertilizer has given the highest values for both characters.

The spacing did influence LAI. The closer spacing recorded higher LAI values. Lower LAI was observed in the wider spacing. To what extent the low LAI is responsible in effecting the grain production will be discussed separately. The number of tillers was more in the closer spacings (20 x 5 cm) while plants were taller in wider spacings (20 x 20 cm). This shows that among the two characters influencing LAI, tiller number is having much greater influence rather than height. Being a spacing experiment the number of plants per unit area is altered drastically with the result that there was much variation in tiller production per unit area. Probably this has masked the influence of height in recording more LAI in treatments which has more tiller production. Murata et al.(1957)

Mehrothra et al. (1975) and Mishra (1976) also recorded higher LAI values with closer spacing.

1.4 Dry matter production at harvest (DMP)

Full dose of fertilizer has given highest DMP followed by 75 and 50 per cent of the fertilizer in all the four seasons (Table 8 a, b, c & d).

The spacing, 20 x 15 cm recorded the highest DMP in three out of four seasons and in the remaining season it was comparable with the spacing 15 x 15 cm. The widest spacing (20 x 20 cm) was occupying the second position. The lowest DMP was noticed in the closest spacing (20 x 5 cm). (Fig.2).

Full dose of fertilizer in combination with the spacing (20 x 15 cm) having a plant population of 33 hills m^{-2} recorded the highest DMP in three out of four seasons.

The above results reveal that fertilizer treatments have influenced steadily the DMP. Maximum impact was by the highest amount of the fertilizers given. It may be recalled that in the case of tiller production also, full dose of fertilizer registered the highest tiller number at panicle initiation stage as well as at harvest.

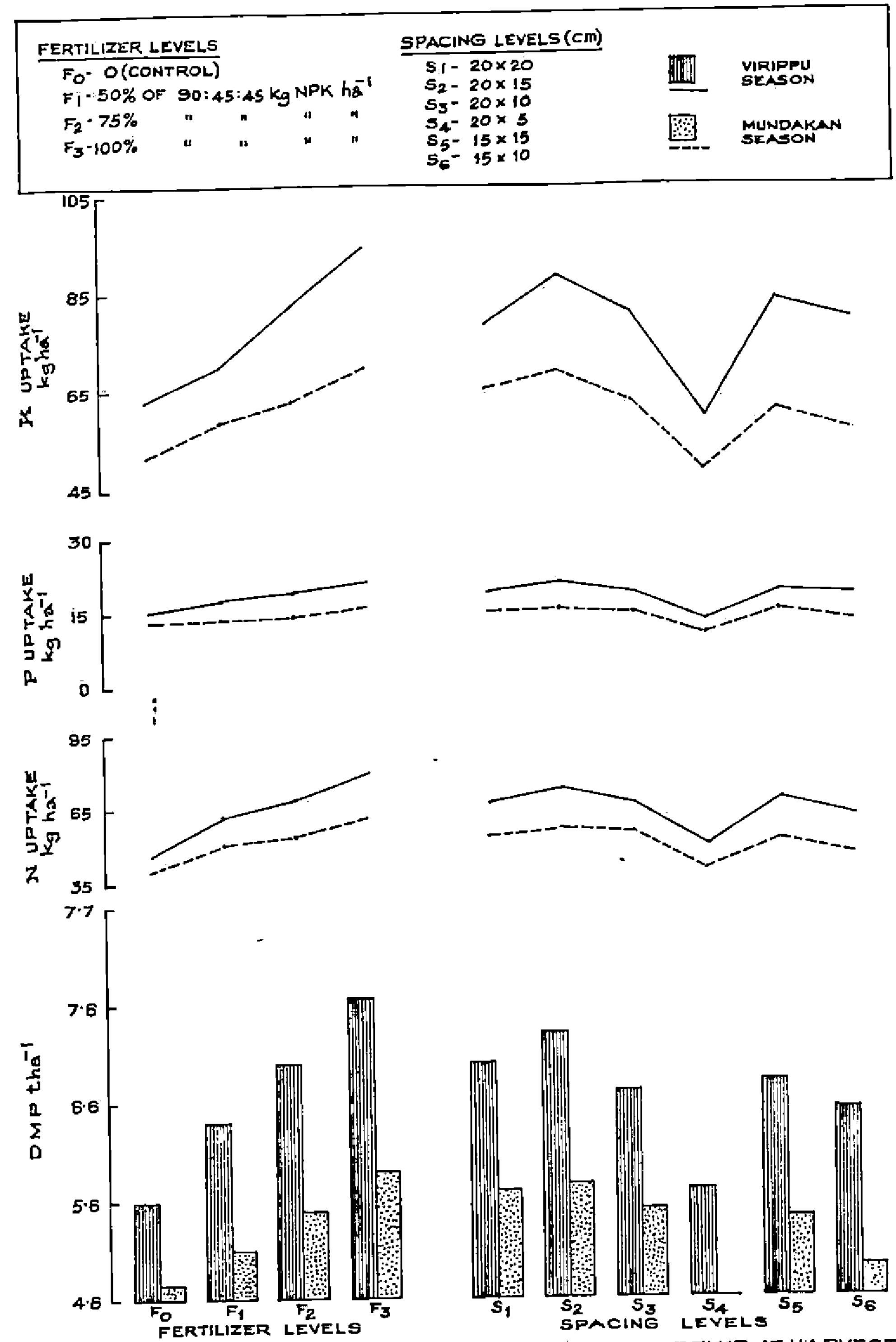


FIG. 2. DRY MATTER PRODUCTION AND NUTRIENT UPTAKE AT HARVEST AS INFLUENCED BY FERTILIZER & SPACING LEVELS.

Table 8 a. Dry matter production of rice (kg ha^{-1}) at harvest as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean	
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)		
F_0 - 0	5947	6147	5495	4655	5786	5302	5555	C.D.(0.05) for F 226.3 (73.4)
F_1 - 50	7043	7157	5999	4876	6699	6056	6305	C.D.(0.05) for S 222.4 (79.0)
F_2 - 75	7369	7373	6846	5186	7242	6808	6804	C.D.(0.05) for S within same F levels 444.8 (223.6)
F_3 - 100	7765	7925	7681	5640	7868	7642	7425	
Mean	7031	7151	6505	5089	6899	6460		C.D.(0.05) for S between F levels 469.9 (231.7)

Table 8 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean	
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)		
F_0 - 0	5333	5708	6157	5633	5875	5389	5686	C.D.(0.05) for F 297.6 (96.5)
F_1 - 50	6493	7551	6642	6263	6295	6092	6556	C.D.(0.05) for S 316.5 (112.5)
F_2 - 75	7677	7782	7338	6479	7117	6996	7232	C.D.(0.05) for S within same F levels 632.9 (318.2)
F_3 -100	8377	9023	7545	6929	7873	7999	7958	
Mean	6970	7516	6921	6331	6790	6619		C.D.(0.05) for S between F levels 652.3 (322.3)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 8 c. Dry matter production of rice (kg ha^{-1}) at harvest as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	5275	5172	5198	4183	5101	4513	4907	C.D.(0.05) for F	236.6 (76.7)
F_1 - 50	6032	5900	5963	4753	5252	4960	5477	C.D.(0.05) for S	168.5 (59.8)
F_2 - 75	6315	6748	6210	4986	5413	4997	5778	C.D.(0.05) for S within same F levels	336.9(169.3)
F_3 - 100	6728	7031	6804	5437	5991	5306	6216		
Mean	6088	6213	6044	4840	5439	4944		C.D.(0.05) for S between F levels	406.3(198.0)

Table 8 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	4759	4509	4765	4075	4897	4598	4601	C.D.(0.05) for F	138.8(45.0)
F_1 - 50	5259	5233	4906	4240	5074	4736	4908	C.D.(0.05) for S	210.3(74.7)
F_2 - 75	5609	5657	5102	4445	5529	4990	5222	C.D.(0.05) for S within same F levels	420.6(211.4)
F_3 - 100	5805	6069	5418	4856	6101	5369	5603		
Mean	5358	5367	5048	4404	5401	4924		C.D.(0.05) for S between F levels	399.6(199.1)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Higher DMP was found to be associated with the wider spacings (20 x 15 and 20 x 20 cm). But these treatments were having lower number of tillers m^{-2} as against higher value in the closest spacing (20 x 5 cm). The pliability of the straw might have been increased as the number of tillers m^{-2} is increased. Cellulose conversion from starch or carbohydrates might not have been fully utilized since the competition between plants was much severe under very close spacing.

The yield attributes like number of filled grains per panicle and 1000 grain weight and grain and straw yields were also more under wider spacings (20 x 15 and 20 x 20 cm). But panicle number and sterility percentage were more in the closer spacings (20 x 5 and 15 x 10 cm). It is evident from the above results that grain yield is decided more by DMP and yield attributes like filled grains per panicle and 1000 grain weight.

It may be argued that inspite of the higher tiller production in the closer spacings of 20 x 5 and 15 x 10 cm at active tillering and panicle initiation stages (Table 5 a, b, c & d), these treatments have recorded a very low DMP. It is interesting to note that straw yield is also very low in these treatments. This is partly because of the fact that the excess tiller production has resulted in lesser accumulation of carbohydrate in each tiller thereby the carbohydrate available for synthesis of cellulose, hemicelluloses and lignin might be lesser in these treatments. It may be particularly mentioned in this connection that straw in these treatments are more pliable or less stiff probably because of the above factors.

The combination of full dose of fertilizer along with a spacing 20 x 15 cm is also significant probably because this combination has recorded highest values for grain yield as well as yield attributes.

2. Yield and yield attributes

2.1. Panicle number m^{-2}

Full dose of fertilizer gave the highest number of panicles m^{-2} (Table 9 a, b, c & d and Fig.3).

More number of panicles were found to be associated with closer spacings (20 x 5 and 15 x 10 cm) having plant populations of 100 and 66 hills m^{-2}.

The combination of full dose of fertilizer with a spacing 20 x 5 cm having a plant population of 100 hills m^{-2}

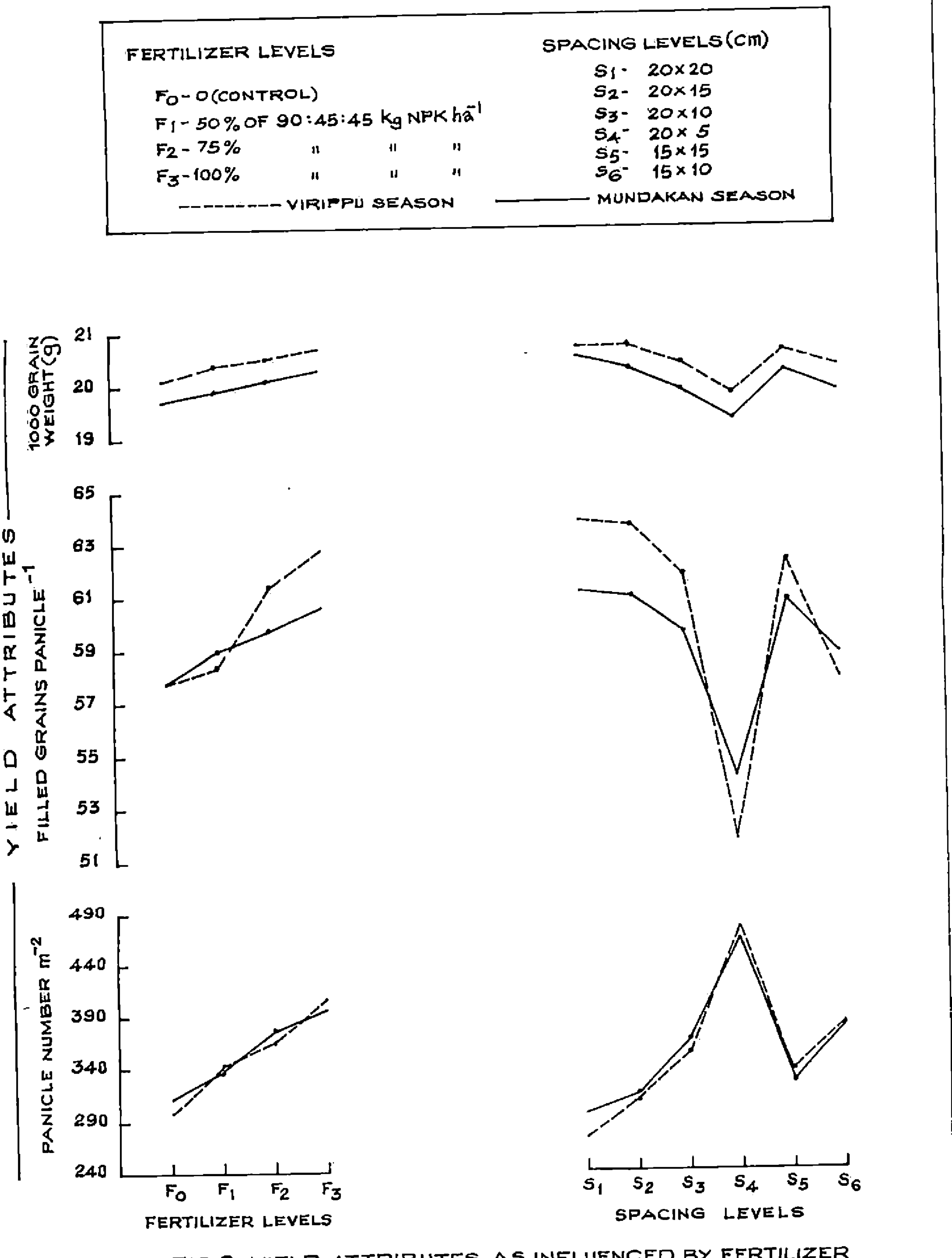


FIG 3. YIELD ATTRIBUTES AS INFLUENCED BY FERTILIZER AND SPACING LEVELS (VIRIPPU AND MUNDAKAN SEASONS 1982 & 1983)

Table 9 a. Number of panicles m^{-2} as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	231	259	277	386	279	270	284
F_1 - 50	297	251	311	400	333	354	324
F_2 - 75	294	330	318	416	330	354	340
F_3 - 100	305	350	367	478	341	351	365
Mean	282	298	318	420	321	332	

C.D.(0.05) for F 14.1 (6.4)
C.D.(0.05) for S 13.5 (6.8)
C.D.(0.05) for S within same F levels 27.1 (13.6)
C.D.(0.05) for S between F levels 32.9 (16.2)

Table 9 b. Virippu (cm)

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	234	273	360	460	317	363	335
F_1 - 50	235	316	380	530	326	416	367
F_2 - 75	295	323	390	540	365	455	395
F_3 - 100	300	344	410	860	376	475	451
Mean	266	314	385	523	346	427	

C.D.(0.05) for F 18.2 (8.3)
C.D.(0.05) for S 24.1(12.1)
C.D.(0.05) for S within same F levels 48.3 (24.3)
C.D.(0.05) for S between F levels 46.5 (23.4)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 9 c. Number of panicles m^{-2} as influenced by fertilizer and spacing levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	250	263	310	380	256	318	296	C.D.(0.05) for F	16.2 (7.4)
F_1 - 50	268	276	316	390	309	338	316	C.D.(0.05) for S	25.4(12.7)
F_2 - 75	303	349	366	400	327	398	357	C.D.(0.05) for S within same F levels	NS (25.5)
F_3 - 100	325	355	409	470	384	419	394		
Mean	287	311	350	410	319	368		C.D.(0.05) for S between F levels	NS (29.3)

Table 9 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	250	298	290	480	293	339	329	C.D.(0.05) for F	18.2 (8.3)
F_1 - 50	280	299	377	505	326	399	364	C.D.(0.05) for S	19.8 (9.9)
F_2 - 75	320	326	420	550	353	416	398	C.D.(0.05) for S within same F levels	39.6(19.9)
F_3 - 100	355	346	430	530	348	405	402		
Mean	308	317	379	516	330	390		C.D.(0.05) for S between F levels	47.4(23.4)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

recorded more panicles m^{-2} in both seasons of the first year.

Nutrients, being the most crucial factor in deciding panicle production, the highest level of fertiliser produced the maximum number of panicles m^{-2} followed by the lower levels in the descending order. The role of individual nutrients such as N, P and K in determining the panicle production is very well established by many of the previous investigators (Yoshida, 1981).

The plant population through spacing has definitely influenced the number of panicles m^{-2}. This is seen to be directly related to the number of tillers produced. The closer spacings with plant populations of 100 and 66 hills m^{-2} recorded the highest value throughout the crop growth stage and naturally they have also produced more panicles m^{-2}. The lower number of panicles m^{-2} associated with the wider spacings having a plant population of 33 and 25 hills m^{-2} might be due to the lower number of tillers m^{-2}. It is paradoxial to observe that the treatments which produced lower number of panicles - have recorded more grain yield as well as DMP.

The combination, full dose of fertilizer with spacing (20 x 5 cm) having a plant population of 100 hills m^{-2} produced more number of panicles in both seasons of the first year.

2 .2 Number of filled grains per panicle

Full dose of fertilizer recorded the highest number of filled grains per panicle followed by the respective lower levels in the descending order (Table 10 a, b, c & d and Fig. 3).

The wider spacings of 20 x 15 and 20 x 20 cm produced more number of filled grains per panicle in most of the seasons. The lowest number was always associated with the closest spacing having a plant population of 100 hills m^{-2}. The combination effect was not significant.

Number of filled grains per panicle is an important yield attributing factor. The applied nutrients have gained to establish their role in influencing this yield attribute. Full dose of fertilizer produced the highest number of filled grains per panicle while the zero level resulted in the lowest number. The ratio between N, P and K being the same in all the doses, the highest level has given

Table 10 a. Number of filled grains panicle^{-1} as influenced by fertilizer and spacing levels. <u>Virippu</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	61.2	60.9	60.0	51.7	61.0	59.9	59.2	C.D.(0.05) for F	0.86 (0.28)
F_1 - 50	61.1	61.1	60.0	52.5	60.9	59.4	59.2	C.D.(0.05) for S	0.86 (0.31)
F_2 - 75	61.6	61.6	60.0	51.8	60.8	60.2	59.3	C.D.(0.05) for S within same F levels	1.73 (0.86)
F_3 - 100	62.3	61.8	60.4	56.8	61.4	59.5	60.4		
Mean	61.6	61.4	60.1	53.2	61.0	59.8		C.D.(0.05) for S between F levels	1.81 (0.89)

Table 10 b. <u>Virippu</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	58.9	58.5	57.4	57.8	61.2	54.8	56.4	C.D.(0.05) for F	4.11 (1.88)
F_1 - 50	74.4	55.5	46.7	44.8	61.1	63.7	57.7	C.D.(0.05) for S	6.87 (3.45)
F_2 - 75	63.3	63.0	63.9	58.2	64.1	68.4	63.5	C.D.(0.05) for S within same F levels	NS (6.91)
F_3 - 100	65.7	71.1	53.9	48.9	79.5	71.1	65.1		
Mean	65.6	62.0	55.5	50.0	66.5	64.5		C.D.(0.05) for S between F levels	NS (7.89)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 10 c. Number of filled grains panicle^{-1} as influenced by fertilizer and spacing levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean
F_0 - 0	60.5	59.7	59.8	49.5	60.7	59.7	58.3
F_1 - 50	60.9	61.0	60.1	52.6	60.6	59.6	59.1
F_2 - 75	61.5	61.4	59.8	53.9	61.4	59.7	59.6
F_3 - 100	62.1	62.1	60.4	55.2	61.9	59.6	60.2
Mean	61.3	61.1	60.0	52.8	61.2	59.7	59.7

C.D.(0.05) for F	1.22 (0.39)
C.D.(0.05) for S	1.144(0.40)
C.D.(0.05) for S within same F levels	2.288(1.15)
C.D.(0.05) for S between F levels	2.462(1.21)

Table 10 d. <u>Mundakan</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean
F_0 - 0	59.8	59.9	58.3	51.8	58.8	54.6	57.2
F_1 - 50	60.7	60.6	58.8	54.6	60.2	59.0	58.9
F_2 - 75	60.9	60.6	59.4	55.7	60.6	57.9	59.2
F_3 - 100	61.7	61.6	59.3	59.3	60.9	58.8	60.3
Mean	60.8	60.7	58.9	55.3	60.1	57.6	

C.D.(0.05) for F	2.15 (0.69)
C.D.(0.05) for S	1.40 (0.49)
C.D.(0.05) for S within same F levels	2.80 (1.41)
C.D.(0.05) for S between F levels	3.53 (1.71)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

the highest value. Hence it is also difficult to disentangle the effects of the individual nutrients.

The wider spacings of 20 x 15, 20 x 20 and 15 x 15 cm have given more number of filled grains per panicle. This is because of the fact that more nutrients are available for each plant when compared to the treatments having higher plant population. This is substantiated by the uptake data (Tables 19 a, b, c & d, 20 a, b, c & d and 21 a, b, c & d) which show more uptake of N, P and K in the wider spacings with lower plant population. The lowest number of filled grains associated with the closest spacing (20 x 5 cm) which accommodated 100 hills m^{-2} might be due to the severe competition for nutrients, light and space faced by each plant.

It may be further noted that panicle number was more in closer spacings with higher plant population even though the number of filled grains per panicle was lowest. The inputs available for each panicle will be lesser in the treatments with more number of panicles, as a result of severe competition, thus reducing the number of filled grains per panicle. Incidently it may be seen that the uptake of N, P and K is lowest in the above treatment. So under situations of severe competition it is the number of filled grains that matters rather than the number of panicles per unit area. This is in spite of the fact that the variety being a panicle number type as in the case with all other dwarf indicas, there is an optimum number of panicles beyond which the number of filled grains as well as yield decreases.

2. 3 Thousand grain weight

Fertilizer levels showed significant effect only in *virippu* seasons (Table 11 a, b, c & d). Full dose of fertilizer gave the highest and zero level - the lowest value of 1000 grain weight (Fig. 3). The zero level was significantly inferior to the higher levels. Same trend was observed in *mundakan* seasons also, though not significant.

The spacing levels showed significance only in both seasons of the first year. Irrespective of the seasons, higher values of 1000 grain weight were associated with the wider spacings of 20 x 20 and 20 x 15 cm and the lowest values with the closest spacing of 20 x 5 cm. The combination effect showed no significant effect on 1000 grain weight.

1000 grain weight is more or less a genetic character (Matsushima, 1970) fluctuating within certain limits as influenced by the environmental conditions. Here, two sets of environments have influenced. First one being fertilizer or nutrients and second one competition.

Table 11 a. Thousand grain weight (g) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	20.15	20.03	19.93	18.85	20.20	20.01	19.86	C.D.(0.05) for F	0.364 (0.118)
F_1 - 50	20.38	21.05	20.11	19.30	20.38	19.85	20.18	C.D.(0.05) for S	0.332 (0.118)
F_2 - 75	20.92	20.99	20.07	19.30	20.64	19.95	20.31	C.D.(0.05) for S within same F levels	NS (0.334)
F_3 - 100	21.36	21.17	20.45	19.45	21.00	20.08	20.59		
Mean	20.70	20.80	20.13	19.23	20.55	19.97		C.D.(0.05) for S between F levels	NS (0.355)

Table 11 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	20.28	20.22	20.06	20.24	20.75	20.44	20.33	C.D.(0.05) for F	NS (0.226)
F_1 - 50	21.06	20.24	21.22	20.50	20.42	20.18	20.60	C.D.(0.05) for S	NS (0.249)
F_2 - 75	20.78	20.96	20.66	20.50	20.36	21.06	20.72	C.D.(0.05) for S within same F levels	NS (0.499)
F_3 - 100	20.78	21.32	20.66	20.52	21.16	20.88	20.89		
Mean	20.73	20.66	20.65	20.44	20.67	20.64		C.D.(0.05) for S between F levels	NS (0.591)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 11 c. Thousand grain weight (g) as influenced by fertilizer and spacing levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean		
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0	0	19.54	19.70	19.34	19.22	20.10	19.18	19.51	C.D.(0.05) for F	NS (0.267)
F_1	50	20.36	19.14	19.60	19.70	19.94	19.48	19.70	C.D.(0.05) for S	0.483(0.243)
F_2	75	20.80	19.90	20.30	19.60	18.88	19.84	19.89	C.D.(0.05) for S within same F levels	NS (0.486)
F_3	100	20.30	20.44	19.78	19.80	19.80	20.00	20.02		
Mean		20.25	19.80	19.76	19.58	19.68	19.63		C.D.(0.05) for S between F levels	NS (0.591)

Table 11 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean		
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0	0	19.65	20.22	20.22	19.02	20.61	19.93	19.94	C.D.(0.05) for F	0.270 (0.087)
F_1	50	20.89	20.78	20.09	18.91	20.78	19.67	20.19	C.D.(0.05) for S	0.274 (0.097)
F_2	75	20.82	20.93	20.12	19.22	20.79	20.30	20.36	C.D.(0.05) for S within same F levels	0.548 (0.275)
F_3	100	21.28	21.32	20.14	19.52	20.93	20.14	20.56		
Mean		20.66	20.81	20.14	19.16	20.78	20.01		C.D.(0.05) for S between F levels	0.573 (0.282)

*90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

The increase in fertilizer levels showed a definite trend to increase the 1000 grain weight and vice versa.

At full dose of fertilizer, N, P and K contents of plants were higher. Higher photosynthetic activity due to the better supply of the above nutrients is evident from the result because these nutrients are involved in the photosynthesis and respiration directly or indirectly (Yoshida, 1981). N is a constituent of proteins which in turn are constituents of protoplasm, chloroplasts and enzymes. P as inorganic phosphate, an energy rich phosphate compound and a coenzyme, is directly involved in photosynthesis. On the other hand, K is involved in the process of opening and closing of stomata that control CO_2 diffusion into green tissues and also activates the enzymes like starch synthetase (Fujino, 1967; Fisher and Hsiaco, 1968; Nitsos and Evans, 1969).

The wider spacings with lower plant population produced higher values of 1000 grain weight while closer spacings with the higher plant population recorded lower values. The wider spacing of 20 x 20 cm accommodated 25 hills m^{-2} as against 100 hills m^{-2} in the closest spacing of 20 x 5 cm i.e. about four times increase in the plant population than the former. Higher the plant population per unit area, lower the quantity of nutrients available for each plant. Competition for light is another factor which would have affected 1000 grain weight. The severe overcrowding in the closest spacing with highest plant population would have led to maximum mutual shading with the result that there would have been lesser net photosynthesis with a consequent reduction in the translocation of the assimilates to the individual grain. The values ranged from 19.16 to 20.44 g with the closest spacing having a plant population of 100 hills m^{-2} whereas it varied from 19.80 to 20.81 g in the wider spacings with plant population of 25 and 33 hills m^{-2}. Even though the variation seems to be numerically lesser, spacing has a profound influence on the grain weight as a whole and this has probably contributed to higher grain yield in wider spacings with lower plant population as against lower grain yield in the closer spacings with higher plant population. Nair and George (1973) also recorded lower 1000 grain weight with closer spacings under Kerala conditions.

2.4. Sterility percentage

Fertilizer levels had no significant effect on the sterility percentage (Table 12 a, b, c & d) while spacing levels showed significant influence on the above character.

Table 12 a. Sterility percentage as influenced by fertilizer and spacing levels.
Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	19.8	18.8	19.0	27.8	17.9	19.7	20.5	C.D.(0.05) for F	NS (1.19)
F_1 - 50	18.7	17.5	19.1	24.3	19.9	19.0	19.8	C.D.(0.05) for S	2.36(1.18)
F_2 - 75	17.3	19.0	19.2	28.0	19.0	19.4	20.3	C.D.(0.05) for S within same F levels	NS (2.37)
F_3 - 100	16.6	17.0	19.6	31.1	19.3	19.3	20.5		
Mean	18.1	18.1	19.2	27.8	19.0	19.3		C.D.(0.05) for S between F levels	NS (2.85)

Table 12 b. Virippu 1983

Fertilizer levels (3 of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x15)			
F_0 - 0	17.2	16.9	28.4	24.4	22.2	22.0	21.9	C.D.(0.05) for F	NS (1.95)
F_1 - 50	19.7	21.8	19.9	23.4	16.7	23.3	20.8	C.D.(0.05) for S	3.06(1.53)
F_2 - 75	21.1	23.0	19.9	23.5	23.9	18.7	21.7	C.D.(0.05) for S within same F levels	6.13(3.07)
F_3 - 100	20.0	16.2	15.5	21.1	22.5	26.0	20.2		
Mean	19.5	19.5	20.9	23.1	21.3	22.5		C.D.(0.05) for S between F.levels	7.85 (3.83)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 12 c. Sterility percentage as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	18.9	19.0	18.9	25.9	19.4	21.0	
F_1 - 50	18.7	16.8	20.7	28.0	17.4	19.1	
F_2 - 75	17.3	17.7	18.8	26.5	18.4	18.3	
F_3 - 100	17.5	17.6	18.2	26.2	18.5	19.0	
Mean	18.1	17.8	19.2	26.7	18.4	19.4	

C.D.(0.05) for F NS (1.16)
C.D.(0.05) for S 1.81(0.91)
C.D.(0.05) for S within same F levels NS (1.32)
C.D.(0.05) for S between F levels NS (2.13)

Table 12 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	16.9	15.3	15.5	24.3	15.2	17.2	17.4
F_1 - 50	13.7	16.0	16.9	24.4	15.6	16.0	17.1
F_2 - 75	17.6	17.2	16.1	22.2	13.3	16.1	17.1
F_3 - 100	15.1	16.1	17.8	22.3	15.1	18.4	17.5
Mean	15.8	16.2	16.6	23.3	14.8	16.9	

C.D.(0.05) for F NS (0.38)
C.D.(0.05) for S 2.12(1.06)
C.D.(0.05) for S within same F levels NS (2.73)
C.D.(0.05) for S between F levels NS (2.50)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

The closest spacing (20 x 5 cm) with a plant population of 100 hills m^{-2} recorded the highest sterility in all the seasons. The combination of fertilizer with spacing did not show significant effect on the sterility percentage in most of the seasons.

In this experiment a very high fertilizer level was not tried so as to create a drastic change in the above proportion of sterility percentage. This might be the reason for the lack of significant difference in sterility percentage due to the fertilizer levels (Kalyanikutty et al., 1968; Eunus and Sadeque, 1974).

Higher sterility percentage associated with the highest plant population of 100 hills m^{-2} (Spacing 20 x 5 cm) is attributed to the severe competition between the plants because of the overcrowding and mutual shading. Higher the competition, higher will be the chaff. Within the range of the fertilizer applied the wider spacing (20 x 20 cm) which accommodated a plant population of 25 hills m^{-2} recorded the lowest sterility. If the population is further increased through closer spacings, competition sets in because nutrient availability is limited. This is applicable to every level of fertilizer tried. Mutual shading consequent to close spacing is one of the reasons attributed to high spikelet sterility in the tropics (IRRI, 1965).

3. Grain yield

Grain yield was significantly influenced by fertilizer as well as spacing levels (Table 13 a, b, c & d). Full dose of fertilizer produced highest grain yield which was significantly superior to other fertilizer levels. The wider spacings 20 x 15 cm (33 hills m^{-2}) and 20 x 20 cm (25 hills m^{-2}) recorded higher grain yield while lower values were recorded by closer spacings 20 x 5 cm (100 hills m^{-2}) and 15 x 10 cm (66 hills m^{-2}).

Full dose of fertilizer combined with a spacing 20 x 15 cm produced the highest grain yield. As is evident from the figure (Fig.4) at other levels of fertilizer also, a spacing 20 x 15 cm gave more grain yield.

From the results, a progressive increase in grain yield was observed with each higher level of fertilizer. During virippu the increase in grain yield from zero level to full dose of fertilizer was higher than that in mundakan in both the years.

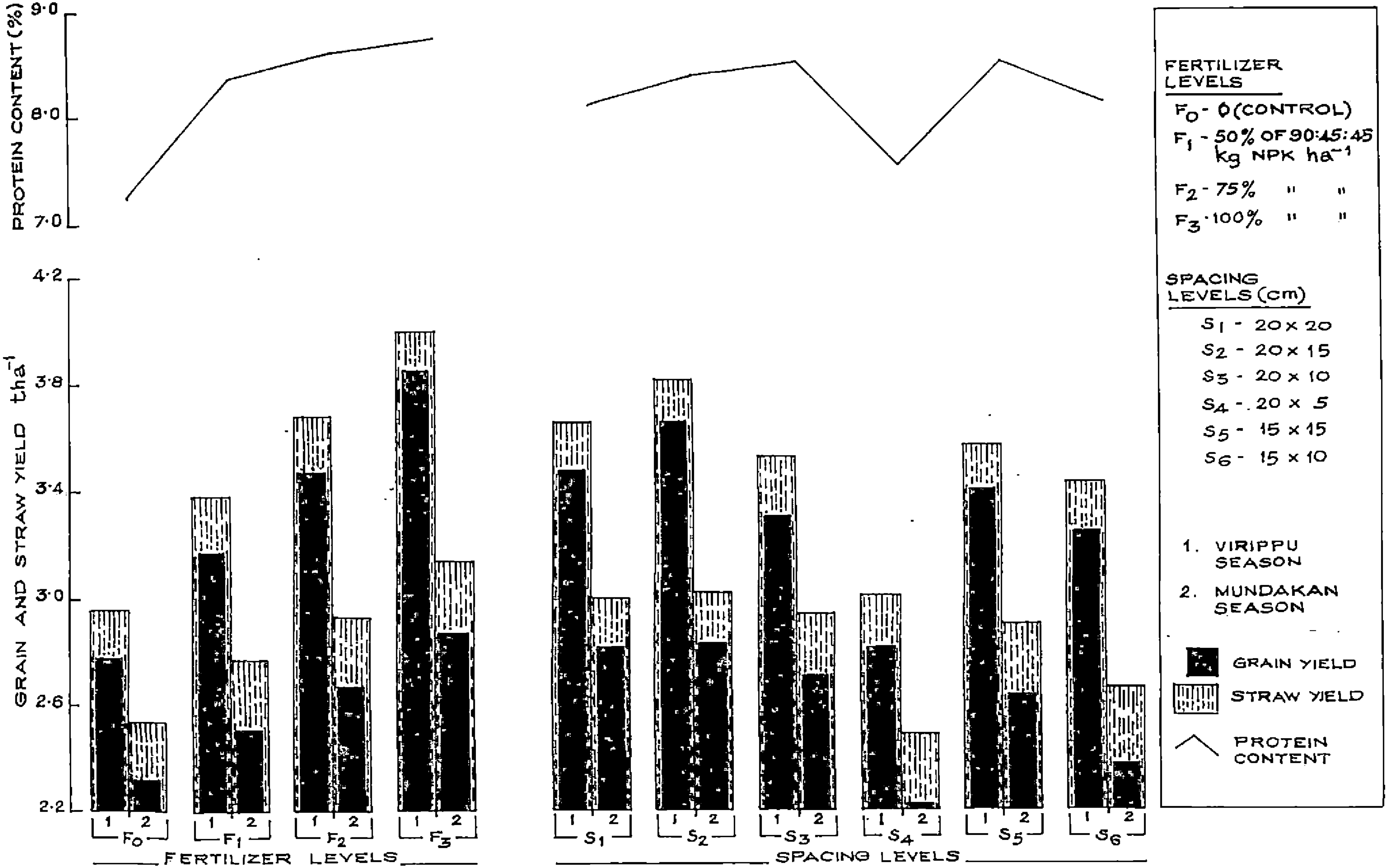


FIG.4 YIELD OF GRAIN, STRAW AND PROTEN CONTENT AS INFLUENCED BY FERTILIZER AND SPACING LEVELS IN VIRIPPU AND MUNDAKAN SEASONS (1982 & 1983).

Table 13 a. Grain yield (kg ha^{-1}) as influenced by fertilizer and spacing levels.
Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2974	3054	2611	2186	2824	2548	2700	C.D.(0.05) for F	128.4 (58.9)
F_1 - 50	3433	3480	2942	2355	3320	2984	3086	C.D.(0.05) for S	125.9 (63.2)
F_2 - 75	3575	3626	3299	2489	3562	3361	3318	C.D.(0.05) for S within same F levels	251.7(126.5)
F_3 - 100	3907	3970	3812	3693	3938	3839	3693		
Mean	3472	3533	3166	2431	3411	3183		C.D.(0.05) for S between F levels	305.0(150.3)

Table 13 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2660	2864	3077	2843	2949	2708	2850	C.D.(0.05) for F	168.4 (77.3)
F_1 - 50	3230	3773	3313	3081	3165	2998	3260	C.D.(0.05) for S	166.2 (83.5)
F_2 - 75	3884	3937	3680	3257	3517	3519	3632	C.D.(0.05) for S within same F levels	332.4(167.1)
F_3 - 100	4209	4528	3790	3549	3951	4022	4008		
Mean	3495	3776	3465	3183	3396	3312		C.D.(0.05) for S between F levels	402.5(198.4)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 13 c. Grain yield (kg ha^{-1}) as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2627	2534	2592	1956	2414	2095	2370	C.D.(0.05) for F	115.2 (52.8)
F_1 - 50	2880	2833	2909	2170	2493	2316	2600	C.D.(0.05) for S	92.5 (46.4)
F_2 - 75	3066	3248	2967	2268	2598	2346	2749	C.D.(0.05) for S within same F levels	184.9 (92.9)
F_3 - 100	3261	3426	3263	2602	2843	2486	2980		
Mean	2958	3010	2933	2249	2587	2311		C.D.(0.05) for S between F levels	231.9 (113.5)

Table 13 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2371	2194	2329	2024	2403	2275	2266	C.D.(0.05) for F	68.9 (31.6)
F_1 - 50	2604	2621	2439	2107	2527	2332	2438	C.D.(0.05) for S	111.3 (55.9)
F_2 - 75	2785	2830	2565	2221	2732	2474	2601	C.D.(0.05) for S within same F levels	NS (111.9)
F_3 - 100	2896	2983	2669	2416	3029	2677	2778		
Mean	2664	2657	2501	2192	2673	2439		C.D.(0.05) for S between F levels	NS (128.1)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

But, the increase in yield from zero to 100 per cent of the fertilizer dose was only 35.3 and 24.3 per cent in _virippu_ and _mundakan_, respectively. It is also interesting to note that the yield increase from zero to 50 per cent of the recommended dose of fertilizer was as low as 14.5 per cent in _virippu_ and 8.5 per cent in _mundakan_. Further, the reasonably good yield at zero level of fertilization ranging from 2.78 to 2.85 t ha^{-1} in _virippu_ versus 2.27 to 2.37 t ha^{-1} in _mundakan_, highlights the adaptability of the variety under low levels of fertility. This is very important from the farmer's point of view because they cannot afford higher doses of fertilizer application mostly due to economic constraints. Under such situations, a variety like IR 42 which can give reasonably good yield without fertilizer application is most welcome. Further, the linear response as observed from the response curve it is seen that this variety can respond to even higher fertilizer doses beyond 90: 45: 45 kg NPK ha^{-1} which was tried in the present investigation (Fig.5). Thus it is evident that IR 42 has the built in ability to tolerate low fertility and at the same time respond to higher

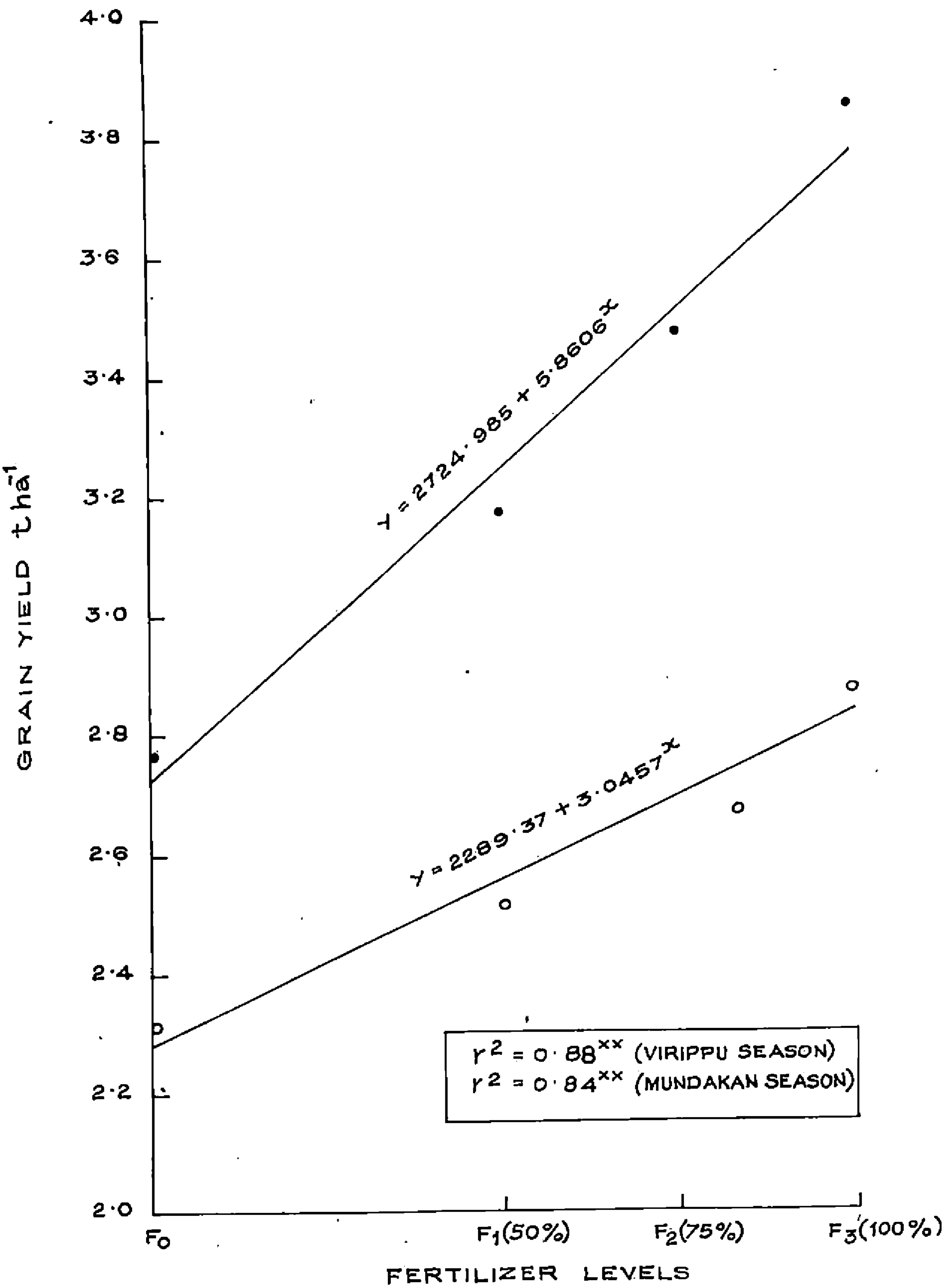


FIG. 5. RELATIONSHIP BETWEEN FERTILIZER LEVELS AND GRAIN YIELD DURING VIRIPPU SEASON (•) AND MUNDAKAN SEASON (o) [TRIAL No. I].

doses of fertilization. Such varieties are always a boon for our poor farmers particularly under the present situation of severe energy crisis.

The data presented on nutrient uptake (Table 19 a, b, c, d; 20 a, b, c, d and 21 a, b, c and d and Fig.2) show that the uptake of nutrients was more during virippu compared to mundakan and the same could be effectively utilized by the crop. As the growth duration was more in virippu, the better vegetative growth together with the well developed root system might have enabled the crop to absorb all nutrients more effectively. According to Yoshida (1981) growth of the root is closely related to the growth of the whole plant. Further, the newer indica types with high tillering rates and good reproductive development can absorb and assimilate large amounts of N throughout the period of growth. Other major nutrients like P and K are also needed throughout the growth period (Atanasiu and Samy, 1983). Hence any reduction in growth duration as in mundakan will definitely reduce the uptake of nutrients and thereby yield. A perusal of the details regarding transplanting and harvest (Table 2) of the experiments in virippu and mundakan shows a difference in duration of about 13 days in the first year and 17 days in the second year between virippu and mundakan.

The fertilizer response as well as the percentage recovery of applied nutrients were also more in _virippu_ compared to _mundakan_ (Table 15). Further, a higher fertilizer response and recovery percentage of applied fertilizer were observed at a lower level i.e., 50 per cent of the fertilizer dose in _virippu_ while in _mundakan_ fertilizer response was more with 75 per cent and recovery percentage of applied fertilizer was highest with 100 per cent of the recommended dose of fertilizer. This again is attributed to the difference in growth duration of the crop during _virippu_ and _mundakan_. Probably, with the help of the well developed root system and better vegetative growth, the crop was able to absorb more from the applied quantity of 50 per cent fertilizer dose in _virippu_ whereas in _mundakan_ due to the reduction in growth duration, the comparatively lesser vegetative growth and poor root system the plants were not able to utilize the applied nutrients efficiently. Hence a major part of the nutrients would have been wasted in _mundakan_. Therefore, more nutrients were needed to give higher values of fertilizer response and percentage recovery of applied fertilizer in _mundakan_.

Yield attributes such as panicle number m^{-2}, number of filled grains per panicle and 1000 grain weight were also more in the treatments receiving full dose and less with zero level of fertilizer (Fig.3). These yield attributes might have influenced the grain yield.

The wider spacings with 25 and 33 hills m^{-2} were at an advantage with respect to grain yield. As the plant population was increased from 25 to 100 hills m^{-2} the yield was reduced from 3.5 to 2.8 t ha^{-1} in <u>virippu</u> and from 2.8 to 2.2 t ha^{-1} in <u>mundakan</u>.

From the response surface (Fig.6 a) it is seen that when the plant population was increased from 25 to 100 hills m^{-2}, the grain yield tended to increase upto 33 hills m^{-2} and thereafter declined, at all the fertilizer levels. But at full dose of fertilizer, 25 hills m^{-2} gave yields comparable with that of 33 hills m^{-2} indicating that the former is sufficient at the highest level of fertility. Since the yield response was more with 33 hills m^{-2}, at lower fertilizer levels, it is advantageous to adopt the above plant population as fertilizer is costlier than seedlings.

The number of filled grains $panicle^{-1}$ and 1000 grain weight were highest and the sterility percentage lowest in the wider spacings. However, the panicle number m^{-2} was lower in these treatments. Still higher grain yield was obtained because of the influence of the other yield attributes mentioned. Further, total DMP at harvest was also more in

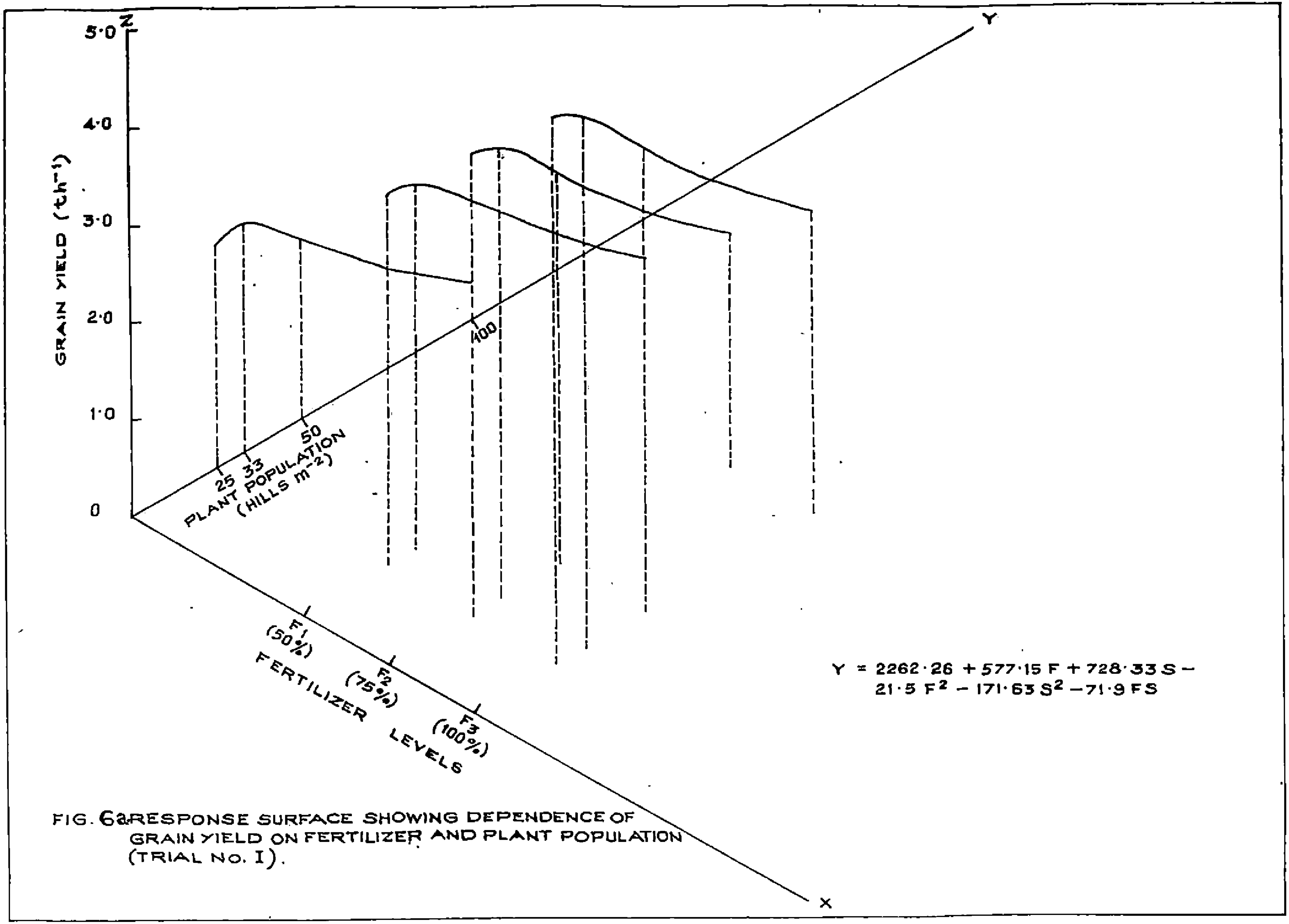


FIG. 6a RESPONSE SURFACE SHOWING DEPENDENCE OF GRAIN YIELD ON FERTILIZER AND PLANT POPULATION (TRIAL No. I).

the wider spacings (33 and 25 hills m^{-2}). The correlation coefficients between yield attributes and yield (Table 14 a) show that a positive correlation exists between filled grains per panicle and grain yield (r 0.76* in virippu and 0.85* in mundakan). Thousand grain weight also possesses a positive correlation with grain yield (r = 0.91** in virippu and 0.93** in mundakan). Whereas panicle number and sterility percentage had negative correlations with the grain yield. Thus it is clear that grain yield was influenced more by filled grains per panicle and thousand grain weight rather than by panicle number. This might be because of several reasons. The optimum LAI in wider spacings without any mutual shading resulted in more net assimilates in the plants. Further, more surface area was available for individual plant resulting in more uptake of nutrients which were better utilized for increasing the number of filled grains per panicle as well as thousand grain weight. It is further noted that a negative correlation exists between panicle number and grain number per panicle. The number of grains per sq.m. determines the yield capacity of a given variety (Yoshida et al., 1972). Thus it is clear that by increasing panicle number alone by way of increasing plant population through spacing cannot increase grain yield because of the negative correlation between panicle number and grains per panicle.

Table 14a. Correlation coefficients between grain yield and yield attributes

Factor	r value	
	Virippu	Mundakan
1. Panicles m^{-2}	-0.217	-0.392
2. Filled grains $panicle^{-1}$	0.761*	0.857**
3. Thousand grain weight	0.914**	0.931**
4. Sterility percentage	-0.309	-0.581

* Significant at 5 per cent level

** Significant at 1 per cent level

The correlation coefficients between plant population with yield attributes and grain yield (Table 14 b) reveal a negative correlation with filled grains, thousand grain weight and grain yield while a positive correlation with panicle number and sterility percentage. DMP also showed a negative correlation with plant population. The influence of plant population, DMP and yield attributes on grain yield was also brought out by path analysis (Fig.6 b). From the data (Table 14 c) it is seen that thousand grain weight has got maximum positive direct effect followed by DMP on grain yield. Thousand grain weight has a negative indirect effect through number of panicles. Even though the direct effect of panicle number is positive, its indirect effect through thousand grain weight and DMP made the total effect negative. The direct effect of plant population is negative while its indirect effect through panicle number is positive. Thus, the thousand grain weight has got the maximum positive direct effect followed by DMP on grain yield as evidenced from the path analysis.

Table 14 b. Correlation coefficients between plant population, yield attributes, and grain yield.

Factor	r value	
	Virippu	Mundakan
1. Panicles m^{-2}	0.884**	0.909**
2. Filled grains panicle^{-1}	-0.753**	-0.928**
3. Thousand grain weight	-0.399	-0.412
4. Sterility percentage	0.830**	0.818**
5. DMP	-0.857**	-0.827**
6. Grain yield	-0.790**	-0.820**

** Significant at 1 per cent level

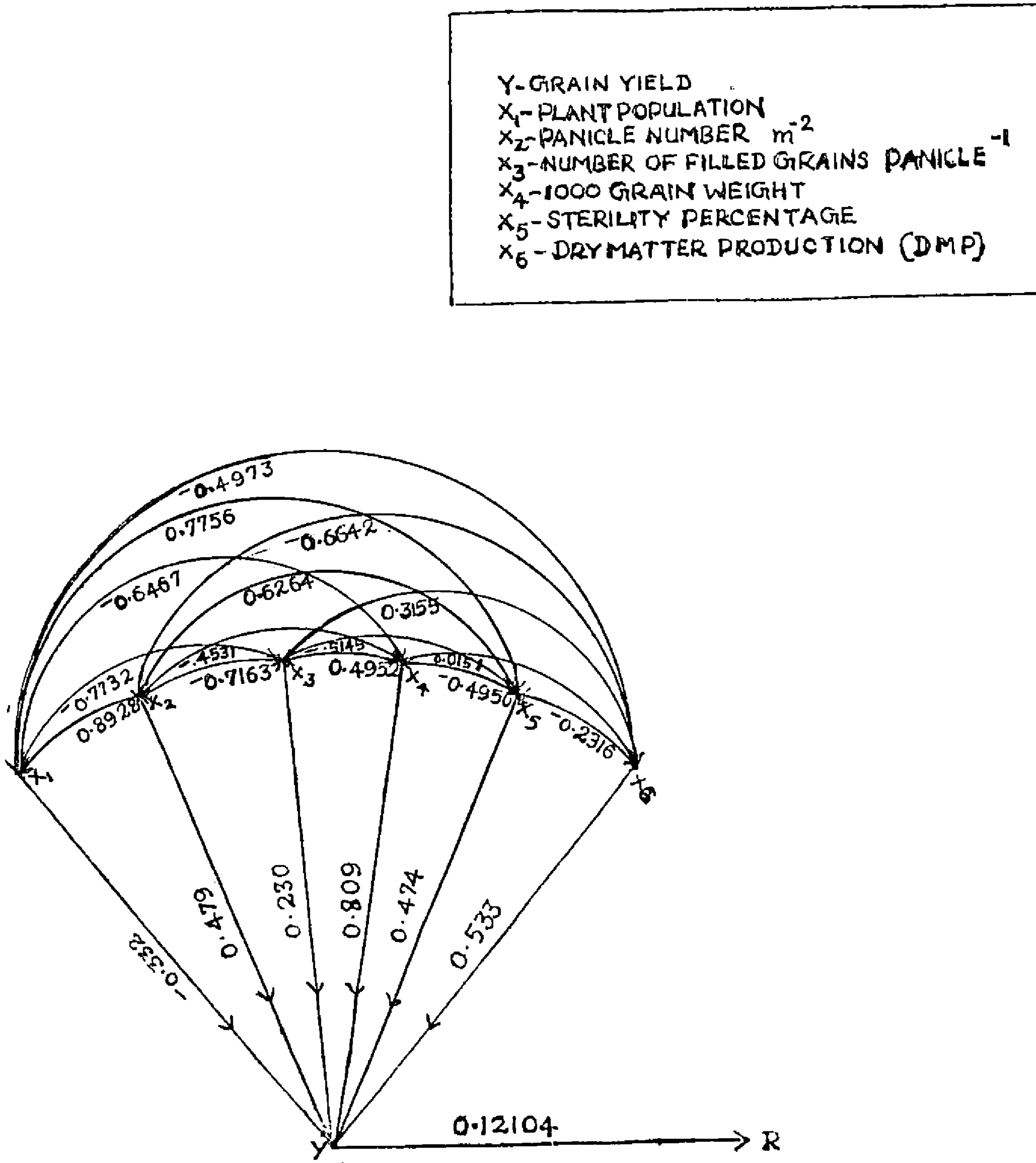


FIG. 6 b. PATH DIAGRAM – DIRECT AND INDIRECT EFFECTS OF CAUSATIVE FACTORS ON GRAIN YIELD

Table 14 c. Direct and indirect effects of causative factors on grain yield

X	1	2	3	4	5	6	Correlation with y
1	-0.332	0.427	-0.178	-0.523	0.367	-0.265	-0.504
2	-0.296	0.479	-0.165	-0.367	0.297	-0.354	-0.407
3	0.257	-0.343	0.230	0.401	-0.244	0.168	0.469
4	0.215	-0.217	0.114	0.809	-0.234	0.008	0.695
5	-0.258	0.300	-0.118	-0.401	0.474	-0.123	-0.127
6	0.165	-0.318	0.073	0.012	-0.110	0.533	0.356

y - Grain yield
x_1 - Plant population (hills m^{-2})
x_2 - Number of panicles m^{-2}
x_3 - Filled grains panicle^{-1}
x_4 - 1000 grain weight
x_5 - Sterility percentage
x_6 - Drymatter production (DMP)

The above results reveal that the plant population beyond 33 hills m^{-2} (spacing 20 x 15 cm) is not desirable in this variety. When the plant population was increased beyond that, the competition factor must have played a dominant role in influencing the yield. The wider spacings enjoy fairly satisfactory conditions of light and space for development and nutrient supply whereas in closer spacings, mutual shading on account of overcrowding occurs. Consequently the net photosynthesis will be reduced. Further, the nutrient supply will also be limited under closer spacings.

Thus it is evident that this variety, even though classified as a high tillering one, requires a comparatively wider spacing of 20 x 15 cm (33 hills m^{-2}) below which is not desirable for grain production. For such varieties closer spacing is definitely harmful because of the reasons already explained.

From the economics (Table 15) it could be seen that highest net return of Rs. 6913 and Rs.3890 were obtained

Table 15. Economics of trial I (Spacing trial)

Treatments			Grain yield kg ha^{-1}	Straw yield kg ha^{-1}	Gross return Rs.ha^{-1}	Cost of cultivation Rs.ha^{-1}	Net return Rs.ha^{-1}	Benefit cost ratio	Fertilizer response	% recovery of applied fertilizer	Return rupee-1 invested on fertilizer
1.	F_0 S_1	V	2817	2939	8573	4903	3670	1.75	-	-	-
		M	2499	2631	7629		2726	1.56	-	-	-
2.	F_0 S_2	V	2959	3090	9008	5150	3858	1.75	-	-	-
		M	2354	2563	7271		2121	1.41	-	-	-
3.	F_0 S_3	V	2844	3102	8790	5273	3517	1.67	-	-	-
		M	2461	2631	7553		2280	1.43	-	-	-
4.	F_1 S_1	V	3331	3575	10237	5301	4936	1.93	5.71	35.61	11.43
		M	2742	3019	8503		3202	1.60	2.70	23.87	7.76
5.	F_1 S_2	V	3657	3848	11162	5598	5564	1.99	7.75	52.33	12.76
		M	2727	2957	8411		2813	1.50	4.14	29.55	6.95
6.	F_1 S_3	V	3128	3323	9579	5721	3858	1.67	3.15	22.54	7.16
		M	2674	2872	8220		2499	1.44	2.36	22.42	4.28
7.	F_2 S_1	V	3730	3947	11407	5550	5857	2.06	6.76	38.02	9.71
		M	2925	3159	9009		3459	1.62	3.15	22.39	6.15
8.	F_2 S_2	V	3782	3952	11516	5797	5719	1.90	6.09	40.15	9.51
		M	3039	3291	9369		3572	1.62	5.07	33.44	6.32
9.	F_2 S_3	V	3490	3749	10729	5920	4809	1.81	4.79	32.04	6.17
		M	2766	3006	8538		2618	1.44	2.26	23.97	2.90
10.	F_3 S_1	V	4056	4181	12293	5774	6519	2.13	6.88	42.39	8.48
		M	3079	3316	9474		3700	1.64	3.22	25.76	5.25
11.	F_3 S_2	V	4249	4396	12894	5981	6913	2.16	7.11	50.70	8.93
		M	3205	3461	9871		3890	1.65	4.72	36.57	5.46
12.	F_3 S_3	V	3801	3968	11570	6104	5466	1.90	5.32	34.89	5.28
		M	2966	3271	9203		3099	1.51	2.81	23.76	2.56

V - VIRIPPU M- MUNDAKAN

Fertilizer levels

F_0 = 0
F_1 = 50% of 90: 45: 45 kg NPK ha^{-1}
F_2 = 75% of 90: 45: 45 kg NPK ha^{-1}
F_3 = 100% of 90: 45: 45 kg NPK ha^{-1}

Spacing levels

S_1 = 20 x 20 cm
S_2 = 20 x 15 cm
S_3 = 20 x 10 cm

Price of rice = Rs. [illegible]
Price of straw = Re. [illegible]

from the combination of full dose of fertilizer with a plant population of 33 hills m^{-2} (spacing 20 x 15 cm) in virippu and mundakan, respectively. The benefit cost ratio was also high (2.15 in virippu and 1.65 in mundakan) in the above combination. The return per rupee invested on fertilizer was more (Rs. 12.76) at 50 per cent of the fertilizer dose with a plant population of 33 hills m^{-2} in virippu as against 25 hills m^{-2} in mundakan. This might be because during virippu the higher plant population together with longer duration of the crop gave more grain and straw yields and thereby higher gross return eventually increasing the return per rupee in vested on fertilizer. But during mundakan the yield itself was low. Further the additional cost involved in planting @ 33 hills as against 25 hills m^{-2} has resulted in reducing the return per rupee invested on fertilizer in the combination of 50 per cent of the fertilizer dose with 33 hills m^{-2} than with 25 hills m^{-2}.

4. Straw yield

Full dose of fertilizer gave the highest straw yield in all the four seasons (Table 16 a, b, c & d). There was proportionate increase in straw yield corresponding to an increase in fertiliser levels in all seasons except during

Table 16 a. Straw yield (kg ha^{-1}) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	3095	3219	2997	2564	3080	2863	2970	C.D.(0.05) for F	111.2 (51.0)
F_1 - 50	3755	3824	3180	2626	3516	3196	3349	C.D.(0.05) for S	113.9 (57.2)
F_2 - 75	3944	3899	3689	2803	3828	3587	3625	C.D.(0.05) for S within same F levels	227.8(114.5)
F_3 - 100	4018	4113	4026	3062	4091	3990	3884		
Mean	3703	3764	3473	2753	3629	3409		C.D.(0.05) for S between F levels	274.4(135.5)

Table 16 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2782	2961	3206	2926	3047	2791	2952	C.D.(0.05) for F	143.3(65.7)
F_1 - 50	3396	3873	3466	3208	3259	3219	3404	C.D.(0.05) for S	156.8 (78.8)
F_2 - 75	3950	4004	3809	3355	3686	3721	3754	C.D.(0.05) for S within same F levels	383.7(157.7)
F_3 - 100	4344	4679	3910	3563	4103	4182	4130		
Mean	3618	3879	3598	3263	3524	3478		C.D.(0.05) for S between F levels	374.6(185.2)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 16 c. Straw yield (kg ha^{-1}) as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2756	2744	2713	2313	2792	2511	2638	C.D.(0.05) for F	159.1 (73.0)
F_1 - 50	3275	3188	3176	2681	2866	2746	2989	C.D.(0.05) for S	108.2 (54.4)
F_2 - 75	3379	3638	3370	2820	2927	2754	3148	C.D.(0.05) for S within same F levels	216.4(108.8)
F_3 - 100	3605	3749	3681	2946	3271	2928	3363		
Mean	3254	3330	3235	2690	2964	2735		C.D.(0.05) for S between F levels	281.8(137.1)

Table 16 d. Mundakan 1983

Fertiliser levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	2507	2382	2548	2147	2594	2418	2433	C.D.(0.05) for F	83.6 (38.4)
F_1 - 50	2762	2725	2567	2220	2651	2502	2571	C.D.(0.05) for S	109.2 (54.8)
F_2 - 75	2939	2943	2642	2315	2911	2619	2728	C.D.(0.05) for S within same F levels	NS (109.8)
F_3 - 100	3027	3173	2861	2539	3198	2802	2933		
Mean	2809	2806	2655	2305	2839	2585		C.D.(0.05) for S between F levels	NS (127.2)

*90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

the *mundakan* season of the first year wherein 75 and 50 per cent of the fertilizer levels were similar.

Wider spacings 20 x 15 and 20 x 20 cm produced more straw yield and were comparable in three seasons. The closer spacings 20 x 5 and 15 x 10 cm gave less straw yield in all the seasons.

The combination effect was significant in three seasons wherein full dose of fertilizer along with a plant population of 33 hills m^{-2} recorded the highest straw yield.

As the level of fertilizer increased, the major component being N, the straw production also increased due to enhanced vegetative growth. The role of N in enhancing vegetative growth is well documented.

Higher straw production was always associated with wider spacings (20 x 15 and 20 x 20 cm) at all the levels of fertilizer tried. A perusal of the data on growth parameters such as height, tiller number, LAI and DMP reveals that height and DMP contributed more towards increased straw production. The correlation coefficients between the above characters and straw yield are given in Table 16 e. Height and DMP possess a positive correlation

Table 16 c. Correlation coefficients between straw yield, growth attributes and DMP

Factor	r value	
	Virippu	Mundakan
1. Height	0.927**	0.889**
2. Number of tillers m^{-2}	-0.157	-0.195
3. Leaf area index (LAI)	0.475	0.487
4. DMP	0.999**	0.998**

** Significant at 1 per cent level

with straw yield (Height r = 0.93** in virippu and 0.89** in mundakan; DMP r = 0.99** in both virippu and mundakan) while LAI and tiller number m^{-2} have a negative correlation with the same.

It is further noted that at zero level of fertility, the average straw production was 2.9 t ha^{-1} in virippu and 2.5 t ha^{-1} in mundakan. This of course is a reasonably good yield especially without fertilizer application. It again proves the ability of the variety to give better straw yields as well, with zero level of fertilizer. Nowadays the farmers are prefering varieties which can give reasonable straw production so as to meet the fodder requirement of their stock. The price of straw is increasing day by day because of the high demand on straw. Thus, this variety is a good choice for the Kerala farmers under the present situation where there is high demand for straw.

5. Harvest index (HI)

Fertilizer levels showed significant effect only in two seasons where the higher level of fertilizer gave more HI (Table 17 a,b, c & d). Even in seasons where the differences were not significant full dose of fertilizer recorded higher HI.

The application of more nutrients always results in better grain production upto a certain level. In most of the seasons, full dose of fertilizer has recorded the highest HI. However, there are ample references in the literature to show that beyond a certain level of fertilization the straw yield is more benefited rather than the grain yield (Lenka, 1971). Probably in this investigation such a high level of fertilization was not reached. Within the levels of fertilizer tried the response to grain yield was proportionately higher than that of straw yield leading to an increase in the enhancement of the HI upto the highest level of fertilization tried.

There was no definite trend with respect to spacing and in two seasons it was not significant also. Combinations also showed no significant effect on HI.

6. Chemical analysis

6.1 Plant analysis

6.1.1. Protein content of grain

Full dose of fertilizer recorded the highest protein content (Table 18 a) and b)) and it was superior to other levels of fertilizer in all the seasons except

Table 17 a. Harvest index (HI) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	48.8	48.7	46.5	46.1	47.8	47.1	47.5	C.D.(0.05) for F	0.53 (0.24)
F_1 - 50	47.8	47.6	48.1	47.3	48.6	48.2	47.9	C.D.(0.05) for S	0.64 (0.32)
F_2 - 75	47.5	48.2	47.2	47.0	48.2	48.3	47.7	C.D.(0.05) for S within same F levels	NS (0.65)
F_3 - 100	49.3	49.1	48.6	46.7	49.0	49.0	48.6		
Mean	48.3	48.4	47.6	46.8	48.4	48.2		C.D.(0.05) for S between F levels	NS (0.75)

Table 17 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	48.9	49.2	49.0	49.2	49.2	49.2	49.1	C.D.(0.05) for F	NS (0.16)
F_1 - 50	48.5	49.8	48.8	49.7	49.3	48.1	49.0	C.D.(0.05) for S	NS (0.25)
F_2 - 75	49.5	49.6	49.1	49.2	48.8	49.3	49.2	C.D.(0.05) for S within same F levels	NS (0.51)
F_3 - 100	49.5	49.2	49.2	49.9	49.1	49.0	49.3		
Mean	49.1	49.4	49.0	49.5	49.1	48.9		C.D.(0.05) for S between F levels	NS (0.59)

* 90: 45: 45 kg NPK ha^{-1}
Values in paranthesis are S.Em +/-

Table 17 c. Harvest index (HI) as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0	- 0	48.9	48.1	49.1	45.9	46.3	45.5	47.3
F_1	- 50	46.8	47.0	47.8	44.7	46.5	45.8	46.4
F_2	- 75	47.6	47.2	46.8	44.5	47.0	46.0	46.5
F_3	- 100	47.5	47.8	47.0	46.8	46.5	45.9	46.9
Mean		47.7	47.5	47.7	45.5	46.6	45.8	

C.D.(0.05) for F NS (0.62)
C.D.(0.05) for S 0.99 (0.50)
C.D.(0.05) for S within same F levels NS ([illegible].00)
C.D.(0.05) for S between F levels NS (1.25)

Table 17 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)		Spacing levels (cm)						Mean
		S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0	- 0	48.8	47.2	47.9	48.5	48.1	48.5	48.2
F_1	- 50	48.5	49.0	48.7	48.7	48.8	48.2	48.7
F_2	- 75	48.6	49.0	49.3	49.0	48.4	48.6	48.8
F_3	- 100	48.9	48.6	48.2	48.7	48.6	48.8	48.6
Mean		48.7	48.5	48.5	48.7	48.5	48.5	

C.D.(0.05) for F 0.46 (0.21)
C.D.(0.05) for S NS (0.23)
C.D.(0.05) for S within same F levels NS (0.45)
C.D.(0.05) for S between F levels NS (0.54)

*90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 18 a. Protein content of grain (%) as influenced by fertilizer and spacing levels. (Pooled data for Virippu 1982 and 1983)

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	7.09	7.52	7.78	6.27	7.82	6.99	7.24
F_1 - 50	8.19	8.54	8.48	8.06	8.60	8.41	8.38
F_2 - 75	8.31	9.03	8.96	8.08	8.88	8.77	8.67
F_3 - 100	9.06	8.95	9.02	8.19	8.99	8.90	8.85
Mean	8.16	8.51	8.56	7.65	8.57	8.27	

C.D.(0.05) for F	0.103 (0.033)
C.D.(0.05) for S	0.154 (0.050)
C.D.(0.05) for S within same F levels	0.309 (0.155)
C.D.(0.05) for S between F levels	0.300 (0.151)

Table 16 b. Protein content of grain (%) as influenced by fertilizer and spacing levels. (Pooled data for mundakan 1982 and 1983)

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	6.94	7.14	7.81	6.23	7.54	6.86	7.09
F_1 - 50	8.17	8.41	8.48	8.11	8.60	8.40	8.36
F_2 - 75	8.25	8.84	8.88	7.83	8.85	8.57	8.54
F_3 - 100	8.85	8.81	8.95	7.92	8.97	8.61	8.68
Mean	8.05	8.30	8.53	7.52	8.49	8.11	

C.D.(0.05) for F	0.196 (0.064)
C.D.(0.05) for S	0.165 (0.054)
C.D.(0.05) for S within same F levels	0.330 (0.165)
C.D.(0.05) for S between F levels	0.360 (0.181)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

the mundakan season of the first year where it was similar to 75 per cent of the recommended dose of fertilizer.

Spacing levels also showed significant effect on protein content of grain. The lowest protein content was recorded in the closer spacings with a plant population of 100 and 66 hills m^{-2}. Plant population of 33, 44 and 50 hills m^{-2} (spacing 20 x 15, 15 x 15 and 20 x 10 cm) recorded the highest values of protein content (Fig -4)

Combination effect was significant in all the seasons except the mundakan season of the first year. Full dose of fertilizer with a plant population of 33 hills m^{-2} and 75 per cent of the recommended dose of fertilizer along with a population of 50 hills m^{-2} were comparable in most of the seasons.

Higher values of protein content were found to be associated with higher levels of fertilizer application. The influence of higher dose of fertilization especially N, in increasing the protein content of grain is discussed elsewhere. Rao (1972), Sreedharan (1975) & Singh and Modgal (1978) also recorded higher protein content with higher rates of N application. But this increase in protein content of full dose of fertilizer level over the control was not much spectacular. The mean difference was only 1.61 and 1.59 per cent in the virippu and mundakan season, respectively. This again proves that protein content was also not much influenced by fertilization in this variety.

The decrease in protein content due to closer spacing was reported earlier by Beachell et al. (1972). Severe competition due to very close planting affects the nutrient absorption and nutrient content of the plant.

Thus it is seen that a wider spacing having a plant population of 33 hills m^{-2} is more beneficial with respect to grain yield as well as protein content.

6.1.2 Nutrient uptake of plants

The highest uptake of all the major nutrients such as N, P and K was noticed in full dose of fertilizer while the lowest value in zero level (19 a,b,c & d, 20 a,b,c & d and 21 a,b,c & d).

N, P and K uptake were highest in treatments having a plant population of 33 hills m^{-2} (spacing 20 x 15 cm) in most of the seasons.

Full dose of fertilizer along with a plant population of 33 hills m^{-2} (spacing 20 x 15 cm) recorded more uptake

Table 19 a. N uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels.
Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	51.5	52.00	47.21	34.28	50.19	41.30	46.01	C.D.(0.05) for F	2.137 (0.980)
F_1 - 50	66.22	70.30	58.75	43.95	67.20	58.62	60.85	C.D.(0.05) for S	2.689 (1.352)
F_2 - 75	71.89	74.97	70.29	47.29	74.16	69.08	67.95	C.D.(0.05) for S within same F levels	5.379 (2.705)
F_3 - 100	79.44	86.75	82.35	52.98	83.11	79.54	77.36		
Mean	67.15	71.01	64.65	44.63	68.67	62.14		C.D.(0.05) for S between F levels	5.236 (2.632)

Table 19 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	44.27	50.93	55.46	42.37	52.62	44.69	48.39	C.D.(0.05) for F	3.531 (1.620)
F_1 -- 50	62.66	74.62	62.85	55.36	60.44	57.76	62.28	C.D.(0.05) for S	3.552 (1.785)
F_2 - 75	71.80	79.85	74.75	58.25	68.96	67.11	70.12	C.D.(0.05) for S within same F levels	7.104 (3.571)
F_3 - 100	85.93	98.01	78.79	66.58	82.85	82.99	82.52		
Mean	66.16	75.85	67.96	55.64	66.22	63.14		C.D.(0.05) for S between F levels	7.310 (3.675)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em±

Table 19 c. N uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels.
<u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	42.86	42.65	46.39	30.86	44.37	34.96	40.35
F_1 - 50	57.95	57.91	57.40	42.38	52.77	48.56	52.83
F_2 - 75	61.03	67.85	63.81	43.23	54.86	49.69	56.74
F_3 - 100	68.86	77.51	71.84	50.74	60.02	53.00	63.66
Mean	57.68	61.48	59.86	41.80	53.01	46.55	

C.D. (0.05) for F 2.663(1.222)
C.D. (0.05) for S 2.697(1.356)
C.D. (0.05) for S within same F levels 5.395(2.712)
C.D. (0.05) for S between F levels 5.540(2.785)

Table 19 d. <u>Mundakan</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	39.17	37.16	41.94	29.72	41.71	36.68	37.73
F_1 - 50	48.46	49.00	46.93	37.25	48.85	44.25	45.79
F_2 - 75	51.82	57.76	52.29	39.98	54.65	48.39	50.82
F_3 - 100	59.42	65.40	56.90	45.98	63.79	53.70	57.70
Mean	49.72	52.33	49.51	38.23	52.25	46.00	

C.D. (0.05) for F 1.446(0.663)
C.D. (0.05) for S 2.418(1.215)
C.D. (0.05) for S within same F levels NS (2.431)
C.D. (0.05) for S between F levels NS (2.256)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthasis are S.Em +/-

Table 20 a. P uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels.
Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	15.82	17.54	14.91	11.50	15.64	14.15	14.93	C.D.(0.05) for F	1.113(0.511)
F_1 - 50	19.24	21.58	16.91	12.37	18.39	16.80	17.55	C.D.(0.05) for S	0.901(0.453)
F_2 - 75	20.36	19.43	18.50	12.36	20.88	19.74	18.54	C.D.(0.05) for S within same F levels	1.802 (0.906)
F_3 - 100	21.55	22.45	22.25	14.43	22.08	21.90	20.78		
Mean	19.24	20.25	18.14	12.67	19.25	18.15		C.D.(0.05) for S between F levels	1.996(1.003)

Table 20 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	14.62	16.04	17.48	12.80	17.05	17.53	15.62	C.D.(0.05) for F	1.039(0.476)
F_1 - 50	17.64	21.77	18.69	13.74	17.66	17.14	17.77	C.D.(0.05) for S	1.036(0.521)
F_2 - 75	21.39	22.57	21.30	14.17	19.73	19.57	19.79	C.D.(0.05) for S within same F levels	2.073(1.042)
F_3 - 100	23.68	25.94	21.19	15.72	22.45	23.40	22.06		
Mean	19.33	21.58	19.66	14.11	19.22	18.96		C.D.(0.05) for S between F levels	2.507(1.236)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 20 c. P uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean		
F_0 - 0	12.89	13.33	14.03	9.68	14.11	12.40	12.75	C.D.(0.05) for F	0.709(0.325)
F_1 - 50	15.54	15.42	15.57	9.97	13.69	12.68	13.81	C.D.(0.05) for S	0.678(0.341)
F_2 - 75	14.38	17.14	16.69	10.71	13.96	12.90	14.30	C.D.(0.05) for S within same F levels	1.356(0.682)
F_3 - 100	16.42	18.44	17.54	12.70	15.97	14.17	15.87		
Mean	14.81	16.08	15.96	10.76	14.43	13.06		C.D.(0.05) for S between F levels	1.417(0.712)

Table 20 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	Mean		
F_0 - 0	12.97	12.50	13.69	8.69	14.14	13.36	12.56	C.D.(0.05) for F	0.502(0.230)
F_1 - 50	14.42	15.09	13.93	9.53	14.29	13.44	13.45	C.D.(0.05) for S	0.666(0.335)
F_2 - 75	15.29	15.71	14.69	10.11	15.47	14.01	14.21	C.D.(0.05) for S within same F levels	NS (0.670)
F_3 -100	16.71	17.53	15.59	11.16	17.74	15.81	15.76		
Mean	14.85	15.21	14.48	9.87	15.41	14.15		C.D.(0.05) for S between F levels	NS (0.775)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 21 a. K uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	67.17	73.72	67.84	49.32	59.50	63.25	65.13	C.D.(0.05) for F	4.916(2.256)
F_1 - 50	76.90	87.63	74.94	53.33	84.02	77.05	75.64	C.D.(0.05) for S	3.706(1.863)
F_2 - 75	82.69	93.45	89.00	56.56	90.64	84.98	82.89	C.D.(0.05) for S within same F levels	7.413(3.727)
F_3 - 100	95.67	103.38	97.60	62.50	99.70	98.62	92.91		
Mean	80.61	89.54	82.34	55.42	85.96	80.98		C.D.(0.05) for S between F levels	8.452(4.249)

Table 21 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	55.89	58.73	66.70	59.05	65.46	59.05	60.81	C.D.(0.05) for F	5.138 (2.358)
F_1 - 50	70.25	87.27	78.06	62.21	74.48	69.81	73.68	C.D.(0.05) for S	5.311 (2.670)
F_2 - 75	83.39	87.13	82.30	67.27	86.56	85.59	82.04	C.D.(0.05) for S within same F levels	10.622 (5.341)
F_3 - 100	95.16	114.97	92.99	70.86	98.51	98.64	95.19		
Mean	76.17	87.03	80.01	64.85	81.25	78.27		C.D.(0.05) for S between F levels	12.779 (6.31)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 21 c. K uptake (kg ha^{-1}) as influenced by fertilizer and spacing levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	54.07	57.06	52.81	43.73	55.78	49.60	52.17	C.D.(0.05) for F	5.180 (2.377)
F_1 - 50	66.05	68.12	68.52	49.21	58.21	56.63	61.12	C.D.(0.05) for S	2.996 (1.506)
F_2 - 75	71.49	83.88	74.09	52.85	63.26	60.83	67.73	C.D.(0.05) for S within same F levels	5.993 (3.013)
F_3 - 100	79.55	89.44	79.31	56.01	75.11	63.88	73.88		
Mean	67.79	74.62	68.68	50.45	63.09	57.73		C.D.(0.05) for S between F levels	7.777 (3.910)

Table 21 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	56.41	51.10	49.26	43.50	53.49	49.94	50.62	C.D.(0.05) for F	3.880 (1.780)
F_1 - 50	58.91	61.47	56.13	45.49	59.84	55.77	56.27	C.D.(0.05) for S	4.870 (2.453)
F_2 - 75	64.82	61.78	61.29	47.94	59.02	56.01	58.48	C.D.(0.05) for S within same F levels	NS (4.906)
F_3 - 100	70.13	77.16	62.48	53.84	69.04	63.47	66.02		
Mean	62.57	62.88	57.29	47.69	60.35	56.30		C.D.(0.05) for S between F levels	NS (5.698)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

of all the above nutrients in all the seasons except the *mundakan* season of the second year.

A perusal of the data on grain and straw yield (Table 13 a, b, c & d and 16 a, b, c & d) show that the above combination which recorded the highest values in the uptake of N, P and K was giving the highest grain and straw production.

6.2 Residual nutrient status of the soil after cropping

Treatments which received full dose of fertiliser recorded the highest value with respect to organic carbon available P and exchangeable K content (Table 22 a, b, c & d, 23 a, b, c & d and 24 a, b, c & d). The lowest values were associated with the zero level. Even if large quantities of fertilizers are added only a portion of them will be utilized by the crop. The rest of the portion will be added to the soil reserve. This might be the reason for the significant difference between the fertilizer treatments with respect to residual nutrient status.

Residual nutrient content of the soil was lowest in the closer spacings (20 x 5 and 15 x 10 cm) with a plant population of 100 and 66 hills cm^{-2} while the highest

Table 22 a. Residual organic carbon content (%) of soil as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	1.81	1.59	1.52	1.40	1.47	1.45	1.54	C.D.(0.05) for F	0.082 (0.037)
F_1 - 50	1.61	1.54	1.56	1.66	1.46	1.63	1.57	C.D.(0.05) for S	0.093 (0.046)
F_2 - 75	1.82	1.60	1.56	1.52	1.54	1.70	1.63	C.D.(0.05) for S within same F levels	0.186 (0.093)
F_3 - 100	1.71	1.73	1.63	1.56	1.85	1.50	1.66		
Mean	1.74	1.62	1.57	1.54	1.58	1.57		C.D.(0.05) for S between F levels	0.221 (0.109)

Table 22 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	1.56	1.51	1.49	1.38	1.39	1.51	1.47	C.D.(0.05) for F	0.038 (0.017)
F_1 - 50	1.62	1.60	1.58	1.36	1.59	1.56	1.55	C.D.(0.05) for S	0.040 (0.020)
F_2 - 75	1.63	1.59	1.56	1.37	1.58	1.55	1.55	C.D.(0.05) for S within same F levels	0.081 (0.041)
F_3 - 100	1.69	1.68	1.63	1.54	1.63	1.59	1.62		
Mean	1.63	1.59	1.56	1.41	1.55	1.55		C.D.(0.05) for S between F levels	0.097 (0.047)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 22 c. Residual organic carbon content (%) of soil as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	1.47	1.47	1.49	1.31	1.47	1.44	1.44
F_1 - 50	1.58	1.56	1.54	1.41	1.55	1.52	1.53
F_2 - 75	1.61	1.58	1.54	1.44	1.56	1.53	1.55
F_3 - 100	1.64	1.60	1.54	1.45	1.58	1.54	1.56
Mean	1.58	1.55	1.53	1.40	1.54	1.51	

C.D.(0.05) for F	0.016	(0.007)
C.D.(0.05) for S	0.022	(0.015)
C.D.(0.05) for S within same F levels	NS	(0.031)
C.D.(0.05) for S between F levels	NS	(0.035)

Table 22 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	1.56	1.53	1.51	1.39	1.49	1.49	1.49
F_1 - 50	1.59	1.57	1.58	1.44	1.56	1.54	1.55
F_2 - 75	1.61	1.59	1.60	1.45	1.60	1.57	1.57
F_3 - 100	1.61	1.60	1.60	1.62	1.62	1.60	1.59
Mean	1.59	1.57	1.57	1.44	1.57	1.55	

C.D.(0.05) for F	0.022	(0.009)
C.D.(0.05) for S	0.023	(0.011)
C.D.(0.05) for S within same F levels	NS	(0.022)
C.D.(0.05) for S between F levels	NS	(0.026)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 23 a. Residual P content of soil (kg ha^{-1}) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	17.06	16.42	16.29	11.80	19.38	15.87	16.14	C.D.(0.05) for F	1.819 (0.834)
F_1 - 50	22.06	22.05	21.46	17.35	22.28	21.38	21.10	C.D.(0.05) for S	1.807 (0.908)
F_2 - 75	25.01	23.19	23.81	16.92	22.64	21.35	22.15	C.D.(0.05) for S within same F levels	NS (1.817)
F_3 - 100	28.46	29.19	24.43	18.50	26.26	22.82	24.94		
Mean	23.15	22.71	21.50	16.14	22.64	20.35		C.D.(0.05) for S between F levels	NS (2.156)

Table 23 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	17.81	17.28	16.97	13.99	17.60	15.42	16.51	C.D.(0.05) for F	1.445 (0.663)
F_1 - 50	23.00	22.15	21.12	17.14	19.85	20.03	20.55	C.D.(0.05) for S	1.610 (0.809)
F_2 - 75	23.62	22.46	22.94	16.16	23.36	21.37	21.65	C.D.(0.05) for S within same F levels	NS (1.619)
F_3 - 100	28.04	26.36	22.64	16.41	23.71	21.55	23.45		
Mean	23.12	22.06	20.92	16.43	21.13	19.59		C.D.(0.05) for S between F levels	NS (1.899)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 23 c. Residual P content of soil (kg ha^{-1}) as influenced by fertilizer and spacing levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	18.05	14.49	15.73	12.78	15.34	15.90	15.38
F_1 - 50	20.09	15.74	16.75	14.34	18.29	18.70	17.32
F_2 - 75	18.73	19.87	18.16	13.02	20.09	21.59	18.57
F_3 -100	24.03	24.68	23.37	14.49	20.59	14.51	20.28
Mean	20.22	18.69	18.50	13.66	18.57	17.68	

C.D.(0.05) for F	2.993	(1.346)
C.D.(0.05) for S	2.235	(1.124)
C.D.(0.05) for S within same F levels	4.471	(2.248)
C.D.(0.05) for S between F levels	5.074	(2.551)

Table 23 d. <u>Mundakan</u> 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)	
F_0 - 0	18.04	15.83	15.54	15.24	16.41	17.17	16.37
F_1 - 50	20.17	21.70	20.88	16.39	21.83	20.81	20.30
F_2 - 75	22.97	23.35	23.49	16.90	22.20	22.55	21.91
F_3 - 100	25.87	25.65	23.31	18.29	25.42	22.67	23.54
Mean	21.76	21.64	20.80	16.71	21.46	20.80	

C.D.(0.05) for F	2.387	(1.095)
C.D.(0.05) for S	1.599	(0.804)
C.D.(0.05) for S within same F levels	NS	(1.608)
C.D.(0.05) for S between F levels	NS	(2.033)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 24 a. Residual K content of soil (kg ha^{-1}) as influenced by fertilizer and spacing levels. Virippu 1982

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	140	129	130	120	133	129	130	C.D.(0.05) for F	4.7 (2.2)
F_1 - 50	148	142	139	123	146	141	140	C.D.(0.05) for S	8.0 (4.0)
F_2 - 75	156	152	153	147	149	142	150	C.D.(0.05) for S within same F levels	NS (8.1)
F_3 -100	159	152	157	146	162	155	155		
Mean	151	144	145	134	147	142		C.D.(0.05) for S between F levels	NS (7.5)

Table 24 b. Virippu 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (16x10)			
F_0 - 0	137	128	130	127	131	133	131	C.D.(0.05) for F	7.2 (3.3)
F_1 - 50	154	149	155	128	154	144	147	C.D.(0.05) for S	7.6 (3.8)
F_2 - 75	155	148	150	130	147	153	147	C.D.(0.05) for S within same F levels	NS (7.6)
F_3 -100	164	157	145	132	155	154	151		
Mean	153	145	145	129	147	146		C.D.(0.05) for S between F levels	NS (7.8)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 24 c. Residual K content of soil (kg ha^{-1}) as influenced by fertilizer and spacing levels. Mundakan 1982

Fertilizer level (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	136	131	126	124	129	134	130	C.D.(0.05) for F	5.0 (2.3)
F_1 - 50	154	153	151	138	152	153	150	C.D.(0.05) for S	6.6 (3.4)
F_2 - 75	155	152	157	137	153	156	152	C.D.(0.05) for S within same F levels	NS (6.7)
F_3 - 100	165	162	157	141	156	157	156		
Mean	152	149	148	135	148	150		C.D.(0.05) for S between F levels	NS (6.6)

Table 24 d. Mundakan 1983

Fertilizer levels (% of recommended dose*)	Spacing levels (cm)						Mean		
	S_1 (20x20)	S_2 (20x15)	S_3 (20x10)	S_4 (20x5)	S_5 (15x15)	S_6 (15x10)			
F_0 - 0	134	127	130	126	131	132	130	C.D.(0.05) for F	7.6 (3.5)
F_1 - 50	154	151	145	125	150	149	146	C.D.(0.05) for S	6.1 (3.1)
F_2 - 75	153	146	148	130	152	149	147	C.D.(0.05) for S within the same F levels	NS (6.1)
F_3 - 100	168	162	149	131	158	153	154		
Mean	152	146	143	128	148	146		C.D.(0.05) for S between F levels	NS (6.8)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

values were associated with the wider spacings (20 x 20 and 20 x 15 cm) having a plant population of 25 and 33 hills m^{-2}. The lower values of residual nutrient content of soil associated with higher plant population might be due to the severe competition resulting in thorough exhaustion of nutrients from the soil.

Combination effect was not significant in all the seasons.

Trial II. Effect of age of seedling and planting density on rice variety IR 42

1. Growth and growth characters

1.1 Height of plants

In both the years and at all stages fertilizer levels did not influence plant height during virippu and mundakan seasons (Table 25 a, b, c & d and 26 a, b, c & d). The narrow difference in the fertilizer levels tried is attributed as the reason for the same.

At harvest, age of seedling had no effect on plant height during virippu in both years whereas in mundakan, 25 days old seedlings recorded more plant height than 35 days old seedlings. Howevever, the plant height of 25 days old seedlings was similar with that of 30 days old seedlings. This is because the older seedlings take more time to get established in the main field and naturally planting younger seedlings are to be preferred for the production of taller plants.

Table 25 a. Height of plants (cm) at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	72.9	69.5	69.8	71.3	71.5	69.3	70.7
F_2	(75)	73.0	71.4	71.3	72.7	71.5	71.5	71.9
Mean		73.0	70.4	70.5	72.0	71.5	70.4	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1	N_2	N_3	
A_1	25	73.6	73.4	71.9	73.0
A_2	30	70.4	70.7	70.2	70.4
A_3	35	72.1	70.4	69.1	70.5
Mean		72.0	71.5	70.4	

C.D.(0.05) for F NS (0.626)
C.D.(0.05) for A 1.56 (0.768)
C.D.(0.05) for N NS (0.768)
C.D.(0.05) for FA NS (1.086)
C.D.(0.05) for FN NS (1.086)
C.D.(0.05) for AN NS (1.331)

Table 25 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	80.7	80.8	80.5	81.1	80.2	80.6	80.7
F_2	(100)	81.1	81.6	82.2	82.2	81.8	80.7	81.6
Mean		80.9	81.2	81.3	81.7	81.0	80.7	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	80.8	86.2	80.7	80.9
A_2	30	83.1	80.5	80.0	81.2
A_3	35	81.7	81.0	80.7	81.3

C.D.(0.05) for F NS (0.616)
C.D.(0.05) for A NS (0.754)
C.D.(0.05) for N NS (0.754)
C.D.(0.05) for FA NS (1.067)
C.D.(0.05) for FN NS (1.067)
C.D.(0.05) for AN NS (1.306)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 25 c. Height of plants (cm) at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings hill^{-1}			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	57.7	60.1	58.2	58.2	59.3	58.5	58.7
F_2 (75)	59.8	62.1	58.8	60.3	59.9	60.4	60.2
Mean	58.7	61.1	58.5	59.3	59.6	59.5	

Age (Days)	Number of seedlings hill^{-1}			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	60.1	58.6	57.6	58.7
A_2 30	60.6	61.8	61.0	61.1
A_3 35	57.1	58.5	59.9	58.5
Mean	59.3	59.6	59.5	

C.D.(0.05) for F	NS	(0.881)
C.D.(0.05) for A	2.19	(1.078)
C.D.(0.05) for N	NS	(1.078)
C.D.(0.05) for FA	NS	(1.525)
C.D.(0.05) for FN	NS	(1.525)
C.D.(0.05) for AN	NS	(1.868)

Table 25 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings hill^{-1}			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	80.7	80.8	80.5	81.7	79.7	80.6	80.7
F_2 (100)	81.1	81.6	82.2	82.2	81.8	80.7	81.6
Mean	80.9	81.2	81.3	81.9	80.8	80.7	

Age (Days)	Number of seedlings hill^{-1}			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	80.8	81.2	80.7	80.9
A_2 30	83.1	80.5	80.0	81.2
A_3 35	82.0	80.6	81.4	81.3
Mean	81.9	80.8	80.7	

C.D.(0.05) for F	NS	(0.624)
C.D.(0.05) for A	NS	(0.764)
C.D.(0.05) for N	NS	(0.764)
C.D.(0.05) for FA	NS	(1.080)
C.D.(0.05) for FN	NS	(1.080)
C.D.(0.05) for AN	NS	(1.322)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 26 a. Height of plants (cm) at harvest as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings hill^{-1}			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	88.1	89.0	87.4	88.4	87.7	88.4	88.2
F_2 (75)	88.9	87.8	88.7	89.8	88.8	86.8	88.4
Mean	88.5	88.4	88.1	89.1	88.2	87.6	

Age (Days)	Number of seedlings hill^{-1}			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	89.0	87.7	88.8	88.5
A_2 30	88.7	89.0	87.5	88.4
A_3 35	89.7	88.0	86.5	88.1
Mean	89.1	88.2	87.6	

C.D.(0.05) for F NS (0.752)
C.D.(0.05) for A NS (0.921)
C.D.(0.05) for N NS (0.921)
C.D.(0.05) for FA NS (1.302)
C.D.(0.05) for FN NS (1.302)
C.D.(0.05) for AN NS (1.594)

Table 26 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings hill^{-1}			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	99.8	101.7	101.9	102.4	100.2	100.7	101.1
F_2 (100)	104.4	102.3	102.9	105.8	102.6	101.3	103.2
Mean	102.1	102.0	102.4	104.1	101.4	101.0	

Age (Days)	Number of seedlings hill^{-1}			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	102.2	101.8	102.3	102.1
A_2 30	105.3	100.7	100.0	102.0
A_3 35	104.8	101.7	100.7	102.4
Mean	104.1	101.4	101.0	

C.D.(0.05) for F NS (1.220)
C.D.(0.05) for A NS (1.495)
C.D.(0.05) for N NS (1.495)
C.D.(0.05) for FA NS (2.114)
C.D.(0.05) for FN NS (2.114)
C.D.(0.05) for AN NS (2.589)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 26 c. Height of plants (cm) at harvest as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	69.3	72.3	68.4	70.9	70.0	69.2	70.0
F_2	(75)	70.3	71.1	69.2	70.4	70.7	69.6	70.2
Mean		69.8	71.7	68.8	70.7	70.3	69.4	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	71.7	70.0	67.8	69.8
A_2	30	71.2	72.0	72.0	71.7
A_3	35	69.2	69.0	68.3	68.8
Mean		70.7	70.3	69.4	

C.D.(0.05) for F NS (0.795)
C.D.(0.05) for A 1.98 (0.974)
C.D.(0.05) for N NS (0.974)
C.D.(0.05) for FA NS (1.378)
C.D.(0.05) for FN NS (1.378)
C.D.(0.05) for AN NS (1.688)

Table 26 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	87.8	85.9	86.7	87.2	87.3	85.8	86.8
F_2	(100)	89.0	88.2	84.5	88.0	87.0	86.7	87.2
Mean		88.4	87.0	85.6	87.6	87.2	86.2	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	89.0	89.7	86.5	88.4
A_2	30	88.4	86.3	86.5	87.0
A_3	35	85.4	85.5	85.8	85.6
Mean		87.6	87.2	86.2	

C.D.(0.05) for F NS (0.702)
C.D.(0.05) for A 1.75 (0.861)
C.D.(0.05) for N NS (0.861)
C.D.(0.05) for FA 2.47 (1.215)
C.D.(0.05) for FN NS (1.215)
C.D.(0.05) for AN NS (1.488)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

The number of seedlings per hill showed no significant difference between stages irrespective of the seasons and years.

1.2 Number of tillers m^{-2}

During *virippu* and *mundakan* seasons of both the years, fertilizer levels showed significant effect on tiller production (Table 27 a, b, c & d and 28 a, b, c and d). Higher level of fertilizer was found to be superior to lower level at all stages. Tiller production, being a vegetative character, has been influenced significantly by higher level of fertilizer particularly N.

During *virippu* seasons of both the years 30 days old seedlings were found to be better upto panicle initiation stage. But by the time of harvest no significant difference was noted among the age levels indicating that seedlings upto 35 days old can be used for planting. But during the *mundakan* seasons number of tillers produced upto panicle initiation stage was highest with 30 days old seedlings and was comparable with that of 25 days old seedlings at harvest. IR 42,being a late maturing variety having a duration of 140/145 days, 25 days old seedlings

Table 27.a Number of tillers m^{-2} at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Viripu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	441	440	428	380	444	485	436
F_2	(75)	504	481	467	433	485	534	484
Mean		473	461	448	407	465	518	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	388	508	522	473
A_2	30	426	455	501	461
A_3	35	406	432	506	448
Mean		407	465	510	

C.D.(0.05) for F 13.6 (6.72)
C.D.(0.05) for A 16.7 (8.24)
C.D.(0.05) for N 16.7 (8.24)
C.D.(0.05) for FA NS (11.64)
C.D.(0.05) for FN NS (11.64)
C.D.(0.05) for AN 29.0(14.26)

Table 27.b Viripu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	542	576	576	541	544	608	565
F_2	(100)	578	625	602	544	621	639	602
Mean		560	601	589	542	583	624	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	511	582	588	560
A_2	30	566	595	641	601
A_3	35	550	572	645	589
Mean		542	583	624	

C.D.(0.05) for F 11.8 (5.80)
C.D.(0.05) for A 14.5 (7.11)
C.D.(0.05) for N 14.5 (7.11)
C.D.(0.05) for FA 20.4 (10.05)
C.D.(0.05) for FN 20.4 (10.05)
C.D.(0.05) for AN 25.0 (12.31)

* 90: 45: 45 kg NPK h

Values in parenthesis [illegible] +/-

Table 27c. Number of tillers m^{-2} at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	599	572	616	556	608	622	595
F_2	(75)	609	637	627	567	627	678	624
Mean		604	604	621	562	618	650	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	577	608	628	604
A_2	30	532	623	658	604
A_3	35	577	622	666	621
Mean		562	618	650	

C.D.(0.05) for F 14.1 (6.91)
C.D.(0.05) for A NS (8.46)
C.D.(0.05) for N 17.2 (8.46)
C.D.(0.05) for FA 24.3 (11.96)
C.D.(0.05) for FN 24.3 (11.96)
C.D.(0.05) for AN 29.8 (14.65)

Table 27d. Mundakan 1983

Fertilizers (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	533	555	564	515	568	569	551
F_2	(100)	581	594	540	481	638	597	572
Mean		558	574	553	498	603	583	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	475	618	580	558
A_2	30	508	600	615	574
A_3	35	511	593	554	553
Mean		498	603	583	

C.D.(0.05) for F 12.5 (5.90)
C.D.(0.05) for A 14.1 (6.90)
C.D.(0.05) for N 14.1 (6.90)
C.D.(0.05) for FA 19.9 (9.80)
C.D.(0.05) for FN 19.9 (9.80)
C.D.(0.05) for AN 24.4 (11.79)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 28 a. Number of tillers m^{-2} at harvest as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	357	349	370	327	372	378	359
F_2	(75)	376	391	377	341	407	396	381
Mean		367	370	374	334	390	387	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	340	379	380	367
A_2	30	330	397	385	370
A_3	35	332	393	396	374
Mean		334	390	387	

C.D.(0.05) for F	15.4	(7.59)
C.D.(0.05) for A	NS	(9.29)
C.D.(0.05) for N	18.9	(9.29)
C.D.(0.05) for FA	NS	(13.15)
C.D.(0.05) for FN	NS	(13.15)
C.D.(0.05) for AN	NS	(16.10)

Table 28 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	389	381	396	367	399	400	389
F_2	(100)	393	405	402	353	421	426	400
Mean		391	393	399	360	410	413	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	350	404	420	391
A_2	30	360	422	398	393
A_3	35	371	405	421	399
Mean		360	410	413	

C.D.(0.05) for F	10.2	(5.02)
C.D.(0.05) for A	NS	(6.14)
C.D.(0.05) for N	12.6	(6.14)
C.D.(0.05) for FA	17.7	(8.68)
C.D.(0.05) for FN	17.7	(8.68)
C.D.(0.05) for AN	21.6	(10.64)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 28 c. Number of tillers m^{-2} at harvest as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizers (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	546	522	547	488	562	566	538
F_2	(75)	527	593	568	508	591	589	562
Mean		536	558	558	498	576	577	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	487	560	562	536
A_2	30	510	568	594	558
A_3	35	497	600	576	558
Mean		498	576	577	

C.D.(0.05) for F	14.5	(7.13)
C.D.(0.05) for A	17.8	(8.72)
C.D.(0.05) for N	17.8	(8.72)
C.D.(0.05) for FA	25.1	(12.34)
C.D.(0.05) for FN	NS	(12.34)
C.D.(0.05) for AN	NS	(15.12)

Table 28 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	527	506	487	468	544	508	507
F_2	(100)	535	566	529	492	581	557	543
Mean		531	536	508	480	562	533	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	476	583	535	531
A_2	30	483	569	555	536
A_3	35	482	535	508	508
Mean		480	562	533	

C.D.(0.05) for F	12.4	(5.9)
C.D.(0.05) for A	15.2	(7.4)
C.D.(0.05) for N	15.2	(7.4)
C.D.(0.05) for FA	21.5	(10.3)
C.D.(0.05) for FN	NS	(10.3)
C.D.(0.05) for AN	26.3	(12.7)

* 90:45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

could not produce sufficient number of tillers at panicle initiation stage. Further, the duration of the crop is lesser in mundakan. By the time of harvest, it was able to make up this gap to a certain extent. Thus at harvest 25 days old seedlings have become comparable with 30 days old seedlings. This shows that the optimum age of seedlings for mundakan crop seems to be 30 days.

Two seedlings per hill were found to be inferior to four and six seedlings per hill in virippu as well as in mundakan during both years. This indicates that this variety needs four to six seedlings per hill to produce enough tillers which ultimately will reflect on the number of panicles. Inspite of it being a late maturing variety two seedlings per hill are not sufficient.

It is further noted that in virippu six seedlings gave the highest number of tillers upto flowering in the first year while in the second year 6 seedlings per hill produced more tiller upto harvest and it was significant upto flowering stage. But during mundakan season of the first year 4 and 6 seedlings were comparable at flowering and at harvest stages whereas in the second year four seedlings per hill were significantly superior to six seedlings per hill from panicle initiation stage onwards.

It is recalled in this connection from the materials and methods, that the spacing for this variety in the _mundakan_ season is 20 x 10 cm as against 20 x 15 cm in _virippu_. A lesser spacing is recommended in _mundakan_ as the time available for tiller production is lesser. At this closer spacing there is not much space for increasing tiller number by planting more than four seedlings while in _virippu_ providing a wider spacing could enable the six seedlings to produce more tillers.

1.3 Leaf area index

In both years during _virippu_ and _mundakan_, fertilizer levels had a significant effect on LAI (Table 29 a, b, c & d). Higher level of fertilizer was superior to lower level. As the fertilizer levels are increased, N being the major component of the fertilizer, vegetative growth especially the tiller production was increased resulting in higher values of LAI. Tanaka et al. (1964), Kawano and Tanaka (1968) also observed similar increase in LAI with N fertilization.

Thirty days old seedlings gave more LAI in both seasons of the first year whereas 35 days old seedlings gave more LAI in the second year. This is attributed to the higher quantity of fertilizers given in the second year.

Table 29(a). Leaf area index (LAI) at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days) A_1 25	A_2 30	A_3 35	Number of seedlings $hill^{-1}$ N_1 2	N_2 4	N_3 6	Mean
F_1	(50)	5.88	6.64	5.90	5.59	6.31	6.53	6.14
F_2	(75)	6.05	7.17	6.81	5.95	6.99	7.08	6.68
Mean		5.96	6.91	6.36	5.77	6.65	6.81	

Age (Days)		Number of seedlings $hill^{-1}$ N_1 2	N_2 4	N_3 6	Mean
A_1	25	5.79	5.96	6.15	5.96
A_2	30	6.37	7.18	7.16	6.91
A_3	35	5.15	6.81	7.11	6.36
Mean		5.77	6.65	6.81	

C.D.(0.05) for F	0.271	(0.13)
C.D.(0.05) for A	0.332	(0.16)
C.D.(0.05) for N	0.332	(0.16)
C.D.(0.05) for FA	NS	(0.23)
C.D.(0.05) for FN	NS	(0.23)
C.D.(0.05) for AN	0.576	(0.28)

Table 29(b). Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days) A_1 25	A_2 30	A_3 35	Number of seedlings $hill^{-1}$ N_1 2	N_2 4	N_3 6	Mean
F_1	(75)	5.83	6.16	6.24	5.13	6.63	6.48	6.08
F_2	(100)	6.02	6.69	6.75	5.64	6.96	6.88	6.49
Mean		5.93	6.43	6.50	5.38	6.80	6.68	

Age (Days)		Number of seedlings $hill^{-1}$ N_1 2	N_2 4	N_3 6	Mean
A_1	25	5.12	6.34	6.32	5.93
A_2	30	5.47	6.95	6.87	6.43
A_3	35	5.66	7.10	6.85	6.50
Mean		5.38	6.80	6.68	

C.D.(0.05) for F	0.128	(0.06)
C.D.(0.05) for A	0.156	(0.07)
C.D.(0.05) for N	0.156	(0.07)
C.D.(0.05) for FA	NS	(0.11)
C.D.(0.05) for FN	NS	(0.11)
C.D.(0.05) for AN	NS	(0.13)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 29.c. Leaf area index (LAI) at panicle initiation stage as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	5.44	5.88	6.41	5.54	6.30	5.89	5.91
F_2	(75)	6.05	7.24	6.40	5.88	6.92	6.88	6.56
Mean		5.74	6.56	6.40	5.71	6.61	6.39	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	5.70	6.00	5.54	5.74
A_2	30	6.37	6.42	6.90	6.56
A_3	35	5.07	7.42	6.72	6.40
Mean		5.71	6.61	6.39	

C.D.(0.05) for F 0.3 (0.15)
C.D.(0.05) for A 0.3 (0.19)
C.D.(0.05) for N 0.3 (0.19)
C.D.(0.05) for FA 0.5 (0.27)
C.D.(0.05) for FN NS (0.27)
C.D.(0.05) for AN 0.67 (0.33)

Table 29.d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	6.16	6.38	6.63	5.33	6.75	7.09	6.39
F_2	(100)	6.35	7.39	7.42	5.81	7.46	7.90	7.06
Mean		6.26	6.89	7.03	5.57	7.10	7.50	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	5.30	6.49	6.98	6.26
A_2	30	5.59	7.35	7.71	6.89
A_3	35	5.82	7.46	7.80	7.03
Mean		5.57	7.10	7.50	

C.D.(0.05) for F 0.214 (0.102)
C.D.(0.05) for A 0.262 (0.128)
C.D.(0.05) for N 0.262 (0.128)
C.D.(0.05) for FA 0.371 (0.181)
C.D.(0.05) for FN NS (0.181)
C.D.(0.05) for AN NS (0.222)

* 90:45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Four seedlings per hill gave the highest LAI followed by six seedlings in virippu seasons of both years. Two seedlings per hill gave significantly lower values. In mundakan six seedlings per hill recorded the highest LAI followed by 4 and 2 seedlings per hill. May be that in mundakan as the duration is lesser, the crop required more number of seedlings to produce sufficient leaf area.

1.4 Dry matter production at harvest

Higher level of fertilizer has given higher DMP than the lower level in all the four seasons (Table 30 a, b, c & d). The higher level of fertilizer has resulted in higher DMP due to the well known reasons. The same trend was observed in the vegetative as well as reproductive characters.

Thirty five days old seedlings gave more DMP in the virippu season in both years. The lowest DMP was always associated with the youngest seedlings i.e., 25 days old seedlings. In mundakan 30 days old seedlings produced more DMP. From the results it is evident that 35 days old seedlings are best for virippu and 30 days for mundakan. During mundakan the duration of the crop is lesser and hence younger seedlings may be better for planting.

Table 30a. Dry matter production of rice (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	6558	6981	7067	6559	6835	7212	6869
F_2 (75)	7219	7500	7765	7116	7680	7688	7495
Mean	6889	7241	7416	6838	7258	7450	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	6688	7007	6972	6889
A_2 30	7080	7447	7195	7241
A_3 35	6746	7320	8183	7416
Mean	6838	7258	7450	

C.D.(0.05) for F	293	(144)
C.D.(0.05) for A	359	(176)
C.D.(0.05) for N	359	(176)
C.D.(0.05) for FA	NS	(249)
C.D.(0.05) for FN	NS	(249)
C.D.(0.05) for AN	622	(305)

Table 30b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	8009	8149	8160	7848	8377	8094	8106
F_2 (100)	8826	8665	8815	8407	9285	8615	8769
Mean	8418	8407	8488	8127	8831	8355	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	8041	8900	8313	8418
A_2 30	8367	8748	8107	8407
A_3 35	7974	8845	8644	8488
Mean	8127	8831	8355	

C.D.(0.05) for F	230	(113)
C.D.(0.05) for A	NS	(139)
C.D.(0.05) for N	282	(139)
C.D.(0.05) for FA	NS	(196)
C.D.(0.05) for FN	NS	(196)
C.D.(0.05) for AN	NS	(240)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 30c. Dry matter production of rice (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	6621	7067	6493	6491	6843	6847	6727
F_2	(75)	6866	7678	7014	6960	7268	7330	7186
Mean		6744	7373	6753	6726	7055	7088	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	6516	6867	6848	6744
A_2	30	7205	7684	7229	7373
A_3	35	6456	6616	7188	6753
Mean		6726	7055	7088	

C.D.(0.05) for F	140	(69)
C.D.(0.05) for A	172	(85)
C.D.(0.05) for N	172	(85)
C.D.(0.05) for FA	NS	(119)
C.D.(0.05) for FN	NS	(119)
C.D.(0.05) for AN	297	(146)

Table 30d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	9777	9698	9441	9282	9944	9690	9639
F_2	(100)	10298	10562	10042	9933	10641	10326	10300
Mean		10037	10130	9742	9608	10293	10008	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	9617	10129	10366	10037
A_2	30	9731	10588	10071	10130
A_3	35	9475	10161	9589	9742
Mean		9608	10293	10008	

C.D.(0.05) for F	212	(104)
C.D.(0.05) for A	259	(127)
C.D.(0.05) for N	259	(127)
C.D.(0.05) for FA	NS	(180)
C.D.(0.05) for FN	NS	(180)
C.D.(0.05) for AN	NS	(221)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Planting 6 seedlings per hill gave more DMP in the first year during both seasons while 4 seedlings per hill in the second year. It may be mentioned in this context that during first year the higher level of fertilizer was limited to 75 per cent of the fertilizer recommendation while during the second year it has gone upto 100 per cent. The response of DMP to the number of seedlings is greatly influenced by the fertilizer levels received in the respective years. In the first year 6 seedlings per hill produced more DMP while in the second year 4 seedlings per hill could produce comparable or more DMP. This may be attributed to the higher amount of fertilization in the second year. This conforms the well accepted theory that in soils of lower fertility more plant population has to be given to derive the maximum benefit from that level of fertility (Yamada and Nakamura, 1968).

2 Yield attributes

2.1 Number of panicles m^{-2}

The fertilizer levels showed significant effect on the number of panicles in virippu and mundakan of both years (Table 31 a, b, c & d). Higher level of fertilizer was superior to the lower levels in all seasons except

Table 31a. Number of panicles m^{-2} as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	315	334	323	293	337	342	324
F_2 (75)	332	334	341	314	343	350	336
Mean	323	334	332	303	340	346	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	297	336	337	323
A_2	30	318	343	341	334
A_3	35	295	340	360	332
Mean		303	340	346	

C.D.(0.05) for	F	7.2	(3.54)
C.D.(0.05) for	A	8.8	(4.32)
C.D.(0.05) for	N	8.8	(4.32)
C.D.(0.05) for	FA	NS	(6.09)
C.D.(0.05) for	FN	NS	(6.09)
C.D.(0.05) for	AN	15.2	(7.46)

Table 31b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	356	351	362	331	364	375	357
F_2 (100)	357	378	385	341	390	389	373
Mean	356	364	374	336	377	382	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	325	368	376	356
A_2	30	328	382	383	364
A_3	35	354	380	387	374
Mean		336	377	382	

C.D. (0.05) for	F	7.7	(3.81)
C.D. (0.05) for	A	9.5	(4.67)
C.D. (0.05) for	N	9.5	(4.67)
C.D. (0.05) for	FA	13.4	(6.60)
C.D. (0.05) for	FN	13.4	(6.60)
C.D. (0.05) for	AN	16.4	(8.08)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 31c. Number of panicles m^{-2} as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	364	354	374	309	382	400	364
F_2	(75)	334	402	388	317	379	429	375
Mean		349	378	381	313	380	415	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	299	340	408	349
A_2	30	318	400	416	378
A_3	35	323	401	420	381
Mean		313	380	415	

C.D. (0.05) for F	NS	(5.81)
C.D. (0.05) for A	14.5	(7.13)
C.D. (0.05) for N	14.5	(7.13)
C.D. (0.05) for FA	20.5	(10.08)
C.D. (0.05) for FN	NS	(10.08)
C.D. (0.05) for AN	25.1	(12.34)

Table 31d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	403	384	378	343	425	397	389
F_2	(100)	416	436	424	372	458	446	425
Mean		409	410	401	358	442	422	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	356	457	416	409
A_2	30	342	446	442	410
A_3	35	375	422	408	401
Mean		358	442	422	

C.D.(0.05) for F	12.1	(5.9)
C.D.(0.05) for A	NS	(7.4)
C.D.(0.05) for N	15.0	(7.4)
C.D.(0.05) for FA	NS	(10.3)
C.D.(0.05) for FN	NS	(10.3)
C.D.(0.05) for AN	26.0	(12.8)

* 90:45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

the mundakan of the first year wherein, though both the fertilizer levels were similar, the higher level recorded more number of panicles.

The results reveal that the number of panicles is significantly more in plants receiving higher quantity of fertilizer except in the mundakan season of 1982 where also higher level of fertilizer has produced more panicles though not significant. One of the objectives of the experiment was to ascertain whether there can be any fertilizer saving in this variety due to the reported nature of its performance under low fertility conditions. However, under the yield potential realized in Kerala the recommended level of fertilizers (90: 45: 45 kg NPK ha^{-1}) seems to be required for panicle production.

The age of seedlings has significant influence on the number of panicles. Youngest seedlings of 25 days old recorded significantly lower number of panicles in three out of four seasons. There seems to be not much difference between 35 and 30 days old seedlings. This shows that under the agro climatic conditions of Kerala, 25 days old seedlings are not ideal for producing sufficient number of panicles for maximum grain production. At the same time the age can be extended upto 35 days without any detrimental effect on panicle production in both the seasons. The duration of the variety is one factor which determines the age of seedlings in the nursery. For varieties of upto 140 days duration there seems to be no harm in planting 35 days old seedlings. This will be definitely adventageous from the farmers point of view since sufficient time gap will be available for transplanting especially during delayed onset of monsoons. This is in conformity with the findings of Sundararajan (1978) and Theetharappan (1983).

The number of seedlings per hill showed significant effect on panicle production while the combination effects did not show a definite trend.

Data on number of seedlings show that eventhough six seedlings per hill gave more panicles in three seasons, it was comparable with 4 seedlings per hill. During the mundakan season of the second year, 4 seedlings per hill recorded the highest number of panicles compared to others. From this result it may be inferred that 2 seedlings per hill is definitely inferior for this variety inspite of the comparative longer duration. At least 4 seedlings should be planted to get sufficient panicle production. This variety is reported to possess high tillering capacity under adequate fertilisation (IARI, 1979). In the present investigation a fertilizer level of 90: 45: 45 kg NPK ha^{-1} is the highest dose given. Probably for this variety, the dose is not sufficient for the full expression of the tiller potential. In these circumstances, higher number of seedlings are to be used for ensuring adequate panicle production. It may be mentioned in this connection that under low fertility conditions higher number of seedlings are generally used to enhance tiller production. Hence the number of seedlings to be planted has to be increased from the presently recommended two to four. Natarajan (1982) also reported increase in panicle number with increase in seedling number from two to six in late maturing types such as Ponni and ASD, 15.

21. 2 Number of filled grains per panicle

Fertilizer levels showed significant effect on number of filled grains per panicle only in mundakan seasons of both years (Table 32 a, b, c & d). Higher level of fertilizer gave significantly higher number of filled grains per panicle. Higher amount of fertilization is always effective in producing more number of filled grains per panicle (Dayanand et al. (1972), Verma and Srivastava (1972), Balasubramaniam (1980) and Sreekumaran (1981).

Table 32 a. Number of filled grains panicle^{-1} as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	67	74	66	60	73	73	69
F_2	(75)	69	70	72	63	78	70	70
Mean		68	72	69	61	76	72	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	64	73	66	68
A_2	30	60	83	74	72
A_3	35	60	72	72	69
Mean		61	76	72	

C.D.(0.05)	for F	NS	(3.10)
C.D.(0.05)	for A	NS	(3.80)
C.D.(0.05)	for N	7.7	(3.80)
C.D.(0.05)	for FA	NS	(5.37)
C.D.(0.05)	for FN	NS	(5.37)
C.D.(0.05)	for AN	NS	(6.58)

Table 32 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	62	69	61	62	68	62	64
F_2	(100)	64	64	67	59	76	60	65
Mean		63	67	64	60	72	61	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	59	68	61	63
A_2	30	63	78	59	67
A_3	35	59	71	62	64
Mean		60	72	61	

C.D.(0.05)	for F	NS	(3.21)
C.D.(0.05)	for A	NS	(3.93)
C.D.(0.05)	for N	8.0	(3.93)
C.D.(0.05)	for FA	NS	(5.56)
C.D.(0.05)	for FN	NS	(5.56)
C.D.(0.05)	for AN	NS	(6.81)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 31 c. Number of filled grains panicle^{-1} as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	61	62	60	52	64	67	61
F_2	(75)	68	69	62	58	70	70	66
Mean		65	66	61	55	67	68	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	57	68	70	65
A_2	30	57	71	68	66
A_3	35	53	63	67	61
Mean		55	67	68	

C.D.(0.05) for F	5.3	(2.60)
C.D.(0.05) for A	NS	(3.14)
C.D.(0.05) for N	6.4	(3.14)
C.D.(0.05) for FA	NS	(4.47)
C.D.(0.05) for FN	NS	(4.47)
C.D.(0.05) for AN	NS	(5.48)

Table 31 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	64	64	63	60	65	65	64
F_2	(100)	70	71	69	65	73	72	70
Mean		67	67	66	63	69	69	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	64	70	68	67
A_2	30	63	71	68	67
A_3	35	61	68	70	66
Mean		63	69	69	

C.D.(0.05) for F	4.8	(2.40)
C.D.(0.05) for A	NS	(2.94)
C.D.(0.05) for N	5.9	(2.94)
C.D.(0.05) for FA	NS	(4.16)
C.D.(0.05) for FN	NS	(4.16)
C.D.(0.05) for AN	NS	(5.09)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

The age of seedling did not exhibit any significant effect on the number of filled grains.

Planting 4 seedlings per hill gave more number of filled grains per panicle in three seasons and it was significantly superior to others in virippu season of the year. It was comparable with 6 seedlings per hill in two seasons. However, in mundakan season of 1982, 6 seedlings per hill gave more grains per panicle eventhough it was comparable with 4 seedlings per hill. Two seedlings per hill produced significantly inferior number of filled grains per panicle in three out of four seasons and lower numbers in the fourth season. Thus from the result it can be reasoned out that 4 seedlings per hill are optimum for obtaining sufficient number of filled grains per panicle.

A perusal of the data on LAI (Table 29 a, b, c & d) shows that 4 seedlings per hill gave higher LAI in most of the seasons. The source available for photosynthesis is decided by the LAI. The same treatment is found to be favouring the highest number of panicles as well as number of filled grains per panicle. Similar relationship with the photosynthesising surface area of the plant with productive attributes such as panicle number and grains per panicle are reported by Tanaka (1972).

It may be further noticed that under a limited supply of nutrition there is an optimum number of seedlings which can produce a definite number of panicles as well as number of filled grains per panicle. An increase in the seedling number does not proportionately increase the panicle number or grains per panicle probably because fertility is the limiting factor there. A lower number of seedlings is definitely inferior since under this limited fertility conditions sufficient panicle production as well as number of grains per panicle cannot be ensured.

2.3. 1000 Grain weight

The results of the data on 1000 grain weight (Table 33 a, b, c & d) show that the fertilizer levels, age of seedlings and number of seedlings could not influence the thousand grain weight in most of the seasons.

Thousand grain weight, generally regarded as a varietal character is not influenced by agronomic attributes such as number, age of seedlings etc. Even the fertilizer application has been reported to be effective only upto a particular level. Further, in the present investigation, the difference in fertilizer levels tried

Table 33 a. Thousand grain weight (g) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	20.73	20.74	20.81	21.12	20.47	20.67	20.76
F_2	(75)	20.29	20.74	21.23	20.37	20.84	21.08	20.76
Mean		20.51	20.74	21.02	20.75	20.66	20.88	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	20.65	20.13	20.76	20.51
A_2	30	20.59	20.81	20.83	20.74
A_3	35	21.00	21.03	21.03	21.02
Mean		20.75	20.66	20.88	

C.D.(0.05) for F NS (0.157)
C.D.(0.05) for A 0.392 (0.193)
C.D.(0.05) for N NS (0.193)
C.D.(0.05) for FA NS (0.272)
C.D.(0.05) for FN 0.554 (0.272)
C.D.(0.05) for AN NS (0.333)

Table 33 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	20.36	21.33	20.98	21.28	20.52	20.87	20.89
F_2	(100)	21.16	21.07	21.33	20.98	21.27	21.31	21.19
Mean		20.76	21.20	21.16	21.13	20.89	21.09	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	21.05	20.33	20.88	20.76
A_2	30	21.32	21.10	21.18	21.20
A_3	35	21.02	21.25	21.20	21.16
Mean		21.13	20.89	21.09	

C.D.(0.05) for F NS (0.164)
C.D.(0.05) for A NS (0.202)
C.D.(0.05) for N NS (0.202)
C.D.(0.05) for FA 0.579 (0.285)
C.D.(0.05) for FN 0.579 (0.285)
C.D.(0.05) for AN NS (0.349)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 33 c. Thousand grain weight (g) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	20.16	21.23	20.59	20.54	20.96	20.47	20.66
F_2	(75)	20.84	20.77	20.54	20.97	20.36	20.82	20.72
Mean		20.50	21.00	20.56	20.76	20.66	20.64	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	20.70	20.58	20.22	20.50
A_2	30	20.93	21.01	21.06	21.00
A_3	35	20.64	20.40	20.65	20.56
Mean		20.76	20.66	20.64	

C.D.(0.05) for F	NS	(0.169)
C.D.(0.05) for A	0.421	(0.207)
C.D.(0.05) for N	NS	(0.207)
C.D.(0.05) for FA	0.595	(0.292)
C.D.(0.05) for FN	0.595	(0.292)
C.D.(0.05) for AN	NS	(0.358)

Table 33 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	20.62	20.98	20.84	21.08	20.80	20.57	20.81
F_2	(100)	21.53	21.57	21.18	21.53	21.27	21.48	21.43
Mean		21.08	21.27	21.01	21.31	21.03	21.02	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	21.23	20.97	21.03	21.08
A_2	30	21.35	21.30	21.17	21.27
A_3	35	21.33	20.83	20.87	21.01
Mean		21.31	21.03	21.02	

C.D.(0.05) for F	0.421	(0.207)
C.D.(0.05) for A	NS	(0.253)
C.D.(0.05) for N	NS	(0.253)
C.D.(0.05) for FA	NS	(0.358)
C.D.(0.05) for FN	NS	(0.358)
C.D.(0.05) for AN	NS	(0.439)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

was only by 25 per cent and hence not much difference in 1000 grain weight could be expected.

3. Grain yield

The highest level of fertilizer recorded more grain yield in all the four seasons (Table 34 a, b, c and d). Thirty five days old seedlings recorded the highest grain yield while 25 days old seedlings produced the lowest grain yield in *virippu* in both years (Fig.7) even though in the second year it was not significant. In contrast, in *mundakan* more grain yield was associated with 30 days old seedlings (Fig.8). The number of seedlings is also a crucial factor in deciding the yield. Two seedlings per hill recorded the lowest grain yield in all the four seasons. During the first year in both the seasons the highest number of six seedlings produced more grain yield while in the second year four seedlings per hill topped in grain production. The combination did not show a definite trend.

Eventhough IR 42 is a low fertilizer responsive variety, the dose of fertilizer applied is only 90:45:45 kg

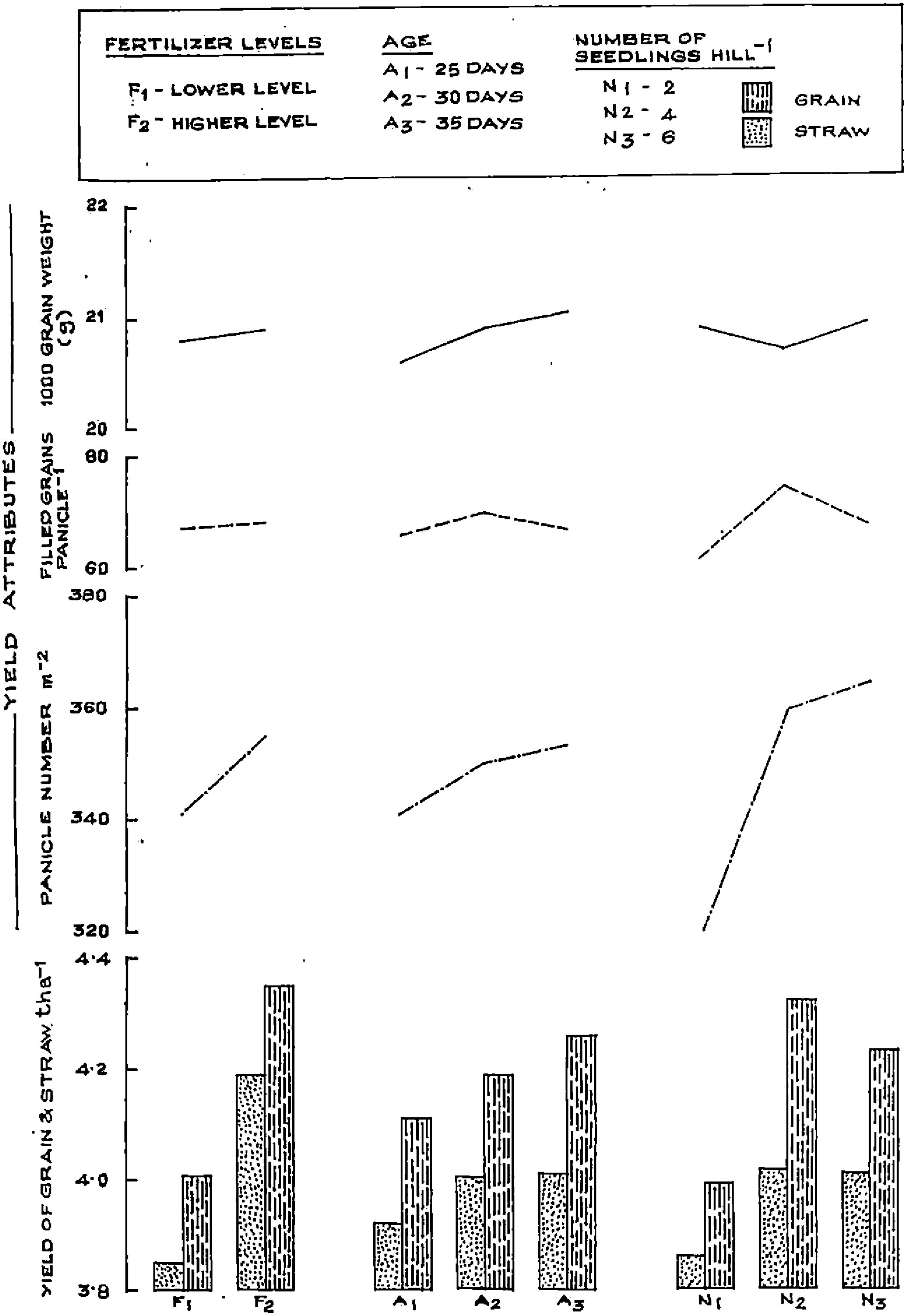


FIG. 7. YIELD OF GRAIN, STRAW AND YIELD ATTRIBUTES AS INFLUENCED BY FERTILIZER LEVELS, AGE AND NUMBER OF SEEDLINGS HILL^{-1} IN VIRIPPU SEASON (1982 & 1983).

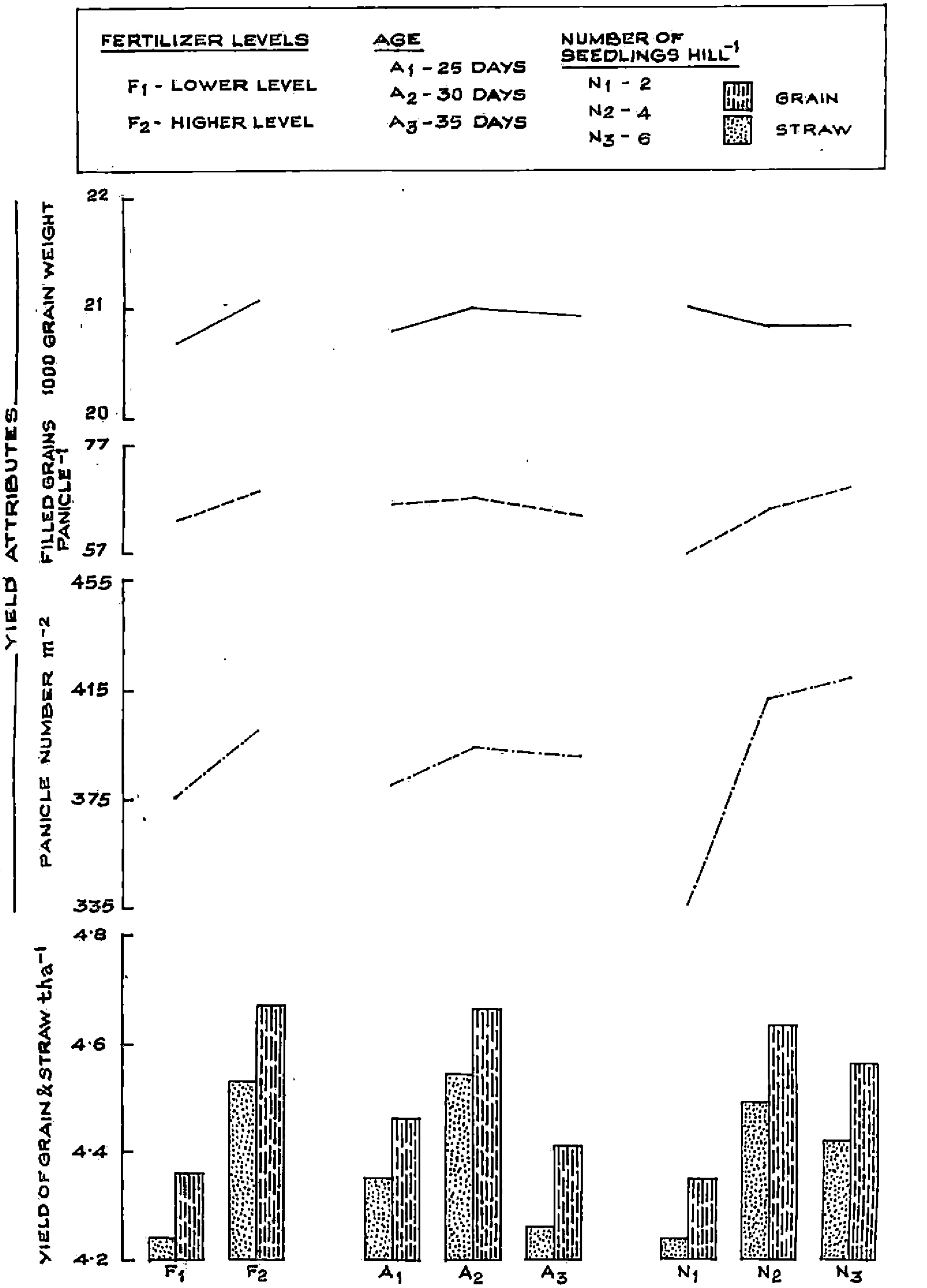


FIG. 8. YIELD OF GRAIN, STRAW AND YIELD ATTRIBUTES AS INFLUENCED BY FERTILIZER LEVELS, AGE AND NUMBER OF SEEDLINGS HILL^{-1} IN MUNDAKAN SEASON (1982 + 1983).

Table 34 a. Grain yield (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	3359	3583	3629	3382	3488	3701	3524
F_2	(75)	3709	3891	4015	3694	3949	3973	3872
Mean		3534	3737	3822	3538	3718	3837	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	3455	3562	3585	3534
A_2	30	3669	3838	3704	3737
A_3	35	3490	3755	4222	3822
Mean		3538	3718	3837	

C.D.(0.05) for F	155.2	(76.2)
C.D.(0.05) for A	190.1	(93.5)
C.D.(0.05) for N	190.1	(93.6)
C.D.(0.05) for FA	NS	(132.2)
C.D.(0.05) for FN	NS	(132.2)
C.D.(0.05) for AN	329.3	(161.9)

Table 34 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	4172	4140	4218	4020	4331	4179	4177
F_2	(100)	4460	4576	4508	4348	4800	4396	4515
Mean		4316	4358	4363	4184	4566	4287	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	4281	4509	4158	4316
A_2	30	4172	4610	4292	4358
A_3	35	4100	4578	4412	4363
Mean		4184	4566	4287	

C.D.(0.05) for F	124.4	(61.2)
C.D.(0.05) for A	NS	(74.9)
C.D.(0.05) for N	152.4	(74.9)
C.D.(0.05) for FA	NS	(105.9)
C.D.(0.05) for FN	NS	(105.9)
C.D.(0.05) for AN	NS	(129.8)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 34 c. Grain yield (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	3420	3673	3343	3360	3541	3535	3479
F_2	(75)	3559	3983	3610	3610	3751	3791	3717
Mean		3490	3828	3477	3485	3646	3663	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	3390	3546	3533	3490
A_2	30	3746	3995	3743	3828
A_3	35	3319	3397	3714	3477
Mean		3485	3646	3663	

C.D.(0.05)	for F	73.2	(36.0)
C.D.(0.05)	for A	89.7	(44.1)
C.D.(0.05)	for N	89.7	(44.1)
C.D.(0.05)	for FA	NS	(62.3)
C.D.(0.05)	for FN	NS	(62.3)
C.D.(0.05)	for AN	155.4	(76.4)

Table 34 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	5089	5039	4915	4828	5180	5035	5014
F_2	(100)	5362	5474	5188	5168	5516	5342	5342
Mean		5226	5257	5052	4998	5348	5188	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	5025	5273	5379	5226
A_2	30	5068	5497	5205	5257
A_3	35	4901	5274	4981	5052
Mean		4998	5348	5188	

C.D.(0.05)	for F	110.0	(54.1)
C.D.(0.05)	for A	134.3	(65.9)
C.D.(0.05)	for N	134.3	(65.9)
C.D.(0.05)	for FA	NS	(93.4)
C.D.(0.05)	for FN	NS	(93.4)
C.D.(0.05)	for AN	NS	(114.6)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

NPK ha^{-1} which is far below the optimum. Even in such a lower dose of fertilizer, it has given a grain yield of 4.5 to 5.3 t ha^{-1}. It is further noticed that at 50 per cent of the recommended dose of fertilizer i.e. with 45: 22.5: 22.5 kg NPK ha^{-1}, the grain yield varied from 3.48 to 3.52 t ha^{-1}. This highlights the adaptability of this variety under low levels of fertilizers. The suitability of this variety under low levels of fertility was reported earlier (IRRI, 1978; 1979a; Khush et al., 1979, Ponnamperuma, 1979).

The grain yield is related to the performance of the yield attributes by the respective treatments. The number of panicles m^{-2} (Table 33 a, b, c & d) showed that the youngest seedlings (25 days old) produced the lowest number. Thirty five days old seedlings produced more number of panicles m^{-2} in virippu season of the second year. During the same season of the first year, 35 and 30 days old seedlings were comparable. In mundakan season of the first year 30 and 35 days old seedlings produced more number of panicles m^{-2}. With respect to 1000 grain weight, highest value was observed in 35 days old seedlings in virippu and 30 days old seedlings in mundakan. This variety being a late maturity one (140-145 days) planting 35 days old seedlings is better during virippu while 30 days old seedlings performed better in mundakan. This is because during mundakan the duration of the crop is lesser and as such the vegetative growth period especially for tiller production is reduced and hence younger seedlings are preferred.

The difference in the fertilizer dose given might be the responsible factor for the differential response of the number of seedlings noticed.

It is further evident from the number of filled grains per panicle (Table 32 a, b, c & d) that six seedlings per hill gave more number of filled grains in mundakan season of the first year while four seedlings per hill produced higher number of filled grains in both seasons of the second year. During mundakan season of the first year, six seedlings per hill recorded more filled grains per panicle while in the second year almost the same number of filled grains was produced by four seedlings per hill. This shows that the available photosynthates were distributed uniformly among all the panicles in the first year even with a low level of fertilizer dose. This again indicates the adaptation of the variety to lower fertility conditions wherein every panicle was made to produce maximum number of grains in a hill which received the highest number of seedlings (Khush et al., 1979; Ponnamperuma, 1979).

4. Straw yield kg ha^{-1}

Higher level of fertilizer recorded more straw yield in virippu and mundakan seasons of both years and it was significantly superior to the lower levels tried (Table 35 a, b, c & d).

It may be seen from the results of tiller production (Table 27 a, b, c & d and 28 a, b, c & d) and LAI (Table 29 a, b, c & d) that these two characters which are directly contributing for straw yield have given higher values than the lower fertilizer dose thereby resulting in higher straw production. It may be pointed out in this connection that the recommended dose of fertilizer is 90: 45: 45 kg NPK ha^{-1} and the major component is N. The influence of N in enhancing the vegetative growth is well known.

During virippu season of the first year 35 days old seedlings gave higher straw yield than others and was comparable with 30 days old seedlings. In the second year also 35 days old seedlings gave more straw production though

Table 35 a. Straw yield (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	3545	3765	3810	3522	3707	3890	3707.
F_2 (75)	3890	4004	4158	3797	4135	4119	4017
Mean	3717	3884	3984	3660	3921	4005	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	3585	3813	3754	3717
A_2	30	3783	4000	3870	3884
A_3	35	3611	3950	4391	3984
Mean		3660	3921	4005	

C.D.(0.05)	for F	156.0	(76.7)
C.D.(0.05)	for A	191.1	(93.9)
C.D.(0.05)	for N	191.1	(93.9)
C.D.(0.05)	for FA	NS	(132.9)
C.D.(0.05)	for FN	NS	(132.9)
C.D.(0.05)	for AN	331.1	'162.7)

Table 35 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	4336	4291	4371	4170	4487	4342	4333
F_2 (100)	4661	4714	4703	4501	4973	4605	4693
Mean	4499	4502	4537	4336	4730	4473	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	4422	4700	4376	4499
A_2	30	4292	4757	4458	4502
A_3	35	4294	4733	4586	4537
Mean		4336	4730	4473	

C.D.(0.05)	for F	124.1	(61.0)
C.D.(0.05)	for A	NS	(74.7)
C.D.(0.05)	for N	152.0	(74.7)
C.D.(0.05)	for FA	NS	(105.7)
C.D.(0.05)	for FN	NS	(105.7)
C.D.(0.05)	for AN	NS	(129.5)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 35 c. Straw yield (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	3549	3766	3492	3473	3661	3672	3602
F_2 (75)	3646	4099	3772	3715	3900	3902	3839
Mean	3597	3932	3632	3594	3781	3787	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	3467	3682	3642	3597
A_2 30	3838	4093	3866	3932
A_3 35	3477	3567	3853	3632
Mean	3594	3781	3787	

C.D.(0.05) for F	80.6	(39.6)
C.D.(0.05) for A	98.8	(48.5)
C.D.(0.05) for N	98.8	(48.5)
C.D.(0.05) for FA	NS	(68.7)
C.D.(0.05) for FN	NS	(68.7)
C.D.(0.05) for AN	171.2	(84.1)

Table 35 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	5202	5169	5023	4942	5287	5165	5131
F_2 (100)	5478	5639	5382	5284	5686	5528	5500
Mean	5340	5404	5203	5113	5487	5347	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	5098	5389	5532	5340
A_2 30	5168	5648	5396	5404
A_3 35	5073	5423	5112	5203
Mean	5113	5487	5347	

C.D.(0.05) for F	116.0	(57.0)
C.D.(0.05) for A	142.1	(69.8)
C.D.(0.05) for N	142.1	(69.8)
C.D.(0.05) for FA	NS	(98.8)
C.D.(0.05) for FN	NS	(98.8)
C.D.(0.05) for AN	NS	(121.08)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

not significant, in *virippu*. But in *mundakan* 30 days old seedlings produced more straw in both years. A perusal of the data on tiller production shows that during *mundakan* in both years, 30 days old seedlings gave the highest tiller number. The reason for increasing the tiller production by this treatment was discussed elsewhere. In the case of height also, 30 days old seedlings have recorded taller plants in *mundakan* season in the first year while in the second year it was similar to 25 days old seedlings which produced taller plants.

So from the point of view of straw production it may be pointed out that in *virippu*, 35 days old seedlings and in the *mundakan*, 30 days old seedlings are the best.

Data on LAI (Table 29 a, b, c & d) and tiller number (Table 27 a, b, c & d and 28 a, b, c & d) have already indicated that four and six seedlings were comparable in most cases. In the straw yield also, almost the same trend is noticed in most of the seasons.

The combination effect was significant only in *virippu* season of the first year. No definite trend could be noticed in other seasons.

5. Harvest index (HI)

HI was unaffected by the treatments in all seasons except *virippu* season of the first year (Table 36 a, b,c & d).

The difference between fertilizer level tried was only 25 per cent in both years. Within that narrow range, there is a corresponding increase in both grain and straw yield with increase in fertilizer doses thereby resulting in the lack of significant difference in HI.

In the case of grain yield during the *virippu* season 35 days old seedlings gave the highest value while 30 days old seedlings in the *mundakan* season. With respect to straw yield as well, the same trend was observed. An increase in grain yield was followed by a corresponding increase in straw yield. Hence it is quite natural that a significant increase in HI is not obtained.

The number of seedlings per hill also followed the same trend as that of the above two characters. IR 42 being a high tillering variety, has the inherent capacity to adapt to varying plant densities. Baba (1959) and Yoshida and Cock (1971) have stressed the adaptability of high tillering genotypes to varying plant densities. Hence for the levels of fertilizer tried no drastic change in grain straw ratio is expected.

Table 36 a. Harvest index (HI) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	48.76	48.65	48.73	48.98	48.44	48.73	48.71
F_2	(75)	49.28	48.82	49.13	49.30	48.83	49.10	49.08
Mean		49.02	48.73	48.93	49.14	48.63	48.92	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	49.24	48.93	48.89	49.02
A_2	30	49.07	48.30	48.83	48.73
A_3	35	49.10	48.67	49.02	48.93
Mean		49.14	48.63	48.92	

C.D.(0.05) for F	0.278	(0.136)
C.D.(0.05) for A	NS	(0.167)
C.D.(0.05) for N	0.340	(0.167)
C.D.(0.05) for FA	NS	(0.236)
C.D.(0.05) for FN	NS	(0.236)
C.D.(0.05) for AN	NS	(0.289)

Table 36 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	49.10	49.02	49.10	49.07	49.11	49.03	49.07
F_2	(100)	49.25	48.88	49.92	49.14	49.10	48.82	49.02
Mean		49.18	48.95	49.01	49.11	49.11	48.93	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	49.29	49.21	49.03	49.18
A_2	30	49.18	48.96	48.72	48.95
A_3	35	48.85	49.15	49.03	49.01
Mean		49.11	49.11	48.93	

C.D.(0.05) for F	NS	(0.080)
C.D.(0.05) for A	NS	(0.097)
C.D.(0.05) for N	NS	(0.097)
C.D.(0.05) for FA	NS	(0.138)
C.D.(0.05) for FN	NS	(0.138)
C.D.(0.05) for AN	NS	(0.169)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 36 c. Harvest index (HI) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	49.07	49.37	48.90	49.17	49.13	49.05	49.11
F_2 (75)	49.25	49.28	48.89	49.27	49.01	49.13	49.14
Mean	49.16	49.32	48.89	49.22	49.07	49.09	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	49.43	49.05	49.01	49.16
A_2 30	49.39	49.39	49.19	49.32
A_3 35	48.84	48.77	49.08	48.89
Mean	49.22	49.07	49.09	

C.D.(0.05) for F NS (0.094)
C.D.(0.05) for A 0.236 (0.116)
C.D.(0.05) for N NS (0.116)
C.D.(0.05) for FA NS (0.164)
C.D.(0.05) for FN NS (0.164)
C.D.(0.05) for AN NS (0.201)

Table 36 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	49.45	49.33	49.45	49.41	49.46	49.36	49.41
F_2 (100)	49.47	49.24	49.08	49.41	49.25	49.13	49.26
Mean	49.46	49.29	49.26	49.41	49.35	49.25	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	49.63	49.45	49.30	49.46
A_2 30	49.47	49.30	49.09	49.29
A_3 35	49.13	49.31	49.35	49.26
Mean	49.41	49.35	49.25	

C.D.(0.05) for F NS (0.081)
C.D.(0.05) for A NS (0.099)
C.D.(0.05) for N NS (0.099)
C.D.(0.05) for FA NS (0.140)
C.D.(0.05) for FN NS (0.140)
C.D.(0.05) for AN NS (0.172)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

G. Chemical analysis

1. Plant analysis

1.1 Protein content of grain

Maximum level of fertilizer has given the highest protein content in all the four seasons (Table 37 a, b, c & d). Generally in cereals, the protein content is low and the transformation of carbohydrates to protein take place after attaining a certain level of carbohydrate production. An increase in protein content beyond a certain level of N was generally followed by a decline in grain yield (IRRI, 1974). This explains the reason for lower protein content in treatments receiving low fertilizer doses particularly N. Bicknell et al. (1972) and Singh and Modgal (1978) reported higher protein content with increased rate of N application.

Protein content was found to be unaffected by different age levels tried in all the four seasons. Protein content is more or less a genetic factor influenced by nutrition only to a certain extent.

Higher number of seedlings produced more protein content in all the seasons. Under low fertility condition both grain and straw yields were increased with six seedlings per hill and the applied fertilizer would have

Table 37 a. Protein content of grain (%) as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days) A1 25	A2 30	A3 35	Number of seedlings hill^{-1} N1 2	N2 4	N3 6	Mean
F_1 (50)	8.6	8.6	8.5	8.2	8.7	8.9	8.6
F_2 (75)	8.9	9.1	9.4	8.9	9.4	9.2	9.2
Mean	8.8	8.9	9.0	8.5	9.1	9.1	

Age (Days)		Number of seedlings hill^{-1} N1 2	N2 4	N3 6	Mean
A_1	25	8.4	9.0	8.9	8.8
A_2	30	8.3	9.0	9.3	8.9
A_3	35	8.8	9.2	8.9	9.0
Mean		8.5	9.1	9.1	

C.D.(0.05) for F	0.21	(0.103)
C.D.(0.05) for A	NS	(0.126)
C.D.(0.05) for N	0.26	(0.126)
C.D.(0.05) for FA	NS	(0.178)
C.D.(0.05) for FN	NS	(0.178)
C.D.(0.05) for AN	NS	(0.219)

Table 37 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days) A1 25	A2 30	A3 35	Number of seedlings hill^{-1} N1 2	N2 4	N3 6	Mean
F_1 (75)	8.2	8.3	8.3	7.9	8.4	8.5	8.3
F_2 (100)	8.4	8.8	8.8	8.2	8.9	8.9	8.7
Mean	8.3	8.5	8.5	8.0	8.7	8.7	

Age (Days)		Number of seedlings hill^{-1} N1 2	N2 4	N3 6	Mean
A_1	25	8.0	8.5	8.5	8.3
A_2	30	8.1	8.7	8.8	8.5
A_3	35	8.0	8.9	8.7	8.5
Mean		8.0	8.7	8.7	

C.D.(0.05) for F	0.20	(0.098)
C.D.(0.05) for A	NS	(0.118)
C.D.(0.05) for N	0.24	(0.118)
C.D.(0.05) for FA	NS	(0.165)
C.D.(0.05) for FN	NS	(0.165)
C.D.(0.05) for AN	NS	(0.203)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 37 c. Protein content of grain (%) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	8.4	8.3	8.4	8.1	8.5	8.5	8.4
F_2 (75)	8.6	8.6	8.8	8.4	8.9	8.8	8.7
Mean	8.5	8.5	8.6	8.3	8.7	8.6	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	8.3	8.5	8.6	8.5
A_2 30	8.2	8.7	8.5	8.5
A_3 35	8.3	8.8	8.7	8.6
Mean	8.3	8.7	8.6	

C.D.(0.05) for F	0.16	(0.078)
C.D.(0.05) for A	NS	(0.095)
C.D.(0.05) for N	0.20	(0.095)
C.D.(0.05) for FA	NS	(0.135)
C.D.(0.05) for FN	NS	(0.135)
C.D.(0.05) for AN	NS	(0.166)

Table 37 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	8.3	8.6	8.3	8.2	8.4	8.5	8.4
F_2 (100)	8.4	8.7	8.9	8.3	9.1	8.6	8.7
Mean	8.3	8.6	8.6	8.3	8.7	8.6	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	8.2	8.4	8.4	8.3
A_2 30	8.3	8.9	8.7	8.6
A_3 35	8.4	8.9	8.5	8.6
Mean	8.3	8.7	8.6	

C.D.(0.05) for F	0.21	(0.103)
C.D.(0.05) for A	NS	(0.127)
C.D.(0.05) for N	0.26	(0.127)
C.D.(0.05) for FA	NS	(0.182)
C.D.(0.05) for FN	0.37	(0.182)
C.D.(0.05) for AN	NS	(0.220)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

been first utilized for grain and straw production. Consequently, no significant difference could be noticed in the protein content between the two higher levels i.e. four and six seedlings per hill. In the second year four seedlings per hill gave more grain and straw yield. It is attributed to the higher level of fertilization in the second year. The higher dose of fertilizer application favoured the grain and straw production and no excess nutrition was usually available to increase the protein content thus resulting in the lack of significant difference between four and six seedlings per hill.

In both years higher number of seedlings gave more protein. In the first year six seedlings per hill with low fertilization produced more protein while during the second year the highest protein content was produced by four seedlings per hill with the application of more fertilizer compared to the first year. This shows the efficiency of four seedlings $hill^{-1}$ in producing more grain yield as well as synthesis of more protein compared to planting six seedlings $hill^{-1}$.

1.2 <u>N uptake</u>

The data on the uptake of N (Table 38 a, b, c & d) reveal the superiority of higher levels of fertilizer in all the seasons.

Table 38 a. [illegible] uptake (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	67.37	72.52	72.78	63.56	71.84	77.27	70.89
F_2	(75)	78.61	83.64	88.32	76.90	87.26	86.42	83.53
Mean		72.99	78.08	80.55	70.23	79.55	81.85	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	67.11	76.01	75.86	72.99
A_2	30	72.28	81.33	80.63	78.08
A_3	35	71.29	81.31	89.05	80.55
Mean		70.23	79.55	81.85	

C.D.(0.05) for F	3.336	(1.640)
C.D.(0.05) for A	4.086	(2.009)
C.D.(0.05) for N	4.086	(2.009)
C.D.(0.05) for FA	NS	(2.841)
C.D.(0.05) for AN	NS	(2.841)
C.D.(0.05) for AN	NS	(3.480)

Table 38 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	80.80	82.82	83.27	75.05	86.94	84.90	82.30
F_2	(100)	92.54	92.81	94.69	84.41	101.46	94.18	93.35
Mean		86.67	87.82	88.98	79.73	94.20	89.54	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	78.61	92.41	89.00	86.67
A_2	30	81.88	94.00	87.58	87.82
A_3	35	78.71	96.18	92.04	88.98
Mean		79.73	94.20	89.54	

C.D.(0.05) for F	3.278	(1.612)
C.D.(0.05) for A	NS	(1.973)
C.D.(0.05) for N	4.014	(1.973)
C.D.(0.05) for FA	NS	(2.791)
C.D.(0.05) for FN	NS	(2.791)
C.D.(0.05) for AN	NS	(3.419)

* 90: 45:45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 38 c. ··· N . uptake (kg ha^{-1}) as influenced by fertilizerl levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	67.66	72.03	66.98	63.92	70.98	71.76	68.89
F_2	(75)	72.03	82.21	75.71	71.29	79.29	79.37	76.65
Mean		69.84	77.12	71.35	67.61	75.13	75.57	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	65.70	71.44	72.39	69.84
A_2	30	72.31	82.33	76.71	77.12
A_3	35	64.81	71.63	77.60	71.35
Mean		67.61	75.13	75.57	

C.D.(0.05) for F	1.900	(0.934)
C.D.(0.05) for A	2.327	(1.144)
C.D.(0.05) for N	2.327	(1.144)
C.D.(0.05) for FA	3.291	(1.618)
C.D.(0.05) for FN	NS	(1.618)
C.D.(0.05) for AN	4.031	(1.982)

Table 38 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	99.95	102.06	97.35	92.63	104.25	102.47	99.78
F_2	(100)	106.21	113.29	109.08	101.16	107.83	109.59	109.53
Mean		103.08	107.67	103.21	96.89	111.04	106.03	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	96.14	105.15	108.95	103.08
A_2	30	98.66	116.09	108.26	107.67
A_3	35	95.87	112.89	102.87	103.21
Mean		96.89	111.04	106.03	

C.D.(0.05) for F	2.250	(1.110)
C.D.(0.05) for A	2.756	(1.358)
C.D.(0.05) for N	2.756	(1.358)
C.D.(0.05) for FA	NS	(1.915)
C.D.(0.05) for FN	NS	(1.915)
C.D.(0.05) for AN	4.773	(2.346)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Thirtyfive days old seedlings were found to be better for *virippu* and 30 days old seedlings for *mundakan* with respect to the uptake of N.

Planting six seedlings per hill was better in the first year while four seedlings per hill in the second year.

On perusal of the data on grain and straw yield (Tables 34 a, b, c & d and 35 a, b, c & d) it is seen that higher level of fertilizer was giving better yield of both grain and straw. This has probably led to higher uptake of N in the higher level of fertilizer.

N uptake was higher in older seedlings (30 and 35 days old) when compared to 25 days old seedlings. Maximum utilization of nutrients starts immediately after the establishment of seedlings. In the older seedlings, the wastage of fertilizer is lesser due to the well developed root system. Between seasons, 30 days old seedlings were better suited for mundakan while 35 days old seedlings seem to be ideal for *virippu* season. As the duration of the crop is lesser in *mundakan*, slightly younger seedlings are to be preferred for achieving maximum vegetative growth. Twentyfive days old seedlings are inferior in all the seasons.

Planting two seedlings per hill was definitely inferior to planting four and six seedlings. This is because as the number of seedlings is more, higher will be the foraging capacity and hence an increased uptake. Lesser number of seedlings probably need more time to attain the same dry matter production as that of the higher number of seedlings.

1.3 P Uptake

Almost the same trend of N is obtained in the uptake of P also. Higher dose of fertilizer gave more uptake, irrespective of the seasons (Table 39 a, b, c & d).

Twentyfive days old seedlings gave significantly lesser uptake of P in all seasons except mundakan season of the second year.

Four and six seedlings were similar and were superior to two seedlings per hill in all seasons.

The above results reveal that higher P uptake was associated with higher levels of fertilization which naturally received more P. Moreover, the grain and straw yield were also more with higher levels of fertilizers.

The higher P uptake in older seedlings might be due to the better absorption of P by more efficient root system of the older seedlings.

Table 39 a. P uptake (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	27.98	31.33	31.05	27.33	30.37	32.67	30.12
F_2	(75)	33.89	35.31	39.27	32.60	37.70	38.18	34.16
Mean		30.94	33.32	35.16	29.97	34.03	35.42	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	29.20	31.58	32.03	30.94
A_2	30	30.05	35.00	34.93	33.32
A_3	35	30.65	35.52	39.31	35.16
Mean		29.97	34.03	35.42	

C.D.(0.05) for F	1.718	(0.845)
C.D.(0.05) for A	2.104	(1.034)
C.D.(0.05) for N	2.104	(1.034)
C.D.(0.05) for FA	NS	(1.463)
C.D.(0.05) for FN	NS	(1.466)
C.D.(0.05) for AN	NS	(1.792)

Table 39 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	33.28	35.42	35.56	30.83	36.63	36.80	34.76
F_2	(100)	37.93	39.38	40.99	34.46	43.07	40.77	39.43
Mean		35.60	37.40	38.28	32.64	39.85	38.79	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	31.44	38.30	37.07	35.60
A_2	30	33.95	39.76	38.49	37.40
A_3	35	32.54	41.50	40.80	38.28
Mean		32.64	39.85	38.79	

C.D.(0.05) for F	1.366	(0.671)
C.D.(0.05) for A	1.673	(0.823)
C.D.(0.05) for N	1.673	(0.823)
C.D.(0.05) for FA	NS	(1.163)
C.D.(0.05) for FN	NS	(1.163)
C.D.(0.05) for AN	NS	(1.425)

* 90: 45:45 Kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 39 c. P uptake (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	24.54	27.54	24.77	22.89	26.84	27.12	25.62
F_2 (75)	26.62	31.41	27.87	25.83	30.14	29.73	28.57
Mean	25.58	29.47	26.22	24.36	28.49	28.43	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	23.33	26.48	26.95	25.58
A_2 30	27.28	31.94	29.19	29.47
A_3 35	22.47	27.05	29.14	26.22
Mean	24.36	28.49	28.43	

C.D.(0.05) for F	1.036	(0.500)
C.D.(0.05) for A	1.269	(0.624)
C.D.(0.05) for N	1.269	(0.624)
C.D.(0.05) for FA	NS	(0.882)
C.D.(0.05) for FN	NS	(0.882)
C.D.(0.05) for AN	2.199	(1.081)

Table 39 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	43.54	42.94	42.14	37.63	45.55	45.44	42.87
F_2 (100)	46.86	49.20	47.17	44.41	50.07	48.73	47.74
Mean	45.20	46.07	44.66	41.02	47.81	47.09	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	41.18	47.09	47.33	45.20
A_2 30	41.45	49.30	47.45	46.07
A_3 35	40.44	47.04	46.49	44.66
Mean	41.02	47.81	47.09	

C.D.(0.05) for F	0.861	(0.423)
C.D.(0.05) for A	1.055	(0.521)
C.D.(0.05) for N	1.055	(0.521)
C.D.(0.05) for FA	1.492	(0.733)
C.D.(0.05) for FN	1.492	(0.733)
C.D.(0.05) for AN	NS	(0.900)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Higher the number of seedlings per hill better the nutrient absorption as the total foraging capacity of roots are more.

1.4 K uptake

The data on K uptake (Table 40 a, b, c & d) show that higher level of fertilizer is giving higher values of K uptake.

Though age levels showed significant effect only in two seasons of the first year, youngest seedlings (25 days old) gave the lowest values in three reasons out of four. Planting two seedlings per hill was always inferior to four and six seedlings per hill.

From the above results, it is seen that higher the fertilizer level, more the uptake of K because at thės level of fertilization more K is applied. Further, the grain and straw yield also were more at higher fertilizer level. Lowest K uptake was observed in two seedlings per hill. Both grain and straw yields were also lowest with two seedlings per hill.

Table 40 a. K uptake (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	87.19	92.64	94.27	86.60	91.60	95.90	91.36
F_2	(75)	94.69	92.21	103.04	92.04	97.77	100.12	96.65
Mean		90.94	92.43	98.65	89.32	94.69	98.01	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	84.46	93.23	95.12	90.94
A_2	30	93.52	95.67	88.10	92.43
A_3	35	89.99	95.16	110.80	98.65
Mean		89.32	94.69	98.01	

C.D.(0.05) for F	4.941	(2.429)
C.D.(0.05) for A	6.051	(2.975)
C.D.(0.05) for N	6.051	(2.975)
C.D.(0.05) for FA	NS	(4.208)
C.D.(0.05) for FN	NS	(4.208)
C.D.(0.05) for AN	10.482	(5.154)

Table 40 b. Virippu 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	98.52	103.36	104.75	90.50	109.67	106.46	102.21
F_2	(100)	109.69	113.97	112.83	100.87	121.84	113.78	112.16
Mean		104.10	108.66	108.79	95.68	115.76	110.12	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	91.88	114.21	106.22	104.10
A_2	30	100.10	116.36	109.53	108.66
A_3	35	95.07	116.70	114.61	108.79
Mean		95.68	115.76	110.12	

C.D.(0.05) for F	4.212	(2.071)
C.D.(0.05) for A	NS	(2.537)
C.D.(0.05) for N	5.159	(2.537)
C.D.(0.05) for FA	NS	(3.587)
C.D.(0.05) for FN	NS	(3.587)
C.D.(0.05) for AN	NS	(4.393)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 40 c. K uptake (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	85.21	92.17	83.87	81.78	88.00	91.47	87.09
F_2	(75)	90.35	99.91	94.08	92.79	96.23	95.33	94.78
Mean		87.78	96.04	88.98	87.29	92.12	93.40	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	83.69	88.85	90.80	87.78
A_2	30	91.92	100.82	95.38	96.04
A_3	35	86.25	86.68	94.00	88.98
Mean		87.29	92.12	93.40	

C.D.(0.05)	for F	2.336	(1.148)
C.D.(0.05)	for A	2.861	(1.406)
C.D.(0.05)	for N	2.861	(1.406)
C.D.(0.05)	for FA	NS	(1.989)
C.D.(0.05)	for FN	NS	(1.989)
C.D.(0.05)	for AN	4.956	(2.437)

Table 40 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	120.65	122.68	118.21	106.14	128.47	126.93	120.51
F_2	(100)	136.13	139.33	131.05	126.22	143.39	136.90	135.50
Mean		128.39	131.00	124.63	116.18	135.93	131.91	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	117.92	132.38	134.87	128.39
A_2	30	116.44	142.73	133.85	131.00
A_3	35	114.20	132.68	127.02	124.63
Mean		116.18	135.93	131.91	

C.D.(0.05)	for F	4.748	(2.333)
C.D.(0.05)	for A	NS	(2.858)
C.D.(0.05)	for N	5.816	(2.858)
C.D.(0.05)	for FA	NS	(4.041)
C.D.(0.05)	for FN	NS	(4.041)
C.D.(0.05)	for AN	NS	(4.951)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

6.2 Soil analysis

2.1 Residual nutrient status of soil

The data on residual organic carbon, P and K content of soil after cropping (Tables 41 a, b, c & d, 42 a, b, c and d and 43 a, b, c and d) show that N, P and K contents of soil were affected by fertilizer treatments only. In all seasons higher level of fertilizer has resulted in better residual status of the above nutrients. This might be because at higher levels of fertilizer, N, P and K contents were also more.

Table 41 a. Residual organic carbon content of soil (%) as influenced by fertilizer, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	1.60	1.62	1.61	1.58	1.63	1.61	1.62
F_2 (75)	1.64	1.62	1.59	1.64	1.61	1.61	1.61
Mean	1.62	1.62	1.60	1.61	1.62	1.61	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	1.65	1.62	1.58	1.62
A_2 30	1.61	1.62	1.64	1.62
A_3 35	1.57	1.62	1.60	1.60
Mean	1.61	1.62	1.61	

C.D.(0.05) for F	NS	(0.041)
C.D.(0.05) for A	NS	(0.049)
C.D.(0.05) for N	NS	(0.049)
C.D.(0 05) for FA	NS	(0.070)
C.D.(0.05) for FN	NS	(0.070)
C.D.(0.05) for AN	NS	(0.086)

Table 41 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	1.51	1.52	1.50	1.52	1.52	1.50	1.51
F_2 (100)	1.66	1.67	1.64	1.64	1.66	1.66	1.65
Mean	1.58	1.60	1.57	1.58	1.59	1.58	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	1.58	1.61	1.56	1.58
A_2 30	1.60	1.59	1.60	1.60
A_3 35	1.56	1.57	1.58	1.57
Mean	1.58	1.59	1.58	

C.D.(0.05) for F	0.069	(0.034)
C.D.(0.05) for A	NS	(0.042)
C.D.(0.05) for N	NS	(0.042)
C.D.(0.05) for FA	NS	(0.059)
C.D.(0.05) for FN	NS	(0.059)
C.D.(0.05) for AN	NS	(0.072)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 41 c. Residual organic carbon content of soil (%) as influenced by fertilizer, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	1.53	1.51	1.54	1.54	1.52	1.52	1.53
F_2 (75)	1.69	1.67	1.62	1.68	1.66	1.64	1.66
Mean	1.61	1.59	1.58	1.61	1.59	1.58	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	1.63	1.61	1.60	1.61
A_2	30	1.62	1.57	1.57	1.59
A_3	35	1.59	1.59	1.57	1.58
Mean		1.61	1.59	1.58	

C.D. (0.05) for F	0.060	(0.029)
C.D. (0.05) for A	NS	(0.035)
C.D. (0.05) for N	NS	(0.035)
C.D. (0.05) for FA	NS	(0.051)
C.D. (0.05) for FN	NS	(0.051)
C.D. (0.05) for AN	NS	(0.062)

Table 41 d. Mundakan 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	1.53	1.54	1.57	1.56	1.54	1.53	1.55
F_2 (100)	1.64	1.62	1.65	1.64	1.63	1.64	1.63
Mean	1.58	1.58	1.61	1.60	1.59	1.59	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	1.60	1.57	1.57	1.58
A_2	30	1.57	1.58	1.60	1.58
A_3	35	1.62	1.61	1.59	1.61
Mean		1.60	1.59	1.59	

C.D. (0.05) for F	0.040	(0.019)
C.D. (0.05) for A	NS	(0.024)
C.D. (0.05) for N	NS	(0.024)
C.D. (0.05) for FA	NS	(0.033)
C.D. (0.05) for FN	NS	(0.033)
C.D. (0.05) for AN	NS	(0.041)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 42 a. Residual P content of soil (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	15.50	15.35	15.76	15.88	15.50	15.22	15.53
F_2 (75)	19.08	19.13	17.73	18.63	18.60	18.75	18.65
Mean	17.29	17.24	16.75	17.25	17.05	16.97	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	17.52	17.34	17.01	17.29
A_2 30	17.42	17.33	16.97	17.24
A_3 35	16.83	16.48	16.94	16.75
Mean	17.25	17.05	16.97	

C.D.(0.05) for F	1.039	(0.511)
C.D.(0.05) for A	NS	(0.625)
C.D.(0.05) for N	NS	(0.625)
C.D.(0.05) for FA	NS	(0.885)
C.D.(0.05) for FN	NS	(0.885)
C.D.(0.05) for AN	NS	(1.083)

Table 42 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	16.10	15.33	14.54	15.12	15.35	15.50	15.32
F_2 (100)	19.08	19.47	18.91	19.62	19.31	18.53	19.15
Mean	17.59	17.40	16.72	17.37	17.33	17.02	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	17.41	17.13	18.22	17.59
A_2 30	17.72	18.11	16.37	17.40
A_3 35	16.98	16.73	16.46	16.72
Mean	17.37	17.33	17.02	

C.D.(0.05) for F	1.223	(0.601)
C.D.(0.05) for A	NS	(0.736)
C.D.(0.05) for N	NS	(0.736)
C.D.(0.05) for FA	NS	(1.041)
C.D.(0.05) for FN	NS	(1.041)
C.D. (0.05) for AN	NS	(1.275)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 42 c. Residual P content of soil (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	16.5	15.8	16.0	16.4	15.8	16.1	16.1
F_2	(75)	18.8	19.5	19.2	19.9	18.9	18.7	19.2
Mean		17.6	17.6	17.6	18.1	17.3	17.4	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	18.07	17.26	17.66	17.6
A_2	30	17.75	17.54	17.77	17.6
A_3	35	18.76	17.28	16.93	17.6
Mean		18.1	17.3	17.4	

C.D.(0.05) for F	1.225	(0.602)
C.D.(0.05) for A	NS	(0.737)
C.D.(0.05) for N	NS	(0.737)
C.D.(0.05) for FA	NS	(0.043)
C.D.(0.05) for FN	NS	(1.043)
C.D.(0.05) for AN	NS	(1.277)

Table 42 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings $hill^{-1}$			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	15.63	15.58	15.61	15.74	15.58	15.50	15.61
F_2	(100)	20.59	20.02	19.21	20.24	19.95	19.63	19.94
Mean		18.11	17.80	17.41	17.99	17.77	17.56	

Age (Days)		Number of seedlings $hill^{-1}$			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	18.47	17.92	17.94	18.11
A_2	30	17.80	18.05	17.57	17.80
A_3	35	17.69	17.35	17.19	17.41
Mean		17.99	17.77	17.56	

C.D.(0.05) for F	0.923	(0.452)
C.D.(0.05) for A	NS	(0.554)
C.D.(0.05) for N	NS	(0.554)
C.D.(0.05) for FA	NS	(0.784)
C.D.(0.05) for FN	NS	(0.784)
C.D.(0.05) for AN	NS	(0.960)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

Table 43 a. Residual K content of soil (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings $hill^{-1}$. Virippu 1982

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (50)	212	203	193	205	205	198	203
F_2 (75)	277	274	272	274	274	275	274
Mean	245	238	233	240	240	236	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	247	244	243	245
A_2 30	234	246	235	238
A_3 35	238	229	231	233
Mean	240	240	236	

C.D.(0.05) for F 14.8 (7.31)
C.D.(0.05) for A NS (8.95)
C.D.(0.05) for N NS (8.95)
C.D.(0.05) for FA NS (12.67)
C.D.(0.05) for FN NS (12.67)
C.D.(0.05) for AN NS (15.51)

Table 43 b. Virippu 1983

Fertilizer (% of recommended dose*)	Age (Days)			Number of seedlings $hill^{-1}$			Mean
	A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1 (75)	202	175	174	189	181	180	184
F_2 (100)	277	269	265	275	269	266	270
Mean	239	222	220	232	225	223	

Age (Days)	Number of seedlings $hill^{-1}$			Mean
	N_1 2	N_2 4	N_3 6	
A_1 25	248	238	232	239
A_2 30	227	220	219	222
A_3 35	223	218	218	220
Mean	232	225	223	

C.D.(0.05) for F 9.955 (4.895)
C.D.(0.05) for A NS (5.995)
C.D.(0.05) for N 12.192 (5.995)
C.D.(0.05) for FA NS (8.478)
C.D.(0.05) for FN NS (8.478)
C.D.(0.05) for AN NS (10.384)

* 90:45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 43 c. Residual K content of soil (kg ha^{-1}) as influenced by fertilizer levels, age and number of seedlings hill^{-1}. Mundakan 1982

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(50)	190	171	169	179	177	174	176
F_2	(75)	199	213	211	209	208	206	208
Mean		194	192	190	194	192	190	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	199	195	190	194
A_2	30	197	190	188	192
A_3	35	187	193	191	190
Mean		194	192	190	

C.D.(0.05) for F 10.2 (5.0)
C.D.(0.05) for A NS (6.2)
C.D.(0.05) for N NS (6.2)
C.D.(0.05) for FA 17.8 (8.7)
C.D.(0.05) for FN NS (8.7)
C.D.(0.05) for AN NS (10.7)

Table 43 d. Mundakan 1983

Fertilizer (% of recommended dose*)		Age (Days)			Number of seedlings hill^{-1}			Mean
		A_1 25	A_2 30	A_3 35	N_1 2	N_2 4	N_3 6	
F_1	(75)	177	171	168	174	172	170	172
F_2	(100)	217	199	194	208	200	201	203
Mean		197	185	181	191	186	185	

Age (Days)		Number of seedlings hill^{-1}			Mean
		N_1 2	N_2 4	N_3 6	
A_1	25	204	200	188	197
A_2	30	187	183	184	185
A_3	35	182	175	185	181
Mean		191	186	185	

C.D.(0.05) for F 12.26 (6.0)
C.D.(0.05) for A NS (7.3)
C.D.(0.05) for N NS (7.3)
C.D.(0.05) for FA NS (10.4)
C.D.(0.05) for FN NS (10.4)
C.D.(0.05) for AN NS (12.7)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Trial III. Evaluation of azolla as a low cost biofertilizer in rice variety IR 42

1. Growth and growth characters

1.1 Height of plants

During the *mundakan* season of the first year treatments showed significant influence on height at all stages except at active tillering. Full recommended dose of fertilizer produced the tallest plants and was superior to all the other fertilizer levels at all stages (Table 44 a and b, 45 a and b). At panicle initiation stage all the higher levels of fertilizer were superior to the next lower levels while at flowering and at harvest 75 and 50 per cent of the recommended dose of fertilizer were comparable. With regard to azolla levels, 20 t ha^{-1} recorded the highest value and was superior to all the other levels of azolla from panicle initiation to harvest while 15 and 10 t of azolla ha^{-1} were similar. Though 50 per cent of the recommended dose of fertilizer along with azolla @ 20 t ha^{-1} gave the highest value it was comparable with full dose of fertilizer in combination with azolla @ 10 t ha^{-1}.

Treatments showed significant effect on height from active tillering to harvest in the second year as well. Among fertilizer levels, full dose of fertiliser recorded the highest value and was superior to others at all stages except at harvest. At harvest 100 and 75 per cent

Table 44 a. Height of plants (cm) at panicle initiation stage as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	50.7	51.4	52.8	56.1	52.8	C.D.(0.05) for F	1.80 (0.82)
F_1 - 50	56.3	53.0	54.5	57.5	55.3	C.D.(0.05) for A	1.43 (0.70)
F_2 - 75	56.7	56.0	56.7	59.4	57.2	C.D.(0.05) for A within same F levels	NS (1.42)
F_3 - 100	61.1	58.2	59.4	59.3	59.5		
Mean	56.2	54.7	55.9	58.1		C.D.(0.05) for A between F levels	NS (1.48)

Table 44 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	43.0	40.8	40.3	44.4	42.1	C.D.(0.05) for F	0.45 (0.21)
F_1 - 50	42.5	49.1	50.2	50.1	48.0	C.D.(0.05) for A	0.57 (0.28)
F_2 - 75	49.3	55.8	50.1	42.8	49.5	C.D.(0.05) for A within same F levels	1.14 (0.57)
F_3 - 100	51.3	51.1	49.7	52.9	51.3		
Mean	46.5	49.2	47.6	47.6		C.D.(0.05) for A between F levels	1.07 (0.53)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 45 a. Height of plants (cm) at harvest as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	60.6	60.6	65.8	64.8	63.0	C.D.(0.05) for F	0.90 (0.42)
F_1 - 50	69.6	69.4	69.9	75.7	71.2	C.D.(0.05) for A	1.49 (0.73)
F_2 - 75	71.3	70.7	70.6	72.0	71.2	C.D.(0.05) for A within same F levels	2.97 (1.47)
F_3 - 100	72.7	73.7	71.3	71.9	72.4		
Mean	68.6	68.6	69.4	71.1		C.D.(0.05) for A between F levels	2.70 (1.34)

Table 45 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	62.3	63.7	65.2	64.8	64.0	C.D.(0.05) for F	0.83 (0.38)
F_1 - 50	68.5	75.8	76.1	75.0	73.9	C.D.(0.05) for A	0.94 (0.46)
F_2 - 75	76.3	78.8	78.2	69.9	75.8	C.D.(0.05) for A within same F levels	1.88 (0.93)
F_3 - 100	72.5	77.8	77.7	77.4	76.4		
Mean	69.9	74.0	74.3	71.8		C.D.(0.05) for A between F levels	1.80 (0.89)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

of the recommended dose of fertilizer were similar and were superior to lower levels. At active tillering and flowering stages, 75 and 50 per cent of the recommended dose of fertilizer were comparable while at panicle initiations stage, each higher level of fertilizer was superior to the next lower level of fertilizer tried.

Azolla @ 10 t ha^{-1} produced taller plants at all stages upto flowering while at harvest azolla @ 15 t ha^{-1} gave taller plants and was similar to azolla @ 10 t ha^{-1}. Full dose of fertilizer in combination with azolla @ 10 t ha^{-1} recorded more height both at active tillering and flowering stages while at harvest, 75 per cent of the recommended dose of fertilizer along with azolla @ 10 t ha^{-1} recorded the highest value. However, full dose of fertilizer in combination with azolla @ 10 t ha^{-1} was comparable with latter.

From the above results, it is seen that during first year full dose of fertilizer and azolla @ 20 t ha^{-1}, respectively were needed for achieving maximum height. But when the combination effect is examined it is seen that, full dose of fertilizer along with azolla @ 10 t ha^{-1} and 50 per cent of the recommended dose of fertilizer in combination with azolla @ 20 t ha^{-1} are similar in their performance. In second year, full dose of fertilizer and azolla @ 10 t ha^{-1} were the best with regard to individual performance. With respect to combination effect full dose of fertilizer along with azolla @ 10 t ha^{-1} gave comparable values with 75 per cent fertilizer and 10 t of azolla ha^{-1}.

The effect of fertilizer on height is mainly due to the effect of N. The role of N in increasing the vegetative growth is well known. At the highest level of fertilizer, there was no need of increasing the azolla beyond 10 t ha^{-1}. But when the fertilizer level was reduced to zero, the quantity of azolla could go upto 20 t ha^{-1}. Then the entire requirement of N of the crop was met from azolla. This is in conformity with the findings of Balasubramaniam (1980), Sathasivan (1980) and Padalia(1981). They observed a linear increase in plant height with graded levels of fertilizer N while Singh (1977 b, d) recorded increased plant height with azolla application. The increased availability of both organic and inorganic fertilizer nutrients resulting from the combined application of both also might have contributed to increase in height. The N supply through combined application of organic and inorganic fertilizers is reported to be more steady and long lasting (Hauang Dong Mai et al. 1981).

Pillai and Vasudevan (1978) and Hesse (1984) have stressed the beneficial effect of application of organic manure in conjunction with inorganic fertilizers.

1.2 Number of tillers m^{-2}

During the first year of the experiment (Table 46 a and b and 47 a and b) full dose of fertilizer recorded the maximum number of tillers and was superior to other levels of fertilizer at all stages. At harvest though full dose of fertilizer gave the highest value it was comparable with 75 per cent of the recommended dose. Azolla @ 10 and 15 t ha^{-1} gave the highest tiller number at active tillering and at harvest stages, respectively. With regard to combinations full dose of fertilizer along with azolla @ 10 t ha^{-1} gave the maximum value at all stages.

Full dose of fertilizer gave the highest number of tillers during the second year also and was superior to other fertilizer levels at all stages except at harvest. At harvest, full dose, 75 and 50 per cent of the recommended dose of fertilizer were similar in their performance. The levels of azolla except 5 t ha^{-1} were comparable in their effect at all the three stages. As to combinations, full dose of fertilizer in combination with azolla @ 10 t ha^{-1} recorded the highest tiller number at all stages.

Table 46 a. Number of tillers m^{-2} at panicle initiation stages as influenced by fertilizer and azolla levels. Mundakan 1982.

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	507	585	625	647	591	C.D.(0.05) for F	14.3 (6.5)
F_1 - 50	574	663	677	698	653	C.D.(0.05) for A	9.8 (4.8)
F_2 - 75	591	685	698	707	670	C.D.(0.05) for A within same F levels	19.6 (9.7)
F_3 - 100	655	732	714	712	703		
Mean	582	666	679	691		C.D.(0.05) for A between F levels	21.5 (10.6)

Table 46 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	491	505	514	523	508	C.D.(0.05) for F	12.5 (5.7)
F_1 - 50	588	650	660	665	641	C.D.(0.05) for A	5.0 (2.4)
F_2 - 75	596	670	676	658	650	C.D.(0.05) for A within same F levels	10.0 (4.9)
F_3 - 100	620	692	680	669	665		
Mean	574	629	633	629		C.D.(0.05) for A between F levels	14.5 (7.2)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 47 a. Number of tillers m^{-2} at harvest as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean
F_0 - 0	368	403	434	442	412
F_1 - 50	452	507	510	515	496
F_2 - 75	470	521	529	505	506
F_3 - 100	498	552	522	482	514
Mean	447	496	499	487	

C.D.(0.05) for F	22.2 (10.2)
C.D.(0.05) for A	9.8 (4.9)
C.D.(0.05) for A within same F levels	19.7 (9.8)
C.D.(0.05) for A between F levels	23.5 (11.1)

Table 47 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean
F_0 - 0	367	384	400	426	394
F_1 - 50	461	507	536	516	505
F_2 - 75	466	531	523	516	509
F_3 - 100	507	554	511	520	523
Mean	450	494	493	495	

C.D.(0.05) for F	21.3 (9.8)
C.D.(0.05) for A	13.6 (6.8)
C.D.(0.05) for A within same F levels	27.3 (13.6)
C.D.(0.05) for A between F levels	30.8 (15.3)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

As in the case of height, tiller number is also a vegetative character and is influenced by the fertilizer component and azolla. Accordingly, the highest fertilizer level has given the maximum tiller number. However, the interaction effect shows that full dose of fertilizer in combination with azolla @ 10 t ha^{-1} is favouring maximum tiller production. This means that at 100 per cent of the recommended dose of fertilizer, azolla can be restricted to 10 t ha^{-1}. It may be recalled that in height also the same combination was found to be optimum. Increased availability of nutrients due to the combined application of both organic and inorganic sources might have resulted in increased tiller production (Huang Dong-mai et al. 1981). Jaikumaran (1981) also recorded higher tiller number with combined application of fertilizer and azolla.

1.3 Leaf area index (LAI)

During the first year of the experiment fertilizer as well as azolla had no significant effect on the LAI at active tillering stage. At panicle initiation stage full dose of fertilizer gave the highest value and was similar to 75 per cent of the recommended dose (Tables 48 a & b). Azolla levels had no significant effect. Among combinations, full dose of fertilizer combined with azolla @ 10 t ha^{-1}

Table 48 a. Leaf area index (LAI) at panicle initiation stage as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	4.44	5.09	5.32	5.51	5.09	C.D.(0.05) for F	0.548 (0.251)
F_1 - 50	5.29	6.11	5.80	6.87	6.02	C.D.(0.05) for A	NS (0.260)
F_2 - 75	6.17	6.84	7.85	6.17	6.76	C.D.(0.05) for A within same F levels	1.048 (0.522)
F_3 - 100	6.80	6.97	6.05	6.63	6.61		
Mean	5.68	6.25	6.26	6.30		C.D.(0.05) for A between F levels	1.039 (0.617)

Table 48 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	4.40	5.13	5.36	5.93	5.21	C.D.(0.05) for F	0.429 (0.196)
F_1 - 50	5.68	6.14	6.21	6.43	6.12	C.D.(0.05) for A	0.261 (0.130)
F_2 - 75	6.03	6.66	7.00	6.00	6.42	C.D.(0.05) for A within same F levels	0.523 (0.260)
F_3 - 100	6.51	7.30	6.54	6.43	6.70		
Mean	5.66	6.31	6.28	6.20		C.D.(0.05) for A between F levels	0.601 (0.299)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

recorded the maximum value. At flowering stage full dose of fertilizer was superior to all the other levels of fertilizer. Azolla @ 10 t ha^{-1} gave the highest value and was similar to the higher levels. Among combinations full dose of fertilizer in combination with azolla @ 10 t ha^{-1} recorded the highest value and was superior to the rest.

During second year of the experiment full dose of fertilizer recorded the maximum LAI at all stages and was on par with 75 per cent of the recommended dose of fertilizer. Application of azolla at 20 t ha^{-1} gave the highest value at active tillering and was comparable with 10 and 15 t ha^{-1}. At panicle initiation stage 10 t of azolla recorded the highest value which was similar to the higher levels of azolla. As to combinations, full dose of fertilizer together with azolla @ 10 t ha^{-1} produced the highest LAI value at panicle initiation whereas at flowering stage azolla levels and their combinations had no significant effect.

Thus the overall trend of the individual effects of two years seems to be in favour of full dose of fertilizer and azolla @ 10 t ha^{-1}. When the combination effect was examined full dose of fertilizer along with azolla @ 10 t ha^{-1} appears to be better. It may be recalled that both in the case of height as well as number of tillers, this combination was giving better performance. Since leaf area is influenced by these two characters, it is quite natural that the same combination is beneficial with regard to LAI also.

In both years LAI increased upto panicle initiation stage and declined thereafter. At panicle initiation stage a value around six was recorded. This is in accordance with the finding of Murata (1969). According to him LAI increases with increase in N application especially before panicle initiation. The LAI of rice plants showed an increasing trend with increase in the level of N (Tanaka, 1972; Yogeswara Rao et al., 1972; Ramaswamy, 1975; Raju, 1979 and Sathasivan, 1980). Mathewkutty (1982) also recorded maximum LAI with combined application of fertilizer and azolla.

1.4 Dry matter production at harvest

Full dose of fertilizer recorded the highest value of dry matter production and was superior to other fertilizer levels during the first year of study (Table 49 a). Each higher level of fertilizer was superior to the next lower level. Azolla @ 15 t ha^{-1} recorded the highest value and was comparable with azolla @ 20 t ha^{-1}.

Table 49 a. Dry matter production of rice (kg ha^{-1}) as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	4848	6005	6701	6933	6122	C.D.(0.05) for F	246.3 (113.0)
F_1 - 50	6792	7389	7689	7707	7394	C.D.(0.05) for A	214.9 (106.9)
F_2 - 75	7814	8063	8342	7754	7993	C.D.(0.05) for A within same F levels	429.8 (213.8)
F_3 - 100	8323	8535	8342	8189	8347		
Mean	6944	7498	7768	7646		C.D.(0.05) for A between F levels	436.1 (216.9)

Table 49 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	5320	5702	5820	6349	5798	C.D.(0.05) for F	313.9 (144.1)
F_1 - 50	6264	6782	7023	7324	6848	C.D.(0.05) for A	166.5 (82.8)
F_2 - 75	6978	7521	7703	7615	7472	C.D.(0.05) for A within same F levels	332.9 (165.6)
F_3 - 100	7237	7861	7604	7340	7510		
Mean	6455	6939	7038	7157		C.D.(0.05) for A between F levels	408.7 (203.3)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Full dose of fertilizer together with azolla @ 10 t ha^{-1} registered the highest dry matter production which was similar to 75 per cent of the recommended dose of fertilizer in combination with azolla @ 15 t ha^{-1}.

During the second year of the study as well, full dose of fertilizer recorded more dry matter production but was comparable with 75 per cent of the recommended dose (Table 49 b). Though azolla @ 20 t ha^{-1} obtained the highest value it was similar to azolla @ 15 t ha^{-1} whereas no significant difference was observed between 15 and 10 t of azolla ha^{-1}. Full dose of fertilizer combined with azolla @ 10 t ha^{-1} registered the maximum dry matter production which was comparable with the combination, 75 per cent of the fertilizer along with azolla @ 15 t ha^{-1}.

Full dose of fertilizer and azolla @ 15 t ha^{-1} individually were found to give the highest dry matter production.

Full dose of fertilizer combined with azolla @ 10 t ha^{-1} was found to be the best in both the years.

On perusal of the data on the yield of grain full dose of fertilizer had recorded the highest value in both years. With respect to azolle levels, azolla @ 15 t ha^{-1} was seen to be better. On considering the effect of combinations, full dose of fertilizer combined with azolla @ 10 t ha^{-1} and 75 per cent of the recommended dose of fertilizer along with azolla @ 15 t ha^{-1} were similar in their performance with the former topping the list. Almost same trend was observed with the yield of straw also so as to make dry matter production go in line with the grain yield. The reason for the better performance of 75 per cent of the recommended dose of fertilizer in combination with azolla @ 15 t ha^{-1} is discussed elsewhere.

2. Yield attributes

2.1 Number of panicles m^{-2}.

In both years fertiliser and azolla levels had significant effect on the number of panicles (Table 50 a & b). Full dose of fertilizer registered the highest number and was comparable with the next two lower levels in the first year. In the second year of study full dose of fertilizer obtained the highest number. Seventy five per cent of the recommended dose was similar to full dose as well as 50 per cent. With regard to azolla during the first year no significant difference was observed between 10 and 15 or 20 t ha^{-1}, though 15 t ha^{-1} registered the highest number

Table 50 a. Number of panicles m^{-2} as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	261	281	330	334	302	C.D.(0.05) for F	24.1 (11.1)
F_1 - 50	341	396	402	409	387	C.D.(0.05) for A	12.1 (6.0)
F_2 - 75	362	412	422	389	396	C.D.(0.05) for A within same F levels	24.2 (12.1)
F_3 - 100	388	341	416	376	405		
Mean	338	383	393	377		C.D.(0.05) for A between F levels	27.4 (13.1)

Table 50 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	262	276	289	320	287	C.D.(0.05) for F	19.0 (8.7)
F_1 - 50	354	391	404	410	390	C.D.(0.05) for A	6.8 (3.3)
F_2 - 75	361	409	417	409	399	C.D.(0.05) for A within same F levels	13.6 (6.8)
F_3 - 100	388	432	422	411	413		
Mean	341	377	383	388		C.D.(0.05) for A between F levels	21.2 (10.5)

*90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

of panicles. In the second year, azolla @ 20 t ha^{-1} produced more panicles than 15 t ha^{-1} though the difference was not significant. Azolla @ 15 and 10 t ha^{-1} were also comparable in their performance. Though the combination of full dose of fertilizer along with azolla @ 10 t ha^{-1} gave the highest number of panicles, it was similar to 75 per cent of the recommended dose with azolla @ 15 t ha^{-1} in both the years.

From the above results it is observed that number of panicles could be increased with azolla levels. But when the azolla levels were increased beyond a certain level along with fertilizer levels, panicle number was reduced indicating that the crop had an optimum requirement of both. At zero level of fertilizer, though there was increase in panicle number with increase in azolla levels, the increase was not proportional. This reveals that azolla at higher levels are not that good even in the absence of fertilizer. This might be because of the slow availability of the nutrients in azolla due to the high content of lignin (Shi-Shu-lian et al., 1983).

2.2 Number of filled grains per panicle

The treatments showed no significant effect on number of filled grains per panicle during the first year of study (Table 51 a). However, during the second year fertilizer as well as azolla levels showed significant effect on the number of grains. Full dose of fertilizer recorded more number and was comparable with 75 per cent of the recommended dose of fertilizer (Table 51 b). Among combinations 75 per cent of the recommended dose along with azolla @ 15 t ha^{-1} gave the highest value and was on par with azolla @ 10 t ha^{-1} with 75 and 100 per cent of the recommended dose of fertilizer.

From the above results it is noticed that with no fertilizer, the number of filled grains was found to increase with increase in azolla levels whereas in combination with fertilizer levels, filled grains were increased only upto a certain level of azolla beyond which there was reduction in the number.

The above result is in agreement with the findings of Kulasoorya and Desilva (1977 b), Singh (1977 a) and Jaikumaran (1981). They could record an increase in the number of filled grains with a combination of fertilizer N plus azolla. The increased availability of nutrients from both organic and inorganic sources due to the combined application might be the reason.

Table 51 a. Number of filled grains panicle^{-1} as influenced by fertilizer levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean
F_0 - 0	62.7	51.4	67.1	62.5	58.4
F_1 - 50	59.3	59.7	63.3	56.2	59.6
F_2 - 75	58.6	58.4	60.7	53.9	57.9
F_3 - 100	60.1	60.3	53.5	62.0	59.0
Mean	60.2	57.5	58.7	58.7	

C.D.(0.05) for F	NS	(2.67)
C.D.(0.05) for A	NS	(2.15)
C.D.(0.05) for A within same F levels	NS	(4.29)
C.D.(0.05) for A between F levels	NS	(4.58)

Table 51 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean
F_0 - 0	51.5	51.9	55.4	62.5	55.3
F_1 - 50	49.4	51.0	53.6	54.6	52.2
F_2 - 75	52.6	68.8	69.6	65.7	64.2
F_3 - 100	64.2	66.4	65.0	63.3	64.7
Mean	54.4	59.5	60.9	61.5	

C.D.(0.05) for F	2.74	(1.21)
C.D.(0.05) for A	1.61	(0.79)
C.D.(0.05) for A within same F levels	3.22	(1.59)
C.D.(0.05) for A between F levels	3.76	(1.87)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

2.3 Thousand grain weight

During first year of the experiment fertilizer and azolla levels had no significant effect on thousand grain weight though there was a decreasing trend in weight with decrease in fertilizer levels (Table 52 a). In the second year full dose of fertilizer gave the highest value and was comparable with 75 per cent of the recommended dose (Table 52 b). Fifty and seventy five per cent of the doses were similar in their performance. The azolla levels and the combinations were not significant in both the seasons.

From the results it is seen that while azolla as such had no effect on increasing the thousand grain weight, fertilizer had only a slight effect. This being a varietal character, much influence is not expected also. However, some of the investigators like Ahmed and Abdul Faiz (1969), Lenka (1969) did get an increase in thousand grain weight while others like Bumus and Sadeque (1964); Sundararajan (1978) did not observe any increase.

2.4 Sterility percentage

During first year of the experiment neither fertilizer nor azolla levels showed any significant effect on sterility percentage (Table 53 a). But in the second

Table 52 a. Thousand grain weight (g) as influenced by fertilizer and azolla levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	19.90	20.00	19.90	20.04	19.96	C.D.(0.05) for F	NS (0.374)
F_1 - 50	20.00	20.10	20.46	20.14	20.18	C.D.(0.05) for A	NS (0.305)
F_2 - 75	20.60	20.48	20.34	20.14	20.39	C.D.(0.05) for A within same F levels	NS (0.611)
F_3 - 100	21.64	20.44	19.94	20.74	20.69		
Mean	20.54	20.26	20.16	20.27		C.D.(0.05) for A between F levels	NS (0.648)

Table 52 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	17.99	18.02	18.42	18.82	18.31	C.D.(0.05) for F	0.413 (0.189)
F_1 - 50	18.92	19.06	19.05	19.30	19.09	C.D.(0.05) for A	NS (0.179)
F_2 - 75	18.94	19.67	19.56	18.85	19.26	C.D.(0.05) for A within same F levels	NS (0.359)
F_3 - 100	19.34	20.05	19.72	19.43	19.64		
Mean	18.80	19.20	19.19	19.11		C.D.(0.05) for A between F levels	NS (0.364)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 53 a. Sterility percentage as influenced by fertilizer and azolla levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean			
	A_1 5	A_2 10	A_3 15	A_4 20				
F_0 - 0	17.66	19.20	22.84	19.56	19.83	C.D.(0.05) for F	NS	(1.193)
F_1 - 50	18.64	16.32	21.40	19.10	18.87	C.D.(0.05) for A	NS	(1.209)
F_2 - 75	21.86	18.94	20.54	25.18	21.63	C.D.(0.05) for A within same F levels	NS	(2.419)
F_3 - 100	19.14	21.22	19.06	23.60	20.76			
Mean	19.33	18.92	20.96	21.86		C.D.(0.05) for A between F levels	NS	(2.411)

Table 53 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean			
	A_1 5	A_2 10	A_3 15	A_4 20				
F_0 - 0	22.60	20.88	19.36	17.90	20.19	C.D.(0.05) for F	1.721	(0.769)
F_1 - 50	21.36	20.98	19.90	18.34	20.15	C.D.(0.05) for A	NS	(1.199)
F_2 - 75	22.62	20.84	20.55	26.90	22.73	C.D.(0.05) for A within same F levels	NS	(2.398)
F_3 - 100	22.28	21.41	25.17	23.44	23.08			
Mean	22.22	21.03	21.25	21.65		C.D.(0.05) for A between F levels	NS	(2.222)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

year, fertilizer levels alone showed significant affect on sterility percentage (Table 53 b). Highest sterility was associated with full dose of fertilizer. When the number of spikelets increases consequent to application of higher levels of N, photosynthetes may not be sufficient to fill all the spikelets. The above result is in conformity with the finding of Jaikumaran (1981) and Sreekumaran (1981).

3. Grain yield

The pooled analysis of data on grain yield for two seasons (Table 54) revealed that higher levels of fertilisers were similar in their effect though highest grain yield was produced by full dose of fertilizer. Both these treatments were superior to other lower levels of fertilizer. Azolla @ 15 t ha^{-1} gave the highest yield. Application of azolla either 10, 15 or 20 t ha^{-1} resulted in similar yield. As to combinations full dose of fertiliser in combination with azolla @ 10 t ha^{-1} recorded the highest yield and was comparable with 75 per cent and 100 per cent (full dose) of the recommended dose of fertiliser, respectively in combination with azolla @ 15 t ha^{-1}.

From the results it is seen that 100 per cent (full dose) of the recommended dose of fertilizer gave more yield even though it was similar to 75 per cent. IR 42 is classified as a variety which gives a fairly high yield at low fertility conditions according to Khush et al. (1979). Even with no fertiliser and with azolla @ 5 t ha^{-1} this variety has given

Table 54. Grain yield (kg ha^{-1}) as influenced by fertilizer and azolla levels (Pooled data for Mundakan 1982 and 1984)

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1}) A_1 5	A_2 10	A_3 15	A_4 20	Mean
F_0 - 0	2524	2913	3115	3304	2964
F_1 - 50	3218	3482	3609	3694	3501
F_2 - 75	3590	3850	3951	3784	3794
F_3 - 100	3830	4039	3919	3750	3884
Mean	3291	3571	3648	3633	

C.D.(0.05) for F	110.7 (35.9)
C.D.(0.05) for A	61.8 (20.0)
C.D.(0.05) for A within same F levels	123.6 (61.5)
C.D.(0.05) for A between F levels	154.0 (76.7)

* 90: 45: 45 Kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

a fairly good yield of 2.5 t ha^{-1}. In spacing trial also, this has given almost the same yield without any azolla or fertilizer (Table 13 a, b, c & d). This again proves the potential of the variety to perform under low fertility conditions. Similar reports on the performance of this variety under such conditions are available (Anon, 1981).

Comparison of the respective individual effect of azolla and fertilizer shows that the fertilizer has given a better response than azolla. By application of 20 t of azolla the yield could be increased to 3.3 t under zero fertilizer level whereas the yield could go upto 3.8 t with 100 per cent of the recommended dose of fertilizer. The low yield in plots which received higher doses of azolla might be due to the high lignin content of azolla. According to Shi-Shu-lian et al. (1981) the lignin content of azolla is about 20.2 per cent which is responsible for the low availability of the nutrients in azolla compared to inorganic fertilizer. Talley and Rains (1980) also reported low availability of N with excessive application of azolla as green manure.

The combination effect seems to be better than the individual effect. Full dose of fertilizer in combination with azolla @ 10 t ha^{-1} has given the highest yield of 4.03 t ha^{-1} closely followed by 75 per cent of the recommended dose of fertilizer along with azolla @ 15 t ha^{-1} which has given about 3.95 t ha^{-1}. However, these two combinations were similar to full dose of fertilizer together with azolla @ 15 t ha^{-1} as well. Full dose of fertilizer gave the best performance with 10 t of azolla. But, when the fertilizer dose was reduced to 75 per cent, it was requiring 15 t of azolla to produce similar yield. This means that when the fertilizer dose is increased to 100 per cent, azolla can be reduced to 10 t ha^{-1}. At the same time increasing azolla levels from 10 t to 15 t in conjunction with 100 per cent recommended dose of fertilizer does not give a proportionate increase in production. Further, it is numerically inferior to the combination 75 per cent of the recommended dose of fertilizer along with azolla @ 15 t ha^{-1}. This shows that at the highest level of fertilizer, increase in azolla from 10 to 15 t or at 15 t of azolla ha^{-1} increasing the fertilizer from 75 to 100 per cent does not give any additional benefit. It is, therefore, assumed that 75 per cent fertilizer with 15 t of azolla is optimum for this variety. A combination of the inorganic plus organic sources of N has been reported to be better than either of the sources of N (Pillai and Vamadevan, 1978). It has also been proved that fertilizer in combination with azolla is the best

(Hesse, 1984). This might be because by an integrated application system involving both organic and inorganic fertilizer will increase the mineralization of the organic form and reduce the immobilization of the inorganic form, thus enhancing the total nutrient availability to the crop. Moreover, the beneficial effect of organic matter in the development of superficial roots which are directly involved in the root respiration and nutrient absorption in rice was reported earlier (Kawata and Soejima 1976). Further, the quinones, degradation products of humic acid is reported to have nitrification inhibition property thus enabling the nutrient especially N more available to the plant. Moreover the phenols produced by the degradation of lignin act as phytohormones and possess a favourable influence on plant metabolism (Flaig, 1975 & 1984) There are also considerable reports to the effect that fertilizer N could be saved to the extent of 20-50 per cent by incorporation of azolla (Kannaiyan et al., 1982; Mathewkutty, 1982; Mandal and Bharati, 1983). Since azolla is a low cost input every effort should be made to popularise its use and thereby reduce the fertilizer dosage.

However, increasing the dose of azolla from 15 to 20 t does not give any additional grain yield. At the same time it results in a decreased grain production as is evident from the Table 54. Azolla response per 100 kg of azolla applied, also showed a decreasing trend when azolla level was increased along with increase in fertiliser levels (Table 55). This might be because of several reasons. Beneficial effect of organic matter application is masked by its higher rates of application along with the full recommended dose of fertilizer. The shorter interval between incorporation of azolla and transplanting might have resulted in CO_2 accumulation during the initial stages of growth of the crop. Since higher concentration of CO_2 is injurious for root development, in the present investigation tiller number m^{-2} was found to be lower in the treatment receiving full dose of fertilizer and highest level of azolla (Table 46 a & b and 47 a & b). Incorporation of organic matter like azolla might have resulted in immediate reduction in redox potential of soil releasing a number of organic as well as inorganic reduced components such as organic acids, H_2S, phenols, Soluble Fe, Mn, Al which are toxic for the growth of the rice plant. Reduced organic compounds are reported to compete with rice roots for respiration (Ponnamperuma, 1978) thus inhibiting root respiration as well as nutrient uptake. A perusal of the data on nutrient uptake (Table 57 a & b, 60 a & b, and 61 a & b) substantiates it. Further, the quinones - the degradation products of humic acid, produced in large quantities were reported to have urease inhibitory activity (Bundy and Bremner, 1973). The soluble urea might have either been washed out of the soil or leached down beyond the root zone.

With regard to the beneficial effect of the particular combination, the data on panicle number (Table 50 a & b) show that the combination 75 per cent of fertilizer plus azolla 15 t ha^{-1} had given the highest number of panicles. The number of filled grains $panicle^{-1}$ (Table 51 a & b) and thousand grain weight (Table 52 a & b) also show that this combination is better. The beneficial effect of all these yield attributes would have resulted in giving higher grain production by this combination.

It may be further seen from the Table that, there seems to exist an optimum combination of azolla for a particular level of fertilizer. At zero level of the fertilizer, 20 t of azolla has given the highest yield while at 50 per cent fertilizer dose, 15 t of azolla seems to be significant whereas at 75 per cent level 10 t of azolla appears to be necessary for highest yield. This shows that as the fertility level increases, the optimum dose of azolla required for grain production is reduced. But a combination of azolla and inorganic fertilizer is always found to be better. With reference to fertilizer saving also the same trend is recorded. At 5 and 10 t of azolla, 100 per cent fertilizer dose is required while at 15 t of azolla 75 per cent of the recommended dose of fertilizer is enough. At 20 t of azolla 50 per cent of the fertilizer dose is sufficient. This means that azolla can substitute fertilizer upto 50 per cent even though there is a numerical reduction in yield of around 300 kg. From the economics (Table 55) it is seen that the combination 75 per cent of the recommended dose with azolla @ 15 t ha^{-1} has given a net return of Rs. 6330 and 100 per cent of the recommended dose of fertilizer with azolla @ 10 t ha^{-1}, Rs. 6508. This shows that the difference is only less than Rs. 200. At the same time the benefit cost ratios were almost equal i.e. 2.12 and 2.13 in the former and latter combinations, respectively. Out of these two combinations, the return per rupee invested on fertilizer was more in the former. Thus it can be seen that 75 per cent of the recommended dose of fertilizer with 15 t of azolla ha^{-1} seems to be optimum from the economic point of view also.

Table 55. Economics of trial III (Azolla trial)

Treatments	Grain yield kg ha^{-1}	Straw yield kg ha^{-1}	Gross return Rs.ha^{-1}	Cost of cultivation Rs. ha^{-1}	Net return Rs.ha^{-1}	Benefit cost ratio	Azolla response per 100 kg of azolla applied	Return $rupee^{-1}$ invested on fertilizer
F_0 A_1	2524	2580	7628	4744	2884	1.60	50.48	-
F_0 A_2	2913	2941	8767	4858	3909	1.80	29.13	-
F_0 A_3	3115	3146	9376	4972	4404	1.88	20.76	-
F_0 A_4	3304	3347	9955	5102	4853	1.95	16.52	--
F_1 A_1	3218	3310	9746	5217	4529	1.86	64.36	10.57
F_1 A_2	3482	3603	10567	5331	5236	1.98	34.82	12.06
F_1 A_3	3609	3747	10965	5445	5520	2.01	24.06	12.67
F_1 A_4	3694	3822	11210	5575	5635	2.01	18.47	12.91
F_2 A_1	3590	3816	10996	5416	5580	2.03	71.80	9.30
F_2 A_2	3850	3966	11666	5530	6136	2.10	38.50	10.13
F_2 A_3	3951	4072	11974	5644	6330	2.12	26.34	10.41
F_2 A_4	3784	3901	11469	5744	5695	1.98	18.92	9.47
F_3 A_1	3830	3950	11610	5615	5995	2.06	76.60	7.88
F_3 A_2	4039	4159	12237	5729	6508	2.13	40.39	8.47
F_3 A_3	3919	4054	11892	5843	6049	2.03	26.12	7.94
F_3 A_4	3750	3935	11435	5973	5462	1.91	18.75	7.27

Fertilizer levels

F_0 = 0
F_1 = 50% of 90: 45: 45 kg NPK ha^{-1}
F_2 = 75% of 90: 45: 45 kg NPK ha^{-1}
F_3 = 100% of 90: 45: 45 kg NPK ha^{-1}

Azolla levels

A_1 = 5 t ha^{-1}
A_2 = 10 t ha^{-1}
A_3 = 15 t ha^{-1}
A_4 = 20 t ha^{-1}

Price of rice= Rs. 2 kg^{-1}
Price of straw = Re.1 kg^{-1}

4. Straw yield

On pooled analysis of the data on straw yield (Table 56) it can be seen that full dose of fertilizer recorded the highest straw yield and was comparable with 75 per cent of the recommended dose of fertilizer. Both were superior to lower levels of fertilizer. Azolla @ 15 t ha^{-1} gave the highest value and was similar to 20 t ha^{-1}. Both of them were superior to the lower levels of azolla. Full dose of fertilizer along with 10 t of azolla recorded the highest straw yield which was comparable with azolla @ 15 t ha^{-1} in combination with 75 and 100 per cent of the recommended fertilizer dose. At zero level and at 50 per cent of the recommended dose of fertilizer, there was a progressive increase in straw yield with increasing levels of azolla upto 20 t ha^{-1}. At 75 per cent level of fertilizer straw yield increased only upto 15 t of azolla while at 100 per cent level of fertilizer increase in yield of straw was only upto 10 t ha^{-1}.

A perusal of the data on height, tiller number and LAI (Tables 44 to 48 a & b) indicates that the treatment combination of full dose of fertilizer along with azolla @ 10 t ha^{-1} recorded uniformly higher values in all these attributes. The role of fertilizer especially N in increasing the vegetative growth and thereby increasing the straw yield

Table 56. Straw yield (kg ha^{-1}) as influenced by fertilizer and azolla levels (Pooled data for Mundakan 1982 and 1984)

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	2580	2941	3146	3337	3001	C.D.(0.05) for F	111.43(36.2)
F_1 - 50	3310	3603	3747	3822	3620	C.D.(0.05) for A	70.24(22.7)
F_2 - 75	3816	3966	4072	3901	3939	C.D.(0.05) for A within same F levels	140.47(69.8)
F_3 - 100	3950	4159	4054	3935	4025	C.D.(0.05) for A between F levels	164.97(82.2)
Mean	3414	3667	3755	3749			

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

with increasing levels of N and azolla were reported by Mathur et al. (1981), Krishnarajan and Balasubramanian (1983), Kannaiyan et al. (1983), Tahmida and Abdul Kader (1983).

From the above results it is observed that higher values of straw yield were always associated with higher levels of fertilizer. A decrease in straw yield at higher levels of azolla especially in combination with higher levels of fertilizer was observed. The harmful effects of higher doses of azolla in conjunction with full dose of fertilizer are discussed elsewhere.

5. Harvest index (HI)

During first year, treatments had no significant effect on HI while during the second year high HI values were associated with zero level of fertilizer (Table 57 a & b). Azolla levels had no significant effect.

The above results reveal that the H.I. in fertilized plots were lower than that of the unfertilized plots. The high HI values associated with zero level might be because in the absence of fertilizer application, there will be reduction in grain as well as straw yield. Conversely, as the fertilizer level increases, N being the major component of fertilizer, both grain and straw yield increases. The increase may not be proportionate. N favours more straw

Table 57 a. Harvest index as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	49.54	49.74	49.75	49.74	49.69	C.D.(0.05) for F	0.119 (0.055)
F_1 - 50	49.25	49.26	49.28	48.97	49.19	C.D.(0.05) for A	NS (0.054)
F_2 - 75	49.26	49.25	49.25	49.21	49.24	C.D.(0.05) for A within same F levels	NS (0.108)
F_3 - 100	49.26	49.26	49.25	49.26	49.25		
Mean	49.33	49.38	49.38	49.30		C.D.(0.05) for A between F levels	NS (0.109)

Table 57 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	49.75	49.76	49.75	49.74	49.75	C.D.(0.05) for F	0.402 (0.185)
F_1 - 50	49.34	49.02	48.82	49.32	49.13	C.D.(0.05) for A	NS (0.201)
F_2 - 75	47.62	49.26	49.23	49.26	48.84	C.D.(0.05) for A within same F levels	0.809 (0.403)
F_3 - 100	49.19	49.26	49.01	48.24	48.93		
Mean	49.00	49.33	49.20	49.14		C.D.(0.05) for A between F levels	0.793 (0.394)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

production and as such the HI is reduced. This is in agreement with the findings of several workers like Sreedharan (1975), Sahu et al. (1980).

6. Chemical analysis

6.1 Plant analysis

6.1.1 Protein content of grains

The pooled analysis of the data on protein content reveals that among fertilizer levels, full dose of fertilizer recorded the highest value (Table 58). Each higher level of fertilizer was superior to the next lower level. Azolla @ 20 t ha^{-1} recorded the maximum value which was superior to all other lower levels of azolla. Even though not significant, the combination of full dose of fertilizer along with azolla @ 20 t ha^{-1} gave the highest protein content.

The above results reveal that both fertilizer and azolla at the highest level individually or in combination gave more protein content.

It may be recalled that the grain yield was highest at the full dose of fertilizer in combination with azolla @ 10 t ha^{-1}. When the azolla levels were increased to 15 and 20 t ha^{-1} along with full dose of fertilizer, there was a reduction in grain yield. This reduction in the later combination was significant. This means that the fertilizer

Table 58. Protein content of grain as influenced by fertilizer and azolla levels. (Pooled data for Mundakan 1982 and 1984)

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	6.70	7.33	7.69	7.80	7.38	C.D.(0.05) for F	0.160 (0.052)
F_1 - 50	7.94	8.32	8.55	8.85	8.42	C.D.(0.05) for A	0.162 (0.053)
F_2 - 75	8.38	8.53	8.88	9.05	8.71	C.D.(0.05) for A within same F levels	0.325 (0.161)
F_3 - 100	8.74	9.06	9.36	9.92	9.27		
Mean	7.94	8.31	8.62	8.91		C.D.(0.05) for A between F levels	0.323 (0.160)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

requirement especially of N for giving highest grain yield is not the same for recording highest protein content.

A higher nutrition seems to favour a higher protein content even though, the yield was decreased at this level. This may be due to the fact that the balance in the synthesis of carbohydrate shifts in favour of protein at higher level of nutrition especially N. This is because azolla gives more N compared to other nutrients. Similar reports of a shift in emphasis from carbohydrate synthesis to protein synthesis at higher level of N has been reported by several investigators (De Datta et al. 1964, Rego, 1973).

It is further noted that the grain yield was lowest in the combination receiving full dose of fertilizer with the highest dose of azolla than treatments receiving full dose of fertilizer with lower doses of azolla. The number of panicles m^{-2} was also lowest in the former combination thus enabling more concentration of N in grains leading to increased protein content.

6.1.2 NPK uptake

N uptake was more in treatments receiving full dose of fertilizer in both years (Table 59 a & b). During the second year full dose and 75 per cent of the recommended dose of fertilizer were comparable. The lowest N uptake was noticed

Table 59 a. N uptake (kg ha^{-1}) as influenced by fertilizer and azolla levels.
<u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	35.60	51.58	58.80	63.61	52.40	C.D.(0.05) for F	4.069 (1.867)
F_1 - 50	62.33	72.03	74.17	78.13	71.67	C.D.(0.05) for A	2.893 (1.439)
F_2 - 75	72.66	80.61	79.98	74.71	76.99	C.D.(0.05) for A within same F levels	5.787 (2.879)
F_3 - 100	82.32	95.73	85.07	81.87	86.26		
Mean	63.23	74.99	74.50	74.58		C.D.(0.05) for A between F levels	6.261 (3.115)

Table 59 b. <u>Mundakan</u> 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	39.94	49.64	54.06	60.25	50.97	C.D.(0.05) for F	4.764 (2.186)
F_1 - 50	68.54	67.40	70.38	74.40	67.71	C.D.(0.05) for A	2.418 (1.203)
F_2 - 75	67.73	77.66	80.63	75.04	75.27	C.D.(0.05) for A within same F levels	4.836 (2.405)
F_3 - 100	72.56	88.97	80.65	70.00	77.90		
Mean	59.72	70.92	71.28	69.92		C.D.(0.05) for A between F levels	6.071 (3.020)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

in azolla @ 5 t ha^{-1}. All the higher levels of azolla were similar. Though full dose of fertilizer in combination with azolla @ 10 t ha^{-1} recorded highest uptake it was comparable with 75 per cent of the recommended dose of fertilizer along with azolla @ 15 t ha^{-1}.

P uptake also followed almost the above trend. Full dose of fertilizer and 75 per cent of the recommended dose of fertilizer were similar in both years (Table 60 a & b). Azolla @ 15 t ha^{-1} registered more P uptake in the first year which was comparable with azolla @ 10 t ha^{-1}. But during the second year azolla @ 10 t ha^{-1} recorded the highest value which was similar to the higher levels of azolla tried. The combinations associated with higher N uptake recorded more P uptake as well.

The trend in the uptake of N and P could be noticed in the case of K uptake also. Full dose of fertilizer recorded more uptake of K in both years (Table 61 a & b) and was comparable with 75 per cent of the recommended dose of fertilizer only in the second year. Azolla @ 20 t ha^{-1} recorded the highest uptake in both years and was similar to azolla @ 10 and 15 t ha^{-1} in the first year. During the second year azolla @ 10 and 15 t ha^{-1} were comparable. The combinations wherein the uptake of N and P was higher topped in K uptake also.

Table 60 a. P uptake (kg ha^{-1}) as influenced by fertilizer and azolla levels.
Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})						
	A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	10.81	13.49	16.00	16.62	14.23	C.D.(0.05) for F	1.682 (0.771)
F_1 - 50	17.23	18.96	19.01	20.21	18.85	C.D.(0.05) for A	1.305 (0.649)
F_2 - 75	19.55	21.25	25.13	19.64	21.39	C.D.(0.05) for A within same F levels	2.610 (1.298)
F_3 - 100	20.64	24.85	23.20	19.54	22.06		
Mean	17.06	19.64	20.84	19.00		C.D.(0.05) for A between F levels	2.741 (1.363)

Table 60 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})						
	A_1 5	A_2 10	A_3 15	A_4 20	Mean		
F_0 - 0	12.35	14.44	15.55	17.46	14.95	C.D.(0.05) for F	1.259 (0.578)
F_1 - 50	16.27	18.31	19.30	20.27	18.54	C.D.(0.05) for A	0.759 (0.377)
F_2 - 75	17.94	21.61	21.64	19.96	20.29	C.D.(0.05) for A within same F levels	1.519 (0.756)
F_3 - 100	19.26	23.20	20.10	18.85	20.35		
Mean	16.46	19.39	19.15	19.14		C.D.(0.05) for A between F levels	1.755 (0.873)

* 90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

Table 61 a. K uptake (kg ha^{-1}) as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	56.53	68.69	73.80	84.77	70.95	C.D.(0.05) for F	4.903 (2.250)
F_1 - 50	78.33	84.89	89.00	92.04	86.07	C.D.(0.05) for A	4.100 (2.039)
F_2 - 75	86.80	93.62	99.07	92.42	99.98	C.D.(0.05) for A within same F levels	8.199 (4.079)
F_3 - 100	100.77	105.44	100.70	93.44	100.09		
Mean	80.61	88.16	90.64	90.67		C.D.(0.05) for A between F levels	8.419 (4.188)

Table 61 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	59.42	66.11	67.31	77.99	67.71	C.D.(0.05) for F	5.649 (2.592)
F_1 - 50	73.15	80.46	84.21	90.64	82.12	C.D.(0.05) for A	2.429 (1.208)
F_2 - 75	84.57	91.49	97.23	94.02	91.82	C.D.(0.05) for A within same F levels	4.858 (2.416)
F_3 -100	87.60	98.99	94.81	91.91	93.33		
Mean	76.19	84.26	85.89	88.64		C.D.(0.05) for A between F levels	

*90: 45: 45 kg NPK ha^{-1}
Values in parenthesis are S.Em +/-

The above results revealed that treatments receiving full dose of fertilizer has given the highest values for N, P and K uptake followed by the lower levels in the descending order. With respect to azolla, higher levels of azolla were always giving more uptake of the above nutrient. But, no significant difference was observed between 10, 15 and 20 t indicating that azolla @ 10 t ha^{-1} is sufficient for the crop. Further, a reduction in the uptake of N, P & K was noticed with the application of higher doses of azolla at full dose of fertilizer. By the combined application of both, a good part of the fertilizer N would have been immobilized resulting in a reduction in the uptake. Findings of Broadbent and Nakashima (1970), Yoshida and Padre (1974) also showed a reduction in N uptake due to the immobilisation of significant amount of fertilizer N when applied in combination with large amounts of organic materials under flooded conditions. This further affects the P and K uptake. Full dose of fertilizer in combination with azolla @ 10 t ha^{-1} was found to be favouring the N, P and K uptake. Both grain and straw yields were higher in the above combination. Further the percentage content of the above nutrients were also higher. Both these aspects might have contributed to high values of N, P and K uptake. Similar results were reported by Gopalaswamy and Raj (1977) and Raju (1978). Higher values of N, P and K uptake with the combined application of azolla with 100 or 75 per cent of N fertilizer was reported by Jaikumaran (1981) under Kerala condition.

6.2 Residual nutrient status of soil after cropping

6.2.1 Organic carbon content of soil

Organic carbon content of soil was influenced significantly by the fertilizer as well as azolla treatments in both years. Treatments which received full dose of fertilizer recorded more residual organic carbon (Table 62 a & b). During first year each higher level of fertilizer was comparable with the next lower level while in the second year each higher level was superior to the next lower level. Azolla levels also followed the same trend as in the case of fertilizer in the respective years. Combination effect was not significant in the first year though full dose of fertilizer in combination with azolla @ 20 t ha^{-1} recorded the highest value and was superior to other combinations in the second year.

From the results it is evident that treatments which received full dose of fertilizer and highest level of azolla i.e. @ 20 t ha^{-1} recorded the highest value of organic carbon. Even though treatments which received full dose of fertilizer resulted in highest dry matter production

62 a. Residual organic carbon content (%) of soil as influenced by fertilizer and azolla levels. Mundakan 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	1.45	1.48	1.50	1.58	1.50	C.D.(0.05) for F	0.064 (0.035)
F_1 - 50	1.48	1.48	1.62	1.61	1.55	C.D.(0.05) for A	0.057 (0.029)
F_2 - 75	1.46	1.59	1.59	1.61	1.56	C.D.(0.05) for A within same F levels	NS (0.058)
F_3 - 100	1.59	1.60	1.62	1.63	1.61		
Mean	1.50	1.54	1.58	1.61		C.D.(0.05) for A between F levels	NS (0.061)

Table 62 b. Mundakan 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	1.48	1.52	1.55	1.62	1.54	C.D.(0.05) for F	0.030 (0.013)
F_1 - 50	1.60	1.61	1.61	1.62	1.61	C.D.(0.05) for A	0.024 (0.012)
F_2 - 75	1.57	1.62	1.62	1.68	1.62	C.D.(0.05) for A within same F levels	0.047 (0.023)
F_3 - 100	1.57	1.62	1.70	1.77	1.67		
Mean	1.56	1.59	1.62	1.67		C.D.(0.05) for A between F levels	0.046 (0.022)

* 90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

still some quantity of nutrient from the fertilizer might have been left in the soil. In the case of azolla also, at the highest level, the uptake could not have been to the fullest extent thereby leaving more residual organic carbon in the soil. The slow availability of azolla N due to the high lignin content might have resulted in higher residual organic carbon in the soil. Slow availability of nutrients of azolla is attributed to the high lignin content (Shi Shu lian et al., 1981). Further, higher residual organic carbon with the application of higher levels of fertilizers were reported by Singh (1979 a) and Arunachalan (1980).

6.2.2 P and K content of soil

During first year, full dose of fertilizer gave the highest P content (Table 63 a) and was comparable with 75 per cent of the recommended dose of fertilizer and superior to other lower levels. But in the second year, though 75 per cent of the recommended dose of fertilizer produced the highest value, it was similar to full dose and 50 per cent of the recommended dose (Table 63 b). Azolla @ 20 t ha^{-1} gave the highest value and was comparable with azolla @ 15 t ha^{-1} in both years. Azolla @ 15 and 10 t ha^{-1} were equal in the first year whereas they were similar in the second year. But azolla @ 10 t ha^{-1} and 5 t ha^{-1} were

Table 63 a. Residual content of soil (kg ha^{-1}) as influenced by fertilizer and azolla levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	10.98	10.87	11.84	12.73	11.61	C.D.(0.05) for F	0.990 (0.454)
F_1 - 50	14.29	16.73	17.86	19.94	17.21	C.D.(0.05) for A	1.669 (0.830)
F_2 - 75	16.48	18.02	18.85	19.62	18.24	C.D.(0.05) for A within same F levels	NS (1.660)
F_3 - 100	17.60	18.78	18.53	19.22	18.54		
Mean	14.84	16.10	16.77	17.87		C.D.(0.05) for A between F levels	NS (1.473)

Table 63 b. <u>Mundakan</u> 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean		
	A_1 5	A_2 10	A_3 15	A_4 20			
F_0 - 0	12.21	13.29	14.10	16.65	14.06	C.D.(0.05) for F	1.951 (0.895)
F_1 - 50	18.50	19.15	19.88	20.56	19.52	C.D.(0.05) for A	1.453 (0.723)
F_2 - 75	18.96	20.97	22.13	21.01	20.76	C.D.(0.05) for A within same F levels	NS (1.446)
F_3 - 100	19.46	20.36	20.55	22.19	20.64		
Mean	17.28	18.44	19.16	20.10		C.D.(0.05) for A between F levels	NS (1.404)

* 90: 45: 45 kg NPK ha-1
Values in parenthesis are S.Em +/-

comparable only in the second year. Though combination effect was not significant full dose of fertilizer with azolla @ 20 t ha^{-1} recorded highest value in the second year.

Highest K content was associated with full dose of fertilizer in both years (Table 64 a & b) followed by the next lower levels in the descending order. Full dose, 75 and 50 per cent of the recommended doses of fertilizer were comparable only in the first year. In the second year full dose and 75 per cent of the recommended dose were similar while 75 and 50 per cent of the recommended dose were also comparable. Azolla levels followed the same trend as in the case of P content. Azolla @ 20 t ha^{-1} recorded more residual K content which was similar to azolla 10 and 15 t ha^{-1} in both years. Though not significant, full dose of fertilizer in combination with azolla 20 t ha^{-1} gave more residual K content.

The above results reveal that more residual P and K status were associated with the application of highest dose of both the fertilizer and azolla individually as well as in combination. Higher the application, more will be the contribution to the soil reserve. Azolla itself contains

Table 64a. Residual K content of soil (kg ha^{-1}) as influenced by fertilizer and azolla levels. <u>Mundakan</u> 1982

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean
	A_1 5	A_2 10	A_3 15	A_4 20	
F_0 - 0	126	135	146	140	137
F_1 - 50	137	149	148	157	148
F_2 - 75	140	146	149	177	152
F_3 - 100	138	166	173	175	163
Mean	135	149	154	161	

C.D.(0.05) for F	16.3	(7.5)
C.D.(0.05) for A	12.8	(6.4)
C.D.(0.05) for A within same F levels	NS	(12.7)
C.D.(0.05) for A between F levels	NS	(12.2)

Table 64 b. <u>Mundakan</u> 1984

Fertilizer levels (% of recommended dose*)	Azolla levels (t ha^{-1})				Mean
	A_1 5	A_2 10	A_3 15	A_4 20	
F_0 - 0	129	136	142	143	138
F_1 - 50	160	159	164	170	159
F_2 - 75	141	159	164	173	160
F_3 - 100	152	169	171	191	171
Mean	141	156	160	170	

C.D.(0.05) for F	11.01	(5.051)
C.D.(0.05) for A	8.29	(4.125)
C.D.(0.05) for A within same F levels	NS	(8.251)
C.D.(0.05) for A between F levels	NS	(7.988)

*90: 45: 45 kg NPK ha^{-1}

Values in parenthesis are S.Em +/-

about 0.24 per cent P and 2 per cent K. Further, the high lignin content of azolla (Shi shu lian et al., 1981) resulted in slow availability thereby encouraging more residual nutrient status. Residual effect of P due to azolla application has already been reported by Mohanakrishnan (1983) under Kerala conditions.

Summary

SUMMARY

A series of investigations were carried out at the Regional Agricultural Research Station, Pattambi, Kerala, India to evaluate some of the low cost agronomic techniques for sustained rice production in IR 42, a rice variety suited to low fertility conditions, during the period from 1982 to 1985.

The results obtained from these trials are summarised hereunder.

Trial I

In this trial, the performance of IR 42 was studied under four levels of fertilizer (zero, 50, 75 and 100 per cent of the recommended dose of 90: 45: 45 kg NPK ha^{-1}) and six spacings (20 x 20, 20 x 15, 20 x 10, 20 x 5, 15 x 15 and 15 x 10 cm). The trial was laid out in split plot design with five replications.

During both years in *virippu* and *mundakan* season, full dose of fertilizer produced tallest plants with more number of tillers and leaf area index.

Irrespective of the year and season the widest spacing, 20 x 20 cm (25 hills m^{-2}) recorded the tallest plants while the closest spacing 20 x 5 cm (100 hills m^{-2}) produced the shortest plants in most of the stages. A reverse trend was noticed with respect to number of tillers and leaf area index.

Dry matter production was also more in treatments which received full dose of fertilizer in all the seasons. The spacing, 20 x 15 cm recorded the maximum dry matter production whereas the spacing, 20 x 5 cm gave the lowest value. The combination of full dose of fertilizer with a spacing 20 x 15 cm (33 hills m^{-2}) gave more dry matter production.

Yield attributes such as number of panicles, number of filled grains and thousand grain weight were highest/maximum with full dose of fertilizer only during virippu season. Sterility percentage was not much influenced by fertilizer levels. Number of panicles and sterility percentage were more in the spacing 20 x 5 cm (100 hills m^{-2}) while number of filled grains $panicle^{-1}$ and thousand grain weight were more in the wider spacings of 20 x 20 cm and 20 x 15 cm (25 and 33 hills m^{-2}).

Grain and straw yields were also influenced significantly by treatments. Full dose of fertilizer, 90: 45: 45 kg NPK ha^{-1} combined with a plant population of 33 hills m^{-2} (spacing 20 x 15 cm) gave the highest grain yield of 4.24 t ha^{-1} in *virippu* and 3.20 t ha^{-1} in *mundakan*. The straw yield was 4.39 t ha^{-1} in *virippu* as against 3.46 t ha^{-1} in *mundakan*. The highest net return of Rs. 6913 and Rs. 3890 were obtained from the *virippu* and *mundakan* crop, respectively from the above combination. The benefit cost ratio was also more in both seasons in the combination.

With respect to protein content of grain as well, the above combination topped the list.

Full dose of fertiliser and the spacing 20 x 15 cm individually or in combination recorded the highest N, P and K uptake.

Residual nutrient status with respect to organic carbon, P and K content of soil was more in the treatments which received full dose of fertilizer. The lower values were associated with zero fertilization and highest plant population of 100 hills m^{-2} (spacing 20 x 5 cm).

Trial II

The effect of seedling age (25, 30 and 35 days) and planting density (2, 4 and 6 seedlings hill^{-1}) were studied at fertility levels of 50 and 75 per cent of 90: 45: 45 kg NPK ha^{-1} in the first year and 75 and 100 per cent of the same in the second year. The trial was laid out in factorial RBD with three replications.

Fertilizer had no influence on the height of plants in all seasons. During virippu seasons, age had no effect on height of plants whereas during mundakan 25 days old seedlings were found to produce taller plants. Plant height was not much influenced by the number of seedlings hill^{-1}.

Higher level of fertilizer recorded more LAI and tiller number.

Age of seedling can go upto 35 days in the virippu season and 30 days in the mundakan season in registering higher tiller production. Highest LAI was associated with 30 days in both seasons of the first year and 35 days in the second year where an increased fertiliser level was given.

Four seedlings hill^{-1} were needed for higher tiller production and LAI values. The lowest values for number of tillers and LAI were found in treatments which had two seedlings $hill^{-1}$.

The dry matter production at harvest was more at the higher level of fertilizer in both years. Thirty five days old seedlings recorded maximum dry matter production in <u>virippu</u> season and 30 days old seedlings in <u>mundakan</u> season. Six seedlings $hill^{-1}$ produced more dry matter in the first year while four seedlings were superior in the second year.

Higher fertilizer level produced more number of panicles in both years. Number of filled grains per panicle was influenced by this treatment only during <u>mundakan</u> season. Thousand grain weight was not influenced by fertilizer levels in most of the seasons.

Seedling age showed significant effect only on number of panicles m^{-2} wherein thirty and thirty five days old seedlings produced more panicles.

Six and four seedlings $hill^{-1}$ produced comparable number of panicles m^{-2} and filled grains $panicle^{-1}$ while 1000 grain weight was not much influenced by this treatment.

Higher grain and straw yields were associated with higher level of fertilizer in both years. Thirtyfive days old seedlings produced more of these attributes in viripppu season and 30 days old seedlings in mundakan season. Six seedlings hill^{-1} recorded maximum production in first year while four seedlings hill^{-1} was better in the second year.

Protein content was also more at higher levels of fertilizer in both years. But age did not influence protein content. Four and six seedlings hill^{-1} gave similar protein content and were higher than with two seedlings hill^{-1}.

The uptake of N, P and K was more at higher level of fertilizer in both years. Seedlings of 25 days old recorded lowest uptake of nutrients. Planting two seedlings was always inferior to four and six seedlings.

Residual nutrient status of the soil after cropping was more at higher level of fertilizer.

Trial III

The biofertilizer azolla was evaluated as a lowcost organic source of nutrition in IR 42. The treatments consisted of four levels each of azolla 5, 10, 15 and 20 t ha^{-1} and fertilizer (0, 50, 75 and 100 per cent of

90: 45: 45 kg NPK ha^{-1}) fitted in a split plot design with five replications.

Fertilizer and azolla had significant influence on vegetative characters like height of plants, tiller production and leaf area index. The combinations of full dose of fertilizer with 10 t of azolla ha^{-1} and 75 per cent fertilizer with 15 t of azolla ha^{-1} were comparable and produced taller plants in both seasons. Tiller production and LAI were however, more in the former treatment in most stages.

The above two combinations were superior with respect to dry matter production at harvest in both seasons.

Full fertilizer with 10 t of azolla and 75 per cent fertilizer with 15 t of azolla produced higher number of panicles than the rest. Number of filled grains per panicle was also more in the above treatment combinations.

A reduction in thousand grain weight was noticed at lower fertilizer levels in both years.

Grain and straw yields were more and comparable in combinations of full fertilizer with 10 t of azolla and 75 per cent fertilizer with 15 t of azolla ha^{-1}. Thus a saving of about 25 per cent of fertilizer could be achieved if an extra dose of 5 t of azolla ha^{-1} was given with 75 per cent fertilizer. The benefit cost ratios were almost equal in both the combinations while the return per rupee invested was more in the latter combination.

Protein content was increased with fertilizer and azolla levels. The combination receiving full dose of fertilizer and azolla @ 20 t ha^{-1} recorded the highest protein content.

The residual organic carbon, P and K contents of soil after every crop were more with the highest dose of fertilizer and azolla.

Conclusion

The results of these experiments led to the following conclusions.

IR 42 - the rice variety known for its better performance under low fertility conditions, can respond to higher doses of fertilizers than 90: 45: 45 kg NPK ha^{-1} as well. In the present investigation highest level(s) of fertilizer tried was only 90: 45: 45 kg NPK ha^{-1}. It is the recommendation for high yielding medium duration group of rice under Kerala condition. This variety is having a duration of 140-145 days in Kerala. Hence it requires higher amount of fertilizers to express its full yield potential.

It is interesting to note that the variety has given reasonably good yields of above 2 t ha^{-1} without fertilizer, in all the seasons. This shows the potential of the variety even under low fertility conditions.

Despite the variety being a late maturing type, increasing number of seedlings $hill^{-1}$ from two to four was found to be advantageous. Especially at low levels of fertility six seedlings $hill^{-1}$ were found to give more grain yield.

The age of seedlings can go upto 35 days in virippu and 30 days in mundakan. This enables the farmers to get more time for land preparation of the main field. The variety will suit well with large number of ordinary farmers who cannot strictly follow the rigidity of nursery age of 20 or 25 days recommended for other modern varieties.

Application of azolla @ 15 t ha^{-1} with 75 per cent fertilizer can save about 25 per cent of the recommended fertilizer dose thereby reducing the fertiliser bill of the farmer.

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* Originals not seen

Appendix

APPENDIX I. Weather data during the cropping period

Standard week and month			Mean temperature (°C) Max.	Mean temperature (°C) Min.	Mean sun shine hours d^{-1}	Mean RH (%) 0720 h	Mean RH (%) 1420 h	Total rainfall (mm)	Evaporation $mm d^{-1}$
1			2	3	4	5	6	7	8
1982									
28	9-15	July	29.6	23.2	1.5	97	77	185.1	-
29	16-22		28.9	22.8	2.3	97	80	186.5	-
30	23-29		29.9	23.5	4.8	95	75	48.4	3.9
31	30-5	August	27.8	22.9	0.9	96	83	260.4	-
32	6-12		28.5	22.7	3.2	96	82	196.6	-
33	13-19		28.6	22.9	-	97	80	119.6	-
34	20-26		29.6	23.3	4.5	97	76	69.8	3.5
35	27-2	September	30.9	23.9	9.2	96	67	18.0	4.7
36	3-9		31.2	22.6	8.6	95	61	-	4.5
37	10-16		30.7	23.4	7.1	95	66	26.4	4.7
38	17-23		31.2	23.7	5.6	94	71	44.8	4.8
39	24-30		31.2	22.1	7.0	97	61	2.2	4.4
40	1-7	October	33.2	23.0	7.5	96	63	8.2	5.1
41	8-14		33.5	23.4	7.4	94	62	31.8	4.2
42	15-21		32.5	23.2	6.6	95	68	6.5	3.7
43	22-28		32.9	23.1	6.8	97	71	117.4	-
44	29-4	November	32.5	23.1	6.8	93	60	206.0	3.7
45	5-11		32.1	23.3	6.3	95	65	208.0	4.0
46	12-18		32.7	23.6	7.2	91	59	0.8	4.0
47	19-25		33.8	23.0	9.1	82	50	-	4.0
48	26-2	December	33.7	23.9	7.6	77	47	-	5.0
49	3-9		32.9	21.9	8.8	76	46	-	5.9
50	10-16		32.7	21.8	9.2	78	45	0.6	6.8
51	17-23		33.5	22.2	9.2	75	38	-	7.2
52	24-31		33.0	21.5	7.7	74	37	-	6.6
1983									
1	1-7	January	33.4	19.8	9.2	75	36	-	5.8
2	8-14		34.1	17.3	9.9	74	31	-	6.0
3	15-21		33.9	21.1	9.1	74	37	-	6.9
4	22-28		34.6	21.8	9.6	73	39	-	6.5
5	29-4	February	35.4	21.4	9.3	81	40	-	6.2
6	5-11		34.5	21.1	9.5	84	40	-	5.4
7	12-18		36.1	22.4	9.4	86	38	-	6.5
8	19-25		36.1	22.3	9.9	93	42	-	5.5
9	26-4	March	35.9	21.5	9.8	91	39	-	7.2
10	5-11		36.7	22.1	9.7	92	33	-	7.2
11	12-18		37.3	24.5	9.5	89	44	-	7.8
12	19-25		35.9	24.3	9.2	88	45	-	7.0
13	26-1	April	37.3	23.7	9.9	90	40	-	7.2
14	2-8		37.8	24.1	9.5	87	42	-	7.1
15	9-15		36.5	24.8	9.3	90	43	-	6.7
16	16-22		36.4	24.6	8.9	85	46	-	7.0
17	23-29		37.0	25.5	9.9	83	46	-	8.2
18	30-6	May	36.6	25.9	8.7	78	46	-	6.8
19	7-13		36.0	25.2	9.4	83	49	6.4	6.2
20	14-20		35.4	26.1	6.2	86	60	93.6	6.7

APPENDIX -I (Contd.)

1			2	3	4	5	6	7	8
21	21-27		34.8	25.5	8.7	88	53	0.6	6.3
22	28-3	June	34.4	25.9	9.0	89	58	27.3	6.1
23	4-10		33.9	25.6	7.6	90	60	1.1	8.6
24	11-17		31.8	24.3	2.8	92	76	87.8	4.1
25	18-24		30.9	24.0	3.6	93	83	100.6	2.0
26	25-1	July	30.2	24.1	2.3	95	79	205.0	2.8
27	2-8		32.0	23.9	7.7	96	68	20.9	2.4
28	9-15		29.4	23.7	3.2	98	88	230.2	-
29	16-22		28.6	22.6	1.8	98	87	253.8	-
30	23-29		29.4	23.6	2.0	96	79	92.2	1.2
31	3-5	August	29.7	23.9	4.0	96	77	104.8	2.0
32	6-12		28.5	23.6	0.9	98	85	146.1	-
33	13-19		28.9	23.6	1.7	99	88	170.4	-
34	20-26		29.6	23.9	2.8	97	80	49.6	-
35	27-2	September	30.4	24.5	5.1	98	77	11.7	-
36	3-9		30.0	23.4	3.1	97	78	174.6	-
37	10-16		29.0	23.5	2.4	99	82	142.9	-
38	17-23		28.1	22.7	2.3	99	86	180.4	-
39	24-30		30.0	23.4	5.1	97	78	38.4	-
40	1-7	October	29.8	23.7	5.4	99	79	53.4	-
41	8-14		31.2	22.0	9.2	96	63	-	4.8
42	15-21		31.5	23.0	6.9	96	67	25.2	-
43	22-28		32.5	23.5	6.1	95	66	83.2	-
44	29-4	November	32.3	23.4	5.6	97	65	61.4	-
45	5-11		32.3	21.8	9.0	92	58	15.0	-
46	12-18		33.1	20.0	10.3	85	50	-	3.7
47	19-25		32.1	21.7	7.5	96	63	31.7	2.9
48	26-2	December	32.4	21.9	8.7	88	50	-	3.9
49	3-9		32.7	23.0	8.2	83	48	4.0	4.8
50	10-16		34.0	23.0	9.6	83	47	-	5.5
51	17-23		31.7	23.3	3.8	82	63	1.0	4.3
52	24-31		31.8	22.9	3.0	91	64	38.5	1.7
1984									
1	1-7	January	33.0	22.9	8.8	77	45	-	5.5
2	8-14		32.2	23.0	6.8	72	45	-	-
3	15-21		33.7	22.0	7.0	90	51	14	3.4
4	22-28		33.7	19.5	9.8	86	43	-	5.8
5	29-4	February	34.1	22.7	8.2	74	39	-	5.5
6	5-11		34.3	24.5	5.5	79	49	-	6.1
7	12-18		34.9	24.9	8.8	86	48	-	-
8	19-25		35.7	23.1	9.4	94	37	-	4.9
9	26-3	March	35.6	24.7	7.3	65	33	-	5.5
10	4-10		33.2	23.2	4.8	89	59	12.0	3.9
11	11-17		36.1	23.3	9.4	93	47	6.0	4.5
12	18-24		37.5	23.6	9.1	93	36	-	4.9
13	25-31		36.9	24.8	8.6	89	47	-	6.1
14	1-7	April	34.7	24.9	5.8	94	60	32.0	3.9
15	8-14		35.4	24.3	8.5	92	59	24.2	3.8
16	15-21		34.4	23.8	6.5	93	65	14.4	3.3
17	22-28		34.2	25.0	8.2	92	58	9.4	4.3
18	29-5	May	35.9	26.1	9.6	88	53	-	5.7
19	6-12		36.2	25.9	9.6	92	60	5.0	5.6
20	13-19		35.8	25.5	8.9	89	56	15.7	3.9

APPENDIX - I (Contd.)

	1	2	2	3	4	5	6	7	8
21	20-26		35.5	25.2	9.9	89	51	16.6	5.6
22	27-2	June	32.3	24.0	5.4	97	71	227.0	2.5
23	3-9		28.9	22.8	2.2	93	83	88.4	1.2
24	10-16		29.7	23.5	1.5	92	92	229.6	0.2
25	17-23		28.7	23.1	2.1	95	89	172.0	0.5
26	24-30		28.6	22.5	2.3	94	85	201.6	1.2
27	1-7	July	28.9	22.9	2.1	96	78	201.4	0.2
28	8-14		28.5	23.3	3.3	94	82	119.1	1.1
29	15-21		27.2	22.3	0.6	97	83	264.8	0.1
30	22-28		29.3	23.6	6.2	96	71	61.6	1.8
31	29-4	August	29.1	23.4	4.6	94	74	76.9	0.6
32	5-11		28.8	23.2	3.9	95	69	57.4	2.1
33	12-18		28.8	23.1	6.2	95	77	64.0	1.3
34	19-25		29.0	23.4	6.0	93	74	18.4	2.0
35	26-1	September	28.1	22.8	4.4	95	76	38.2	1.8
36	2-8		29.5	22.8	7.7	92	72	3.0	3.5
37	9-15		29.7	22.8	5.8	96	67	8.6	3.8
38	16-22		31.3	23.6	7.7	94	64	4.0	4.4
39	23-29		31.2	23.6	4.9	95	73	49.8	2.3
40	30-6	October	29.6	22.9	1.5	93	86	155.8	-
41	7-13		28.8	23.1	4.2	92	70	95.4	1.8
42	14-20		30.1	18.9	9.4	92	53	-	3.7
43	21-27		31.0	22.8	7.4	92	68	40.8	3.1
44	28-3	November	32.7	22.2	9.6	91	50	48.4	2.9
45	4-10		31.9	23.0	6.8	93	59	-	4.1
46	11-17		33.0	22.5	7.2	94	54	-	3.2
47	18-24		32.5	22.9	6.1	85	58	12.8	3.7
48	25-1	December	31.2	20.5	5.5	91	60	17.6	2.3
49	2-8		32.4	21.6	8.2	85	49	-	3.9
50	9-15		33.0	18.1	10.1	85	42	-	3.7
51	16-22		31.9	17.2	9.8	84	47	-	4.4
52	23-31		33.9	20.9	9.9	93	50	-	3.5
1985									
1	1-7	January	32.1	23.8	6.0	89	76	56.2	2.8
2	8-14		32.2	20.7	9.4	91	62	-	4.5
3	15-21		32.7	22.6	8.8	77	49	--	5.7
4	22-28		33.5	21.6	9.9	83	40	-	6.6
5	29-4	February	34.7	20.7	9.7	82	43	-	6.2
6	5-11		33.6	20.1	7.4	95	50	-	4.2
7	12-18		34.6	22.4	9.3	98	51	-	4.9
8	19-25		35.5	21.7	9.9	83	42	-	6.0
9	26-4	March	36.2	22.1	7.1	93	48	-	3.2

EVALUATION OF LOWCOST AGRONOMIC TECHNIQUES FOR SUSTAINED RICE PRODUCTION

By

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ABSTRACT

Three field experiments were conducted at the Regional Agricultural Research Station, Pattambi, Kerala to evaluate some of the low cost agronomic techniques for sustained rice production during the period from 1982 to 1985. In the first experiment the performance of IR 42, a rice variety suited to low fertility conditions was assessed under varying levels of nutrition and spacing. Fertilizer, age of seedlings and planting density, for IR 42 were the experimental variables for the second experiment. In the third trial, azolla was evaluated as a low cost biofertilizer for IR 42. The first and third trials were laid out in split plot design while the second trial in factorial RBD.

The rice cultivar IR 42 proved its mettle under the low fertility conditions. In fact, it gave an average yield of 2.78 t ha^{-1} in virippu and 2.32 t ha^{-1} in mundakan without any fertilizer application.

A plant population of 33 hills m^{-2} (spacing 20 x 15 cm) in conjunction with full dose of fertilizer

of 90: 45: 45 kg NPK ha^{-1} recorded substantially more grain yield of 4.24 and 3.20 t ha^{-1} in virippu and mundakan seasons, respectively. Relatively lower grain and straw yields were registered by the treatment 100 hills m^{-2} (spacing 20 x 5 cm) at all levels of fertilizer application. The net return and benefit cost ratio were more in the former combination.

Increasing the seedling number $hill^{-1}$ from two to four or six was also found to be beneficial for this variety. At lower levels of fertilizer six seedlings $hill^{-1}$ recorded higher grain yields. However, at higher levels four seedlings $hill^{-1}$ were found to be superior.

During virippu season planting of 35 days old seedlings was found to perform better compared to 30 and 25 days old seedlings whereas in mundakan season, 30 days old seedlings were found preferable in terms of grain yield.

Recommended dose of fertilizers (90: 45: 45 kg NPK ha^{-1}) with azolla @ 10 t ha^{-1} and 75 per cent of the same with azolla @ 15 t ha^{-1} recorded similar grain yields indicating that an extra dose of 5 t of azolla ha^{-1} could substantially reduce the chemical fertilizer requirement and save as much as 25 per cent of the fertilizer. The benefit cost ratios were almost equal in both the combinations while the return per rupee invested was more in the latter combination. The finding appears to caution against excessive use of azolla expecting better exploitation of all the benefits attributed to it. Nevertheless, data on the residual fertility of the soil after each crop indicate that residual fertility was higher in the plots receiving full dose of fertilizer along with the highest level of azolla, 20 t ha^{-1}.