SPACING-CUM-FERTILISER INVESTIGATION ON RICE VARIETY, MASHURI, IN THE ONATTUKARA TRACT

By
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DECLARATION

I hereby declare that this thesis entitled "Spacing-cum-fertiliser investigation on rice variety, Mashuri, in the Onattukara tract" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

SOBHANA S.

Vellayani,
7th March, 1983.

CERTIFICATE

Certified that this thesis entitled "Spacing-cum-fertiliser investigation on rice variety, Mashuri, in the Onattukara tract" is a record of research work done independently by Smt. SOBHANA, S, 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

In this era of science, there is hardly any domain where science and technology do not play a significant role. On the food front, as in many other spheres of economy, modern science and technology has contributed much to make man's life comfortable and pleasant. Even now efforts in the sphere of research and development are being intensively carried out in different parts of the world to increase the area and production per unit area of rice. Such an endeavour is imperative in order to support the ever-increasing population.

The Kerala state sports an area of 8.54 lakh ha under rice with an annual production of 12.54 lakh tonnes. Since independence, the waves of the first gradual and then rapid progress of food grain production which swept over the entire nation, were felt in this state also. The Green Revolution and the launching of the High Yielding Variety Programme highly revolutionised the concept of crop production, their impact being high especially on rice production. Even so, the prospect of doubling or even trebling today's production figures looms on the horizon, inspiring scientists in the field to great extents. Breeding has a definite role here, but agronomy, and consequently crop management, exert tremendous influence.

The present investigation was aimed at satisfying the dire need for a suitable spacing and a recommendable fertiliser dosage for the Mashuri variety of rice. This is a Malaysian variety and a cross between Taichung-65 x Mayang Ebos 80/2. It is a photo-insensitive variety with 135-145 days duration and gives good grain and straw yields.

The present investigation was conducted in the Onattukara tract which consists of a cultivated area of 68,340 ha of which 28,340 ha is under rice. The soil of this tract is of the sandy loam type and the climate is warm, humid and tropical. The tract is strictly rainfed and receives a good share of both South West and North East monsoons. Paddy fields are sometimes flooded during the early half of the second crop season due to the shallow water table.

The facts that farming becomes a paying proposition only under suitable fertilisation, and that the variety can respond to a still higher level of fertiliser than what it receives now, shows that a higher and optimum level has to be determined. Though the variety is tall, it can respond fairly to higher levels of nitrogen than other tall varieties like Pankaj and Jagannath without any fear of lodging. Furthermore, earlier reports indicate that the sandy soils of the tract are low in potash owing to the open texture and heavy leaching nature of the soil (Nambiar and Alexander, 1968). All these are pointers to the definite truth that grain and straw yields of the variety can be again increased through adequate fertilisation.

Furthermore, proper plant spacing is one of the important factors to obtain higher yields in transplanted rice. In general, under poor fertility conditions, as in sandy soils, spacing between hills should be somewhat narrower to obtain enough production of early tillers per unit area. Panicles of early tillers are heavier than the panicles derived from late tillers. In wider spacing, formation of more tillers per plant is encouraged, but with narrower spacings, formation of more ear-bearing tillers are encouraged, which may be heavy as well (Chatterjee and Maiti, 1981). In general, where the number of panicles is about 400 per square metre, the yield is usually high. Further, with this high count of tillers, the crop matures uniformly within a short period. Owing to these facts, spacing was another aspect studied.

The objectives of the present investigation are hence listed below,

1. To investigate the effects of different levels of N, P and K on growth and yield of medium duration, tall indica rice for second crop in Onattukara.
2. To study the uptake of major nutrients as influenced by the different levels of N, P and K.
3. To determine the optimum spacing for medium duration, tall indica rice for second crop season.
4. To work out the cost-benefit ratios under different levels of N, P and K and under different spacings for medium duration, tall indica rice.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Considerable amount of research work has been done on the different aspects of rice cultivation since the advent of science and technology. However, research on the nutritive aspects of rice or spacing adopted for planting different cultivars, is very limited. The following review deals with the effects of different levels of nitrogen, phosphorus and potassium, different spacings and the interaction between the two on the growth, yield attributes, grain and straw yields, quality of grain and the uptake of nutrients by rice.

Effect of Nitrogen on Growth Characters

a. Height of the Plant

Lenka and Behera(1967) observed that increased doses of nitrogen from zero to 120 kg/ha increased plant height significantly. Lenka(1969) reported that response of height was very pronounced and increased progressively with increased nitrogen levels of zero, 40, 80 and 120 kg/ha. Ramanujam and Rao (1971) observed positive correlation in plant height at tillering and flowering stages with the levels of applied nitrogen. Sumbali and Gupta (1972) found that plant height increased with increased levels of nitrogen upto 200 kg/ha, consequently increasing the straw yield. In an experiment at Bangkhen Rice Experiment Station, Koyama and Niamsrichand (1973) found an increase in plant height with increasing rates of nitrogen upto 93 kg/ha. Sadayappan et al.(1974) reported that plant height increased with increasing doses of nitrogen and that maximum height was obtained with 200 kg N/ha, which was, however, on par with 150 and 100 kg N/ha. Lenka et al.(1976) obtained increase in plant height with increasing levels of nitrogen upto 180 kg/ha. Trials conducted by Mengel and Wilson(1981) also revealed that nitrogen application significantly increased plant height.

However, Eunus and Sadeque (1974) drew the conclusion that plant height was unaffected by different levels of nitrogen, after detailed studies in sandy loam soil.

b. Tiller Count

Shrivastava et al.(1970) reported that in the variety Taichung(Native)-1, the increase in tiller due to increased nitrogen levels from zero to 100 kg/ha was mainly responsible for increased grain yields, even though it seemed to affect the production of grains per panicle adversely. In pot experiments conducted by Pande and Narkhede (1972) rice variety Taichung 65 gave increased tiller counts with increasing nitrogen levels upto 90 kg/ha, and was higher when it was given in two instalments, rather than when it was applied in single or three split applications. Lenka et al. (1976) observed that increase in nitrogen levels from zero to 180 kg/ha increased the number of tillers per plant. Murty and Murty (1978) reported increased tillering with increased nitrogen levels from 60 to 120 kg N/ha. According to reports by Raju (1979), rice cv Jaya grown on a sandy clay loam soil gave significant increases in number of tillers per hill with increased nitrogen levels upto 180 kg N /ha.

From the foregoing review, it was observed that nitrogen fertilisation favourably influenced tiller number.

Effect of Nitrogen on Yield Attributes

a) <u>Productive Tiller Count and Number of Panicles per Hill</u>

In a trial on the nitrogen requirement of IR-8 and Taichung (Native)-1, Gupta *et al.*(1970) observed an increase in the number of fertile tillers per plant with nitrogen upto 135 kg/ha. Similar increase in the number of panicles per hill with levels above 90 kg N/ha was reported by Ramanujam and Rao(1971). Muthuswamy *et al.* (1972) reported from a trial conducted to assess the fertiliser requirements for three rice varieties, viz., Karuna, Kaveri and Kanchi, that increase in nitrogen levels increased the productive tillers and that the highest was for 160 kg N/ha. In a trial on IR-8 rice with the object of determining the optimum level of nitrogen, Subramanian and Kolandaiswamy(1973) observed that the total number of productive tillers per square metre increased with increase in nitrogen levels upto 240 kg/ha. Rethinam(1974) reported that increasing rates of nitrogen from zero to 160 kg/ha produced linear increases in average number of productive tillers per hill.

Gowda and Panikar (1977) obtained increased number of productive tillers per hill with increased nitrogen levels upto 160 kg/ha. Subbiah *et al.*(1977) found an increase in panicle number upto 200 kg N/ha. Dixit and Singh(1979), after a detailed study on the response of rice varieties to nitrogen levels, observed that application of 80 kg N/ha significantly increased the number of ear bearing tillers over zero and 40 kg N/ha.

The review points out that panicle number was considerably increased by nitrogen application.

b) Panicle Length and Panicle Weight

Lenka (1969) observed that the length of panicle increased with the levels of nitrogen, viz. zero, 40, 80 and 120 kg/ha. In rice variety ADT-27 a trial on the influence of nitrogen supply on growth factors conducted by Ramanujam and Rao (1971) revealed that panicle length increased with increase in applied nitrogen upto 180 kg/ha. Singh (1971) reported an increase in panicle length with increase in nitrogen levels from zero to 160 kg/ha. Panda and Leeuwrik (1972) also observed increase in panicle length with nitrogen application. Trials by Sadayappan *et al.* (1974) revealed that panicle length was influenced by nitrogen application, but treatments 50, 100, 150 and 200 kg N/ha were all on par. Raj *et al.* (1974) observed increase in panicle length by the addition of nitrogen and the maximum panicle length was recorded with the highest levels of 200 and 250 kg N/ha. Chang and Su (1977) and Subbiah et al.(1977) reported that length and weight of panicles increased with increasing rates of nitrogen upto 200 kg/ha. Similarly, Singh et al.(1979a) observed that panicle length increased with nitrogen rates upto 120 kg/ha. Report by Raju(1979) revealed increase in panicle length with increased nitrogen doses upto 180 kg N/ha.

Subbiah and Morachan(1974), however, reported decrease in panicle weight as the levels of nitrogen increased and they attributed this to lodging of these varieties under higher levels of nitrogen.

c) Number of Grains per Panicle

Gupta et al.(1970) reported that increasing the rates of applied nitrogen from zero to 135 kg/ha increased the number of grains per ear. In an experiment on the response of high yielding rice varieties to high levels of nitrogen, Panda and Leeuwrik(1972) observed an increase in the number of fertile and sterile spikelets per panicle upon increasing nitrogen levels upto 200 kg/ha. Increase in spikelet number per panicle with increased rate of nitrogen upto 94 kg/ha was also observed by Koyama and Niamsrichand (1973). In a trial conducted by Prasad and Sharma (1973) the higher nitrogen level of 225 kg/ha more than doubled the total number of spikelets per panicle as against the control with no nitrogen. Subbiah *et al.* (1975) observed an increase in the grain number per panicle by increasing the nitrogen dosage from zero to 100 kg/ha. Singh *et al.* (1979a) obtained significant increase in the grain number per panicle upon increasing rates of nitrogen application upto 120 kg/ha. Experiments conducted by Dixit and Singh (1979) showed a significant increase in the number of grains per panicle with 80 kg N/ha, as compared with 0 kg N/ha.

The review cited above indicates that increasing the rates of applied nitrogen increased the grain number per panicle.

Contrary to this, Shrivastava *et al.* (1970) observed significant decrease in number of grains per ear with increased nitrogen application. Similar results were also reported by Purushothaman and Morachan (1974), Sadayappan *et al.* (1974) and Lenka *et al.* (1976), Natarajan et al.(1974) observed no significant increase in number of grains per panicle with successive increment of nitrogen levels.

d) Thousand Grain Weight

Panda and Leeuwrik (1972) reported that nitrogen increased 1000 grain weight upto 200 kg/ha. According to the results of trials conducted by Sadayappan et al.(1974) there was an influence on the weight of thousand grains by nitrogen application, but the treatments from 50 to 200 kg N/ha were all on par. Positive increase in thousand grain weight due to nitrogen application were also obtained by Gowda and Panikar (1977). Raju (1979) reported significant increase in thousand grain weight with nitrogen application.

Contrary to these results, Muthuswamy et al.(1972), Natarajan et al.(1974) and Lenka et al. (1976) reported that the weight of thousand grains remained unaffected by nitrogen application. Research reports of Shrivastava et al. (1970) and Ramanujam and Rao (1971) indicated that increasing nitrogen application decreased thousand grain weight.

Effect of Nitrogen on Yield

a) Grain Yield

Rethinam et al. (1975) observed that the increase in yield was sequential to the graded levels of nitrogen and a maximum yield was obtained with 160 kg N/ha in both tall and dwarf indica rice varieties. Trials conducted by Sahu and Murty (1975) revealed that grain paddy yield increase in nitrogen levels upto 160 kg/ha. Pillai et al. (1975) observed significant response in grain yield upto 80 kg N/ha.

Satyanarayana and Sharma (1976) reported that increase in nitrogen rates from zero to 120 kg/ha increased average paddy yield in six early maturing rice cultivars. In field trials on rice variety, Padma, Sharma and De (1976) observed that increasing the nitrogen rates from zero to 150 kg/ha increased average grain yields, but that further increase in nitrogen rates gave no additional yield. Singh and Singh (1976) observed that average grain yield increased from 1.44t/ha to 2.0 t/ha with increase in nitrogen application from 30 to 90 kg N/ha. From investigations by Venkatachari et al. (1976), it was evident that maximum yield of rice could be obtained at 150 kg N/ha, whereas the response per kg of applied nitrogen was highest at 50 kg N/ha.

In experiments in farmers' fields, Gowda and Panikar (1977) observed that yield response to nitrogen was linear in varieties Jaya, IR-8 and IR-5. According to the research results of Rao (1977), paddy yields of eight rice cultivars given zero to 200 kg N/ha increased with increase in N rates, the highest yield being 8.68 t/ha. but the economic optimum nitrogen rate was 100 kg/ha. Roy et al.(1977) reported that in irrigated trials with long duration rice cultivar, Pankaj, grain yields were highest with 120 kg N/ha applied in four equal split dressings. An investigation by Dargan and Chhillar (1978) to study the effect of nitrogen on rice yields showed that significant increase in grain yield was obtained with 100 kg N/ha over control. Murty and Murty (1978) observed that rice yields increased with nitrogen rates upto 120 kg/ha and increases were attributed to increases in tillering. Poulose et al.(1978) reported that rice variety IR-8 gave maximum grain yield with 80 kg N/ha whereas PTB-9 gave highest yield with 40 kg N/ha. Experiments conducted by Prasad and Rathi (1978) revealed significant yield increase with nitrogen. Venkateswarlu (1978) observed that application of 250 kg N/ha increased the grain yield significantly over nitrogen rates of 50, 100, 150 and 200 kg/ha. In investigations on rice varieties, Padma and Bala, it was realised by Singh and Modgal (1979) that yield increases were significant with nitrogen rates upto 90 kg/ha and that this nitrogen rate was on par with 120 kg N/ha. Dixit and Singh (1979) observed that grain yields increased from 2.18 t/ha with no nitrogen to 4.19 t/ha with 80 kg N/ha. Panda and Das (1979) observed that increasing the rates of applied nitrogen from zero to 200 kg/ha increased the average paddy yields from 6.13 to 8.96 t/ha in seven dwarf rice cultivars tried. Raju (1979) reported increase in grain yields with nitrogen doses upto 180 kg/ha. Mengel and Wilson (1981) also reported that grain yield increased with increased nitrogen application.

Ramanujam and Rao (1971), however, recorded decreased paddy yield with the application of more than 90 kg N/ha. Trials conducted by Fagundo <u>et al.</u> (1978) with four nitrogen levels from zero to 240 kg/ha showed increase in tillering, but had very little effect on final yield.

b) Straw Yield

In a trial on the influence on nitrogen supply on growth factors of rice, Ramanujam and Rao (1971) observed that straw yield increased with increase in applied nitrogen upto 180 kg/ha. Similar results have also been reported by Rao and Ramanujam (1971) in the variety, ADT-27. Muthuswamy *et al.* (1972) observed a significant increase in straw yield upto 120 kg N/ha. According to Panda and Leeuwrik (1972) nitrogen levels upto 200 kg/ha increased yield of straw. Sumbali and Gupta (1972) reported that straw yield was increased upto 200 kg N/ha mainly due to the fact that plant height, number of leaves and effective tillers per hill were increased with increased nitrogen levels. Trials by Sadayappan *et al.* (1974) also revealed that nitrogen influenced the straw yield significantly and in this respect nitrogen levels of 150 kg/ha and 200 kg/ha were on par. Singh *et al.* (1974) noticed considerable increase in straw yields due to increasing doses of nitrogen. According to Rethinam *et al.* (1975), the straw yield in rice varieties, Cauvery and Padma, was influenced by increased doses of nitrogen. Venkateswarlu (1978) reported that straw yields increased upto 200 kg N/ha and beyond this dose it decreased. Dargan and Chhillar (1978) observed an increase in straw yield due to application of 100 kg N/ha over control.

Contrary results have been obtained by Daniel (1970), according to which rice straw yields were found unaffected by nitrogen application in rice variety PTB-9.

Effect of Nitrogen on Quality of Grain

In pot experiments with zero to 350 lb/acre N applied to rice on a sandy loam soil, Ahmed and Faiz (1969) observed that grain protein content increased and starch content decreased with increasing nitrogen supply. Latchanna and Rao (1969) reported that increases in the rates of applied nitrogen from 45 to 135 kg/ha were accompanied by the linear increases in protein contents of rice cultivars Taichung(Native)-1 and Tainan-3. Linear response in nitrogen content of the grain to applied nitrogen was observed in ADT-27 by Sivappah et al. (1969). Ramanujam and Rao (1970) recorded an increase in the grain protein content corresponding to increased nitrogen levels from 30 to 180 kg/ha. Investigations by Ghosh et al.(1971) revealed that increase in nitrogen rates were accompanied by linear increase in grain protein content. Kulkarni (1973) reported that increasing rates of applied nitrogen from zero to 150 kg/ha increased grain protein contents in six, tall indica and semi-dwarf rice cultivars. On a sandy clay loam, maximum protein content of grain was obtained with 120 kg N/ha applied after flowering, as per reports by Abraham et al.(1974). Kumar and George (1974) observed an increase in grain protein content with increase in nitrogen doses. In trials on eight early paddy varieties, Srivastava and Verma (1974) obtained increased grain protein content with successive increases in nitrogen upto the maximum rate of 200 kg N/ha. Considerable increase in grain protein content with nitrogen application was reported by Nagarajah et al. (1975) and Rabindra et al.(1977). Dutta and Barua (1978) observed that nitrogen rates from zero to 80 kg/ha increased grain protein, non-protein nitrogen, crude fibre, lipid, phosphorus and iron contents, while it decreased grain calcium and starch contents. Raju(1979) reported increased protein content of grain with applied nitrogen.

In contrast to the above results it was observed by Muthuswamy et al. (1973a) that forms and levels of nitrogen had no effect on the crude protein content of grain. Subramanian et al. (1974) also observed no significant difference in protein content with nitrogen application.

Content and Uptake of Nitrogen

An investigation undertaken by Sims and Place (1968) to study the nutrient uptake of rice at different nitrogen levels revealed that increasing nitrogen application increased nitrogen uptake in the three cultivars tried, viz., Vegold, Nato and Blue Bonnet-50. Similar results were obtained by Ahmed and Faiz (1969) in pot trials. Sivappah et al. (1969) reported that nitrogen uptake in grain was influenced by nitrogen fertiliser alone. According to research reports of Ramanujam and Rao (1970) there was obvious increase in the total nitrogen content with increased nitrogen levels. Koyama and Niamsrichand (1973) observed that the nitrogen content of plants at harvest consistently increased with nitrogen rate. They found a linear relationship between total nitrogen absorbed by plants and level of applied nitrogen. In trials conducted by Prasad and Jha (1973) it was observed that uptake of nitrogen increased with increasing level of nitrogen. Trials by Ramaswamy and Raj (1974) revealed that nitrogen and green manure application increased nitrogen uptake. They obtained significant correlation between grain, straw and root growth and uptake of nitrogen by grain, straw and root. Field experiments by Nagarajah et al.(1975) showed that although nitrogen application at flag leaf and heading stages resulted in high fertiliser nitrogen uptake, they did not bring about substantial increases in grain yield; instead the grain protein content was considerably increased. Gopalswamy and Raj (1977) reported that increasing rates of applied nitrogen from zero to 200 kg/ha produced linear increases in the uptake of nitrogen. Application of nitrogen upto 120 kg/ha increased the uptake as reported by Agarwal (1978). Similar increases were also noticed by Singh and Modgal (1978) and Raju (1978). Significant increases in nitrogen uptake with rates upto 80 kg/ha was reported by Rai and Murty (1979).

Loganathan and Raj (1972) reported that nitrogen uptake by rice grain was highest in plants receiving 80 kg P_2O_5/ha and did not vary with different nitrogen levels.

From the results of trials with four rice cv grown during the _kharif_ and _rabi_ seasons, it was concluded by Patnaik and Nanda (1969) that the uptake of nitrogen by plants was highest upto the flowering stage and most of the absorbed nitrogen was later translocated from vegetative parts to panicle. Sadanandan _et al_.(1969) reported that the nitrogen content in paddy straw decreased from tillering stage onwards. Muthuswamy _et al_.(1974) reported that increasing the application of nitrogen increased the nitrogen uptake in the plant and that more than half of the total nitrogen requirement was absorbed between panicle initiation and flowering. According to reports by Reddy _et al_.(1978), maximum nitrogen uptake was seen at harvest compared to maximum tillering and panicle initiation stages. Singh and Modgal (1979) observed that the difference in nitrogen concentration in plant due to nitrogen levels were greatest at the panicle initiation stage and started becoming narrower with increasing age of crop.

Effect of Phosphorus on Growth Characters

a. Height of the Plant

Place *et al.* (1970) reported that increasing phosphorus application decreased plant height. Aaron *et al.* (1971) observed that increased dressings of phosphorus increased plant height. Trials conducted by Nair *et al.* (1972) at the Rice Research Station, Pattambi, revealed that phosphorus application did not have any significant influence on the mean height of the plant at maturity. Field investigations by Rao *et al.* (1974) to study the response of IR-5 rice for phosphorus showed that height of the plant was not significantly influenced by the application of phosphorus upto 80 kg/ha. Alexander *et al.* (1974 a) reported that plant height was unaffected by phosphorus. Results of investigations on three varieties TKM-6, ADT-27 and Co-33 by Kalyanikutty and Morachan (1974) showed that phosphoric acid did not have any marked effect on plant height. Bhardwaj *et al.* (1974) reported that there was no significant difference between 0, 30 and 60 kg P_2O_5/ha in influencing the plant height.

Review on plant height indicated that the height of plants was considerably influenced by phosphorus application.

b. Tiller Count

In a glass house pot experiment, Terman et al. (1970) observed that tillering increased markedly with amount of applied phosphorus in low P soil, slightly on medium P soil and there was no response in high P soil. Nair et al (1972) reported that phosphorus application resulted in increased tillering. Trials by Bhardwaj et al. (1974) also revealed that the number of tillers per plant increased with increasing rates of phosphorus upto 60 kg/ha. Bhattacharya and Chatterjee (1978) also found that application of phosphorus with nitrogen aided early tillering.

Contrary to these results, Kalyanikutty and Morachan (1974) reported that phosphorus application did not markedly affect number of tillers per plant. Suseelan et al. (1978) also observed that phosphorus did not significantly affect tiller production.

Effect of Phosphorus on Yield Attributes

a. Productive Tiller Count and Number of Panicles per Hill

Place et al. (1970) recorded increase in the number of panicles with increase in the levels of phosphorus applied from zero to 56 kg P_2O_5/ha. Phosphate fertilizer effected a significant increase in the number of productive tillers with 59.7 kg P_2O_5/ha as reported by Majumdar (1971). Investigations by Nair *et al.* (1972) revealed that phosphorus application resulted in significantly higher number of productive tillers per hill over the control. Bhattacharya and Chatterjee (1978) observed an increase in the production of early tillers with phosphorus application which resulted in more number of productive tillers per hill.

However, detailed studies conducted by Alexander *et al.* (1974a) on the rice cv Triveni proved that the number of fertile tillers remained unaffected by phosphate application. Similar results were also obtained by Sadanandan and Sasidhar (1976).

b. Panicle Length and Panicle Weight

Investigations by Place *et al.* (1970) revealed that increasing levels of phosphorus application from zero to 56 kg P_2O_5/ha increased panicle weight. Similarly, Majumdar (1971) observed significant increases in panicle length with phosphate application upto 59.7 kg P_2O_5/ha.

Alexander *et al.* (1974a) found no difference in panicle length by phosphorus application.

c. Number of Grains per Panicle

Aaron *et al.* (1971) observed that increased dressings of applied P increased the number of grains per panicle. According to reports by Majumdar (1971), number of grains per panicle was significantly increased by application of 59.7 kg P_2O_5/ha. Singh and Varma (1971) observed distinct increase in the number of grains per panicle by the application of 90 and 60 kg P_2O_5/ha over 30 kg/ha. Bhattacharya and Chatterjee (1978) suggested that early tillering was aided by application of phosphorus and that early tillers gave more number of filled spikelets per panicle.

Nevertheless, Alexander *et al.* (1974a) found that the grain number per panicle was unaffected by phosphorus application. Sadanandan and Sasidhar (1976) and Suseelan *et al.* (1978) also did not observe any significant effect on the number of filled grains per panicle with increasing rate of applied phosphorus.

d. Thousand Grain Weight

Majumdar (1971) reported that phosphorus application caused an increase in the 1000 grain weight with 59.7 kg P_2O_5/ha. Singh and Varma (1971) observed significant increases in the weight of thousand grains with 90 and 100 kg P_2O_5/ha over 30 kg P_2O_5/ha. Research reports of Thandapani and Rao (1976) revealed that increasing levels of phosphorus from zero to 45 kg/ha increased 1000 grain weight whereas further application decreased it.

Place et al. (1970) recorded decrease in 1000 grain weight with increase in levels of phosphorus applied from zero to 56 kg P_2O_5/ha. Alexander et al. (1974a) observed that phosphate application did not affect 1000 grain weight.

Effect of Phosphorus on Yield

Padmakumari et al. (1969) reported from pot trials with an acid peat soil, that phosphorus rates upto 100 kg/ha gave significant increases in grain yield over zero kg P_2O_5/ha. Dev et al. (1970) observed that increases in the rates of applied P_2O_5 from 30 to 90 kg/ha were accompanied by linear increases in the average paddy yields from 3 to 4.32 t/ha at Ramba where the available soil P was 9 kg/ha and from 4.44 to 6.1 t/ha at Gharaunda, where the available soil P was 3 kg/ha. In trials on sandy loam soil with rice cv Taichung (Native)-1 application of 40 kg P_2O_5/ha resulted in increased paddy yields compared with no phosphorus application, according to Khatua and Sahu (1970). Aaron et al. (1971) observed that increased dressings of applied phosphorus increased the yield of paddy. Majumdar (1971) noticed that phosphatic fertilisation showed a trend towards increased grain yield with high dose upto 59.4 kg P_2O_5/ha. Increases in grain yields with phosphate application were also obtained by Kalyanikutty and Morachan (1974). Gopalakrishnan et al.(1975) found that when phosphorus fertilisers were applied to the soil they tended to increase the yield of grain and not straw. Field trials by Dixit and Singh (1977) showed that grain yield increased from 2.4 t/ha with no phosphorus application to 2.7 t/ha with 40 kg P_2O_5/ha. Agarwal (1978) observed that paddy yields of dwarf rice cv Sarjoo-49 grown on sandy loam soils of low phosphorus content were increased from 4.54 to 4.94 t/ha with increases in P_2O_5 rates from zero to 120 kg/ha. Ageeb and Yousif (1978) reported that additions of P_2O_5 produced significantly higher yields of rice with an optimum economic level at 43 kg P_2O_5/ha. Increase in grain yield with increasing levels of applied phosphorus upto 100 kg/ha was noticed by Rabindra (1978). Ittiyavarah *et al.* (1979) observed that application of nitrogen alone without phosphorus produced progressive decreases in yield and the plants showed phosphorus deficiency symptoms. Increased yield with increased phosphate application was also reported by Singh *et al.* (1979b), Singh and Jaiprakash (1979) and Agarwal (1980).

Moolani and Sood (1966) found that paddy yields declined with increasing rates of phosphate application. In a field trial with rice cv IR-8, Shukla (1969) observed that paddy yield was not affected by phosphorus. Nair and Pisharody (1970), in an experiment with rice on laterite sandy loam soil, found that the paddy yields were not increased with 22.4 to 56.0 kg P_2O_5/ha in four forms applied alone or with various rates of nitrogen and/or potash. Investigations by Rao *et al.* (1974) showed that paddy yield obtained with 40 kg P_2O_5/ha was not further significantly increased by increasing the rate to 80 kg P_2O_5/ha. Significant decrease in yield with higher rates of applied phosphorus was obtained by Samui and Bhattacharya (1976) and Robinson and Rajagopalan (1977).

Effect of Phosphorus on Quality of Grain

In a field trial with rice cultivars, Patni-6, TN-1 and IR-8, Kadrekar and Mehta (1975) observed that the optimum phosphorus level for grain protein content was 40 kg P_2O_5/ha with all cultivars. Agarwal (1978) reported that increasing the rate of applied phosphorus from zero to 120 kg/ha increased the crude protein content of the grain from 9.76 to 10.28 per cent.

However, a decrease in crude protein content of the husked grain with increased phosphorus application from zero to 120 lb/acre was obtained by Karim et al. (1967). Ageeb and Yousif (1978) observed a reduction in grain protein percentage from 7.11 to 5.81 by increasing the phosphorus level from zero to 107 kg P_2O_5/ha, but the total protein yield seemed unaffected. This was attributed to the increase in paddy yield.

Content and Uptake of Phosphorus

Pathak et al.(1972) noticed that the uptake of phosphorus was more by grain compared to straw and that the highest uptake was obtained with a fertiliser level of 100:50:50 of NPK, irrespective of the variety studied. Trials conducted by Sadayappan and Kolandaiswamy (1974) revealed that increasing nitrogen rates from zero to 200 kg/ ha increased phosphorus content of the plant from 0.129 to 0.177 per cent. Increased phosphorus content of straw was also noticed by Raju (1978) with increased nitrogen application from zero to 180 kg/ha. Singh et al.(1979b) found that increasing the rates of nitrogen from 80 to 160 kg/ha increased the grain phosphorus content. Iruthayaraj and Morachan (1980) reported that the uptake of phosphorus was more with 240 kg N/ha than with lower levels.

However, trials conducted by Loganathan and Raj (1972) revealed that phosphorus uptake by paddy grain remained unaffected by nitrogen application. Phosphorus content decreased with increased nitrogen application according to Agarwal (1978).

Oommen et al.(1972) reported that the percentage of total phosphorus in the plant increased with an increased dose of phosphorus from 25.75 to 51.50 kg P_2O_5/ha. Pot trials by Krishnaswamy et al.(1974) revealed that application of 180 kg P_2O_5/ha gave the highest grain phosphorus contents. Gupta *et al.* (1975) reported from pot trials on five rice cultivars that uptake of phosphorus increased with higher rates of applied phosphorus. Investigations on dwarf rice cv Sarjoo-49, by Agarwal (1978) revealed that grain phosphorus contents were increased with phosphorus application upto 120 kg P_2O_5/ha. Suseelan *et al.* (1978) found that there was a significant increase in phosphorus absorption with increasing rates of phosphorus fertiliser at all stages of growth.

However, Alexander *et al.* (1974b) could not obtain any significant influence on phosphorus uptake with different rates of its application.

Trials by Singh *et al.* (1976) revealed that phosphorus uptake and translocation were highest with the application of 160 kg K_2O/ha. Increase in grain phosphorus content with applied potassium was also noticed by Agarwal (1978).

Naphede (1969) observed that the rate of phosphorus absorption was much higher at 40 to 90 days after transplanting than at other periods and increased with increase in phosphate supply. A trial on three high yielding paddy varieties by Muthuswamy et al.(1973b) showed that more than half of the total requirement of phosphorus was absorbed between the stages of panicle initiation and flowering. Mohamed Ali and Morachan (1973) reported that the uptake of phosphorus was higher in the early stages and decreased with crop growth. Thandapani and Rao (1974) found that increases in rates of applied phosphorus from zero to 75 kg/ha were accompanied by linear increases in its contents in roots, shoots and grain. They also found that the phosphorus contents in roots and shoots were the highest at the tillering stage and decreased gradually with age. Iruthayaraj and Morachan (1980) found that the uptake of phosphorus was high at harvest stage.

Effect of Potassium on Growth Characters

a. Height of the Plant

Kalyanikutty and Morachan (1974) observed that potash application did not markedly affect plant height. Rao et al.(1974) found no significant increase in plant height by the application of potassium upto 80 kg K_2O/ha.

b. Tiller Count

Investigations undertaken by Kulkarni et al.(1975)

showed that the effect of potash was significant on the total number of tillers. Singh and Singh (1979) obtained increased tillering with application of potash upto 60 kg/ha in two split dressings. Similarly, Chamura and Mizusawa (1979) observed that in rice, the number of tillers produced increased with increasing uptake of potash.

Contrary to these reports, Kalyanikutty and Morachan (1974) could not obtain any marked increase in tiller number due to potash application. Uexkull (1976) found that applied potassium slightly decreased tillering.

Effect of Potassium on Yield Attributes

a) Productive Tiller Count

Trials on the response of paddy to fertilisers in Shimoga district showed that the effect of potassium was significant on the number of effective tillers, according to Kulkarni *et al.* (1975).

However, Rao et al. (1974) reported that the number of productive tillers was not significantly influenced by the application of potash even upto 80 kg K_2O/ha.

b. Panicle Length

Summarising the results of trials with rice cv Jaya, Singh and Singh (1979) concluded that application of 60 kg K_2O/ha in split dressings increased panicle length.

However, Rao *et al*(1974a) reported that application of potassium even upto 80 kg K_2O/ha did not have any marked influence on the length of panicle.

c. Number of Grains per Panicle

Kalyanikutty and Morachan (1974) observed no significant effect on the number of grains per panicle by supplying potassium. According to reports by Rao *et al*. (1974a), application of potash even upto 80 kg K_2O/ha did not influence the number of filled grains and chaff per panicle.

d. Thousand Grain Weight

Singh and Singh (1979) found increases in thousand grain weight with application of 60 kg K_2O/ha.

Research findings of Kalyanikutty and Morachan(1974) and Rao *et al*.(1974) however, showed that potassium application had no effect on the weight of thousand grains.

Effect of Potassium on Yield

Vijayan and Sreedharan (1972) reported that rice cv IR-8 yielded 3.18 t grains/ha without potassium and 3.45, 3.60, 3.62 and 3.63 t/ha with 20,40,60 and 80 kg K_2O/ha respectively. Rao *et al* (1974) found that a single basal application of 40 kg K_2O/ha gave better results during the rabi season. Experiments conducted by Singh and Dubey (1975) revealed that with rice cv Jaya, Yields were increased from 3.52 to 4.14 t/ha with increasing potassium rates from zero to 60 kg K_2O/ha and that 120 kg K_2O/ha gave no additional yield. Average paddy yields increased from 2.06 to 2.28 and 2.61 t/ha when potassium rates were increased from zero to 22.5 and 45 kg K_2O/ha respectively. (Sahu and Ray, 1976). Response of high yielding rice cultivars to the application of nitrogen, phosphorus and potassium were studied by Uexkull (1976) and it was found that applied potassium slightly decreased yields in the absence of phosphorus and increased in its presence. The response was 5.40 kg paddy in the dry season and 8.3 to 11.7 kg paddy in the wet season per kg of K_2O applied. Trials conducted by Halm and Dartey (1977) revealed that grain yields increased from 2.33 t/ha with no potash to 2.69 t/ha with the application of 37.20 kg K_2O/ha.

Robinson and Rajagopalan (1977) observed that application of potassium increased the grain yield significantly and the highest grain yield of 4.04 t/ha was recorded at 150 kg K_2O/ha, which was 14.10 per cent more than the control. Agarwal (1980) recorded significant increase in grain yield with potassium upto 60 kg K_2O/ha.

Contrary to these reports, Shukla (1969) observed that potassium application had no significant effect on the grain yield of paddy. Similar results were reported by Pandey and Das (1973). Ageeb and Yousif (1978) reported that different doses of potassium either alone or in combination with phosphorus had no response.

Effect of Potassium on Quality of Grain

Increase in protein content with increased potassium application from 20 to 40 kg K_2O/ha reported by Chavan and Magar (1971). Agarwal (1978) observed that increasing the rate of potassium from nil level to 120 kg K_2O/ha increased the crude protein content of grain from 9.62 to 10.17 per cent.

However, Karim *et al.* (1967) reported a decrease in the crude protein content of the husked grain with increase in potassium levels from zero to 80 lb/acre.

Content and Uptake of Potassium

Sadayappan and Kolandaiswamy (1974) observed an increase in the potassium content with increase in nitrogen level upto 100 kg N/ha. According to reports by Agarwal (1978), there was a marked increase in the potassium uptake upto 120 kg N/ha, but beyond this level only marginal increase was noted. Field trials conducted by Singh and Modgal (1978) revealed that an increase in the dose of nitrogen applied from 30 to 120 kg/ha increased the uptake of potassium by the crop at harvest. They also found that only ten per cent the absorbed potassium was translocated to the grain.

Agarwal (1978) reported that increase in the rates of applied phosphorus upto 60 kg P_2O_5/ha increased the potassium content in the plant.

Loganathan and Raj (1972) observed that different combinations of phosphorus and nitrogen had little effect on the uptake of potassium by straw. Thandapani and Rao (1974) found that phosphorus levels had very little effect on the content of potassium at three stages of the crop, namely tillering panicle initiation and flowering.

Sadanandan et al. (1969) found that the percentage content and uptake of potassium significantly increased with higher doses of potassium. According to Agarwal (1978) there was an increase in the potassium content of the plant with increase in the levels of potassium applied upto 60 kg K_2O/ha. Singh and Jaiprakash (1979) also observed that the application of potassium increased its uptake significantly.

Sadanandan et al. (1969) observed that potassium percentage in the plant was high at tillering and flowering phases. They also found that the potassium uptake rose steadily to a maximum at flowering, remained steady at that level till flowering was completed and declined thereafter towards maturity. However, uptake studies by Mohamed Ali and Morachan (1973) revealed that uptake of potassium was highest at harvesting stage. Muthuswamy et al. (1973b) noticed a very high degree of relationship among the uptake of potassium at flowering and harvesting stages and the final yield. Here, one-fourth of the absorbed potassium was translocated to the grain. Rai and Murty (1976) conducted pot trials to study the uptake of nutrients in relation to growth periods and found that the absorption of potassium was vigorous at early stage, its uptake retarded during the lag phase and potassium content decreased after flowering in all the cultivars.

Effect of Spacing on Growth Characters

1. Height of the Plant

Fagundo *et al.* (1978) reported that low density planting led to increased height. Field trials conducted by Ibrahim *et al.* (1980) revealed that plant height increased with increased spacing.

However, Chang and Su (1977) observed that plant height increased as spacing decreased.

2. Tiller Count

Field trials conducted by Chang and Su (1977) showed that the number of tillers per hill at 50 days after transplanting decreased with decrease in spacing.

Fagundo *et al.* (1978) reported that high plant densities reduced tillering. Ibrahim *et al.* (1980) observed that tillering was increased by increased spacing.

3. Leaf Area Index

In trials conducted by Chang (1968) on japonica rice cv Chianung-242 and Tainan-3 with four spacings, namely 30 cm x 20 cm, 30 cm x 15 cm, 30 cm x 10 cm and 30 cm x 5 cm, it was found that leaf area index in both cultivars increased with reduction in spacing. Golingai and Mabbayad (1969) observed that leaf area index increased with increase in the number of plants/ha. Fagade and Datta (1971) reported that increasing plant density increased the LAI of all cultivars tried, at flowering. Summarising the results of field trials conducted at Holeila farm, Chang and Su (1977) observed that LAI at earing increased with decreased spacing. From a trial on the effect of plant population an LAI of rice, Pothiraj *et al.* (1977) observed that the maximum LAI of 7.31 at flowering was given by a plant population of 100 hills/m^2 and that reducing the hill number/m^2 reduced LAI at all stages. Ghosh *et al.* (1979) reported that LAI at ear emergence and dough stage was related to yield and was higher with

b. Panicle Length and Panicle Weight

Chang (1968) reported from trials conducted on japonica rice cv Chianung-242 and Tainan-3, that panicle weight was slightly reduced by closer spacing. Chang and Su (1977) observed that length and weight of panicles increased with increased spacing.

c. Number of Grains per Panicle

Trials conducted by Chang(1968) revealed that grain number per panicle decreased with reduction in spacing for the two varieties used by him. Number of grains per panicle increased with increased spacing from 25 cm x 12.5 cm to 25 cm x 50 cm (Chang and Su, 1977).

d. Thousand Grain Weight

Chang (1968) reported that reducing spacing from 30 cm x 20 cm to 30 cm x 5 cm increased the weight of thousand grains in japonica rice cv Chianung-242 and Tainan-3.

Effect of Spacing on Yield

A trial conducted at Hyderabad during two successive seasons with two varieties, at spacings of 15 cm x 10 cm, 15 cm x 15 cm and 15 cm x 20 cm, revealed that close spacing increased the grain yield of one variety only, which was a hybrid (Husain, 1967). Chang (1968) observed that grain yields increased with reduced spacing from 30 cm x 20 cm to 30 cm x 5 cm. In trials in which rice cv IR-8 was grown at ten spacings, the highest grain yield 92.8 kg/ha was given by a spacing of 7.7 cm x 7.5 cm followed by 15.0 cm x 7.5 cm with 75.5 kg (Hukkeri et al. 1968). Mandal and Mahapatra (1968) obtained higher grain yields from sowing at a spacing of 15 x 15 cm than 22.5 cm x 15.0 cm or 7.5 cm x 15.0 cm. In a field trial at Laguna, Golingai and Mabbayad (1969) observed that paddy yields were decreased by decrease in the number of plants/ha. Rice cv Culture 120 35 when transplanted at spacings of 10 cm x 10 cm, 10 cm x 15 cm or 15 cm x 15 cm gave increased paddy fields from 4.92 t/ha with 15 cm x 15 cm to 5.64 t/ha with 10 cm x 10 cm spacing (Nair and George, 1973). Singh and Singh (1973) observed that higher plant population obtained with 15 cm x 10 cm spacing recorded 11.1% higher grain yield than 20 cm x 10 cm spacing. A field experiment conducted at Bichpuri, Agra during two successive kharif seasons, by Kumar et al.(1975) revealed

that a spacing of 15 cm x 15 cm gave superior yields than 25 cm x 25 cm. Four rice cultivars planted at five different spacings gave decreased yields with increased spacings (Majid et al. 1976). According to reports by Parashar (1976), IR-8 paddy gave the highest paddy yields of 6.46 t /ha at 7.5 cm x 7.5 cm and the lowest yield of 3.8 t/ha at 30 cm x 15 cm. Fagade and Ojo (1977) observed that spacing at 10 cm x 10 cm gave highest paddy yields of 4.15 t/ha whereas 25 cm x 25cm gave the lowest yield of 2.93 t/ha. When rice cv Pankaj was transplanted at spacings of 10 cm x 10 cm, 15cm x 15 cm , 20 cm x 20 cm , 25 cm x 25 cm and 30 cm x 30 cm, yields decreased with plant spacing of 30 cm x 30 cm (Ghosh et al.1979). Patel et al.(1979) reported that transplanting seedlings of three rice cv at a between-plant spacing of 15 cm in rows 15, 20, 25 and 30 cm apart gave average paddy yields of 6.18, 5.9, 5.6 and 5.43 t/ha respectively. In trials with two late maturing rice cv grown at a spacing of 10 x 10 or 20, 20 x 15, 20 or 25, 30 x 20 or 30 or 50 x 50 cm, paddy yields were highest at a spacing of 10 cm x 10 cm and progressively decreased with increasing spacings (Murty and Murty. 1980).

increased fertiliser and denser planting but interactions were not significant. From trials using four spacings and three levels of nitrogen, Chang (1968) concluded that grain yields increased with reduction in spacing and increase in applied nitrogen. The trial revealed that the number of panicles per hill and grain number per panicle decreased while 1000 grain weight and grain fertility increased with reduced spacing, whereas panicle number per hill increased and grain fertility decreased with increased nitrogen. Panicle weight was unaffected by nitrogen but was slightly reduced by closer spacing.

Mandal and Mahapatra (1968) reported that when two rice cv were sown at three spacings and given nitrogen at three rates, higher grain yields were obtained from sowing at a spacing of 15 cm x 15 cm than 22.5 cm x 15 cm or 7.5 cm x 15 cm and applying 33 kg N/ha compared with unfertilised plots. Sood and Singh (1971) observed that the number of ear bearing tillers, plant height and grain yield of tall indica rice increased with increasing nitrogen rates from zero to 90 kg/ha and that upto 45 kg N/ha the optimum spacing was 15 cm x 15 cm and above this it was 22.5 cm x 22.5 cm. An investigation on the effect of various levels of nitrogen and spacing on the

However, Lal and Singh (1967) observed that slightly higher grain and straw yields per hectare were obtained where wide spacings were used, but the increases were not significant. Chang and Su (1977) reported that grain yields increased with increased spacing. Koregave and Khuspe (1969) found that there were non-significant differences in grain yield of rice cv Chinoor grown at spacings of 9 x 9, 9 x 12, 9 x 15 or 9 x 18 inches. Similar results were also obtained by Kulandaivelu and Kaliappan (1971), Yadava et al. (1976) and Venkateswarlu and Singh (1980).

Combined Effects of Fertiliser Levels and Spacing on Growth Yield and Yield Attributes of Rice

Literature pertaining to the interactional effects of spacing and fertiliser levels on growth yield and yield attributes of rice are comparatively limited.

A trial conducted by Husain (1967) at Hyderabad comparing spacings of 15 x 10, 15 x 15 and 15 x 20 cm and fertiliser dosages of 34 kg N + 17 kg P_2O_5 and 67 kg N + 34 kg P_2O_5 revealed that grain yields increased with increased fertiliser and denser planting but interactions were not significant. From trials using four spacings and three levels of nitrogen, Chang (1968) concluded that grain yields increased with reduction in spacing and increase in applied nitrogen. The trial revealed that the number of panicles per hill and grain number per panicle decreased while 1000 grain weight and grain fertility increased with reduced spacing, whereas panicle number per hill increased and grain fertility decreased with increased nitrogen. Panicle weight was unaffected by nitrogen but was slightly reduced by closer spacing.

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Majid *et al*.(1976) reported that paddy yields decreased with increased spacing but these differences diminished with increased fertility levels. Chang and Su (1978) reported that grain yields increased with increased rate of nitrogen and increased spacing with a greater response to nitrogen than to spacing. Fagundo *et al*.(1978) found that there was an interaction between nitrogen and low density, leading to increased height. Paddy yields of rice cv. Sona increased with increase in fertilizer rates from 60 kg N + 30 kg P_2O_5 + 30 kg K_2O/ha to 120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha and decreased with increases in between-plant spacing from 5 to 10 and 15 cm in rows 15 cm apart (Reddy *et al*. 1978). Ghosh *et al*. (1979) observed that yields decreased with increased plant spacing while there was no significant yield response to increased nitrogen application. Field trials conducted by Ibrahim *et al*. (1980) revealed that increased nitrogen and increased spacing resulted in increased plant height, increased tillering and increased grain and straw yields.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to determine the effects of plant spacing and different levels of nitrogen, phosphorus and potash on the growth and yield of medium duration, tall indica rice variety, Mashuri, in the sandy loam tracts of Onattukara, during the second crop season. The various methods employed and materials used are described here.

Location

The field experiment was conducted in the wet lands of the Rice Research Station, Kayamkulam. This research station is situated at $9^{o}8'$ North Latitude and $76^{o}8'$ East Longitude and at an altitude of 3.05 metres above mean sea level. The Station is located in the Onattukara tract and gives a true representation of the soil type and climatic features of the tract.

Soil

The soil of the experimental area is of the sandy loam type as is indicated by the mechanical analysis of the

Table 1. - Physical and chemical characteristics of the soil of the experimental area

1. Physical properties	
(i) Mechanical composition	
Coarse sand	- 67.6%
Fine sand	- 18.2%
Silt	- 3.3%
Clay	- 10.4%
2. Chemical characteristics	
Total nitrogen	- 0.045%
Total P_2O_5	- 0.121%
Available P_2O_5	- 0.0024%
Total K_2O	- 0.0188%
Available K_2O	- 0.0037%
pH	- 5.3

soil. Chemically, the soil exhibits a moderately acidic reaction (pH 5.3). It had a low content of nitrogen, medium content of available phosphorus and very low content of available potash. The data regarding the mechanical composition and chemical nature of the soil is given in Table 1.

Climate

A warm humid tropical climate prevails over the Onattukara tract. The tract receives a good share of the South West monsoon and some amount of the North East monsoon.

The measures for the meteorological parameters of rainfall, minimum and maximum temperatures, and relative humidity for the experimental period were obtained from the meteorological observatory of the Regional Station, Central Plantation Crops Research Institute, Kayamkulam. The average weekly values of the meteorological parameters and their variation from the corresponding values for the second crop seasons of the past five years were worked out. These are presented in Appendix I and Fig.1. From this data it is obvious that the weather conditions prevailing over the area during the experimental season were normal.

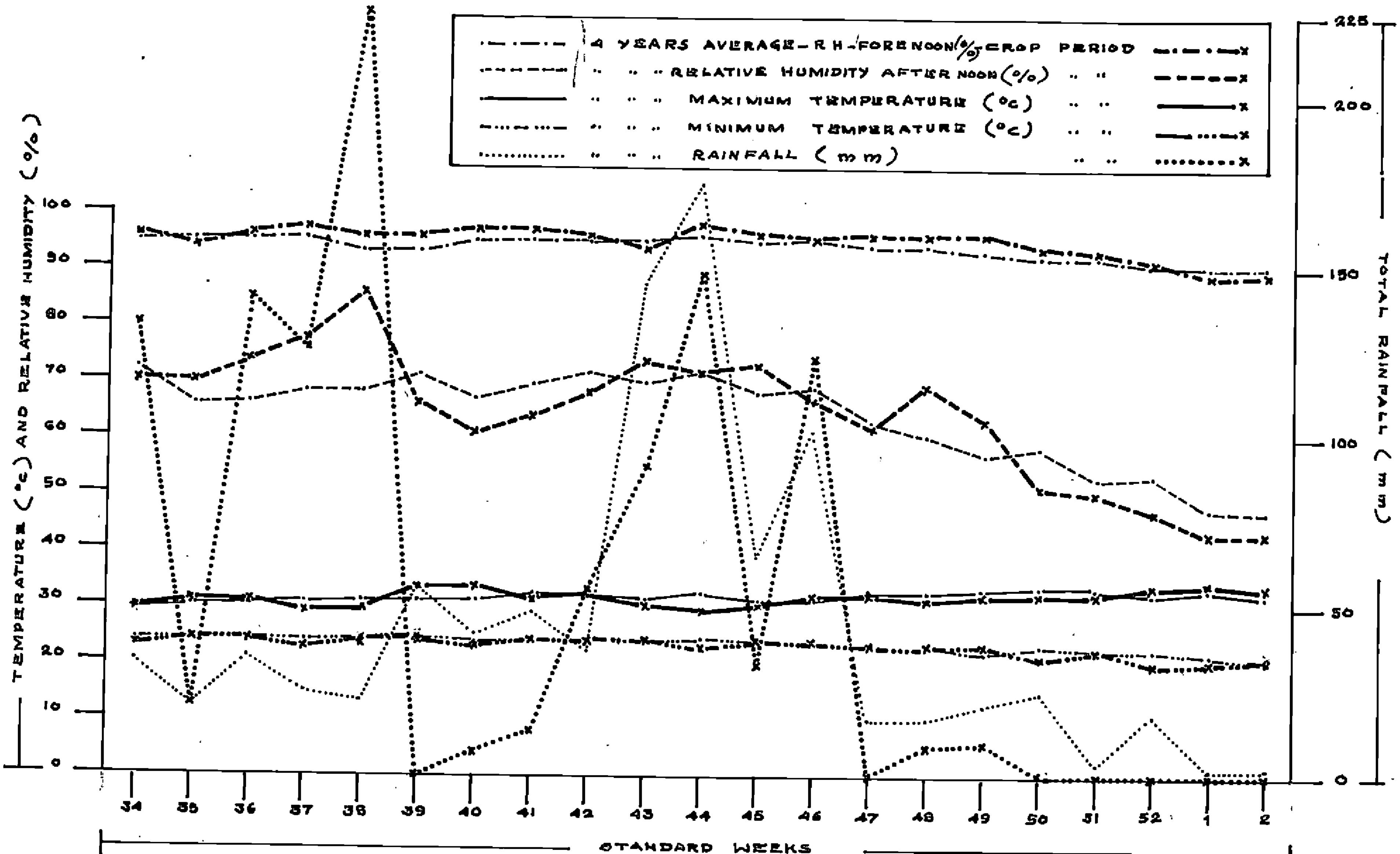

FIG: 1 WEATHER CONDITIONS DURING THE CROP PERIOD (1981-'82) AND CORRESPONDING AVERAGES FOR THE LAST FIVE YEARS (1976-'77 TO 1980-'81)

Season

The field trial was carried out during the second crop season of the year 1981-82. This season normally extends from August-September to December-January.

MATERIALS

Variety Under Trial

The variety studied was Mashuri, which is a medium duration, tall indica rice cultivar. This is the progeny of a cross between Taichung-65 x Mayang Ebos 80/2, evolved in Malaysia. The variety has a duration of 135-145 days. It responds well to nitrogen application but lodges at higher nitrogen levels.

The seeds for the experiment were obtained from the Rice Research Station, Pattambi.

Fertilisers Used

Fertilisers with the following analysis were used for the experiment-

Urea	--	46 per cent N
Superphosphate	--	16 per cent P_2O_5
Muriate of potash	--	60 per cent K_2O

METHODS

Treatments

The treatments consisted of sixteen factorial combinations of four levels of fertilisers and four spacings. These are listed below.

(i) Levels of N, P and K

l_1 - 50:25:25 kg/ha NPK

l_2 - 60:30:30 kg/ha NPK

l_3 - 70:35:35 kg/ha NPK

l_4 - 80:40:40 kg/ha NPK

(ii) Spacings

s_1 - 10 cm x 5 cm

s_2 - 10 cm x 10 cm

s_3 - 15 cm x 10 cm

s_4 - 20 cm x 10 cm

Treatment combinations

1. l_1s_1 - 50:25:25 kg/ha NPK with 10 cm x 5 cm spcing
2. l_1s_2 - 50:25:25 kg/ha NPK with 10 cm x 10 cm spacing
3. l_1s_3 - 50:25:25 kg/ha NPK with 15 cm x 10 cm spacing
4. l_1s_4 - 50:25:25 kg/ha NPK with 20 cm x 10 cm spacing

5. l_2s_1 - 60:30:30 kg/ha NPK with 10 cm x 5 cm spacing
6. l_2s_2 - 60:30:30 kg/ha NPK with 10 cm x 10 cm spacing
7. l_2s_3 - 60:30:30 kg/ha NPK with 15 cm x 10 cm spacing
8. l_2s_4 - 60:30:30 kg/ha NPK with 20 cm x 10 cm spacing

9. l_3s_1 - 70:35:35 kg/ha NPK with 10 cm x 5 cm spacing
10. l_3s_2 - 70:35:35 kg/ha NPK with 10 cm x 10 cm spacing
11. l_3s_3 - 70:35:35 kg/ha NPK with 15 cm x 10 cm spacing
12. l_3s_4 - 70:35:35 kg/ha NPK with 20 cm x 10 cm spacing

13. l_4s_1 - 80:40:40 kg/ha NPK with 10 cm x 5 cm spacing
14. l_4s_2 - 80:40:40 kg/ha NPK with 10 cm x 10 cm spacing
15. l_4s_3 - 80:40:40 kg/ha NPK with 15 cm x 10 cm spacing
16. l_4s_4 - 80:40:40 kg/ha NPK with 20 cm x 10 cm spacing

Design and Layout of the Experiment

The experiment was laid out in a 4 x 4 factorial experiment in randomised block design with sixteen treatment combinations and three replications. The allocation of the various treatment combinations to different plots was as per the method advocated by Yates (1964). The plan of layout is diagramatically represented in Fig.2.

The details of the layout are furnished below:

Design = 4 x 4 factorial experiment in Randomised Block Design

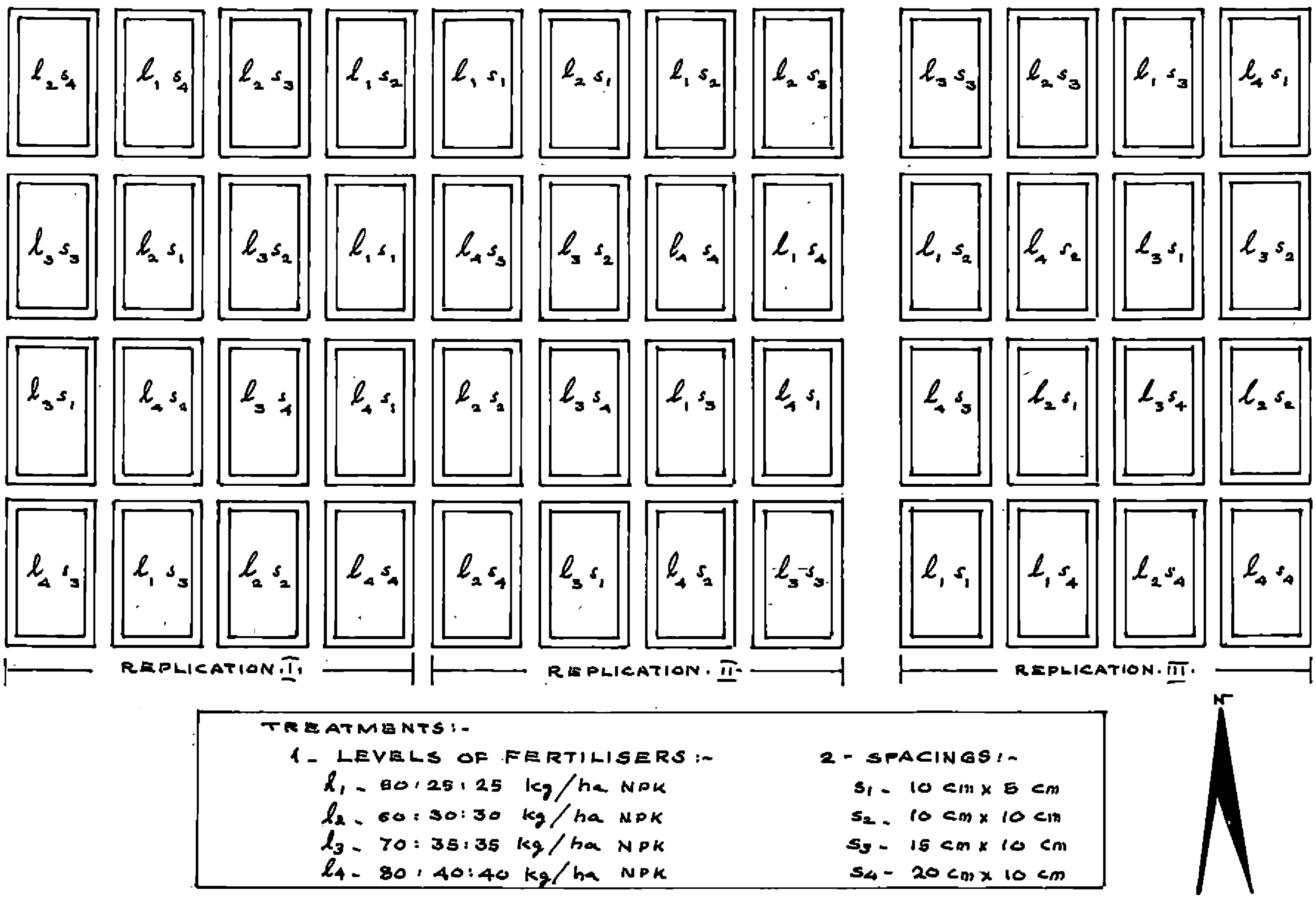

FIG: 2 LAY OUT PLAN - 4 x 4 FACTORIAL EXPERIMENT

Replications = 3

Gross plot size = 5.0 m x 4.0 m

Border = 2 rows

Total number of plots = 48

Field Culture

Nursery

An area of 100 square metres was prepared for a wet nursery. At the time of land preparation, cattle manure at the rate of 1 kg per square metre was added and incorporated thoroughly. Twelve kilograms of seeds were sown broadcast in the nursery on 30th August, 1981. The seedlings were irrigated daily. No fertilisers were applied. The seedlings were ready for transplantation on 28th September, 1981.

Main Field

Land preparation

The area was first ploughed thoroughly. The layout of the experiment was prepared on 28th September, 1981, after measuring out the area for each plot. One soil sample was collected each from the area representing the three replications. Bunds were constructed and plastered well and irrigation channels were dug between every two plots. The area within each plot was perfectly levelled. The basal dose of fertiliser was given to each plot according to the treatment allocated.

Transplanting

Healthy seedlings of 30 days growth were uprooted from the nursery after previously irrigating the nursery. These seedlings were transplanted in the mainfield at a depth of 2 to 3 cm and at the rate of two seedlings per hill. Rope planting was practised giving the appropriate plant and row spacing in each plot in accordance with the treatment allocated. Transplanting was carried out on 30th September, 1981. Gap filling was done on 5th October, 1981.

Fertiliser Application

Fertilisers, namely, urea, superphosphate and muriate of potash were given according to treatment to the experimental plots. This was in accordance with the recommendation in the Package of Practices (Anon, 1978) for the Onattukara tract. Accordingly, nitrogen, as urea, was applied in five equal split dressings at planting, 15th, 38th, 53rd and 70th day. These periods coincided with the stages of early tillering, necknode differentiation, early reduction division and heading stages of the crop respectively. Potash, as Muriate of potash was also applied in five equal split doses along with nitrogen. Entire dose of phosphorus, as superphosphate, was applied as basal. The fertilisers were applied to each plot in appropriate quantities according to the treatment.

Weeding

Hand weeding was conducted twice, the first, fifteen days after planting and the second, thirty five days after planting.

Irrigation and Drainage

Transplanting was done in a thin layer of standing water. The crop received constant showers of the North East monsoon during the early days of its growth. Excess water was drained out and water level was always maintained at approximately 5 to 7 cm depth. During the later period of crop growth, the field was irrigated regularly, the irrigation being regulated according to necessity. The water in the field was drained two weeks prior to harvest and this dry condition was maintained upto harvest.

Plant Protection

Routine plant protection measures were adapted as and when required.

Harvest

The crop was harvested after 137 days of growth. The border rows of all plots were harvested and threshed separately. One panicle each from the observation plants were collected for observation of panicle characteristics and chemical analysis of grain. The crop in each net plot was harvested and threshed. The grain and straw of each plot were sundried separately for two days and plotwise yield of grain and straw were recorded.

Observations

Two rows of plants were left out on all four sides of each plot as border. On the northern side of each plot, another two rows were left out as destructive rows. This was done for collecting plants during each observation for determining the plant nutrient content by chemical analysis and for recording dry weight. Another row was left out on the same side as a border row. Twenty hills were selected and marked as observation plants within the net plot for biometric observations. This fixture of observation plants was done at random within the net plot. Observations were taken at tillering, panicle initiation, heading, flowering and harvest stages respectively.

A. Observations on Growth Characters

i. Height of Plant

Within each net plot, the twenty hills marked out for observation were subjected to height measurements during the five stages mentioned earlier. Height was measured every time from the base of the hill to the tip of the longest leaf. At harvest, height was measured from the base of the hill to the tip of the panicle. The mean height was worked out and recorded.

ii. Number of Tillers per Hill

Tiller number from each of the twenty hills fixed for observation, was counted at all the five above mentioned stages. The mean values for each plot were worked out and recorded.

iii. Number of Leaves per Hill

The total number of green leaves from the observation plants were counted, average worked out and recorded.

iv. Leaf Area Index

Leaf Area Index for each plot was determined at tillering, panicle initiation, heading and flowering according to the method suggested by Gomez (1972).

Six sample hills were selected each time. In each hill, the number of tillers was counted. Then the middlemost tiller was separated out from each hill. The total leaf area of the middlemost tiller was worked out after taking the length and breadth of each leaf of the tiller. The area of each leaf was obtained as the product of the length(L), breadth (B) and an adjustment factor(K). This factor K was taken as 0.75.

Area of one leaf = L x B x K

Leaf area per hill = Total leaf area of middle tiller x Total number of tillers.

$$\text{Leaf Area Index} = \frac{\text{Sum of leaf area/hill of six sample hills } (cm^2)}{\text{Area of land covered by 6 hills } (cm^2)}$$

v. Dry matter production

This observation was taken from six hills uprooted each at tillering, panicle initiation, heading, flowering and harvest. At each observation six hills were uprooted from the destructive rows of each plot. These were dried first and then subjected to oven-drying at $80^{\circ} \pm 5^{\circ}C$. The dried plants were weighed and the dry matter content was expressed in kg/ha.

B. Observation on Yield Components

One panicle each was collected from the twenty observation hills of each plot before harvest. These panicles were used for determining the various panicle and grain characteristics and for chemical analysis of the grain.

i. Number of productive tillers per hill

The number of productive tillers per hill was counted for each of the twenty observation hills. The mean value was worked out for each treatment.

ii. Length of panicle

The length of the twenty panicles collected from each plot was measured, from the neck to the tip. The average was worked out for each plot, and expressed in centimetres.

iii. Weight of panicle

Each panicle was separately weighed. The mean weight of twenty panicles was worked out for each treatment and expressed in grams.

iv. Number of spikelets per panicle

Entire spikelets from each panicle were removed and counted. The mean of the number of spikelets for twenty panicles was worked out.

v. Number of filled grains per panicle

The filled grains were separated out from the spikelets removed from each panicle. These were counted and the mean computed for twenty panicles.

vi. Thousand grain weight

One thousand filled grains were counted out from the grain harvested from each plot. These were weighed and the weight was recorded in grams.

vii. Sterility percentage

Using the data regarding the total spikelets per panicle and the number of sterile grains per panicle, the sterility percentage was computed.

C. Observations on Grain and Straw Yield

i. Grain yield

The grain separated by threshing the plants harvested from each net plot was sundried for two days to a moisture content of fourteen per cent. The dried grain was winnowed, cleaned and the weight recorded. The yield was expressed in kg/ha.

ii. Straw yield

The straw from each net plot area was sundried after threshing and weighed. The weight was expressed in kg/ha.

iii. Grain:straw ratio

The ratio between the grain and straw yields was worked out for individual plots.

iv. Harvest Index

From the data on grain and straw yields obtained for each plot the harvest index was worked out and expressed in percentage. The formula used is given below:

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

Chemical Analysis

A. Plant Analysis

Six hills were uprootedfrom the destructive rows of each plot. These plants were initially sundried, then oven-dried at a temperature of $80^{\circ}C \pm 5^{\circ}C$ till a constant weight was obtained. The dried plant material was weighed. It was then pounded using a Wiley mill and sieved through a 2 mm sieve. This was then digested and the digest was chemically analysed. At harvest the grain and straw were also dried and ground separately. The nitrogen, phosphorus and potash contents were separately determined.

i. Nitrogen Content

The total nitrogen content of the digest of each sample was analysed employing the modified micro-Kjeldahl method (Jackson, 1967).

ii. Phosphorus Content

The total phosphorus content was determined colorimetrically using the vanado-molybdo-phosphoric yellow colour method (Jackson, 1967). The colour intensities were read in a Klett-Summerson photoelectric colorimeter.

iii. Potash Content

An 'EEL' flame photometer was used to determine the total potash content.

B. Uptake Studies

The total quantities of the three major nutrients, viz. nitrogen, phosphorus and potash absorbed by the crop at tillering, panicle initiation, flowering heading and harvest were calculated. The value of total uptake was obtained as the product of the content of these nutrients in the plant and the weight of dry matter. The values were expressed in kg/ha.

C. Grain Protein Content

The percentage of protein in the grain was calculated and recorded as the product of the content of nitrogen in the grain and a factor, 6.25 (Simpson *et al*. 1965)

D. Soil Analysis

Soil samples were collected from the experimental site before and after the experiment. Three representative samples were collected from the area belonging to the three replications before the experiment. After the harvest of the crop, soil samples, representative of each plot were collected. The samples were oven-dried at 105°C and powdered and sieved through a 2.0 mm sieve. The total nitrogen, available phosphorus and available potash contents of the soil before the experiment were determined. Soil samples collected after the experiment were subjected to chemical analysis for available nitrogen, phosphorus and potash. Total nitrogen content was estimated by the modified micro-Kjeldahl method (Jackson, 1967), available nitrogen content by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus content by Bray's method (Jackson, 1967) and available potash by ammonium acetate method (Jackson, 1967).

Statistical Analysis

Tabulated data for the various characteristics were statistically analysed, employing the technique of analysis of variance for factorial experiments in randomised block design. The significance was tested by 'F' test (Cochran and Cox, 1965). Important correlations were also worked out.

RESULTS

RESULTS

A field experiment was conducted in the sandy loam soil of the Rice Research Station, Kayamkulam during the second crop season of 1981-82, for assessing the effects of various nutrient levels and spacings on the growth and yield of a medium duration, tall indica rice variety, Mashuri. The observations recorded were statistically analysed and the results are presented below. The mean tables are presented in Tables 2 to 28 and the abstract of the analysis of variance tables in Appendices I to VIII.

A. Growth Characters

1. Height of Plants

Data on the mean height of plants taken at tillering, panicle initiation, heading, flowering and harvest stages are presented in Tables 2 (a) to 2(e) and their analysis of variance in the Appendix II.

It was observed that the height of plants was significantly increased at all stages of growth by increasing the fertiliser levels and spacings. At tillering stage, the highest level of fertiliser, 80:40:40 kg/ha NPK, recorded a height of 58.96 cm which was significantly superior to the lower three levels. The lowest level of fertiliser viz., 50:25:25 kg/ha NPK was on par with the treatment 60:30:30 kg/ha NPK. At panicle initiation, heading, flowering and harvest stages, 80:40:40 kg/ha NPK gave significantly taller plants (71.67 cm, 81.09 cm, 95.36 cm and 99.68 cm respectively), while 50:25:25 kg/ha NPK gave significantly shorter ones (67.46 cm, 76.03 cm, 84.70 cm and 87.07 cm respectively).

Increased spacing also resulted in increased plant height at all growth stages. At tillering stage, 20 cm x 10 cm spacing gave a height of 58.66 cm while the closest spacing of 10 cm x 5 cm recorded only 54.93 cm height. At panicle initiation stage 20 cm x 10 cm spacing produced significantly taller plants and 10 cm x 5 cm spacing produced significantly shorter plants, while 10 cm x 10 cm and 15 cm x 10 cm spacings were on par. At heading stage, there was significant increase in plant height due to increased spacings. At flowering stage, the same trend was noticed but 10 cm x 5 cm and 10 cm x 10 cm spacings were found to be on par. At harvest, there was

Table 2(a). - Height of plants of tillering stage (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	52.77	53.63	56.73	57.05	55.04
60 :30 :30	56.58	53.00	55.62	57.42	55.66
70 :35 :35	53.23	59.04	59.10	57.23	57.15
80 :40 :40	57.13	58.80	56.95	62.95	58.96
Mean	54.93	56.12	57.10	58.66	

C.D. (0.05) for fertiliser levels - 0.948
C.D. (0.05) for spacings - 0.948
C.D. (0.05) for 1 x s combinations - 1.895

Table 2(b). - Height of plants at panicle initiation stage (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	62.40	72.15	68.25	67.02	67.46
60 :30 :30	65.23	67.25	69.70	69.12	67.82
70 :35 :35	66.53	62.25	64.45	79.60	68.21
80 :40 :40	71.57	67.38	67.23	80.50	71.67
Mean	66.43	67.26	67.41	74.06	

C.D.(0.05) for fertiliser levels - 0.656
C.D.(0.05) for spacings - 0.656
C.D.(0.05) for 1 x s combinations - 1.312

Table 2(c). - Height of plants at heading stage (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10 cm	15cm x 10cm	20cm x 10cm	
50:25:25	66.32	70.71	81.76	85.33	76.03
60:30:30	66.82	76.68	78.54	84.52	77.14
70:35:35	80.73	69.92	77.40	84.65	78.18
80:40:40	76.35	76.37	79.52	92.10	81.09
Mean	72.56	73.92	79.31	86.65	

C.D (0.05) for fertiliser levels = 1.05
C.D (0.05) for spacings = 1.05
C.D. (0.05) for l x s combinations = 2.10

Table 2(d). - Height of plants at flowering stage (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	79.34	75.27	92.90	91.27	84.70
60:30:30	75.02	87.27	82.53	95.40	85.06
70:35:35	86.40	87.23	89.39	99.00	90.51
80:40:40	96.45	90.26	94.22	100.51	95.36
Mean	84.30	85.01	89.76	96.55	

C.D. (0.05) for fertiliser levels = 1.23
C.D (0.05) for spacings = 1.23
C.D. (0.05) for lx s combinations = 2.46

Table 2(e).-Height of plants at harvest (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	80.10	81.20	93.37	93.60	87.07
60 :30 :30	81.10	93.97	93.27	97.03	91.34
70 :35 :35	93.40	91.57	94.50	103.16	95.66
80 :40 :40	93.87	97.47	99.87	107.50	99.68
Mean	87.12	91.05	95.25	100.32	

C.D. (0.05) for fertiliser levels = 1.25

C.D. (0.05) for spacings = 1.25

C.D.(0.05) for l x s combinations = 2.49

Table 3(a). - Number of tiller per hill at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10 cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	2.53	3.17	5.20	5.82	4.18
60 :30 :30	3.08	4.7	5.37	6.22	4.84
70 :35 :35	4.40	6.07	6.15	7.30	5.98
8) ;40 :40	5.85	6.65	6.65	6.82	6.49
Mean	3.97	5.15	5.84	6.54	

C.D.(0.05) for fertiliser levels = 0.918

C.D.(0.05) for spacings = 0.918

significant difference between all spacings, with the widest spacing recording the maximum height of 100.32 cm and the closest spacing recording the least height of 87.12 cm.

The various treatment combinations also influenced plant height significantly. At all the growth stages l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) was found to produce the tallest plants closely followed by l_3s_4 (70:35:35 kg/ha NPK with 20 cm x 10 cm spacing). The treatment recording the least height was observed to be l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) at tillering, panicle initiation, heading, flowering and harvest stages.

2. Tiller Count

The mean values for the number of tillers per hill at the five different growth stages of the crop are presented in Tables 3(a) to 3(e) and their respective analysis of variance in Appendix II.

Tiller number per hill showed significant increases at all growth stages owing to increased fertiliser levels. At tillering stage, 80:40:40 kg/ha NPK gave the maximum tiller count of 6.49, and 50:25:25 kg/ha NPK gave the least count of 4.18, while 60:30:30 kg/ha NPK was found to be on par with 50:25:25 kg/ha NPK, and 70:35:35 kg/ha NPK with 80:40:40 kg/ha NPK. At panicle initiation stage there were significant increases in tiller counts with increased fertiliser levels, but fertiliser levels of 60:30:30 kg/ha NPK and 70:35:35 kg/ha NPK were found to be on par. The highest fertiliser level of 80:40:40 kg/ha NPK recorded maximum tiller counts of 11.77, 8.6 and 4.88 at heading, flowering and harvest stages respectively. This was significantly superior to the lower three levels, all of which significantly differed from one another.

An increase in spacing significantly increased the number of tillers per hill. At tillering stage, maximum tiller number was obtained with the widest spacing and least with the closest spacing. At this stage, however, 10 cm x 10 cm spacing was found to be on par with 15 cm x 10 cm spacing and 15 cm x 10 cm spacing did not differ significantly from 20 cm x 10 cm spacing. There were significant differences between spacings at panicle initiation, heading, flowering and harvest stages also with 20 cm x 10 cm spacing giving the highest tiller counts of

Table 3(b). - Number of tiller per hill at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15 cm x 10cm	20cm x 10cm	
50:25:25	5.78	6.83	8.40	8.90	7.48
60:30:30	6.28	8.47	9.30	10.3	8.59
70:35:35	7.95	8.72	9.70	11.72	9.52
80:40:40	8.60	9.87	10.62	12.87	10.49
Mean	7.15	8.47	9.51	10.95	

C.D.(0.05) for fertiliser levels = 0.94
C.D.(0.05) for spacings = 0.94

Table 3(c). - Number of tillers per hill at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	7.21	8.03	8.90	9.64	8.45
60:30:30	7.53	8.98	10.63	11.40	9.64
70:35:35	8.85	10.12	11.13	12.62	10.68
80:40:40	9.90	11.07	12.72	13.37	11.77
Mean	8.37	9.55	10.85	11.76	

C.D.(0.05) for fertiliser levels = 0.935
C.D.(0.05) for spacings = 0.935

Table 3(d).- Number of tillers per hill at flowering stage

Fertiliser levels (Kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	4.29	4.94	5.73	6.67	5.41
60:30:30	5.33	5.73	6.66	8.14	6.47
70:35:35	6.17	7.15	8.16	8.82	7.58
80:40:40	6.95	8.08	9.27	10.11	8.6
Mean	5.69	6.48	7.46	8.44	

C.D.(0.05) for fertiliser levels = 0.135
C.D.(0.05) for spacings = 0.135
C.D.(0.05) for l x s combinations = 0.270

Table 3(e). - Number of tillers per hill at harvest

Fertiliser levels (Kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	2.01	2.40	2.60	4.12	2.78
60:30:30	2.00	3.73	4.51	3.80	3.51
70:35:35	2.97	3.21	4.63	6.03	4.21
80:40:40	3.06	4.27	5.57	6.63	4.88
Mean	2.51	3.40	4.33	5.15	

C.D.(0.05) for fertiliser levels = 0.184
C.D.(0.05) for spacings = 0.184
C.D.(0.05) for lx s combinations = 0.368

10.95, 11.76, 8.44 and 5.15 respectively and 10 cm x 5 cm spacing giving the lowest counts of 7.15, 8.37, 5.69 and 2.51 respectively.

The various treatment combinations were observed to have profund influence upon tiller number at flowering and harvest stages. At tillering panicle initiation and heading, there was no significant difference between treatments. Treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the highest count at all growth stages and l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) gave the least. At flowering and harvest stages, l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave significantly superior values and was closely followed by l_3s_4 (70:35:35 kg/ha NPK with 20 cm x 10 cm spacing) and l_4s_3 (80:40:40 kg/ha NPK with 15 cm x 10 cm spacing).

3. Number of Leaves per Hill

The mean values on the number of leaves per hill at tillering, panicle initiation, heading, flowering and harvest stages are given in Tables 4(a) to 4(e) and their respective analysis of variance in Appendix II.

An increase in fertiliser level exerted considerable influence on the number of leaves per hill at all growth stages. At tillering stage, 80:40:40 kg/ha NPK gave the highest leaf number of 11.47 which was significantly superior to the lower three levels. There was no significant difference between 50:25:25 kg/ha NPK and 60:30:30 kg/ha NPK. Similarly 60:30:30 kg/ha NPK was found to be on par with 70:35:35 kg/ha NPK. The fertiliser levels differed significantly from each other at panicle initiation, heading, flowering and harvest stages, with a noticeable trend of increased leaf number with increased fertiliser levels.

There was significant increase in the number of leaves per hill as the spacings grew wider. At tillering stage 20 cm x 10 cm spacing gave the highest leaf number of 10.49, while spacings of 10 cm x 5 cm and 10 cm x 10 cm were found to be on par. There was no significant difference between spacings of 10 cm x 10 cm and 15 cm x 10 cm. The same trend was noticed at panicle initiation stage. At heading stage spacings of 10 cm x 5 cm and 10 cm x 10 cm were on par, whereas 15 cm x 10 cm spacing was significantly superior to 10 cm x 10 cm spacing and 20 cm x 10 cm

Table 4(a). Number of leaves per hill at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	8.13	8.56	7.72	9.87	8.57
60 :30 :30	8.35	8.46	9.21	9.72	8.94
70 :35 :35	8.34	9.06	9.63	10.15	9.29
80 :40 :40	11.30	10.68	11.65	12.24	11.47
Mean	9.03	9.19	9.55	10.49	

C.D.(0.05) for fertiliser levels = 0.396
C.D.(0.05) for spacings = 0.396
C.D.(0.05) for l x s combinations = 0.792

Table 4(b). - Number of leaves per hill at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	15.45	16.17	15.98	18.15	16.44
60 :30 :30	15.40	13.12	18.25	21.70	17.12
70 :35 :35	17.30	20.83	17.43	19.98	18.89
80 :40 :40	21.27	20.77	21.05	20.05	20.79
Mean	17.36	17.72	18.18	19.97	

C.D.(0.05) for fertiliser levels = 0.649
C.D.(0.05) for spacings = 0.649
C.D.(0.05) for lx s combinations = 1.297

Table 4(c).- Number of leaves per hill at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	16.55	19.43	16.82	25.73	19.63
60:30:30	16.02	17.19	21.43	24.77	19.85
70:35:35	18.47	16.20	24.05	27.93	21.66
80:40:40	21.42	21.15	26.26	28.50	24.33
Mean	18.12	18.49	22.14	26.73	

C.D.(0.05) for fertiliser levels = 0.551
C.D.(0.05) for spacings = 0.551
C.D.(0.05) for l x s combinations = 1.103

Table 4(d).- Number of leaves per hill at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	11.82	12.21	18.20	19.93	15.54
60:30:30	13.93	18.13	15.43	23.95	17.86
70:35:35	15.40	15.73	23.37	26.63	20.26
80:40:40	17.67	20.85	25.23	27.45	22.80
Mean	14.71	16.73	20.56	24.49	

C.D.(0.05) for fertiliser levels = 0.554
C.D.(0.05) for spacings = 0.554
C.D.(0.05) for l x s combinations = 1.107

Table 4(e). - Number of leaves per hill at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	6.27	8.90	10.97	13.73	9.97
60 :30 :30	7.06	11.17	12.00	14.30	11.13
70 :35 :35	8.97	11.67	13.93	14.87	12.36
80 :40 :40	10.17	13.40	16.00	16.40	13.99
Mean	8.12	11.29	13.23	14.83	

C.D. (0.05) for fertiliser levels = 0.612
C.D. (0.05) for spacings = 0.612

Table 5(a). Leaf Area Index at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	3.18	1.71	2.29	2.21	2.35
60 :30 :30	2.84	2.54	2.20	2.13	2.43
70 :35 :35	3.14	3.74	2.34	1.93	2.79
80 :40 :40	5.41	3.34	3.83	1.44	3.51
Mean	3.64	2.83	2.67	1.93	

C.D. (0.05) for fertiliser levels = 0.285
C.D. (0.05) for spacings = 0.285
C.D. (0.05) for lx s combinations = 0.57

spacing was superior to 15 cm x 10 cm giving a leaf number of 26.73. The four spacings showed significant differences at flowering and harvest stages, when the highest number of leaves (24.49 and 14.83 respectively) were obtained with the widest spacing and the lowest values (14.71 and 8.12 respectively) with the closest spacing.

The interactions between fertiliser levels and spacings also showed significant differences at all stages except harvest. The highest leaf number was given by l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) at tillering stage, which was 12.24 and the lowest values of 7.72 by l_1s_3 (50:25:25 kg/ha NPK with 15 cm x 10 cm spacing) and 8.13 by l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) the two of which were on par. Treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave significantly higher values than treatment l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) at panicle initiation, heading and flowering stages.

4. Leaf Area Index

Mean values for the leaf area indices at tillering, panicle initiation, heading and flowering stages are furnished in Tables 5(a) to 5(d) and the analysis of variance in Appendix III.

The successive increments of fertiliser levels wielded a significant influence on the leaf area index at all four growth stages. Fertiliser levels, 80:40:40 kg/ha NPK produced significantly superior values for leaf area index at tillering, panicle initiation, heading and flowering stages (3.51, 6.08, 8.23 and 4.00 respectively) over the lower three levels. The treatment, 50:25:25 kg/ha NPK recorded the lowest leaf area index at all stages but was found to be on par with 60:30:30 kg/ha NPK at tillering and panicle initiation stages and with 60:30:30 kg/ha NPK and 70:35:35 kg/NPK at heading stage.

The various spacings were also found to evoke significant differences in leaf area index. The highest values were supplied by the closest spacing of 10 cm x 5 cm at all four stages which were 3.64, 6.17, 9.57 and 5.54 at tillering, panicle initiation, heading and flowering stages respectively. The spacing of 20 cm x 10 cm was found to be inferior to the other three spacings at tillering and panicle initiation stages, but was found to be on par with 15 cm x 10 cm spacing at heading and flowering stages.

Table 5(b). - Leaf Area Index at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	4.65	5.35	5.80	4.21	5.00
60 :30 :30	6.12	4.90	4.28	4.87	5.04
70 :35 :35	7.38	6.30	3.64	4.42	5.44
80 :40 :40	6.52	6.85	7.25	3.69	6.08
Mean	6.17	5.85	5.24	4.30	

C.D.(0.05) for fertiliser levels = 0.297
C.D.(0.05) for spacings = 0.297
C.D.(0.05) for lx s combinations = 0.593

Table 5(c). Leaf Area Index at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	11.35	5.99	5.39	6.23	7.24
60 :30 :30	5.50	12.82	5.54	5.57	7.36
70 :35 :35	11.56	8.23	5.15	4.80	7.44
80 :40 :40	9.87	7.96	8.12	6.96	8.23
Mean	9.57	8.75	6.05	5.89	

C.D.(0.05) for fertiliser levels = 0.252
C.D.(0.05) for spacings = 0.252
C.D.(0.05) for lx s combinations = 0.504

Table 5(d).- Leaf Area Index at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	4.54	2.53	1.86	2.13	2.77
60 :30 :30	7.26	2.97	2.01	1.12	3.34
70 :35 :35	4.46	3.67	3.56	3.51	3.80
80 :40 :40	5.90	3.23	3.57	3.48	4.00
Mean	5.54	3.10	2.70	2.56	

C.D.(0.05) for fertiliser levels = 0.290
C.D.(0.05) for spacings = 0.290
C.D.(0.05) for lx s combinations = 0.580

Table 6(a). - Dry matter production at tillering stage (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	664.44	684.41	655.56	610.28	653.67
60 :30 :30	689.44	762.22	673.33	626.67	687.92
70 :35 :35	709.44	786.67	687.41	636.00	704.88
80 :40 :40	725.56	866.67	716.95	685.28	748.62
Mean	697.22	774.99	683.31	639.56	

C.D.(0.05) for fertiliser levels = 13.26
C.D.(0.05) for spacings = 13.26
C.D.(0.05) for lx s combinations = 26.52

The effect of the treatment combinations on leaf area index was significant at all four stages of growth. Treatment l_4s_1 (80:40:40 kg/ha NPK with 10 cm x 5 cm spacing) proved itself significantly superior to all other treatment combinations at two growth stages. At tillering and panicle initiation stages l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the lowest leaf area indices, but was found to be on par with l_2s_4 (60:30:30 kg/ha NPK with 20 cm x 10 cm spacing) and l_3s_4 (70:35:35 kg/ha NPK with 20 cm x 10 cm spacing). At heading stage, treatment l_3s_4 (70:35:35 kg/ha NPK with 20 cm x 10 cm spacing) gave the lowest leaf area index while at flowering stage l_2s_4 (60:30:30 kg/ha NPK with 20 cm x 10 cm spacing) was inferior to all other treatment combinations.

5. Dry Matter Production

Data on the mean values for dry weight expressed in kg/ha at tillering, panicle initiation, heading, flowering and harvest stages are furnished in Tables 6(a) to 6 (e). The corresponding analysis of variance is given in Appendix III.

Substantial increases in dry matter production were wrought by the increasing fertiliser levels at all the growth stages. Significantly different values were given by the various treatments, with 80:40:40 kg/ha NPK supplying the highest dry weights of 748.62 kg/ha, 2454.31kg/ha 4978.61 kg/ha, 6769.94 kg/ha and 7843.33 kg/ha respectively at tillering, panicle initiation, heading, flowering and harvest stages. Fertiliser level, 50:25:25 kg/ha NPK was found to be inferior to all other levels at all stages of growth.

Dry matter production was considerably influenced by the various spacings at all the five growth stages. Spacing 10 cm x 10 cm was observed to give the highest dry weight at tillering, panicle initiation, heading, flowering and harvest stages, closely followed by 10 cm x 5 cm spacing. It was noticed that 15 cm x 10 cm spacing was significantly superior to 20 cm x 10 cm spacing but inferior to 10 cm x 5 cm and 10 cm x 10 cm spacings.

The various treatment combinations were also found to wield significant influence on this aspect at all stages of growth excepting panicle initiation stage.

Table 6(b).- Dry matter production at panicle initiation stage (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	2308.89	2352.19	2306.30	2226.94	2298.58
60:30:30	2388.89	2484.44	2344.07	2311.64	2382.26
70:35:35	2451.67	2501.11	2401.11	2378.61	2433.13
80:40:40	2481.67	2546.67	2408.89	2380.02	2454.31
Mean	2407.78	2471.10	2365.09	2324.30	

C.D.(0.05) for fertiliser levels = 19.71

C.D.(0.05) for spacings = 19.71

Table 6(c). - Dry matter production at heading stage (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	4735.19	5121.11	4546.66	4524.41	4731.84
60:30:30	4768.89	5234.44	4655.19	4574.62	4808.29
70:35:35	4806.67	5393.33	4735.56	4602.50	4884.52
80:40:40	4894.45	5491.11	4831.11	4697.78	4978.61
Mean	4801.30	5309.99	4692.13	4599.83	

C.D.(0.05) for fertiliser levels = 31.52

C.D.(0.05) for spacings = 31.52

C.D.(0.05) for lx s combinations = 63.04

Table 6(d). - Dry matter production at flowering stage (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	5506.11	5580.00	5421.85	5361.39	5467.34
60 :30 :30	6638.89	6667.78	5320.37	5529.44	6039.12
70 :35 :35	6759.45	6843.33	6327.41	5441.94	6343.03
80 :40 :40	6578.33	7733.32	6425.59	6342.50	6769.94
Mean	6370.69	6706.11	5873.81	5668.82	

C.D.(0.05) for fertiliser levels = 23.25
C.D.(0.05) for spacings = 23.25
C.D.(0.05) for lx s combinations = 46.50

Table 6(e). - Dry matter production at harvest.(kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	6643.89	6918.89	6407.04	6478.33	6612.04
60 :30 :30	7567.78	7760.00	7350.00	6552.94	7307.68
70 :35 :35	7508.33	7815.66	7418.52	7494.17	7559.15
80 :40 :40	7590.00	8820.00	7461.11	7502.22	7843.33
Mean	7327.50	7828.61	7159.17	7006.92	

C.D.(0.05) for fertiliser levels = 26.84
C.D.(0.05) for spacings = 26.84
C.D.(0.05) for lx s combinations = 53.69

Treatment l_1s_4 (50:25:25 kg/ha NPK with 20 cm x 10 cm spacing) gave significantly lower values compared to other treatments at tillering, save l_2s_4(60:30:30 kg/ha NPK with 20 cm x 10 cm spacing) and l_3s_4(70:35:35 kg/ha NPK with 20 cm x 10 cm spacing). At flowering and harvest stages l_1s_4 (50:25:25 kg/ha NPK with 20 cm x 10 cm spacing) was significantly inferior to all other treatments, but at heading stage, this same treatment recording the lowest value, was observed to be on par with l_2s_4(60:30:30 kg/ha NPK with 20 cm x 10 cm spacing). Treatment l_4s_2(80:40:40 kg/NPK with 10 cm x 10 cm spacing) proved to be significantly superior to the other treatments at all growth stages.

B. Yield and Yield Components

1. Productive Tiller Count

The mean values relating to the number of productive tillers per hill are furnished in Table 7 and the analysis of variance in the Appendix IV.

It was observed that higher levels of fertilisers favourably influenced the number of productive tillers per hill. There were significant increases in this aspect in accordance with the increasing fertiliser levels ranging from 50:25:25 kg/ha NPK to 80:40:40 kg/ha NPK, the former recording the lowest value of 1.56 and the latter giving the highest count of 2.77.

Significant increases were noticeable with the increasing spacings as well. The spacing of 20 cm x 10 cm gave the maximum number of productive tillers (2.82) and the spacing of 10 cm x 5 cm gave the minimum number (0.95).

The treatment combinations were also found to exert significant influence here. The highest productive tiller count was recorded by l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) which was significantly superior to all other treatments. The lowest value was noticed for l_2s_1 (60:30:30 kg/ha NPK with 10 cm x 5 cm spacing) which differed significantly from the other treatments excepting l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing).

2. Length of Panicle

The mean values for the length of panicle are presented in Table 8 and the analysis of variance in Appendix IV.

It could be seen from the results that the treatments receiving higher doses of fertiliser gave appreciable increases in panicle length. Longest panicles of 19.73 cm mean length were obtained with 80:40:40 kg/ha NPK, which treatment was significantly superior to the lower levels. Fertiliser level, 50:25:25 kg/ha NPK gave the shortest panicles, but was found to be on par with 60:30:30 kg/ha NPK.

Panicle length was also found to be influenced by spacings, 20 cm x 10 cm spacing giving the longest panicles of 19.67 cm mean length, and 10 cm x 5 cm spacing giving the shortest panicles of 18.85 cm mean length. Spacings 10 cm x 10 cm and 15 cm x 10 cm were, however, not found to differ significantly.

The various treatment combinations also produced significant influence on the mean length of panicle, with treatment l_2s_3(60:30:30 kg/ha NPK with 15 cm x 10 cm spacing) giving the maximum value and treatment l_3s_3(70:35:35 kg/ha NPK with 15 cm x 10 cm spacing) giving the minimum value.

Table 7. - Number of productive tillers per hill

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	0.77	1.15	1.43	2.88	1.56
60 :30 :30	0.70	2.71	2.68	1.42	1.88
70 :35 :35	0.90	1.37	2.61	3.03	1.98
80 :40 :40	1.44	2.47	3.19	3.97	2.77
Mean	0.95	1.93	2.48	2.82	

C.D. (0.05) for fertiliser levels = 0.034
C.D. (0.05) for spacings = 0.034
C.D. (0.05) for l x s combinations = 0.068

Table 8. - Length of panicle (cm)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	18.31	18.11	19.40	19.44	18.82
60 :30 :30	18.11	18.40	20.72	18.65	18.97
70 :35 :35	19.69	20.35	17.77	20.27	19.52
80 :40 :40	19.28	20.11	19.23	20.31	19.73
Mean	18.85	19.24	19.28	19.67	

C.D. (0.05) for fertiliser levels = 0.193
C.D. (0.05) for spacings = 0.193
C.D. (0.05) for lx s combinations = 0.385

3. Panicle Weight

The values on mean weight of panicle expressed in grams and the corresponding analysis of variance are presented in Table 9 and Appendix IV respectively.

An increasing trend was noticed in the weight of panicle with increasing fertiliser levels. The highest panicle weight of 1.95g was recorded by 80:40:40 kg/ha NPK, which was significantly superior to the lower levels. Fertiliser levels of 70:35:35 kg/ha NPK and 60:30:30 kg/ha NPK were found to be on par , while being significantly superior to 50:25:25 kg/ha NPK.

Considerable influence were also noticed on the panicle weight with various spacings. Spacing of 20 cm x 10 cm gave the heaviest panicles of 1.96g mean weight, while 10 cm x 5 cm spacing proved itself significantly inferior to the other three. Spacings 10 cm x 10 cm and 15 cm x 10 cm did not differ significantly in this respect.

The various treatment combinations were also found to bring about significant influences on panicle weight. Treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) produced the heaviest panicles whereas

Table 9. - Weight of panicle (g)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.56	1.62	1.80	1.84	1.71
60:30:30	1.52	1.74	1.94	1.96	1.79
70:35:35	1.80	1.98	1.52	1.98	1.82
80:40:40	1.86	1.92	1.97	2.05	1.95
Mean	1.69	1.81	1.81	1.96	

C.D.(0.05) for fertiliser levels = 0.032

C.D.(0.05) for spacings = 0.032

C.D.(0.05) for lx s combinations = 0.065

Table 10. - Number of spikelets per panicle

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	98.87	97.08	99.15	95.51	97.65
60:30:30	90.80	92.09	104.84	111.90	99.91
70:35:35	101.67	104.67	103.91	97.91	102.04
80:40:40	112.20	112.80	112.45	116.74	113.55
Mean	100.88	101.66	105.09	105.52	

C.D.(0.05) for fertiliser levels = 3.87

C.D.(0.05) for spacings = 3.87

C.D.(0.05) for lx s combinations = 7.73

treatment l_2s_1 (60:30:30 kg/ha NPK with 10 cm x 5 cm spacing) produced the lightest ones.

4. Number of Spikelets per Panicle

Data on the mean number of spikelets per panicle are furnished in Table 10 and the corresponding analysis of variance in Appendix IV.

Progressive increases were noticed in the spikelet number per panicle with each successive increment of fertiliser. The maximum value of 113.55 was given by 80:40:40 kg/ha NPK which was significantly superior to the lower levels. Fertiliser level 50:25:25 kg/ha NPK gave the least number of spikelets, but was on par with 60:30:30 kg/ha NPK. Fertiliser level 70:35:35 kg/ha NPK, even though on par with 60:30:30 kg/ha NPK proved itself significantly superior to 50:25:25 kg/ha NPK.

The number of spikelets was found to be significantly influenced by the various spacings as well. The spacings of 10 cm x 10 cm, 15 cm x 10 cm and 20 cm x 10 cm could not be distinguished statistically from each other, even though an increasing trend was noticed in the number of spikelets per panicle with increased spacings. The spacing of 10 cm x 5 cm proved to be inadequate compared to the other spacings in producing higher spikelet number per panicle, but was statistically on par with 10 cm x 10 cm spacing.

The results revealed that the treatment combinations also produced significant influences on the number of spikelets per panicle. Treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the highest number while treatment l_2s_1 (60:30:30 kg/ha NPK with 10 cm x 5 cm spacing) gave the lowest.

5. Number of Filled Grains per Panicle

Table 11 supplies the data on the mean number of filled grains per panicle and the Appendix IV presents the corresponding analysis of variance.

An increasing trend was evident in the number of filled grains per panicle with increasing fertiliser levels. A significantly superior value of 89.67 was given by 80: 40:40 kg/ha NPK. Fertiliser level 70:35:35 kg/ha NPK, even though giving a higher value, was found to be on par with 60:30:30 kg/ha NPK. The lowest value was obtained in the case of 50:25:25 kg/ha NPK, which did not differ significantly from 60:30:30 kg/ha NPK, but was inferior to 70:35:35 kg/ha NPK.

Table 11. - Number of filled grains per panicle

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	77.48	77.16	78.59	76.07	77.33
60:30:30	71.39	72.04	83.47	88.72	78.90
70:35:35	83.32	84.43	82.98	76.98	81.93
80:40:40	90.27	86.80	90.76	90.85	89.67
Mean	80.62	80.11	83.95	83.15	

C.D.(0.05) for fertiliser levels = 3.83

C.D.(0.05) for l x s combinations = 7.66

Table 12. - Sterility percentage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	21.63	20.54	20.71	20.32	20.80
60:30:30	21.33	21.83	20.39	19.72	20.82
70:35:35	18.12	19.37	20.20	21.42	19.78
80:40:40	19.61	23.01	19.33	22.20	21.04
Mean	20.17	21.19	20.16	20.92	

Increasing the spacing caused the number of filled grains per panicle to increase though the increase was not significant. The spacings of15 cm x 10 cm and 20 cm x 10 cm gave the highest values. The least value was obtained in the case of 10 cm x 5 cm spacing.

There was significant influence on this aspect by the various treatment combinations. The highest number of filled grains per panicle was given by treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) and the lowest number by l_2s_1 (70:35:35 kg/ha NPK with 10 cm x 5 cm spacing).

6. Sterility Percentage

The mean values for the percentage sterility are presented in Table 12 and the analysis of variance in Appendix IV.

The results revealed that fertiliser levels, spacings and their combinations did not substantially influence the percentage sterility. However, the trend noticed was an increase in sterility with increasing fertiliser levels.

7. Thousand Grain Weight

Data relating to the mean values for thousand grain weight expressed in grams are furnished in Table 13 and the respective analysis of variance in Appendix IV.

There was a considerable increase in the thousand grain weight resulting from increased fertiliser levels. The highest value was obtained with 80:40:40 kg/ha NPK, which was on par with 70:35:35 kg/ha NPK, but superior to the two lower levels. Fertiliser level 50:25:25 kg/ha NPK gave the lowest value, but was observed to be on par with 60:30:30 kg/ha NPK and 70:35:35 kg/ha NPK.

With regard to spacing, no pronounced influence was observed. Even so, the general trend noticed was an increase in the thousand grain weight with wider spacings. The various treatment combinations failed to evoke any considerable influence on the weight of thousand grains.

8. Grain Yield

The data pertaining to the grain yield as influenced by the various fertiliser levels, spacings and their combinations are presented in Table 14 and the analysis of variance in Appendix V.

The results provided conclusive evidence for the fact that the maximum grain yield of 2632.96 kg/ha was

Table 13. - Thousand grain weight (g)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	24.53	24.81	25.37	25.56	25.07
60 :30 :30	25.06	25.83	25.27	26.16	25.58
70 :35 :35	25.71	25.62	26.24	26.14	25.93
80 :40 :40	26.65	26.44	26.77	27.23	26.77
Mean	25.49	25.68	25.91	26.27	

C.D. (0.05) for fertiliser levels = 1.01

Table 14. - Yield of grain (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	2195.24	2500.49	2047.49	2042.61	2196.46
60 :30 :30	2500.82	2790.47	2423.97	2302.08	2504.34
70 :35 :35	2546.28	2840.48	2485.23	2395.24	2566.81
80 :40 :40	2592.08	2918.26	2582.07	2439.44	2632.96
Mean	2458.61	2762.43	2384.69	2294.84	

C.D. (0.05) for fertiliser levels = 20.79
C.D. (0.05) for spacings = 20.79
C.D. (0.05) for 1x s combinations = 41.57

produced by 80:40:40 kg/ha NPK which significantly differed from the lower levels. Grain yield increased significantly with fertiliser levels. The lowest yield of 2196.46 kg/ha was obtained with 50:25:25 kg/ha NPK.

The various spacings were also found to exert considerable influence on grain yield. The highest yield of 2762.43 kg/ha was obtained with 10 cm x 10 cm spacing, which was closely followed by 10 cm x 5 cm spacing. Spacing 15 cm x 10 cm was significantly inferior to 10 cm x 5 cm spacing but superior to 20 cm x 10 cm spacing.

The treatment combinations differed significantly from each other in this respect. The treatment l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) sporting the highest grain yield, was superior to all other treatments. The lowest grain yield was obtained in the case of l_1s_4 (50:25:25 kg/ha NPK with 20 cm x 10 cm spacing), which was on par with l_1s_3 (50:25:25 kg/ha NPK with 15 cm x 10 cm spacing).

9. Straw Yield

The mean values on yield of straw as influenced by the various treatments are presented in Table 15 and the corresponding analysis of variance in Appendix V.

The analysis of the data on yield of straw revealed that it was influenced by the various fertiliser levels considerably. There was significant and progressive increase in the yield of straw with each successive increment of fertiliser from 50:25:25 kg/ha NPK to 80:40:40 kg/ha NPK, the latter yielding a maximum of 5633.95 kg/ha straw and the former, a minimum of 5222.64 kg/ha.

Considering spacing, significant influences were wrought by the various spacings. The spacing of 10 cm x 10 cm was found to produce the highest straw yield of 5997.29 kg/ha, followed by 10 cm x 5 cm spacing, which was significantly superior to 15 cm x 10 cm spacing. Inferior to these three was 20 cm x 10 cm spacing which gave the minimum straw yield.

The treatment combinations also exerted a significant influence on straw yield. Treatment l_4s_2(80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) was found to be significantly superior to the other treatments, while the lowest value was given by l_1s_4(50:25:25 kg/ha NPK with 20 cm x 10 cm spacing).

Table 15. - Yield of straw (kg/ha)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10 cm	
50:25:25	5100.96	5863.00	5035.16	4891.45	5222.64
60:30:30	5313.06	5905.61	5288.97	5167.79	5418.86
70:35:35	5504.64	6021.63	5250.92	5306.22	5520.85
80:40:40	5587.79	6198.94	5393.24	5355.82	5633.95
Mean	5376.61	5997.29	5242.07	5180.32	

C.D.(0.05) for fertiliser levels = 26.78
C.D.(0.05) for spacings = 26.78
C.D.(0.05) for l x s combinations = 53.56

Table 16. Grain:straw ratio

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	0.43	0.43	0.41	0.42	0.42
60:30:30	0.47	0.47	0.47	0.44	0.46
70:35:35	0.46	0.47	0.47	0.45	0.46
80:40:40	0.46	0.47	0.48	0.46	0.47
Mean	0.46	0.46	0.46	0.44	

C.D.(0.05) for fertiliser levels = 0.006
C.D.(0.05) for spacings = 0.006
C.D.(0.05) for l x s combinations = 0.011

10. Grain:Straw Ratio

The mean values for the grain:straw ratio are presented in Table 16 and the analysis of variance in Appendix V.

The results indicated that increasing fertiliser levels increased the grain:straw ratio. However, 60:30:30 kg/ha NPK, 70:35:35 kg/ha NPK and 80:40:40 kg/ha NPK were observed to be on par. Treatment 50:25:25 kg/ha NPK was significantly inferior to the three higher levels.

In the case of spacing, 20 cm x 10 cm was found to be significantly inferior to the closer spacings. There was no significant difference between spacings 10 cm x 5 cm, 10 cm x 10 cm and 15 cm x 10 cm.

The combination effect of the levels of fertilisers and spacings was also found to be significant. Treatment l_4s_3 (80:40:40 kg/ha NPK with 15 cm x 10 cm spacing) was observed to give the highest value, while treatment l_1s_3 (50:25:25 kg/ha NPK with 15 cm x 10 cm spacing) gave the lowest.

11. Harvest Index

The data on harvest index is furnished in Table 17 and the analysis of variance in Appendix V.

It was obvious from the mean table that fertiliser levels had a pronounced effect on harvest index. Fertiliser level 50:25:25 kg/ha NPK gave the lowest value and differed significantly from the higher levels. There was no significant difference between 60:30:30 kg/ha NPK and 70:35:35 kg/ha NPK, even though the latter gave a slightly higher value. Treatment 80:40:40 kg/ha NPK recorded the highest value, but was on par with 70:35:35 kg/ha NPK and superior to the lower levels.

The various spacings were also found to wield a significant influence on the harvest index. The lowest value was given by spacing 15 cm x 10 cm, which differed significantly from the other spacings. There was significant difference between 15 cm x 10 cm and 10 cm x 5 cm spacings, even though the latter recorded a slightly higher value. The highest value for harvest index was given by 10 cm x 10 cm spacing, which was, however, on par with 10 cm x 5 cm spacing.

The effect of treatment combinations was also significant. The highest value was given by l_4s_3 (80:40:40 kg/ha NPK with 15 cm x 10 cm spacing) and the lowest with l_1s_3 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing).

Table 17. - Harvest Index (%)

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	43.02	42.65	40.67	41.73	42.02
60 :30 :30	47.04	47.25	45.83	44.55	46.17
70 :35 :35	46.26	47.17	47.33	45.14	46.48
80 :40 :40	46.39	47.08	47.88	45.55	46.72
Mean	45.68	46.04	45.43	44.24	

C.D.(0.05) for fertiliser levels = 0.431
C.D.(0.05) for spacings = 0.431
C.D.(0.05) for l x s combinations = 0.862

Table 18. - Protein content(%) in grain

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	6.44	7.05	6.90	7.30	6.92
60 :30 :30	6.83	6.96	7.64	7.85	7.32
70 :35 :35	7.10	7.23	7.83	8.60	7.69
80 :40 :40	7.93	8.34	8.42	8.63	8.33
Mean	7.08	7.40	7.70	8.10	

C.D.(0.05) for fertiliser levels = 0.379
C.D.(0.05) for spacings = 0.379

C. Quality Factor

1. Protein Content of Grain

Data relating to the mean values for the protein content of grain are presented in Table 18 and the analysis of variance in Appendix V.

It was observed that the levels of fertilisers had a significant effect on the grain protein content. The fertiliser level 80:40:40 kg/ha NPK gave the maximum grain protein (8.33 per cent) and differed significantly from the lower levels. There was no significant difference between 60:30:30 kg/ha NPK and 70:35:35 kg/ha NPK, even though the latter showed a slightly higher value. The fertiliser level 50:25:25 kg/ha NPK was significantly inferior to the higher levels.

With regard to spacing, wider spacings were found to give higher grain protein contents, and 20 cm x 10 cm spacing was significantly superior to the closer spacings, giving a value of 8.1 per cent. Spacing 10 cm x 5 cm was on par with 10 cm x 10 cm spacing, while 15 cm x 10 cm spacing was on par with 10 cm x 10 cm spacing, but superior to 10 cm x 5 cm spacing.

The combination effect of fertiliser levels with various spacings was not significant.

D. Chemical Composition

1. Nitrogen Content of Plants

The data on total nitrogen content expressed as percentage of plant parts on dry weight basis in shoot dry matter at tillering, panicle initiation, heading, flowering and harvest stages and in grain at harvest stage are presented in Tables 19(a) to 19(f) and the respective analysis of variance in Appendix V.

The various levels of fertilisers were observed to influence significantly the plant nitrogen contents at all growth stages. Plant nitrogen content was highest with 80:40:40 kg/ha and lowest with 50:25:25 kg/ha NPK at tillering, panicle initiation, heading, flowering and harvest stages. Fertiliser level, 60:30:30 kg/ha NPK was on par with 70:35:35 kg/ha NPK at all growth stages. There was no significant difference between 50:25:25 kg/ha NPK and 60:30:30 kg/ha NPK at panicle initiation and harvest stages while 70:35:35 kg/ha NPK was on par with

80:40:40 kg/ha NPK at panicle initiation and heading stages. Nitrogen content in grain was highest with 80:40:40 kg/ha NPK and lowest with 50:25:25 kg/ha NPK.

The various spacings also showed significant influence on nitrogen contents at all five growth stages. Spacings 10 cm x 5 cm and 10 cm x 10 cm were on par, though the latter was slightly higher at all the stages of crop growth. Similarly, 10 cm x 10 cm spacing and 20 cm x 10 cm spacing were on par but significantly superior to the closer two spacings at tillering stage. The same trend was noticeable at all growth stages. Grain nitrogen content was highest with 20 cm x 10 cm spacing and lowest with 10 cm x 5 cm spacing. Spacings 10 cm x 5 cm and 10 cm x 10 cm were on par. There was no significant difference between spacings 10 cm x 10 cm and 15 cm x 10 cm, but the latter was significantly superior to 10 cm x 5 cm spacing.

The treatment combinations were not found to influence the nitrogen contents significantly, except at tillering and flowering stages. At tillering stage treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm

Table 19(a) - Nitrogen content (%) in plants at tillering stage

Fertiliser level (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.69	1.64	1.43	1.76	1.63
60:30:30	1.68	1.70	1.91	1.85	1.79
70:35:35	1.70	1.71	1.99	1.98	1.85
80:40:40	1.90	1.92	2.09	2.14	2.01
Mean	1.74	1.74	1.86	1.93	

C.D.(0.05) for fertiliser levels = 0.09

C.D.(0.05) for spacings = 0.09

C.D.(0.05) for l x s combinations = 0.18

Table 19(b) - Nitrogen content (%) in plants at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.26	1.31	1.46	1.30	1.33
60:30:30	1.22	1.25	1.74	1.70	1.48
70:35:35	1.33	1.50	1.83	2.16	1.71
80:40:40	1.44	1.74	1.94	1.98	1.78
Mean	1.31	1.45	1.74	1.79	

C.D.(0.05) for fertiliser levels = 0.26

C.D.(0.05) for spacings = 0.26

Table 19(c)- Nitrogen content (%) in plants at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	1.11	1.16	1.23	1.38	1.22
60 :30 :30	1.20	1.24	1.46	1.53	1.36
70 :35 :35	1.23	1.36	1.69	1.59	1.47
80 :40 :40	1.26	1.54	1.73	1.70	1.56
Mean	1.20	1.33	1.53	1.55	

C.D. (0.05) for fertiliser levels = 0.102
C.D. (0.05) for spacings = 0.102

Table 19(d) - Nitrogen content (%) in plants at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	1.03	1.07	1.16	1.26	1.13
60 :30 :30	1.14	1.12	1.26	1.30	1.21
70 :35 :35	1.51	1.21	1.33	1.31	1.34
80 :40 :40	1.20	1.30	1.44	1.36	1.33
Mean	1.22	1.18	1.30	1.31	

C.D. (0.05) for fertiliser levels = 0.105
C.D. (0.05) for spacings = 0.105
C.D. (0.05) for 1 x s combinations = 0.210

Table 19(e)- Nitrogen content (%) in straw at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	0.73	0.75	0.79	0.81	0.77
60:30:30	0.75	0.77	0.80	0.82	0.79
70:35:35	0.79	0.80	0.83	0.81	0.81
80:40:40	0.82	0.84	0.85	0.83	0.84
Mean	0.77	0.79	0.82	0.82	

C.D.(0.05) for fertiliser levels = 0.025
C.D.(0.05) for spacings = 0.025

Table 19(f)- Nitrogen content (%) in grain

Fertiliser levels. (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.03	1.13	1.10	1.17	1.11
60:30:30	1.09	1.12	1.22	1.26	1.17
70:35:35	1.13	1.16	1.25	1.38	1.23
80:40:40	1.27	1.33	1.35	1.38	1.33
Mean	1.13	1.18	1.23	1.30	

C.D.(0.05) for fertiliser levels = 0.06
C.D.(0.05) for spacings = 0.06

spacing) was found to give the highest value though being on par with treatment l_4s_3(80:40:40 kg/ha NPK with 15 cm x 10 cm spacing). At flowering stage the highest values were given by treatments l_4s_3(80:40:40 kg/ha NPK with 15 cm x 10 cm spacing) and l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing), both of which were on par. The various treatment combinations failed to influence the grain nitrogen content significantly.

2. Phosphorus Content of Plants

The data on the total phosphorus content of plant dry matter at all five growth stages and in grain at harvest are presented in Tables 20(a) to 20(f) and their respective analysis of variance in Appendix VI.

An increasing trend was noticed in the phosphorus content of plants with increased fertiliser levels. There was significant difference between the four levels at tillering, panicle initiation and flowering stages, the lowest level of 50:25:25 kg/ha NPK giving the lowest content and the highest level of 80:40:40 kg/ha NPK giving the highest content. At heading stage, the same increasing trend was noticeable. However, 50:25:25 kg/ha NPK was on par with 60:30:30 kg/ha NPK, which did not differ significantly from the higher two levels. At harvest, 80:40:40 kg/ha NPK was on par with 70:35:35 kg/ha NPK while both were significantly superior to the lower two levels. Phosphorus content in grain also increased with increased fertiliser levels, the lowest content being obtained with 50:25:25 kg/ha NPK and the highest with 80:40:40 kg/ha NPK. Fertiliser levels 60:30:30 kg/ha NPK and 70:35:35 kg/ha NPK were found to be on par.

An increasing trend in plant phosphorus content was noticeable as the spacings grew wider. The least content was obtained with 10 cm x 5 cm spacing at all the growth stages, though it was found to be on par with 10 cm x 10 cm spacing at tillering and with 10 cm x 10 cm and 15 cm x 10 cm spacing at heading and flowering stages. At tillering, flowering and harvest stages, 10 cm x 10 cm spacing was found to be significantly inferior to 20 cm x 10 cm spacing but on par with 15 cm x 10 cm spacing. Grain phosphorus content also tended to increase with increased spacings, though the spacings of 10 cm x 5 cm, 10 cm x 10 cm and 15 cm x 10 cm were observed to be on par.

Table 20 (a) - Phosphorus content (%) in plants at tillering stage

Fertiliser levels (Kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	0.26	0.26	0.27	0.26	0.26
60:30:30	0.28	0.28	0.28	0.29	0.28
70:35:35	0.29	0.30	0.31	0.32	0.31
80:40:40	0.32	0.33	0.34	0.36	0.34
Mean	0.29	0.29	0.30	0.31	

C.D. (0.05) for fertiliser levels = 0.008
C.D. (0.05) for Spacings = 0.008
C.D. (0.05) for l x s combinations = 0.016

Table 20 (b) - Phosphorus content (%) in plants at panicle initation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	0.47	0.48	0.47	0.47	0.47
60:30:30	0.52	0.55	0.50	0.54	0.53
70:35:35	0.53	0.53	0.57	0.58	0.55
80:40:40	0.52	0.56	0.60	0.61	0.57
Mean	0.51	0.53	0.54	0.55	

C.D. (0.05) for fertiliser levels = 0.007
C.D. (0.05) for Spacings = 0.007
C.D. (0.05) for l x s combinations = 0.014

Table 20(c) - Phosphorus content (%) in plants at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	0.39	0.40	0.39	0.42	0.40
60 :30 :30	0.43	0.45	0.46	0.48	0.46
70 :35 :35	0.43	0.47	0.48	0.49	0.47
80 :40 :40	0.46	0.48	0.49	0.67	0.52
Mean	0.43	0.45	0.46	0.51	

C.D.(0.05) for fertiliser levels = 0.06
C.D.(0.05) for spacings = 0.06

Table 20(d) - Phosphorus content (%) in plants at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	0.31	0.32	0.31	0.33	0.32
60 :30 :30	0.33	0.32	0.34	0.35	0.34
70 :35 :35	0.33	0.34	0.34	0.37	0.36
80 :40 :40	0.35	0.36	0.35	0.38	0.36
Mean	0.33	0.34	0.34	0.36	

C.D.(0.05) for fertiliser levels = 0.007
C.D.(0.05) for spacings = 0.007

Table 20(e)- Phosphorus content (%) in straw at harvest

Fertiliser levels (kg/ha NPK)	Spacings 10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10 cm	Mean
50:25:25	0.21	0.22	0.21	0.23	0.22
60:30:30	0.22	0.22	0.23	0.25	0.23
70:35:35	0.24	0.25	0.25	0.27	0.25
80:40:40	0.24	0.25	0.26	0.26	0.25
Mean	0.22	0.24	0.24	0.25	

C.D.(0.05) for fertiliser levels = 0.008
C.D.(0.05) for spacings = 0.008

Table 20(f)- Phosphorus content (%) in grain

Fertiliser levels (kg/ha NPK)	Spacings 10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	Mean
50:25:25	0.63	0.65	0.66	0.66	0.65
60:30:30	0.69	0.67	0.68	0.69	0.68
70:35:35	0.69	0.68	0.70	0.70	0.69
80:40:40	0.73	0.74	0.72	0.76	0.74
Mean	0.69	0.69	0.69	0.70	

C.D.(0.05) for fertiliser levels = 0.011
C.D.(0.05) for spacings = 0.011
C.D.(0.05) for lx s combinations = 0.022

The combinations of fertiliser levels and spacings also wielded significant influence on plant phosphorus content at tillering and panicle initiation stages and on grain phosphorus content. The highest content was given in all cases by l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) and the lowest by l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing).

3. Potash Content of Plants

The data on the potash content of plants at tillering, panicle initiation, heading, flowering and harvest and in grain at harvest are supplied in Tables 21(a) to 21(f) and their corresponding analysis of variance in Appendix VI.

There was a progressive and significant increase in plant potash contents with each successive increment of fertiliser from 50:25:25 kg/ha NPK to 80:40:40 kg/ha NPK at tillering, panicle initiation, heading, flowering and harvest stages. The same trend was noticed in the case of grain potash content.

Increasing spacings also produced increased plant potash content at all growth stages and in grain at harvest.

Spacings 10 cm x 10 cm and 15 cm x 10 cm were statistically on par at tillering, panicle initiation and flowering stages. This was true for grain potash content as well. Spacing 20 cm x 10 cm was superior to the closer spacings at all stages except tillering and heading stages when it was found to be statistically on par with 15 cm x 10 cm spacing. Spacing 10 cm x 5 cm was significantly inferior to the wider spacings at all stages except tillering and harvest stages, when it was on par with 10 cm x 10 cm spacing.

The various treatment combinations were not found to have any significant influence on this aspect except at harvest. Treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the highest contents and treatment l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) gave the lowest value at all five growth stages. With regard to grain potash content there was significant difference between the various treatments, the treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) giving the highest and l_1s_1 (50:25:25kg/ha NPK with 10 cm x 5 cm spacing) giving the lowest values.

Table 21(a) - Potash content (%) in plants at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.24	1.27	1.28	1.31	1.28
60:30:30	1.30	1.34	1.35	1.35	1.34
70:35:35	1.35	1.41	1.41	1.43	1.40
80:40:40	1.44	1.48	1.49	1.48	1.47
Mean	1.33	1.38	1.38	1.39	

C.D.(0.05) for fertiliser levels = 0.011
C.D.(0.05) for spacings = 0.011

Table 21(b) - Potash content (%) in plants at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.38	1.41	1.41	1.43	1.41
60:30:30	1.45	1.44	1.47	1.48	1.46
70:35:35	1.50	1.52	1.51	1.55	1.52
80:40:40	1.55	1.55	1.57	1.58	1.56
Mean	1.47	1.48	1.49	1.51	

C.D.(0.05) for fertiliser levels = 0.019
C.D.(0.05) for spacings = 0.019

Table 21(c) Potash content (%) in plants at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	1.50	1.54	1.55	1.53	1.53
60 :30 :30	1.60	1.62	1.64	1.66	1.63
70 :35 :35	1.63	1.65	1.66	1.68	1.66
80 :40 :40	1.70	1.69	1.72	1.72	1.71
Mean	1.61	1.63	1.64	1.65	

C.D.(0.05) for fertiliser levels = 0.014

C.D.(0.05) for spacing = 0.014

Table 21(d)- Potash content (%) in plants at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	1.62	1.66	1.65	1.68	1.65
60 :30 :30	1.66	1.68	1.68	1.72	1.69
70 :35 :35	1.70	1.73	1.74	1.77	1.74
80 :40 :40	1.76	1.75	1.75	1.79	1.76
Mean	1.69	1.71	1.71	1.74	

C.D.(0.05) for fertiliser levels = 0.012

C.D.(0.05) for spacings = 0.012

Table 21(e) - Potash content (%) in straw at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	1.38	1.41	1.40	1.45	1.41
60:30:30	1.43	1.39	1.41	1.49	1.43
70:35:35	1.46	1.47	1.47	1.52	1.48
80:40:40	1.49	1.51	1.54	1.57	1.53
Mean	1.44	1.45	1.46	1.51	

C.D.(0.05) for fertiliser levels = 0.009
C.D.(0.05) for spacings = 0.009
C.D.(0.05) for l x s combinations = 0.019

Table 21(f)- Potash content (%) in grain

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	0.39	0.42	0.46	0.44	0.43
60:30:30	0.45	0.48	0.47	0.48	0.47
70:35:35	0.49	0.51	0.51	0.54	0.51
80:40:40	0.53	0.57	0.55	0.58	0.56
Mean	0.47	0.50	0.50	0.51	

C.D.(0.05) for fertiliser levels = 0.01
C.D.(0.05) for spacings = 0.01
C.D.(0.05) for lx s combinations = 0.02

E. Uptake Studies

1. Uptake of Nitrogen

The data on the uptake of nitrogen expressed in kilograms per hectare at tillering, panicle initiation, heading, flowering and harvest stages are presented in Tables 22 (a) to 22(e) and their analysis of variance in Appendix VII.

The data revealed that there was significant increase in the nitrogen uptake with increased levels of fertilisers at all stages. The maximum values of 15.02, 43.47, 77.40, 89.29 and 65.51 kg/ha were obtained with 80:40:40 kg/ha NPK at tillering, panicle initiation, heading, flowering and harvest stages respectively. But this fertiliser level was on par with 70:35:35 kg/ha NPK at panicle initiation and flowering stages. The minimum values for nitrogen uptake was recorded by 50:25:25 kg/ha NPK, which was statistically inferior to the higher levels at all stages except tillering, when it was found to be on par with 60:30:30 kg/ha NPK.

With regard to spacing, there was significant influence on this aspect with various spacings at all

Table 22(a)- Uptake of nitrogen (kg/ha) at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	11.24	11.23	9.28	10.74	10.62
60:30:30	11.58	12.96	12.86	11.59	12.25
70:35:35	12.07	13.46	13.69	12.59	12.95
80:40:40	13.79	16.63	14.99	14.66	15.02
Mean	12.17	13.57	12.70	12.40	

C.D.(0.05) for fertiliser levels = 0.711
C.D.(0.05) for spacings = 0.711
C.D.(0.05) for lx s combinations = 1.42

Table 22(b)- Uptake of nitrogen(kg/ha) at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	29.09	30.81	29.97	32.51	30.59
60:30:30	29.13	31.03	39.84	40.23	35.06
70:35:35	32.62	37.52	51.86	43.62	41.41
80:40:40	35.74	44.31	47.70	46.12	43.47
Mean	31.65	35.92	42.34	40.62	

C.D.(0.05) for fertiliser levels = 6.18
C.D.(0.05) for spacings = 6.18

Table 22(c)- Uptake of nitrogen(kg/ha) at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	52.53	59.40	55.92	62.61	57.61
60:30:30	57.30	64.91	67.98	69.99	65.05
70:35:35	59.11	73.37	80.03	73.17	71.42
80:40:40	61.67	84.47	83.60	79.88	77.40
Mean	57.65	70.54	71.83	71.41	

C.D.(0.05) for fertiliser levels = 5.01
C.D.(0.05) for spacings = 5.01

Table 22(d) - Uptake of nitrogen (kg/ha) at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	56.72	59.71	62.90	67.55	61.72
60:30:30	75.69	74.72	67.03	71.87	72.33
70:35:35	102.35	82.82	84.16	71.29	85.15
80:40:40	78.94	100.54	91.44	86.26	89.29
Mean	78.42	79.45	76.38	74.24	

C.D.(0.05) for fertiliser levels = 7.01
C.D.(0.05) for l x s combinations =14.01

Table 22(e). - Uptake of nitrogen (kg/ha) at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	55.16	51.87	50.58	52.44	52.51
60 :30 :30	56.76	59.75	58.79	53.74	57.26
70 :35 :35	59.31	62.53	61.58	60.71	61.03
80 :40 :40	62.23	74.09	63.42	62.27	65.51
Mean	58.37	62.06	58.59	57.29	

C.D.(0.05) for fertiliser levels = 2.78
C.D.(0.05) for spacings = 2.78
C.D.(0.05) for l x s combinations = 5.56

Table 23(a). - Uptake of phosphorus (kg/ha) at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	1.73	1.78	1.78	1.59	1.72
60 :30 :30	1.93	2.13	1.89	1.82	1.94
70 :35 :35	2.06	2.36	2.13	2.03	2.15
80 :40 :40	2.32	2.86	2.44	2.47	2.52
Mean	2.01	2.28	2.06	1.98	

C.D.(0.05) for fertiliser levels = 0.068
C.D.(0.05) for spacings = 0.068
C.D.(0.05) for l x s combinations = 0.136

stages except flowering. Spacing 20 cm x 10 cm showed higher uptake values compared to the other three spacings at tillering, flowering and harvest stages. This increase was not significant at flowering stage. The lowest values were given by 10 cm x 5 cm spacing at all stages.

The influence of the various treatment combinations on this aspect was significant only at tillering, flowering and harvest stages. At all growth stages, treatment l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) gave the highest uptake values which was statistically on par with l_4s_3 (80:40:40 kg/ha NPK with 15 cm x 10 cm spacing) and l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing at tillering, flowering and harvest stages. Treatments l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing), l_1s_2 (50:25:25 kg/ha NPK with 10 cm x 10 cm spacing) l_1s_3 (50:25:25 kg/ha NPK with 15 cm x 10 cm spacing) and l_1s_4 (50:25:25 kg/ha NPK with 20 cm x 10 cm spacing) produced lower values compared to the other treatments.

2. <u>Uptake of Phosphorus</u>

The data on the uptake of phosphorus at different growth stages as influenced by levels of fertilisers and spacings are presented in Tables 23(a) to 23(e) and their respective analysis of variance in Appendix VII.

There was significant difference between the various fertiliser levels with regard to the phosphorus uptake. The trend noticed was an increase in uptake as fertiliser level increased. Thus the maximum uptake values of 2.52, 14.03, 24.01, 24.37 and 19.83 kg/ha were given by 80:40:40 kg/ha NPK at tillering, panicle initiation, heading flowering and harvest stages respectively. The minimum values were obtained with 50:25:25 kg/ha NPK at all the growth stages.

With regard to spacing, 10 cm x 10 cm was significantly superior to all other spacings at all growth stages, except panicle initiation stage, when it was found to be on par with 20 cm x 10 cm spacing. Spacing 10 cm x 5 cm gave the lowest values at all stages.

Considering the treatment combinations, l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) was found statistically superior to the others at all growth stages. Treatment l_1s_4 (50:25:25 kg/ha NPK with 20 cm x

Table 23(b). - Uptake of phosphorus (kg/ha) at panicle initiation stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	10.85	11.29	10.84	10.47	10.86
60:30:30	12.42	13.58	11.72	12.48	12.55
70:35:35	13.00	13.26	13.69	13.80	13.43
80:40:40	12.91	14.26	14.45	14.52	14.03
Mean	12.30	13.10	12.67	12.82	

C.D.(0.05) for fertiliser levels = 0.183
C.D.(0.05) for spacings = 0.183
C.D.(0.05) for l x s combination = 0.366

Table 23(c). - Uptake of phosphorus (kg/ha) at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	18.47	20.48	17.73	19.00	18.92
60:30:30	20.99	23.55	21.41	21.96	21.98
70:35:35	20.67	25.35	22.73	22.55	22.83
80:40:40	22.51	26.35	23.67	23.49	24.01
Mean	20.66	23.93	21.39	21.75	

C.D.(0.05) for fertiliser levels = 0.32
C.D.(0.05) for spacings = 0.32
C.D.(0.05) for l x s combinations = 0.64

Table 23(d). - Uptake of phosphorus (kg/ha) at flowering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	17.07	17.86	16.81	17.69	17.36
60:30:30	21.91	21.33	18.09	19.35	20.17
70:35:35	22.30	23.27	21.52	20.14	21.81
80:40:40	23.03	27.84	22.49	24.10	24.37
Mean	21.08	22.58	19.73	20.32	

C.D.(0.05) for fertiliser levels = 0.48
C.D.(0.05) for spacings = 0.48
C.D.(0.05) for l x s combinations = 0.96

Table 23(e). - Uptake of phosphorus (kg/ha) at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	13.96	14.53	14.10	14.90	14.37
60:30:30	16.65	17.85	16.17	16.38	16.76
70:35:35	18.02	19.54	18.55	20.23	19.09
80:40:40	18.22	22.93	18.65	19.50	19.83
Mean	16.71	18.71	16.87	17.76	

C.D.(0.05) for fertiliser levels = 0.588
C.D.(0.05) for spacing = 0.588
C.D.(0.05) for l x s combinations = 1.176

10 cm spacing) gave significantly lower values but was on par with l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) in all cases.

3. Uptake of Potash

The data on the uptake of potash as influenced by the various fertiliser levels and spacings at different stages of growth are presented in Tables 24(a) to 24(e) and their analysis of variance in Appendix VIII.

Increasing fertiliser levels significantly increased the potash uptake by plants at all the growth stages. The maximum values for uptake, namely, 11.03, 38.36, 84.97, 119.27 and 119.74 kg/ha were given by 80:40:40 kg/ha NPK at tillering, panicle initiation, heading, flowering and harvest stages respectively. The minimum values were given by 50:25:25 kg/ha NPK at all growth stages.

The spacing of 10 cm x 10 cm was found to be significantly superior to the other spacings in this respect at all the growth stages. The other spacings did not show any definite trend in this respect nor did they differ significantly from each other.

Table 24(a) - Uptake of potash (kg/ha) at tillering stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	8.23	8.69	8.43	7.99	8.34
60:30:30	8.96	10.22	9.09	8.46	9.18
70:35:35	9.58	11.09	9.69	9.10	9.87
80:40:40	10.45	12.83	10.68	10.14	11.03
Mean	9.30	10.71	9.48	8.92	

C.D.(0.05) for fertiliser levels = 0.205
C.D.(0.05) for spacings = 0.205
C.D.(0.05) for l x s combinations = 0.411

Table 24(b)- Uptake of potash (kg/ha) at Panicle initiation stage

Fertiliser level (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	31.86	33.17	32.53	31.85	32.35
60:30:30	34.64	36.52	33.75	34.21	34.78
70:35:35	36.77	37.77	36.50	36.88	36.98
80:40:40	38.47	40.01	37.34	37.60	38.36
Mean	35.43	36.87	35.03	35.13	

C.D.(0.05) for fertiliser levels = 0.572
C.D.(0.05) for spacings = 0.572

Table 24(c) - Uptake of potash (kg/ha) at heading stage

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	71.02	78.86	70.48	69.22	72.40
60:30:30	76.30	84.80	76.35	75.94	78.35
70:35:35	78.35	88.99	78.61	77.32	80.82
80:40:40	83.21	92.77	83.09	80.80	84.97
Mean	77.22	86.36	77.13	75.82	

C.D.(0.05) for fertiliser levels = 0.713
C.D.(0.05) for spacings = 0.713

Table 24(d) - Uptake of potash (kg/ha) at flowering stage

Fertilizer levels (kg/ha NPK)	Spacings				Mean
	10cm x 5 cm	10cm x 10cm	15cm x 10cm	20cm x10cm	
50:25:25	89.20	92.63	89.46	90.07	90.34
60:30:30	110.20	112.35	89.33	95.11	101.75
70:35:35	114.91	118.39	110.10	96.32	109.93
80:40:40	115.78	135.33	112.45	113.53	119.27
Mean	107.52	114.68	100.34	98.76	

C.D.(0.05) for fertiliser levels = 0.805
C.D.(0.05) for spacings = 0.805
C.D.(0.05) for l x s combinations = 1.61

Table 24 (e)- Uptake of potash (kg/ha) at harvest

Fertiliser levels (kg/ha NPK)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50:25:25	91.69	97.56	89.70	93.93	93.22
60:30:30	108.22	107.86	103.64	97.90	104.40
70:35:35	109.62	114.89	109.05	113.91	111.87
80:40:40	113.09	133.18	114.90	117.78	119.74
Mean	105.65	113.37	104.32	105.88	

C.D.(0.05) for fertiliser levels = 0.734
C.D.(0.05) for spacings = 0.734
C.D.(0.05) for l x s combinations = 1.47

At all stages of growth excepting panicle initiation and heading stages, treatment combination l_4s_2(80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) was significantly superior to the other treatments. Lowest values for potash uptake were recorded at all stages by l_1s_1(50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) which was closely followed by l_1s_4(50:25:25 kg/ha NPK with 20 cm x 10 cm spacing).

F. Soil Analysis

1. Available Nitrogen, Available Phosphorus and Available Potassium content of the soil after the experiment

Tables 25, 26 and 27 and Appendix VIII present the mean values and analysis of variance respectively of the residual nutrient status of the experimental plots.

There was no significant influence by the levels of fertilisers, spacings and their combinations on the available nitrogen, available phosphorus and available potassium content of the soil after the experiment. However, the general trend noticeable was an increase in these values with increasing fertiliser levels.

Table 25. - Available soil nitrogen content(kg/ha) after the experiment

Fertiliser levels (kg/ha)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	28.39	29.01	29.26	29.43	29.02
60 :30 :30	29.36	29.46	29.41	29.49	29.43
70 :35 :35	29.39	29.53	29.49	29.67	29.52
80 :40 :40	29.42	29.48	29.56	29.69	29.54
Mean	29.14	29.37	29.43	29.57	

Table 26. - Available soil phosphorus content(kg/ha) after the experiment

Fertiliser levels (kg/ha)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	42.60	42.10	43.00	43.25	42.74
60 :30 :30	42.78	43.01	43.21	43.30	43.08
70 :35 :35	42.96	43.40	43.23	43.30	43.22
80 :40 :40	43.21	43.36	43.20	43.51	43.32
Mean	42.89	42.97	43.16	43.34	

Table 27. - Available soil potash content (kg/ha) after the experiment

Fertiliser levels (kg/ha)	Spacings				Mean
	10cm x 5cm	10cm x 10cm	15cm x 10cm	20cm x 10cm	
50 :25 :25	70.68	71.13	71.12	72.15	71.27
60 :30 :30	69.71	69.90	71.30	70.66	70.39
70 :35 :35	71.07	71.35	71.46	72.40	71.57
80 :40 :40	71.16	71.64	72.12	71.63	71.64
Mean	70.65	71.01	71.50	71.71	

G. Economics of Production

The economics of production are given in Table 28. The maximum profit of Rs.3656.03 was obtained in the treatment l_4s_2(80:40:40 kg/ha NPK with 10 cm x 10 cm spacing). The treatment l_1s_1(50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) gave the least profit of Rs.1817.24.

However, taking into consideration the benefit: cost ratio the maximum value of 2.05 was given by treatment l_2s_3(60:30:30 kg/ha NPK with 15 cm x 10 cm spacing), closely followed by l_4s_4(80:40:40 kg/ha NPK with 20 cm x 10 cm spacing). The lowest ratio was obtained in the case of treatment l_1s_1(50:25:25 kg/ha NPK with 10 cm x 5 cm spacing).

H. Correlation Studies

The values of simple correlation coefficients are presented in Table 29.

The uptake of nitrogen, phosphorus and potash by the crop at harvest were significantly and positively correlated with grain yield and the correlation coefficients were 0.706, 0.729 and 0.806 respectively.

Table 28. - Economics of rice production per hectare

Treatments	Total income from yield of grain and straw Rs. ps	Cost of fertilisers (Urea + Superphoshate +muriate of potash)	Labour charges Rs. ps	Total expenses for fertilisers and labour	Net profit Rs. ps	Benefit: cost ratio
1	2	3	4	5	6	7
		Rs. ps		Rs. ps		
l_1s_1	5887.24	167.00	3903.00	4070.00	1817.24	1.45
l_1s_2	6732.24	167.00	3612.00	3779.00	2953.24	1.78
l_1s_3	5629.76	167.00	3030.00	3197.00	2432.76	1.76
l_1s_4	5550.50	167.00	3030.00	3197.00	2353.50	1.74
l_2s_1	6457.78	200.40	3903.00	4103.40	2354.36	1.57
l_2s_2	7194.32	200.40	3612.00	3812.40	3381.92	1.89
l_2s_3	6637.24	200.40	3030.00	3230.40	3406.84	2.05
l_2s_4	6143.65	200.40	3030.00	3230.40	2913.25	1.9
l_3s_1	6622.67	233.80	3903.00	4186.80	2485.87	1.6
l_3s_2	7328.35	233.80	3612.00	3845.80	3482.55	1.91
l_3s_3	6403.01	233.80	3030.00	3263.80	3139.21	1.96
l_3s_4	6293.87	233.80	3030.00	3263.80	3030.07	1.93

(table cond..)

Table 28 (contd.)

1	2	3	4	5	6	7
l_4s_1	6733.86	267.20	3903.00	4170.20	2563.66	1.61
l_4s_2	7535.23	267.20	3612.00	3879.20	3656.03	1.94
l_4s_3	6621.37	267.20	3030.00	3297.20	3324.17	2.01
l_4s_4	6385.86	267.20	3030.00	3297.20	3088.66	1.94

Treatments:

l_1s_1 - 50:25:25 kg/ha NPK with 10cm x 5cm spacing
l_1s_2 - 50:25:25 kg/ha NPK with 10cm x 10cm "
l_1s_3 - 50:25:25 " " " 15cm x 10cm "
l_1s_4 - 50:25:25 " " " 20cm x 10cm "

l_2s_1 - 60:30:30 " " " 10cm x 5 cm "
l_2s_2 - 60:30:30 " " " 10cm x 10cm "
l_2s_3 - 60:30:30 " " " 15cm x 10cm "
l_2s_4 - 60:30:30 " " " 20cm x 10cm "

l_3s_1 - 70:35:35 kg/ha NPK with 10cm x 5cm spacing
l_3s_2 - 70:35:35 kg/ha NPK with 10cm x 10cm "
l_3s_3 - 70:35:35 " " " 15cm x 10 cm "
l_3s_4 - 70:35:35 " " " 20cm x 10cm "

l_4s_1 - 80:40:40 " " " 10cm x 5 cm "
l_4s_2 - 80:40:40 " " " 10cm x 10cm "
l_4s_3 - 80:40:40 " " " 15cm x 10cm "
l_4s_4 - 80:40:40 " " " 20cm x 10cm "

Price of 1 kg grain - Rs.1.52
" 1 kg straw - Rs.0.50
" 1 kg urea - Rs.2.40
" 1kg super-phosphate- Rs.0.55
" 1 kg.MOP - Rs.1.33

Labour charges per day for men - Rs.16.05
Labour charges per day for women- Rs.14.55

Table 29- Values of Simple correlation coefficients

Sl. No.	Characters correlated	Correlation coefficient
1.	Grain yield x Dry matter production	0.898*
2.	Grain yield x Nitrogen uptake	0.706*
3.	Grain yield x Phosphorus uptake	0.729*
4.	Grain yield x Potash uptake	0.806*
5.	Dry matter production x Nitrogen uptake	0.832*
6.	Dry matter production x Phosphorus uptake	0.861*
7.	Dry matter production x Potash uptake	0.940*
8.	Protein yield x Nitrogen uptake	0.425*
9.	Protein yield x Phosphorus uptake	0.657*
10.	Protein yield x Potash uptake	0.586*

* Significant at 0.05 level

Dry matter production at harvest was positively correlated with grain yield with a correlation coefficient of 0.898. Correlations of nitrogen, phosphorus and potash uptake with dry matter production at harvest showed that they were significantly positive.

It was also noticed that the uptake of nitrogen, phosphorus and potash at harvest were significantly and positively correlated with protein yield, the 'r' values being 0.425, 0.657 and 0.586 respectively.

DISCUSSION

DISCUSSION

The present investigation is an attempt to ascertain the effects of different fertiliser levels and spacings on the performance of rice cultivar, Mashuri, in the Onattukara tract. The results obtained from the study are discussed below.

A. Growth Characters

1. Height of Plants

The results presented in Tables 2(a) to 2(e) and Fig.3 revealed that there were significant increase in the height of plants at all stages of growth owing to increased fertiliser application. The increase was more prominent during the later stages of growth. The treatment receiving the highest dose of nitrogen, namely, 80:40:40 kg/ha NPK, recorded the maximum height at all growth stages. The influence of nitrogen fertilisation upon encouraging the vegetative growth of plants, particularly plant height, is a well-established fact. It is a constituent element of plant protein and other physiologically indispensable compounds. Supply of

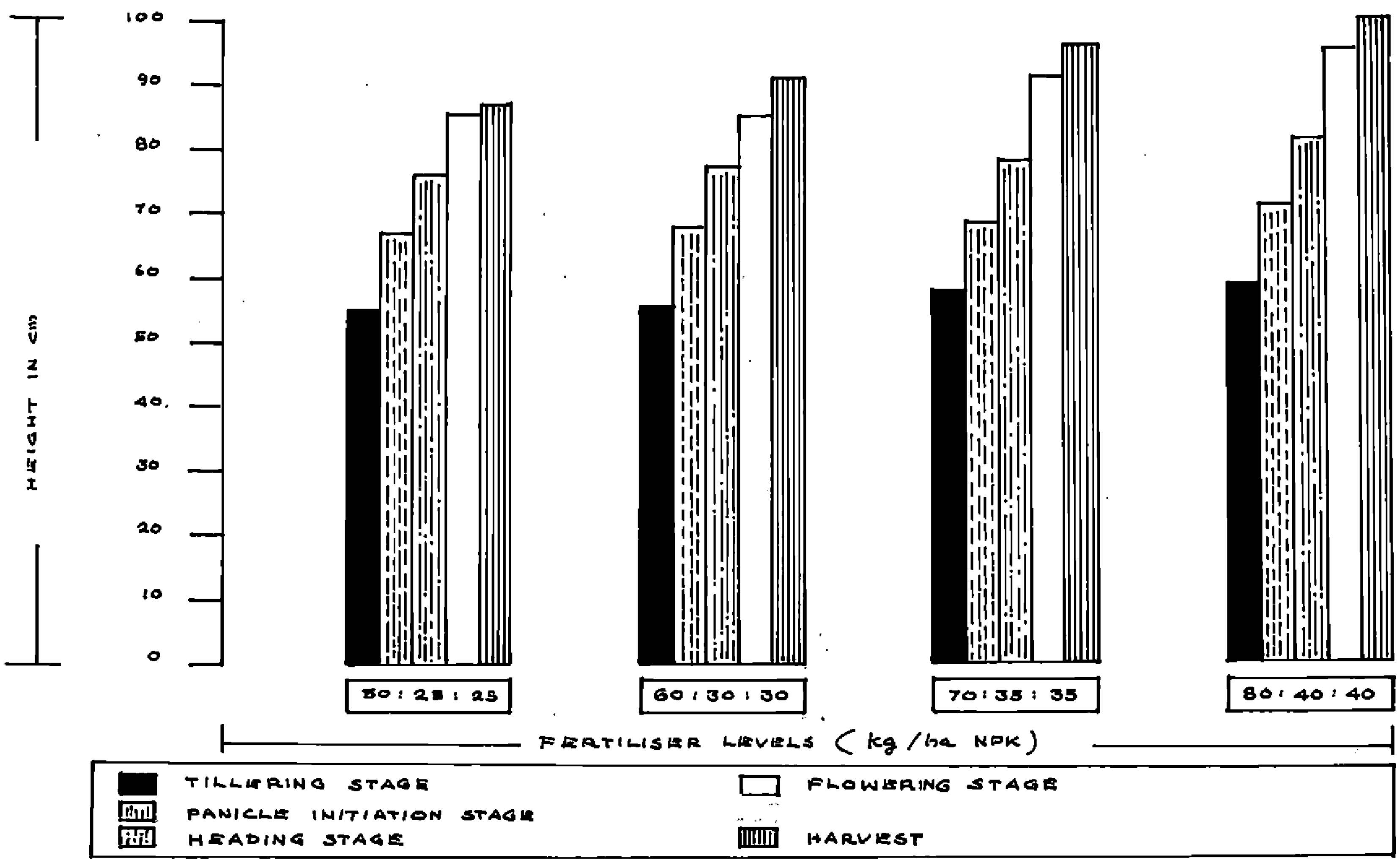

FIG: 3 HEIGHT OF THE PLANTS AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT FERTILISER LEVELS nitrogen in adequate quantities facilitates a rapid formation of protoplasm, resulting in a more succulent plant. Research reports of several scientists brings to light this fact. The effect of nitrogen discussed above has been reported by Lenka and Behera (1967), Lenka (1969), Ramanujam and Rao (1971), Sadayappan et al. (1974) and Raju (1979).

With regard to spacing, it was evident from the results indicated in Tables 2(a) to 2(e) and Fig.4 that the wider the spacing, the taller the plants. At all stages of growth, the widest spacing under trial, 20 cm x 10 cm gave the maximum height of plants. This influence became more evident with the age of plants. Wider spacing facilitates more sunlight to enter the plant canopy, reaching even to the basal portions of the clump. Planting at wider intervals, reduces mutual shading, which is an important fact in the case of a tall indica variety. More sunlight results in more photosynthesis, which in turn paves the way for more growth resulting from a greater contribution of photosynthates. The influence of spacing on plant height has already been stressed by Fagundo et al.(1978) and Ibrahim et al. (1980).

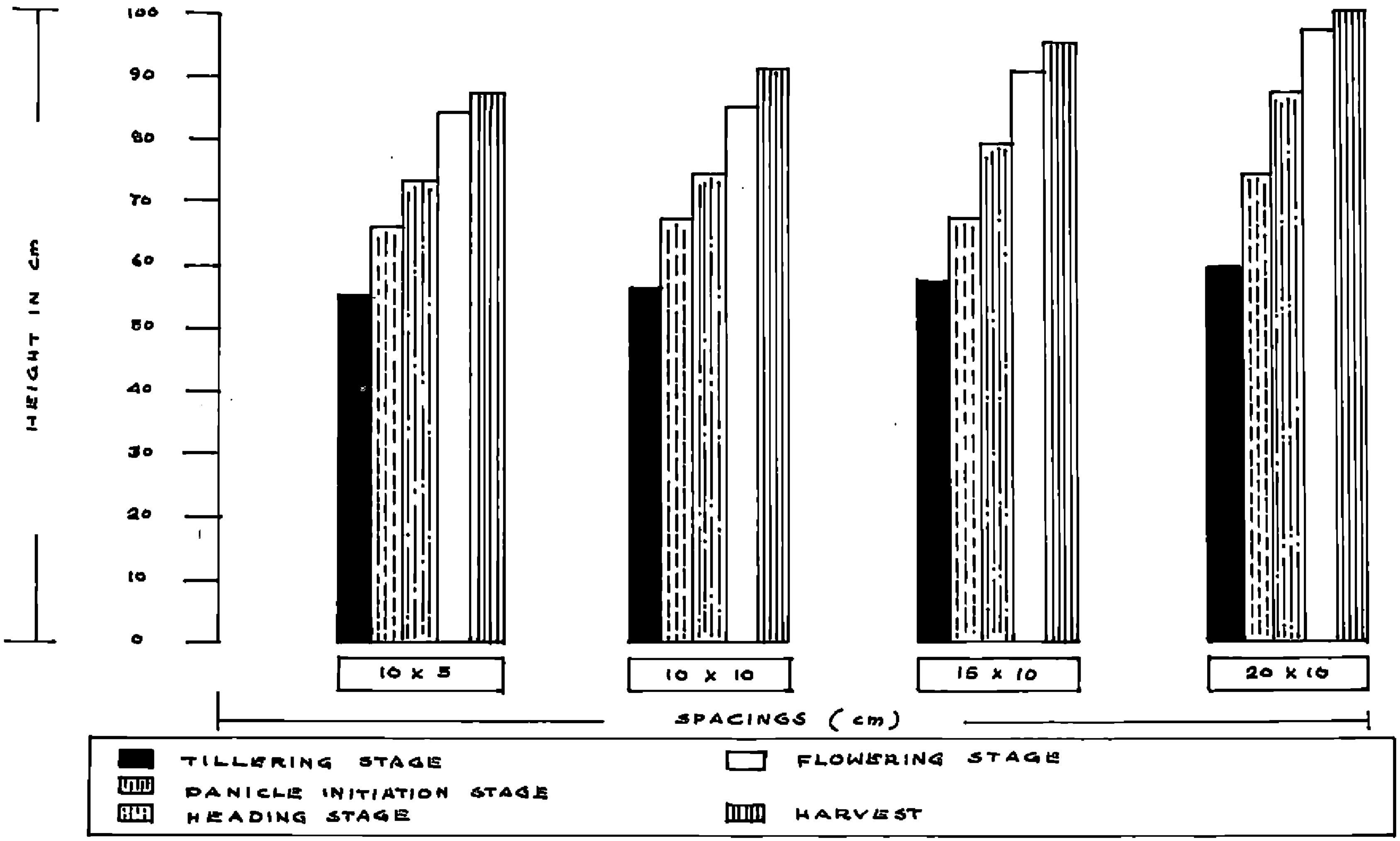

FIG: 4 HEIGHT OF THE PLANTS AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT SPACINGS

The results made it obvious that the treatment combination l_4s_4(80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) produced the tallest plants. The cumulative effect of both increased fertilizers and wider spacing must have resulted in this increase.

2. Tiller Count per Hill

From the results furnished in Tables 3(a) to 3(e) and Fig.5, it could be seen that there was a definite increase in the tiller counts as fertiliser levels increased. The highest number was recorded by 80:40:40 kg/ha NPK at all stages. This was due to the increase of all the three nutrient elements, each of which had an influence on this aspect, the most pronounced being that of nitrogen. It is well established that nitrogen nutrition is essential for rapid growth and production of more tillers. The increasing trend resulting from increased nitrogen application noticed here is supported by similar results obtained by Shrivastava et al.(1970), Pande and Narkhede (1972) and Raju (1981). Phosphorus was also found to have an influence here as it is a nutrient encouraging more active tillering which enables rice plants to recover more rapidly after any adverse

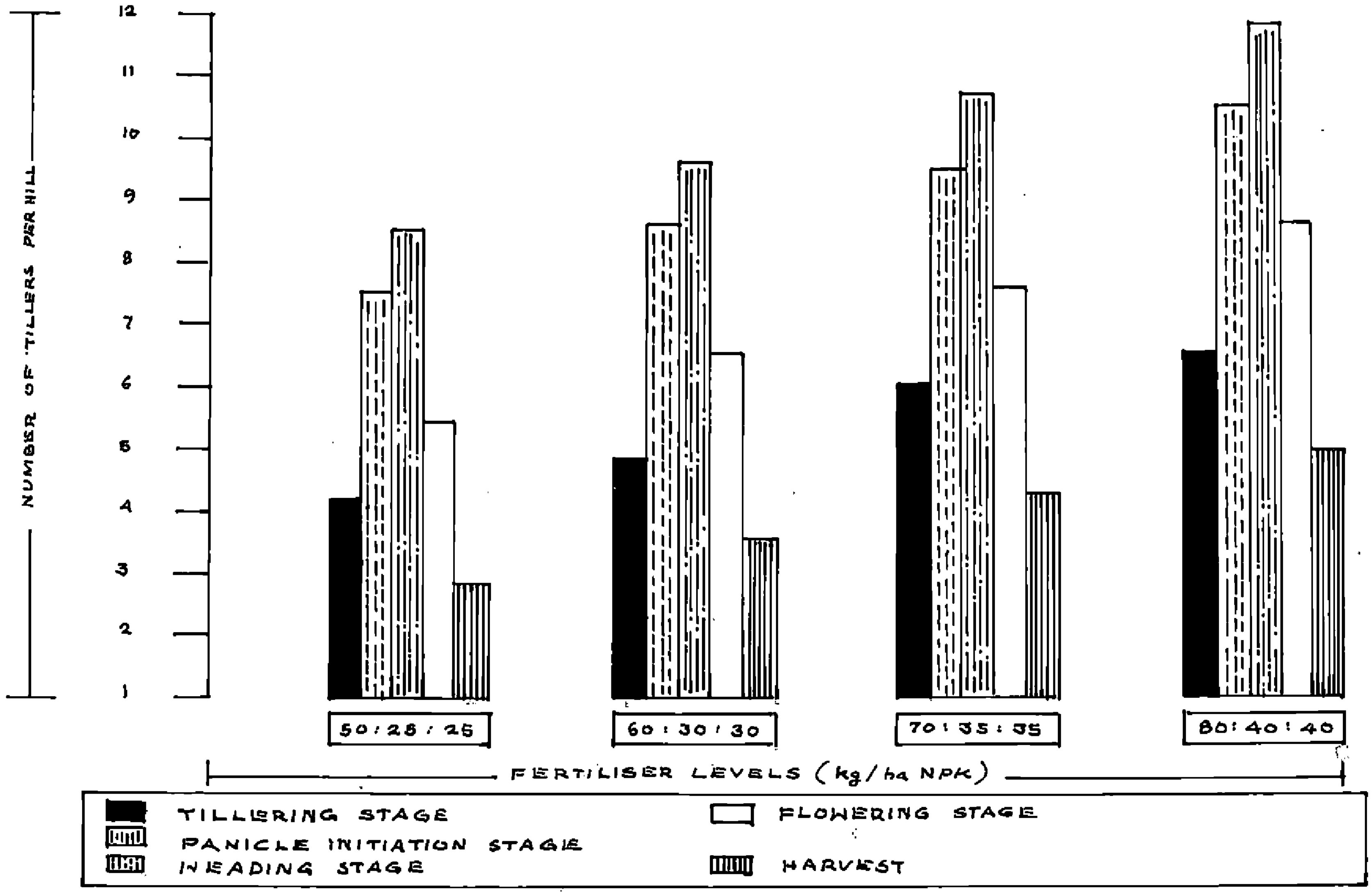

FIG: 5 NUMBER OF TILLERS PER HILL AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT FERTILISER LEVELS situation. Research findings of Terman and Allen(1970) and Nair et al.(1972) support the results obtained in this study that increased tillering results from increased phosphorus application. Potassium being an element helping in protein production of plants might have exerted some influence on growth and tiller production. Increasing tiller counts with increasing potassium levels have been obtained by Kulkarni et al.(1975) and Singh and Singh (1979).

An increase in spacing increased the number of tillers per hill as is seen from the results presented in Tables 3(a) to 3(e) and Fig.6. The spacing of 20 cm x 10 cm, which was the widest under trial, gave the maximum tiller counts at all stages. In general under poor fertility conditions, spacing between hills should be somewhat narrow so as to obtain enough production of tillers per unit area, regardless of plant type. However, in wider spacing, formation of more tillers per plant is encouraged, probably because of the lesser competition between plants for the various growth requirements in this case. The result obtained in this study is supported by the findings of Chang and Su (1977) and

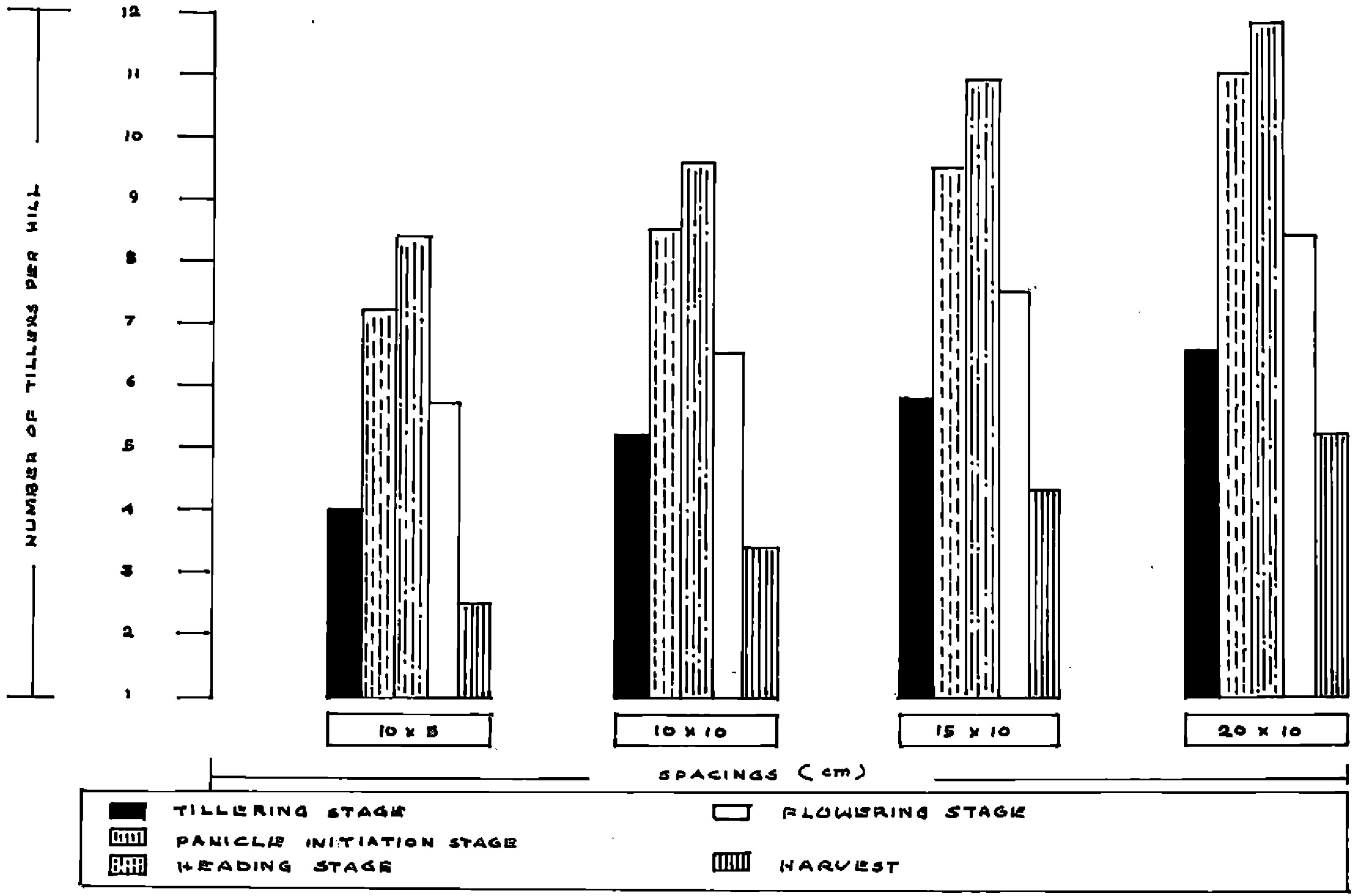

FIG: 6 NUMBER OF TILLERS PER HILL AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT SPACINGS

Chatterjee and Maiti(1981).

The different treatment combinations were found to have a pronounced influence upon tillering. The treatment l_4s_4(80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) recorded the highest tiller counts at all growth stages. Since tiller number is increased with increased fertiliser levels and increased spacings, combination of the two could produce a cumulative effect.

3. Number of Leaves per Hill

Results portrayed in Tables 4(a) to 4(e) and Fig.7 revealed that there was significant increase in the number of leaves per hill, owing to increased nutrition at all growth stages. The maximum leaf number was obtained with the treatment supplying maximum nitrogen, viz. 80:40:40 kg/ha NPK. Sumbali and Gupta (1972) while studying the response of paddy to nitrogen observed that the number of leaves increased with increasing levels of nitrogen. This is in conformity with the above finding. Besides, the trend noticed in this trial confirms to the accepted behaviour of nitrogen in increasing the vegetative growth (Tisdale and Nelson, 1956).

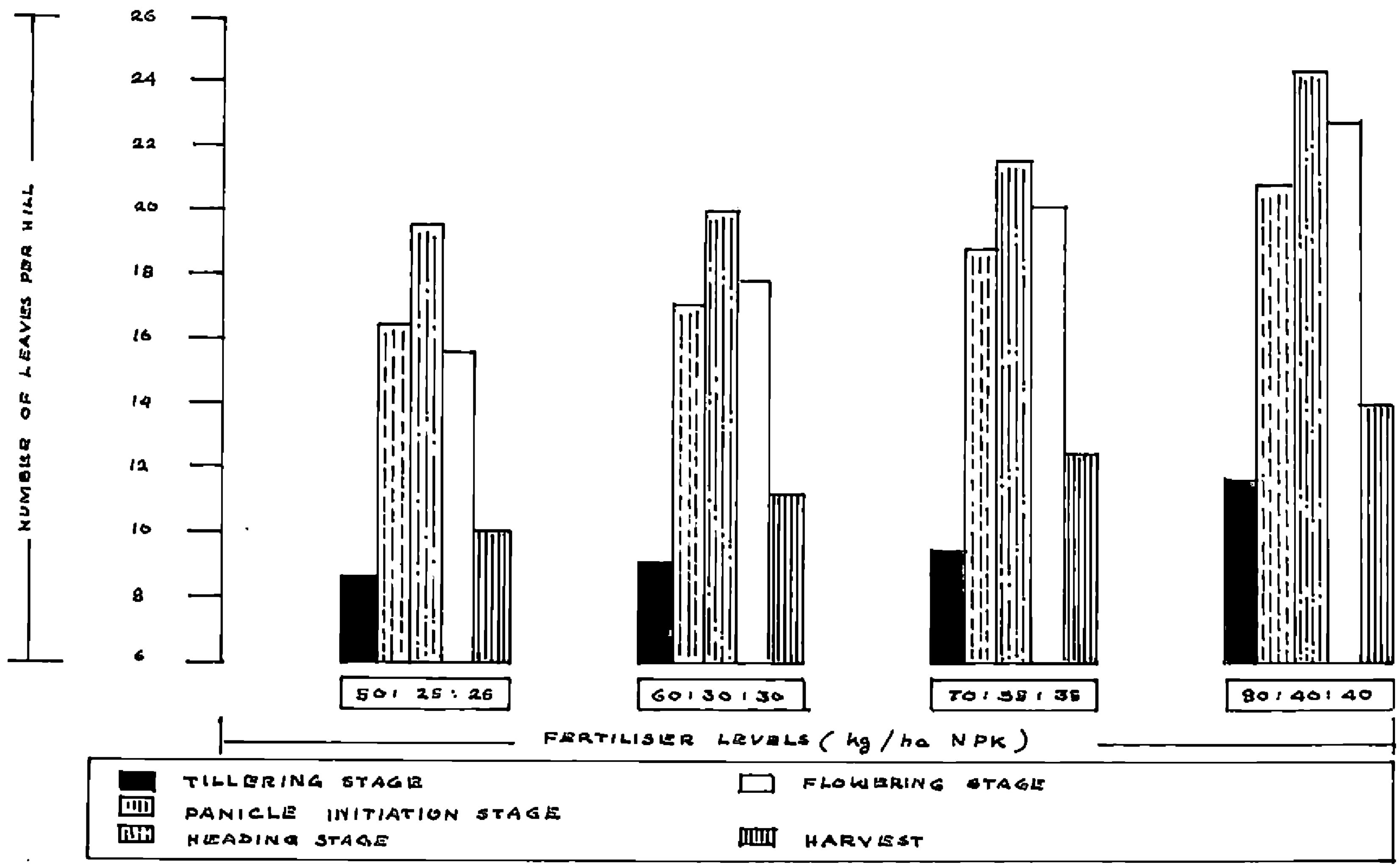

FIG: 7 NUMBER OF LEAVES PER HILL AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

The results (Tables 4 (a) to 4 (e) and Fig.8) pertaining to the influence of spacing upon the number of the leaves per hill revealed that the leaf number showed an increasing trend with wider spacings. The spacing of 20 cm x 10 cm was found to record the highest leaf number. Here again, the fact that increased production of photosynthates results in profuse vegetative growth assumes importance. Photosynthate manufacture may have been profoundly increased by increased sunlight which was obtained in abundant quantities with wider spacings due to lesser mutual shading.

The treatment combinations between fertiliser levels and spacings also showed significant differences, with l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) giving the highest leaf number at all stages. From this it can be concluded that the spacing of 20 cm x 10 cm with the highest fertiliser level of 80:40:40 kg/ha NPK is the best for the production of more number of leaves per hill.

4. Leaf Area Index

It may be noted from Tables 5(a) to 5(d) and Fig.9 that progressive increases in leaf area index were brought

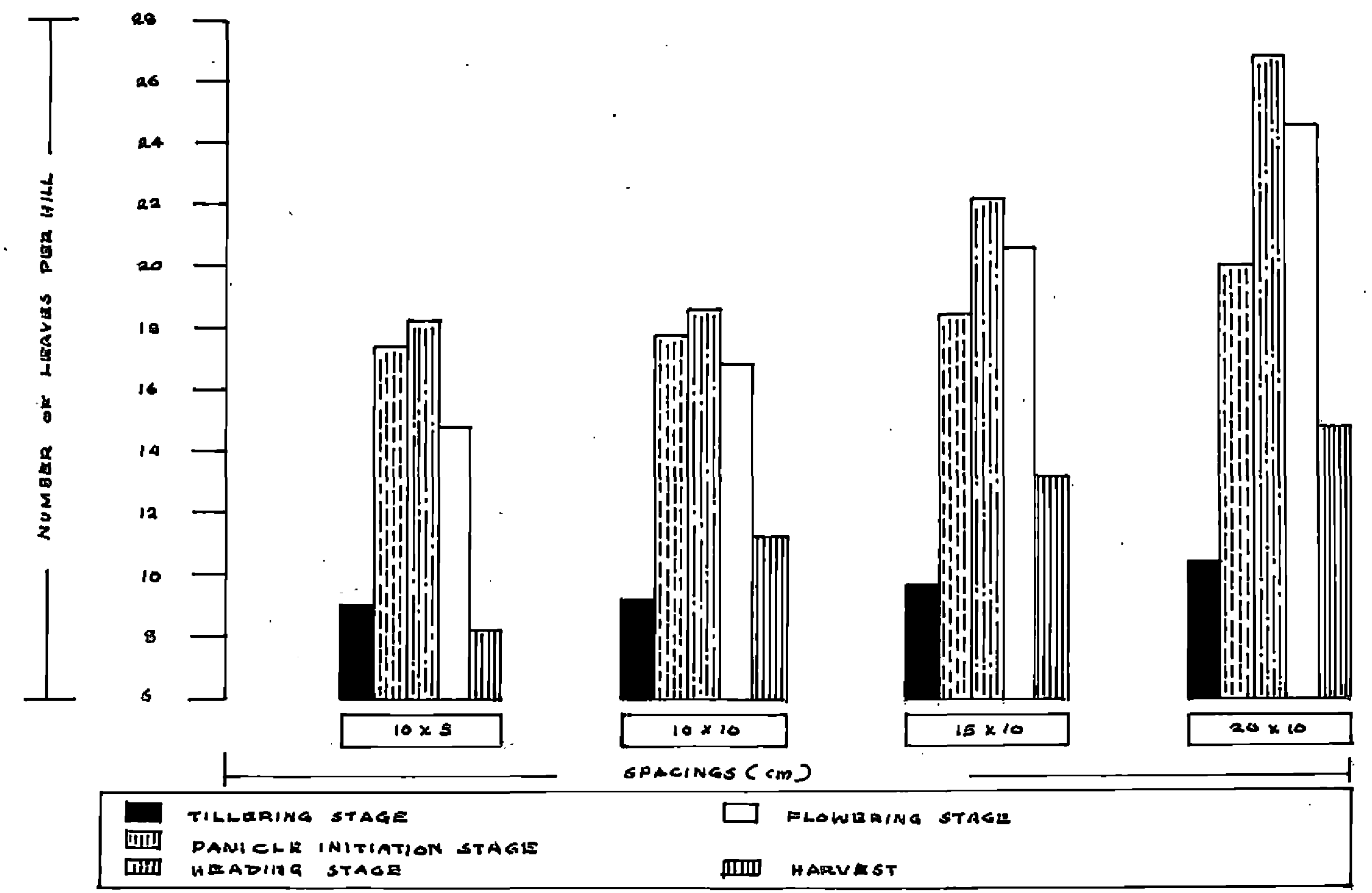

FIG: 8 NUMBER OF LEAVES PER HILL AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT SPACINGS about by increasing fertiliser levels. The fertiliser level of 80:40:40 kg/ha NPK gave the highest value at all growth stages. Further, it was noticed that the leaf area index was maximum at heading and minimum at tillering. After heading, there was a general decline in leaf area index. Leaf area index being a function of the number of tillers and the size of the leaf, an increase in any or both of these produces a corresponding increase in the leaf area index. The highest fertiliser level of 80:40:40 kg/ha NPK has been shown to record the highest number of tillers and maximum height of plants. Increased height of plants is a resultant of increased length of leaves. Hence, it follows naturally that the same treatment produces the highest leaf area index. This observation is in conformity with the report (Anon, 1979), that increase in leaf area index is caused by increase in number of tillers and size of leaves and the leaf area index reaches its highest value a little before heading.

The results (Tables 5(a) to 5(d) and Fig.10 indicated that spacing, 10 cm x 5 cm was superior to the wider spacings in giving higher values for leaf area index. This was found to be, in spite of the fact that closer spacings produced lower number of tillers and shorter

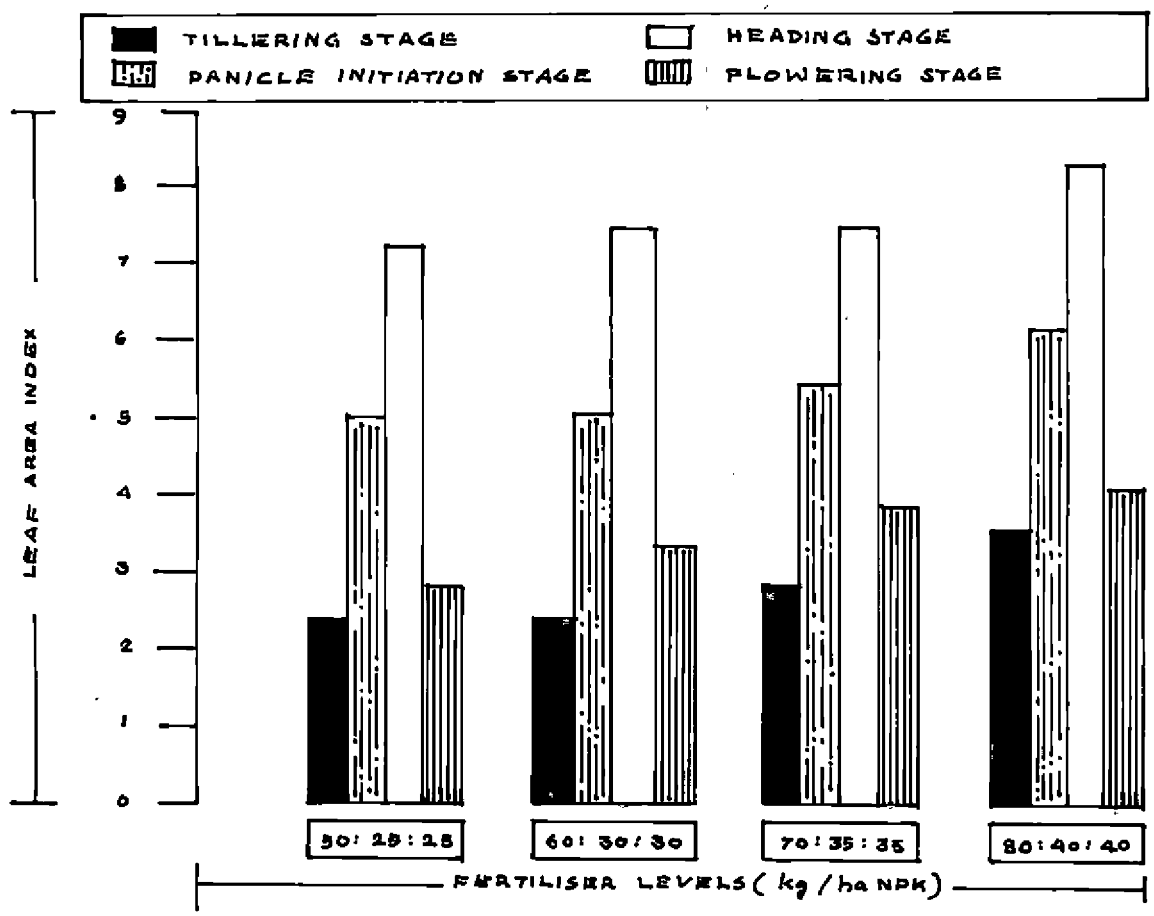

FIG: 9 LEAF AREA INDEX AT TILLERING, PANICLE INITIATION, HEADING AND FLOWERING AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

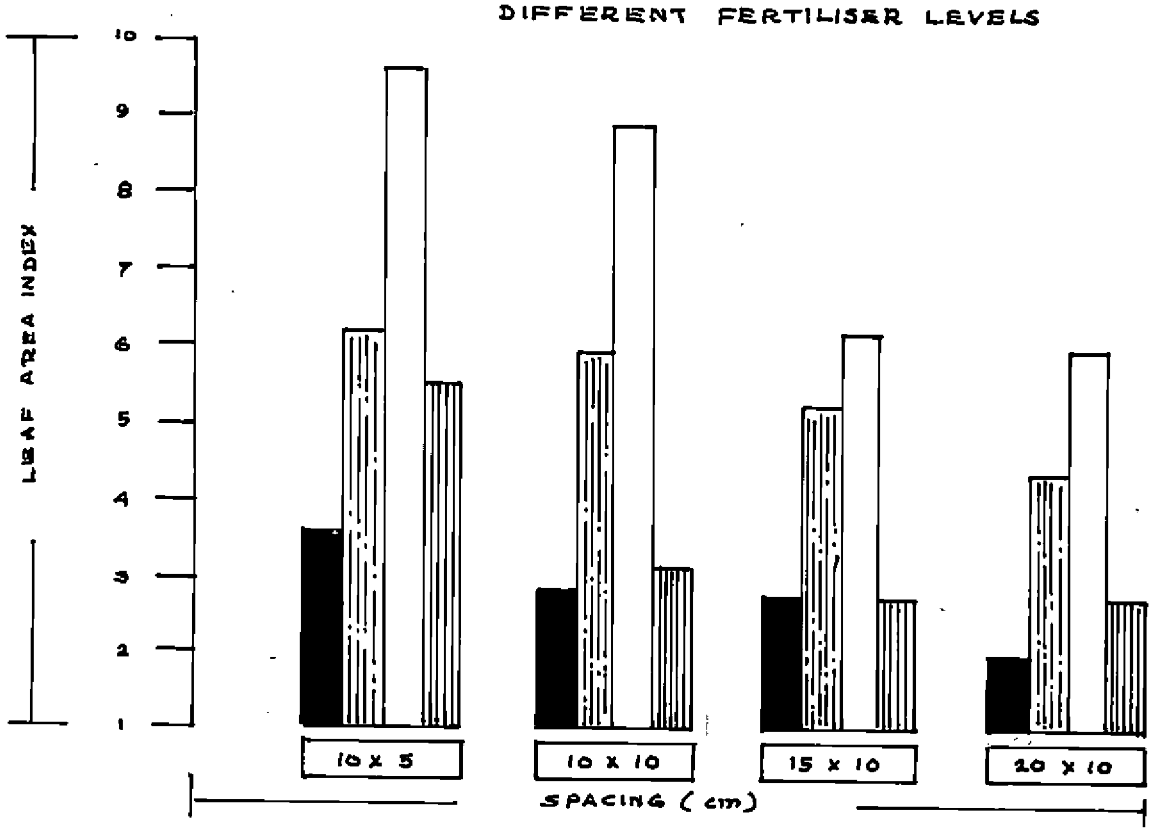

FIG: 10 LEAF AREA INDEX AT TILLERING, PANICLE INITIATION, HEADING AND FLOWERING AS INFLUENCED BY DIFFERENT SPACINGS plants at all stages of crop growth. An explanation could be that leaf area index being the leaf area per unit land area, reduction in land area resulting from closer spacings gave rise to a higher index for leaf area. In trials conducted by Chang (1968) on japonica rice cv Chianung-242 and Tainan-3, it was found that leaf area index in both cultivars increased with reduction in spacing. The results obtained in this study is further supported by the research findings of Golingai and Mabbayad (1969) and Fagade and Datta (1971).

Considering the treatment combinations l_4s_1 (80:40: 40 kg/ha NPK with 10 cm x 5 cm spacing) gave the highest values at all stages of growth. It is evident that the highest fertiliser level and closest spacing, the two of which individually produced the highest leaf area indices, combined to give significantly superior results over all other treatment combinations.

5. Dry Matter Production

According to the results presented in Table 6(a) to 6(e) and Fig.11, substantial increases in dry matter production were wrought by the increasing fertiliser levels at all stages of growth. Increased supply of nitrogen in conjunction with phosphorus and potassium seems to have resulted in improving the overall growth of the rice plants and hence, in more dry matter production. Nitrogenous compounds contribute significantly to the total dry weight of plants. According to Black(1968), about ten per cent of the total plant weight is constituted by nitrogenous compounds in a plant containing 1.60 per cent nitrogen. Thus it is obvious that a higher nitrogen supply tends to increase the plant weight. Furthermore, increasing nitrogen application causing an increase in vegetative growth, produces taller plants with more tillers. These combine to give higher plant weights. Along with the overall growth, the increase in the uptake of nutrients also might have contributed to the total dry matter production. This result is in accordance with the findings of Ramanujam and Rao (1971), Murty and Murty (1978) and Singh and Modgal (1979). Influence of phosphorus and potassium on dry matter production may be due to the increased root production and general plant growth resulting from an increased supply of these nutrients. Increased root production facilitates increased uptake of all nutrients. Terman <u>et al</u>.(1970) found a marked

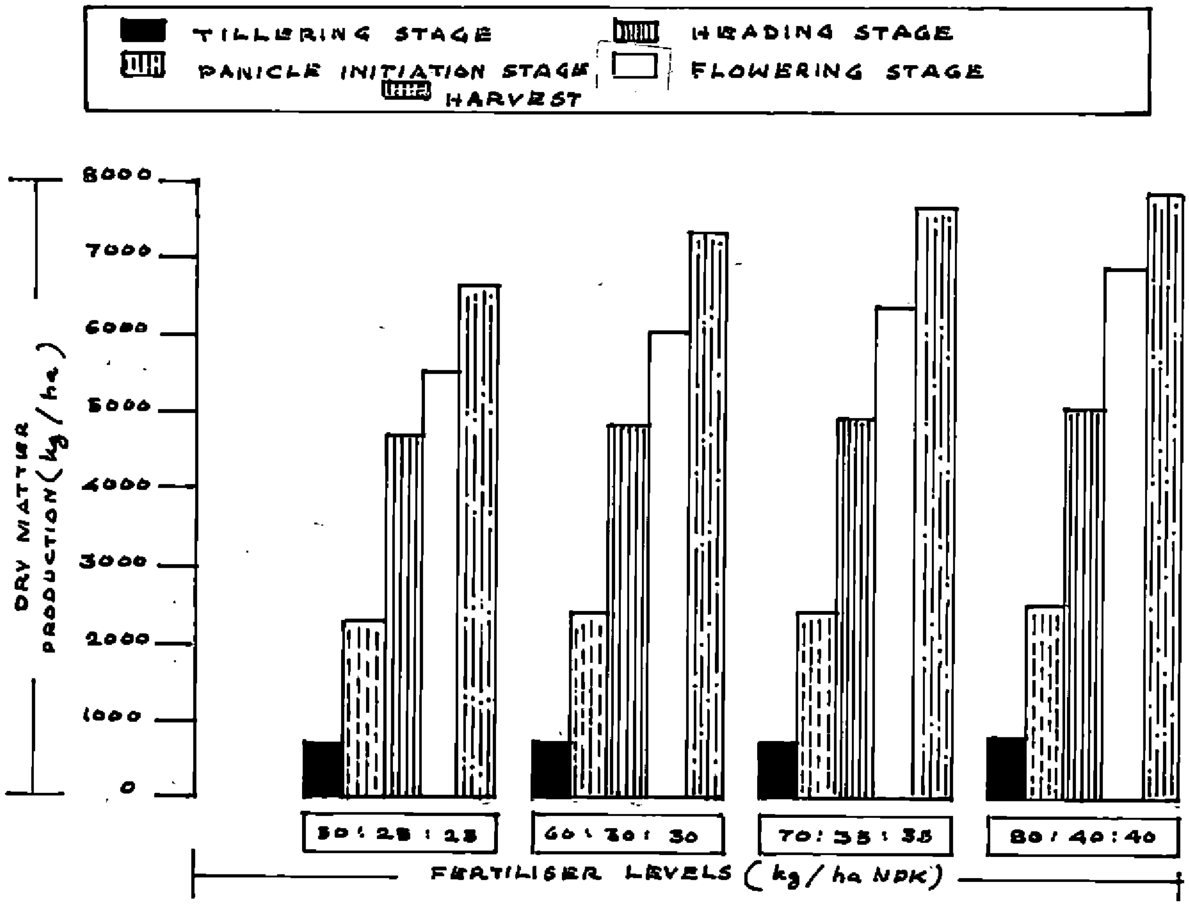

FIG: 11 DRY MATTER PRODUCTION AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

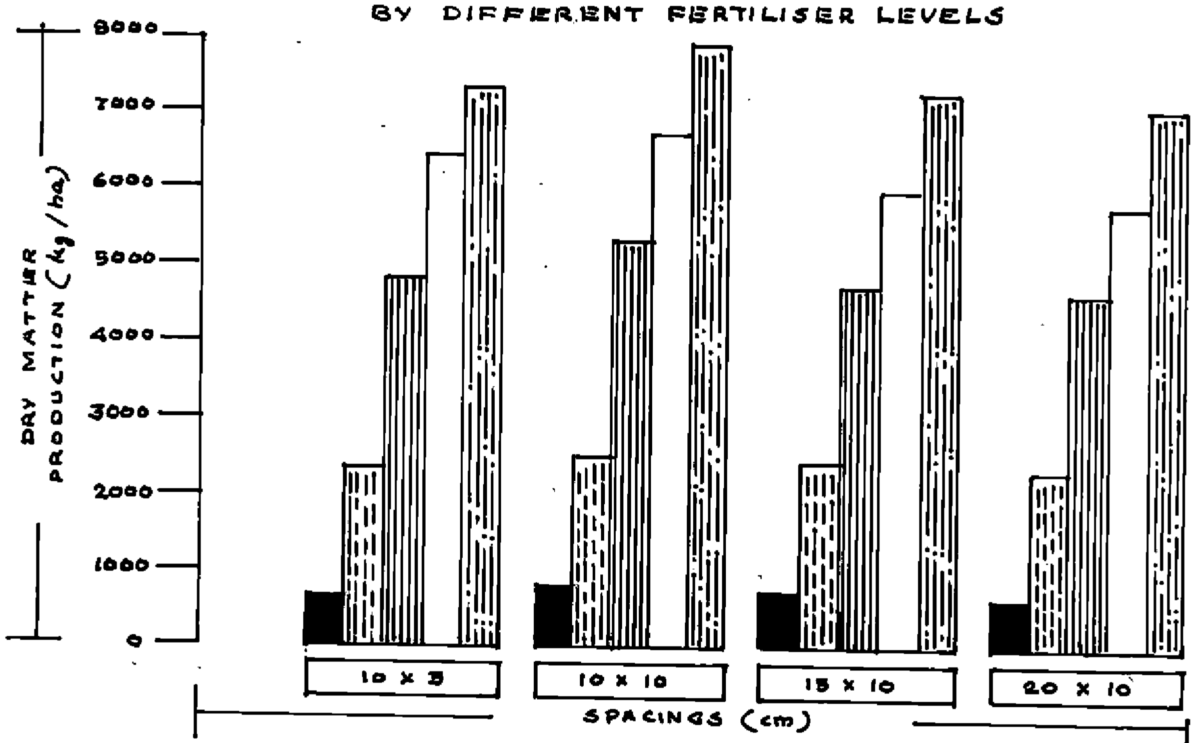

FIG: 12 DRY MATTER PRODUCTION AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT SPACINGS increase in dry matter production with increased amount of applied phosphorus.

The results presented in the Tables 6(a) to 6(e) and Fig.12 showed that closer spacings gave higher dry matter in spite of the fact that they were significantly inferior to the wider spacings in influencing plant height and tiller number. This might have resulted from an increased number of plants per unit area in the closer spacings. Highest dry matter production was obtained with 10 cm x 10 cm spacing, which was found to be ranking over 10 cm x 5 cm spacing. The higher number of plants per unit area in the latter case was compensated in the former by a significant increase in plant height, tiller number and overall growth, all of which resulted in a higher dry matter production 10 cm x 10 cm spacing. Moreover, the absorption of nutrients by plants was also higher in the case of the 10 cm x 10 cm spacing, than in 10 cm x 5 cm spacing, as in indicated by Tables 19,20 and 21. This may also have exerted an influence here.

The results further indicated that treatment l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) gave the highest dry weight. The cumulative and complimentary effects of this treatment on plant height, tiller production and leaf area index, combined with the higher number of plants per unit area, might have added together to this increase in dry matter production.

B. Yield and Yield Components

1. Productive Tiller Count

Results presented in Table 7 and Fig.13 revealed that progressive increases in fertiliser levels brought about significant increases in the productive tiller count per hill. Fertiliser level, 80:40:40 kg/ha NPK proved itself superior to the lower levels in this respect. Nitrogen nutritionhas a profound influence upon increasing the number of productive tillers per hill. In a trial conducted by Gupta et al.(1970), it was observed that there was an increase in the number of fertile tillers per plant, upon application of increased nitrogen levels. This finding supports the results obtained in this study. Phosphorus application is also found to promote increased production of ear-bearing tillers. Recent investigations by Bhattacharya and Chatterjee (1978) have revealed that

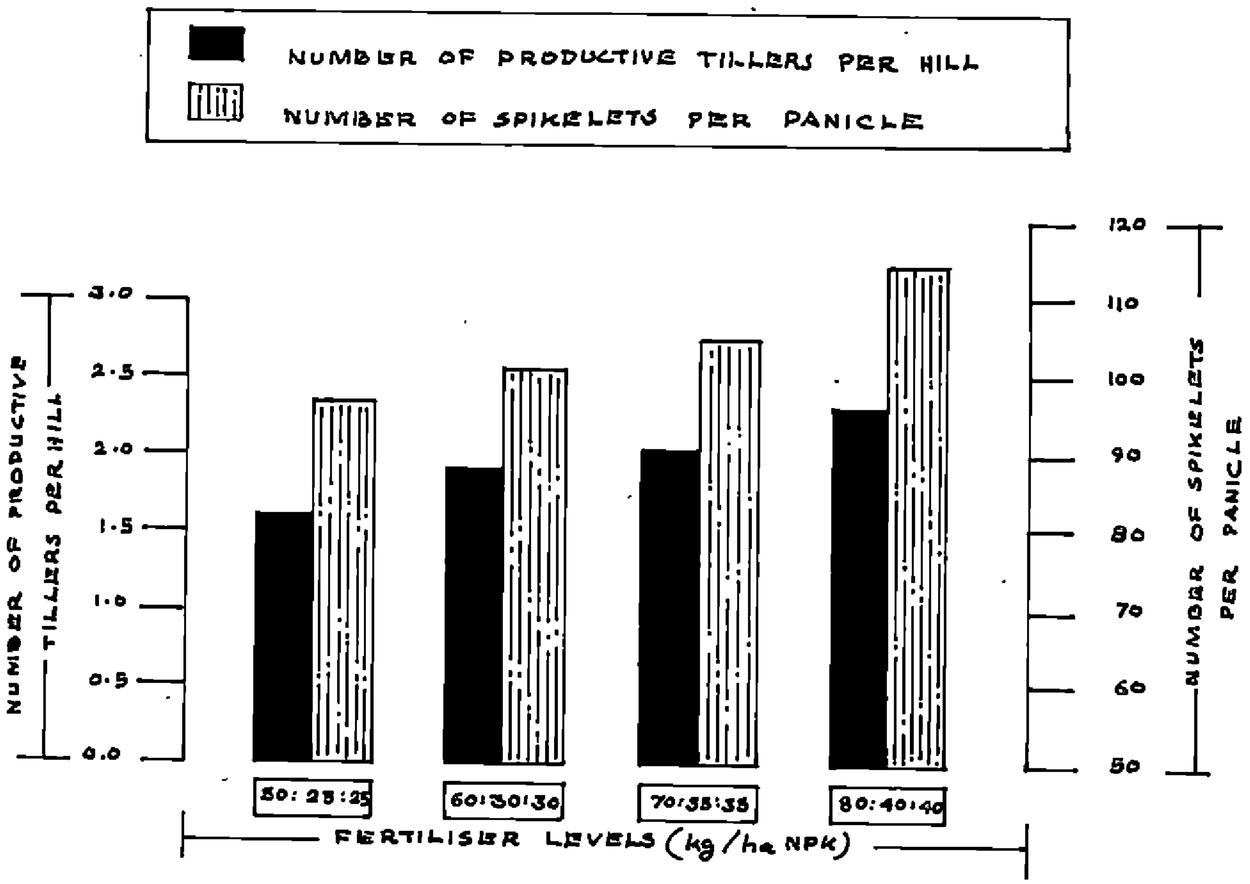

FIG: 13 NUMBER OF PRODUCTIVE TILLERS PER HILL AND NUMBER OF SPIKELETS PER PANICLE AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

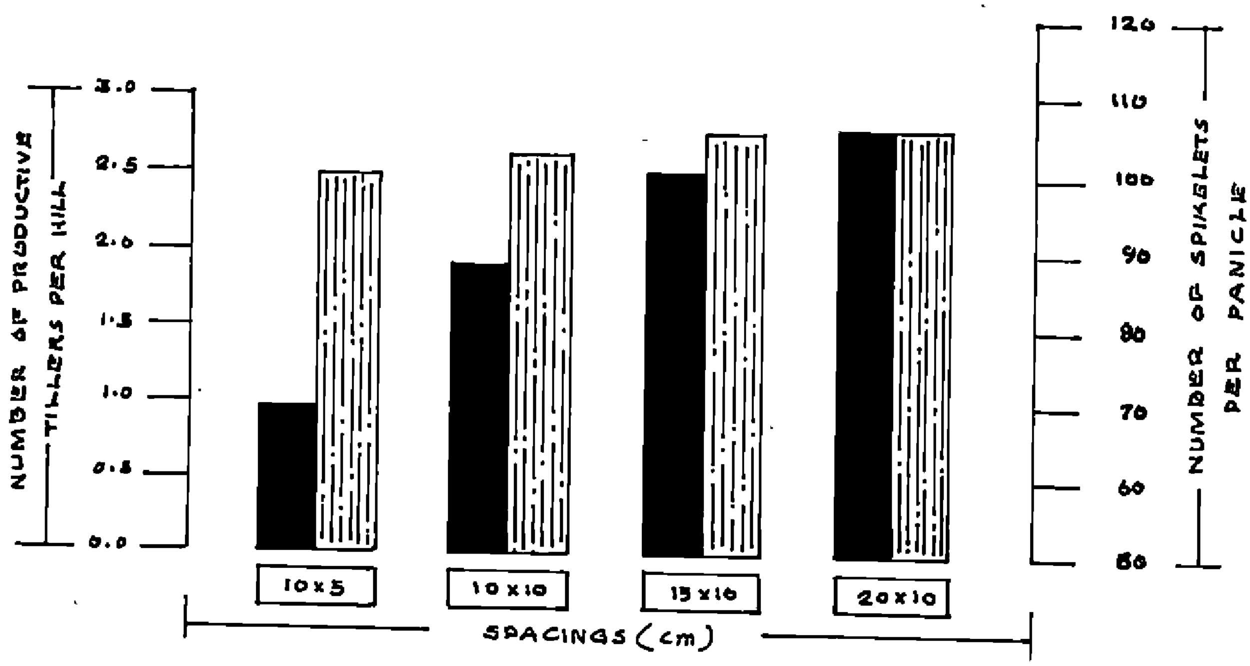

FIG: 14 NUMBER OF PRODUCTIVE TILLERS PER HILL AND NUMBER OF SPIKELETS PER PANICLE AS INFLUENCED BY DIFFERENT SPACINGS phosphorus manuring increased early tiller formation, a greater part of which ultimately provided panicles. Potassium, the increase of which along with the other two nutrients gave the above results, is another nutrient exerting a beneficial effect upon productive tiller production. The role of potassium in increasing number of productive tillers and consequently panicle production has been stressed by Padmaja (1976).

The results presented in Tables 7 and Fig.14 revealed an increase in the productive tiller count per hill with increased spacing. Chang (1968) reported that the number of productive tillers per hill decreased with reduced spacing. However, when the panicle number is considered on a unit area basis, closer spacings provided more number of productive tillers than wider ones. According to Chatterjee and Maiti (1981), in wider spacing formation of more tillers per plant is encouraged but with narrower spacing, formation of more ear-bearing tillers per unit area is encouraged.

With regard to the treatment combinations the highest productive tiller count was recorded by l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing). Considering the individual effects of fertiliser levels and spacings, 80:40:40 kg/ha NPK and spacing 20 cm x 10 cm proved themselves superior in producing higher number of productive tillers per hill. In consequence, a combination of 80:40:40 kg/ha NPK with 20 cm x 10 cm spacing proved to be the best to give more number of productive tillers per hill.

2. Length and Weight of Panicle

As depicted in Tables 8 and 9 and Fig.15, the length and weight of panicles were substantially increased with increasing fertiliser levels and the highest fertiliser level of 80:40:40 kg/ha NPK could be adjudged significantly superior to the lower levels. It is an established fact that early tillers produced heavier panicles than late tillers. Application of higher doses of fertilisers encouraged formation of early tillers. The role of nitrogen in increasing size of grain is well known. Chang and Su (1977) and Subbiah *et al.* (1975) reported that length and weight of panicles increased with increasing rates of nitrogen. As for phosphorus, recent investigations by Bhattacharya and Chatterjee (1978) have revealed that phosphorus manuring increased early tiller formation, a

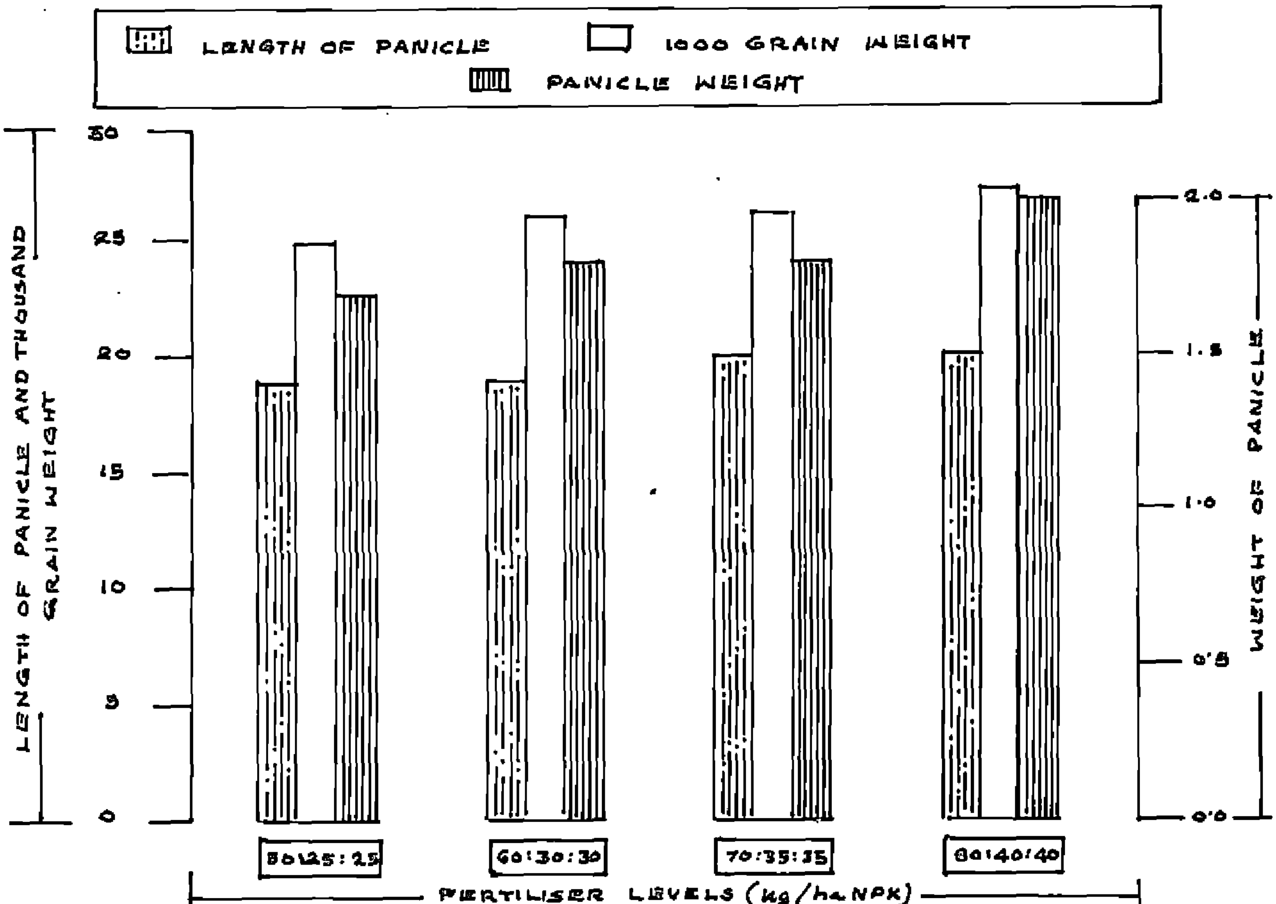

FIG:15 LENGTH OF PANICLE (cm), 1000 GRAIN WEIGHT (g) AND PANICLE WEIGHT (g) AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

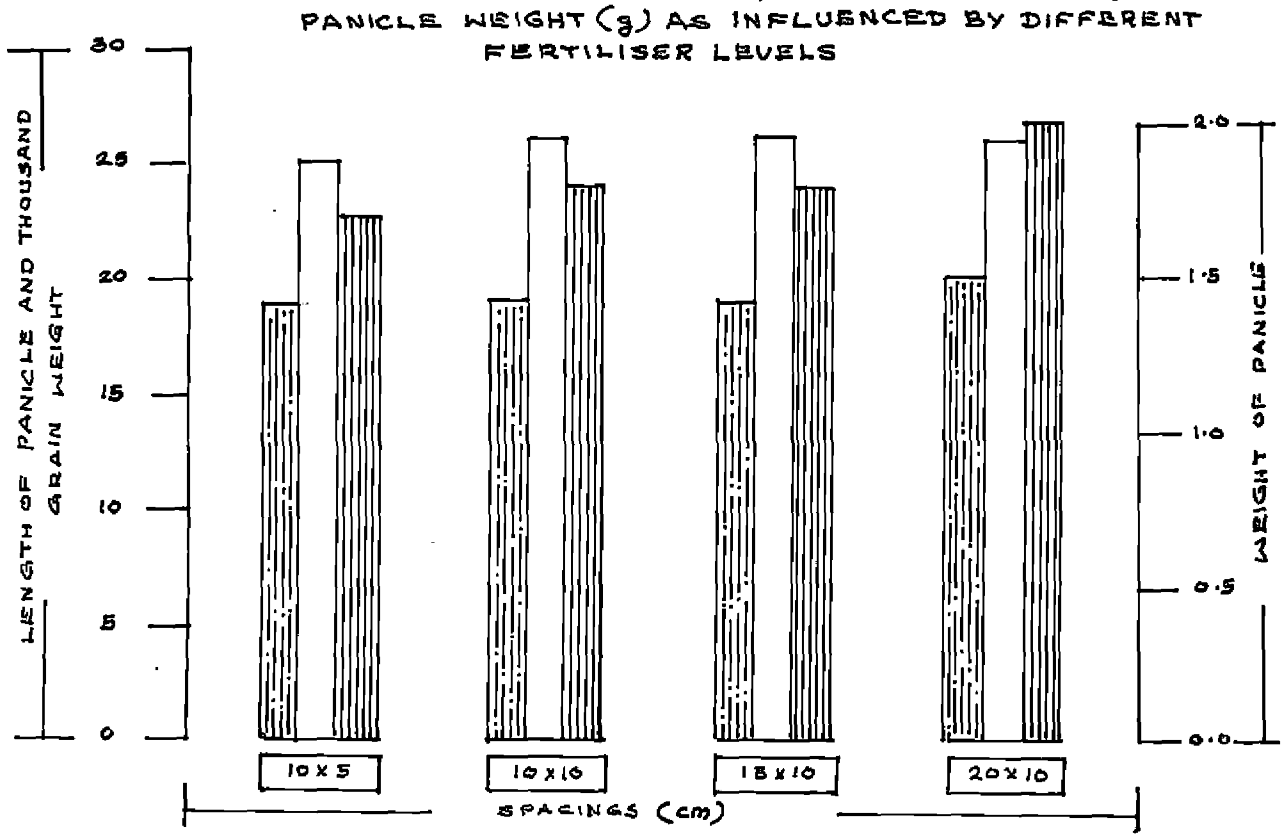

FIG:16 LENGTH OF PANICLE (cm) THOUSAND GRAIN WEIGHT (g) AND PANICLE WEIGHT (g) AS INFLUENCED BY DIFFERENT SPACINGS greater part of which ultimately provided more grains of heavier weights. With regard to potassium, summarising the results of trials with rice cv Jaya, Singh and Singh (1979) concluded that increased application of potassium increased panicle length.

The results presented in Tables 9 and 10 and Fig.16 revealed an increasing trend in the length and weight of panicle with increased spacings. This is in concordance with the findings of Chang (1968) and Chang and Su (1977) who reported that length and weight of panicle increased with increasing spacings.

With regard to combination effects of fertiliser levels and spacings, the argument that a combination of the fertiliser levels and the spacing producing the longest and heaviest panicles proved to the best owing to a cumulative effect of the two, again holds good.

3. Number of Spikelets and Number of Filled Grains per Panicle

It is indicated by the results furnished in Tables 10 and 11 and Fig.13 that the number of spikelets as well as filled grains per panicle increased with increased nutrient supply, the fertiliser level of 80:40:40 kg/ha NPK recording the highest value and ranking over the lower levels. Among the nutrients, nitrogen had a major effect in increasing the number of grains per panicle. Gupta et al. (1970) reported that increasing the rates of applied nitrogen increased the number of spikelets and filled grains per ear. Phosphorus is another nutrient which is purported to have a beneficial influence over the number of grains per panicle (Aaron et al. 1971). Ghose et al. (1960) propounded that increased absorption of nutrients, especially nitrogen at panicle initiation stage, favoured increased production of grains per panicle. The present investigation also denoted that there was an increased uptake of all three nutrients at different stages of growth due to increased application of these nutrients, which might have, as a consequence increased the grain number per panicle.

Data in Tables 10 and 11 and Fig.14 indicated that the influence of spacing was pronounced only in the case of the number of spikelets per panicle, and the trend observed was an increase in spikelet and grain number per panicle with wider spacings. Trials conducted by Chang(1968) revealed that grain number per panicle decreased with reduction in spacing.

Considering treatment combinations, the results indicated that treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10cm spacing) proved to be significantly superior to all others. This is a combination of the best fertiliser level and the best spacing and therefore, here again the cumulative effect of the two could be the reason.

4. Sterility percentage

The results presented in Table 12 indicated that fertiliser levels, spacings and their combinations did not substantially influence the percentage sterility. However, the trend noticed was an increase in percentage sterility as nutrition increased. In this context it may be recalled that the total number of spikelets as well as filled grains per panicle increased as the nutrient level increased. But the increase in the total spikelet number in the treatment receiving the highest fertiliser level, was not followed by a corresponding increase in the number of filled grains. This resulted in an increased count of unfilled grains and consequently, a higher sterility percentage in this treatment. At the same time, increasing the level of nitrogen might have increased the unfilled grains, thereby resulting in a higher sterility percentage in treatments receiving higher nitrogen levels. Similar results of increased sterility percentage with higher levels of nitrogen have been reported by Muthuswamy et al. (1972).

5. Thousand Grain Weight

The results presented in Table 13 and Fig.15 and 16 portrayed the fact that there was considerable increase in the thousand grain weight resulting from increased fertiliser levels. The highest fertiliser level of 80:40:40 kg/ha NPK gave a significantly superior value over the lowest level of 50:25:25 kg/ha NPK. Nitrogen is known to influence the size of grain benefically. Hence, it is natural that increased application of nitrogen causes the weight of thousand grains to increase through an increase in the weight of individual grains. Positive increases in thousand grain weight due to nitrogen application were also reported by Panda and Leeuwrik (1972) and Sadayappan et al.(1974). Increased uptake of the nutrient with increased supply, especially at flowering and maturity stages, may have paved the way for higher translocation into the grains, thus increasing grain weight. This fact is supported by the results of Kiuchi and Ishizaka (1960). Phosphorus manuring alone is capable of increasing weight of grains as is evident from the reports of Bhattacharya and Chatterjee (1978). With regard to potassium, it is found to induce plump development of grains through its role in helping in the formation and translocation of starches, sugar and oils. Supporting the result obtained in this study is the finding of Singh and Singh (1979), wherein increases in thousand grain weight were obtained with increased application of potash. To add to these effects, phosphorus and potassium are found to induce better root development, thereby increasing nutrient absorption. Absorption of nutrients assumes tremendous importance during the stages of flowering and maturity owing to the influence on grain development. In this study higher doses of phosphorus and potassium might have resulted in a higher absorption of all three nutrients causing the formation of heavier grains.

The various spacings and treatment combinations were not found to exert any significant influence on this aspect.

6. Grain Yield

The data presented in Table 14 and Fig.17 showed that the fertilisers at higher levels produced distinguishable increases in the total yield of grain. It is discernible from the results that 80:40:40 kg/ha NPK resulted in the highest grain yield, whereas 50:25:25 kg/ha NPK supplied the minimum amount of grain. A reference to the previous data on plant height, tiller count, leaf area index, productive tiller count, panicle number per square metre, length and weight of panicle and thousand grain weight indicate that all these aspects showed improvement with higher nutrition. The effects of all these compounded to give the highest grain yield with the highest fertiliser level. The beneficial effect of NPK fertilisation in increasing the grain yield of rice is well established. Nitrogen has a definite role in photosynthesis which is directly related to starch synthesis and yield. The favourable influence of nitrogen upon grain yield is stressed by several workers like Rethinam et al.(1975), Sahu and Murty (1975) and Pillai et al.(1975). The role of phosphorus in increasing grain yield has been defined in the works of Padmakumari et al. (1969), Dev et al.(1970) and Khatua and Sahu (1970). Potassium has probably increased the grain yield through its role in the manufacture and translocation of starch (Russel, 1973).

The results (Table 14 and Fig.18) further indicated that the highest grain yield was obtained with 10 cm x 10 cm spacing followed by 10 cm x 5 cm spacing, the two of which were significantly superior to the wider spacings. The widest spacing of 20 cm x 10 cm recorded the least yield. Increasing the spacing was found to cause a decline in yield. This is because of the fact that as the planting intervals grow wider, the number of plants per unit area decreases. Consequently, the yield per unit area declines. The highest number of productive tillers, panicle length and weight, number of spikelets and filled grains per panicle obtained with the wider spacings are all easily compensated in the narrower spacings by the higher number of plants and consequently higher number of panicles per unit area. However, spacing 10 cm x 5 cm proved to be inferior to spacing 10 cm x 10 cm. This may be due to the fact that extremely close spacing produces lesser number of tillers and shorter and lighter panicles. Spacing 10 cm x 10 cm has the infinite advantage of a higher value for these as well as an increased number of panicles per unit area. Besides, between-plant competition for all growth factors is considerably lesser in 10 cm x 10 cm spacing. All these facts compounded to prove this spacing superior to the other three. Research reports of Husain (1967), Chang (1968), Hukkeri et al. (1968) and Mandal and Mahapatra (1968) support the fact that yield increased with narrower spacings.

With regard to treatment combinations l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) was found to give the maximum yield. Fertiliser level 80:40:40 kg/ha NPK had proved itself superior to the lower levels and spacing 10 cm x 10 cm has been shown to give the highest yield. Therefore, a combination of the two would produce a cumulative and complimentary effect, thus showing itself superior to the other treatments.

7. Straw Yield

The result presented in Table 15 and Fig.17 indicated that as the fertiliser levels increased, the straw yields also increased. The highest fertiliser level of 80:40:40 kg/ha NPK was significantly superior to the lower levels and yielded maximum straw. A perusal of the data on plant height, number of tillers and leaf number clearly reveal that all of these increased as NPK fertilisation increased. Thus a higher contribution of vegetative matter was obtained with higher nutrient levels. Nitrogen alone produces a profuse vegetative growth at higher levels. The beneficial effect of nitrogen on increasing straw yields has been shown through various trials of several research workers like Ramanujam and Rao (1971), Muthuswamy et al. (1972) and Panda and Leeuwrik (1972).

Considering spacing, the highest straw yield on a unit area basis, was obtained in the case of 10 cm x 10 cm spacing (Table 15 and Fig.18). The wider spacings proved significantly inferior to the narrow spacings in this respect. This is obviously due to an increased number of plants per unit area which gives an infinite advantage for the closer spacings over the wider ones. The result obtained in this study is supported by the works of Kumar et al.(1975). However, among the two closer spacings, 10 cm x 10 cm spacing was better than 10 cm x 5 cm spacing. A reference to the data on plant height and tiller number reveals that both values were significantly higher for 10 cm x 10 cm spacings over 10 cm x 5 cm spacing. This combined with the lesser competition between plants, gave

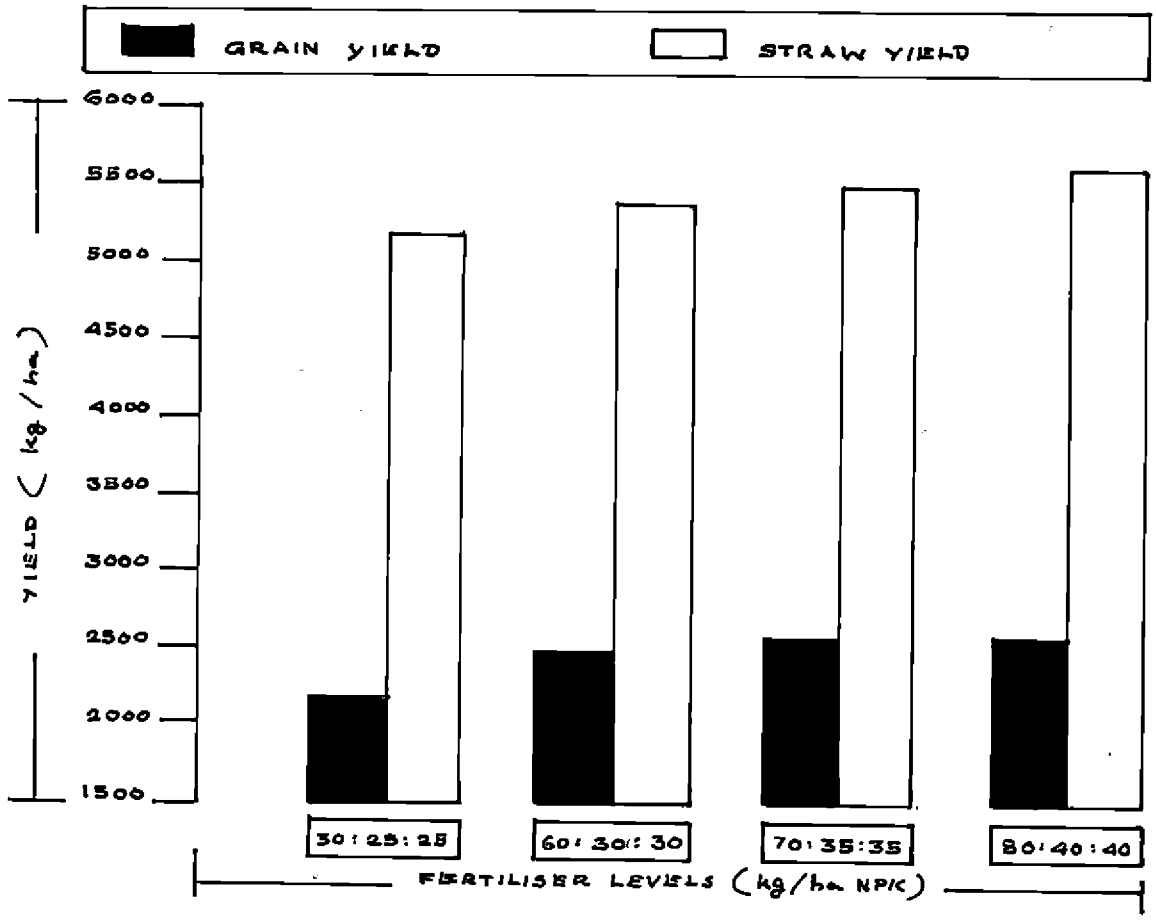

FIG: 17 GRAIN YIELD AND STRAW YIELD AS INFLUENCED BY DIFFERENT FERTILISER LEVELS

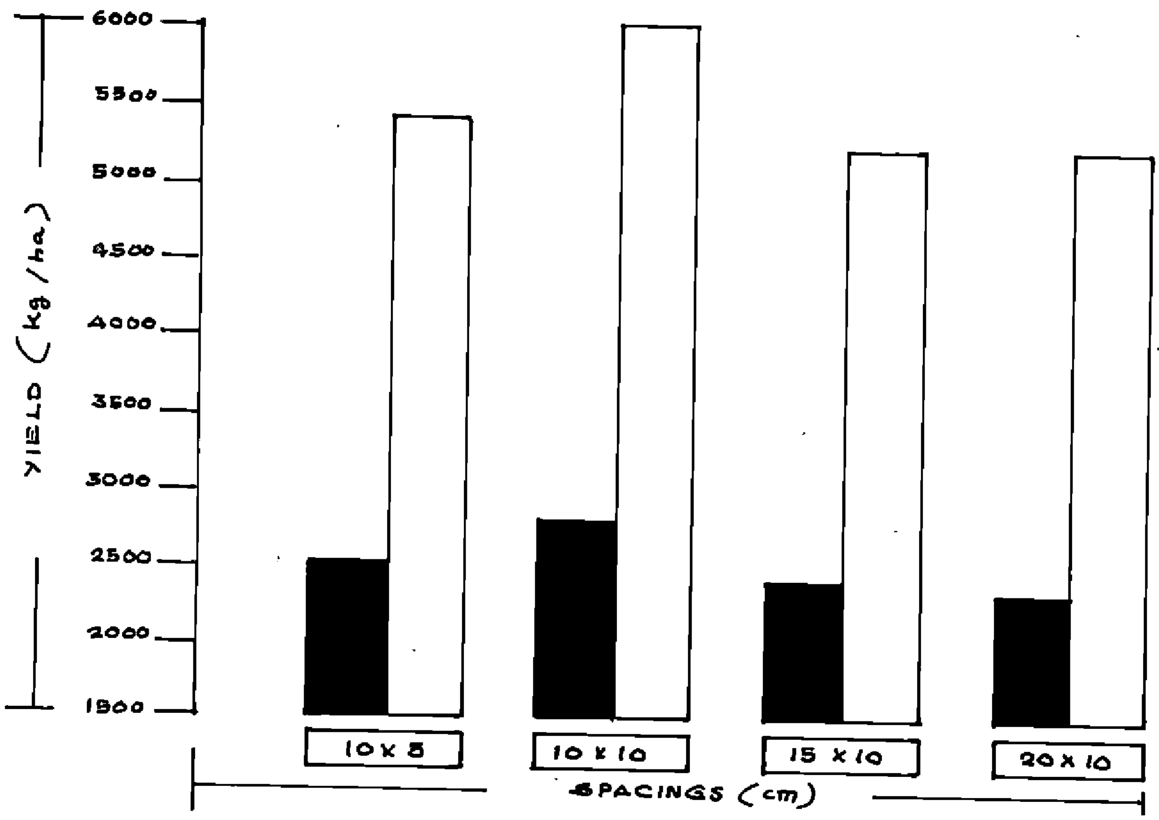

FIG: 18 GRAIN YIELD AND STRAW YIELD AS INFLUENCED BY DIFFERENT SPACINGS the spacing of 10 cm x 10 cm an advantage of 10 cm x 5 cm spacing, even though the latter had a higher number of plants per square metre.

The treatment combination of 80:40:40 kg/ha NPK and 10 cm x 10 cm spacing was found to be significantly superior to the other treatments owing to the cumulative influence of fertiliser level 80:40:40 kg/ha NPK and spacing 10cm x 10 cm each of which individually provided the best yield.

8. Grain: Straw Ratio

As per the results presented in Table 16, the grain: straw ratio was not significantly influenced by the various fertiliser levels. However, the lowest fertilisers level of 50:25:25 kg/ha NPK recorded a significantly lower value than the three higher levels. This could be due to the fact that increasing the levels of phosphorus and potassium along with nitrogen had a beneficial effect in the production of grain rather than in straw. The combined effect of the fertilisers was more pronounced in the yield of grain than in straw. Hence treatments receiving higher levels of all three nutrients recorded a higher value for grain:straw ratio than the treatment receiving the lowest fertiliser level, viz. 50:25:25 kg/ha NPK.

There was significant difference between the various spacing in this respect. The spacing of 20 cm x 10 cm recorded the lowest grain:straw ratio. This may be due to the fact that the reduction in grain yield resulting from wider spacing was not upto the extent as the reduction in straw yield owing to wider spacing. The other three spacings were on par statistically.

The treatment combinations were also found to exert significant influence on this aspect. The combined effects of the fertiliser level 80:40:40 kg/ha NPK and spacing 15 cm x 10 cm, each of which individually produced the best value, proved to be superior to all other treatments. This might have been due to some complimentary effect.

9. Harvest Index

The results presented in Table 17 revealed that the influence of fertiliser levels over harvest index was not very pronounced. Even so, an increasing trend in harvest index was noticed with higher nutrient levels. Even though, nitrogen by itself tends to decrease harvest index, a combination of nitrogen with phosphorus and potassium brings about more evident increases in grain than in straw.

This could be interpreted to give the result obtained here.

The various spacings also showed a pronounced influence on harvest index. Highest value was obtained with 10 cm x 10 cm spacing which had the combined advantage of taller plants and more tillers with higher number of plants per unit area in producing more straw than grain.

The various treatment combinations also varied significantly from each other in this respect.

C. Quality Factor

1. Protein Content of Grain

Chemical analysis of the grain (Table 18) revealed that the grain protein content increased with increasing fertiliser levels, mainly nitrogen, and that the highest grain protein was recorded by the treatment receiving the highest nitrogen level of 80 kg/ha N. Nitrogen is the most important constituent of protein. Even though the kind of protein formed is largely influenced by genetic factors, the amount of protein is governed by environmental factors, especially the supply of nitrogen (Tisdale and Nelson, 1956). Similar increase in protein content of grain with increasing nitrogen supply has been reported by Kulkarni (1973) and Abraham et al. (1974).

The grain protein content was also found to increase with increase in spacing though the increase was not highly pronounced. However, the widest spacing of 20 cm x 10 cm proved itself significantly superior to the closer spacings in this respect. Fertiliser supply especially that of nitrogen, remaining constant, the absorption of nitrogen and other nutrients per plant will always be more in wider spacings. In closer spacings the plant population being higher, competition for nutrients will also be higher. Hence, the spacing facilitating the maximum absorption of nitrogen would naturally record the highest value for grain protein content.

The various treatment combinations failed to have any significant influence on the grain protein content. Even so l_4s_4 the treatment receiving the combined advantages of the best fertiliser level and the best spacing (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the highest value for grain protein.

D. Chemical Composition and Uptake Studies

1. Nitrogen Content and Uptake

The results presented in Tables 19(a) to 19(f) and Fig.19 revealed that content of nitrogen in plants increased with increased supply of nutrient at all stages of growth. The effect was not highly pronounced but the highest level of nutrient supply (80:40:40 kg/ha NPK) was always found to be significantly higher than the lowest level of 50:25:25 kg/ha NPK, where the nitrogen level was considerably lower. Increasing the supply of nitrogen to the crop facilitates the crop roots to absorb more nitrogen, which is translocated to the shoot portion. Thus the content in the shoot records higher value in this case than the treatments receiving lower supply. This is in concordance with the research reports of Ramanujam and Rao (1970) according to which there was obvious increase in the total nitrogen content with increased nitrogen levels. Along with nitrogen, the supply of phosphorus and potassium was also increased which increased the root growth of the plants. This enabled the plants to absorb increased level of the nutrient. The nitrogen content in the grain also showed increases with increasing nitrogen application. This might be due to the higher content of nitrogen recorded at flowering stage as reported by Rai and Murty (1976).

With regard to the nitrogen uptake by plants, there were increases with increasing nitrogen application at all stages of growth, but the increase was more pronounced only at the later stages, as is shown by Tables 22(a) to 22(e). The uptake was at its lowest at tillering stage and thereafter it increased and reached a maximum at flowering. This finding is in corroboration to the results of Patnaik and Nanda (1969) that the uptake of nitrogen by plants was highest upto flowering stage, after which most of the absorbed nitrogen is translocated to the grain. The increasing dry matter production with increased levels of applied nitrogen also helped in moulding this trend of uptake.

From the results, it was clear that increasing spacings influenced the nitrogen content of the plants, though to a lesser extent compared to the fertiliser levels. The highest content in plants at all stages of growth and in grain at harvest was observed in the case of the widest

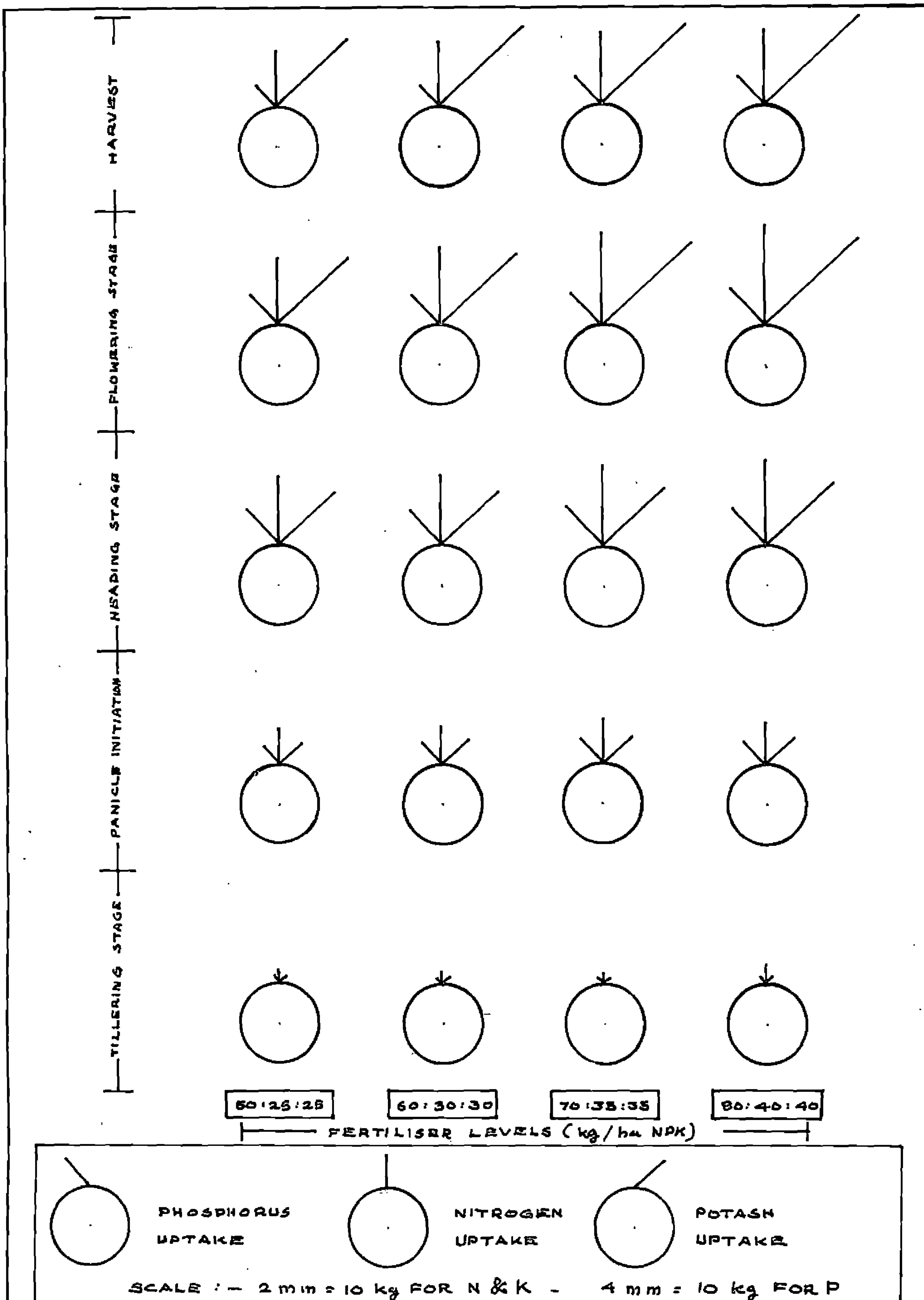

FIG: 19 UPTAKE OF NITROGEN, PHOSPHORUS AND POTASH AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT FERTILISER LEVELS spacing of 20 cm x 10 cm. This is due to the fact that between-plants, competition is least in this case, as density of population is least here. Fertiliser level remaining constant, increasing the spacing results in definite increases in nutrient absorption by individual plants to give a higher percentage content of nutrient in all plant parts inclusive of grain.

The influence of the various spacings and the various treatment combinations upon nitrogen uptake also showed significance. Among the various spacings, 10 cm x 10 cm was found to give the highest uptake at tillering, flowering and harvest while at panicle initiation and heading, it was observed to be on par with the other spacings. This may be due to the increased dry matter production observed in the case of this spacing at all growth stages.

<u>Phosphorus Content and Uptake</u>

The results presented in Tables 20(a) to 20(f) and Fig.19 indicated an increase in phosphorus in the plant parts at all growth stages and in grain at harvest with increased fertiliser levels. This increase was highly significant during tillering and panicle initiation stages. It was observed that the plant content of phosphorus increased upto panicle initiation and there after it declined. This finding is in conformity with the reports of Thaung (1960) that more of the applied phosphorus was absorbed during the first seven to nine weeks of crop growth.

The increase in plant phosphorus contents with increased supply of the nutrient at all growth stages, noticed in this study, is supported by the findings of Oommen et al. (1972) and Suseelan et al. (1978). This could be a direct result of the increased supply of the nutrient which enabled the plants to absorb more of it and accumulate it in the plant parts. Further, it could be explained by the accompanying increase in nitrogen levels which may have an influence on the unit root absorbing surface to absorb P_2O_5 (McLean, 1957). Trials conducted by Sadayappan and Kolandaiswamy (1974) and Raju (1978) reveal that there was an increased phosphorus content in straw with increased nitrogen application.

The phosphorus content in grain also showed a similar trend of increase with increased fertiliser application. This is supported by the report of Pathak et al. (1972) according to which the uptake of phosphorus was more by grain compared to straw and that the highest uptake was obtained with a fertiliser level of 100:50:50 kg/ha of NPK. Agarwal (1978) also reported that grain phosphorus contents were increased with higher application of phosphorus.

The tables 23(a) to 23(e) and Fig.20 showed that uptake of phosphorus increased at all growth stages with increased fertiliser application, with 80:40:40 kg/ha NPK giving the highest values for uptake. This increase could possible be a net result of the increases in dry matter production at the various growth stages. The uptake was found to increase from tillering and reach a maximum at harvest. Trials conducted by Iruthayaraj and Morachan (1980) revealed that uptake of phosphorus was higher with higher levels of nitrogen. Higher levels of phosphorus itself is also found to increase the uptake as is shown by Gupta *et al.* (1975). Trials by Singh *et al.* (1976) revealed that phosphorus uptake and translocation were higher with increase application of potassium. This could be due to the increased root growth and consequently better absorption of the nutrient followed by rapid translocation induced by potassium.

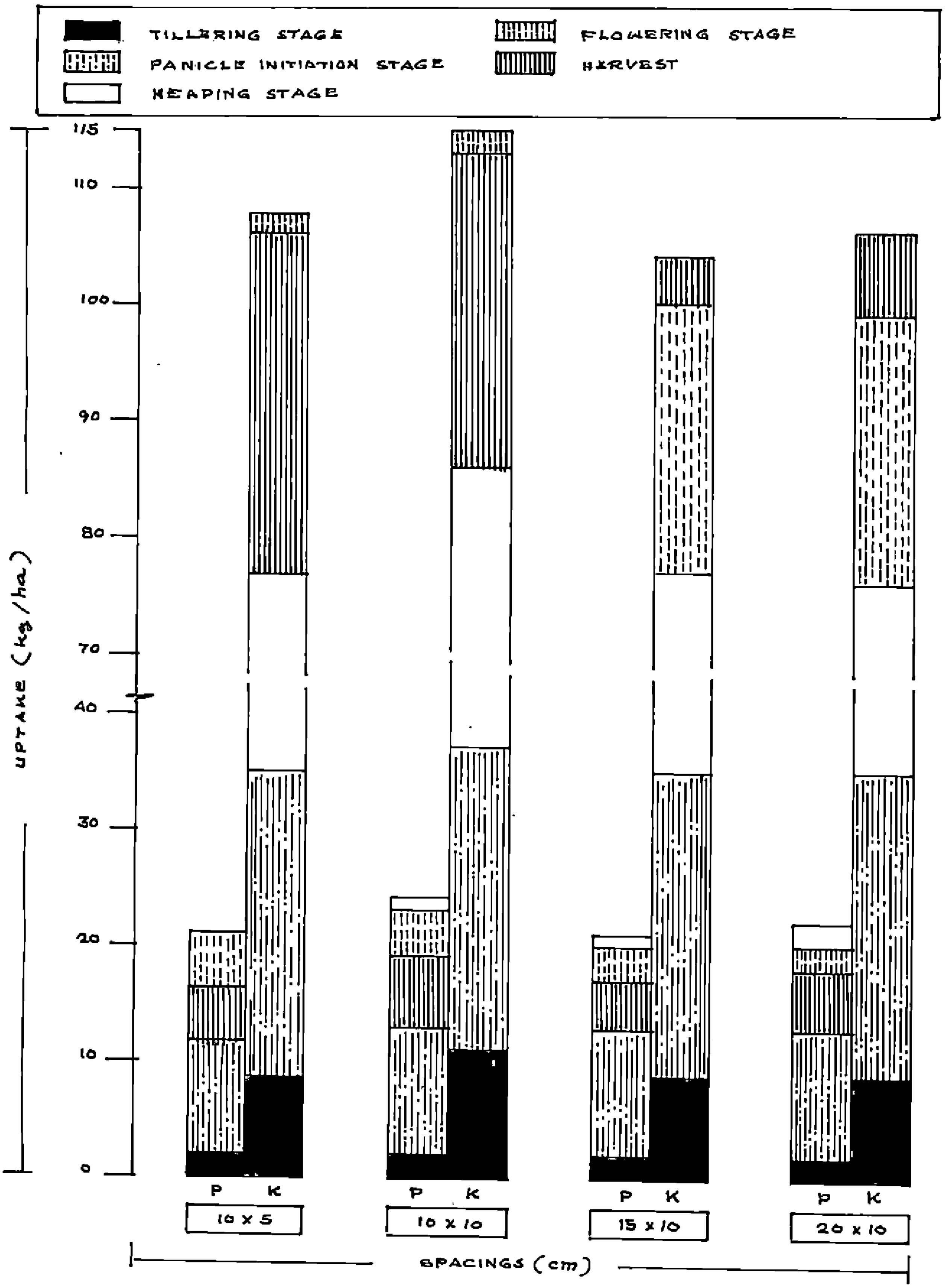

FIG: 20. UPTAKE OF PHOSPHORUS AND POTASH AT TILLERING, PANICLE INITIATION, HEADING, FLOWERING AND HARVEST AS INFLUENCED BY DIFFERENT SPACINGS

With regard to spacings, the results propounded that increased spacings increased the content of the nutrient in plant parts at all growth stages and in grain at harvest. The influence of spacing was significant at all stages and at panicle initiation the plant phosphorus content was at its maximum. As in the case of nitrogen, the influence of spacing on content here too may be explained by the significant lack of competition between plants at wider spacings.

In the case of phosphorus uptake the various spacings were found to have more influence after panicle initiation. This could be a resultant of the higher dry matter production at the later stages. At all growth stages, spacing 20 cm x 10 cm proved itself significantly superior to the other spacings. This again could be attributed to the increased contribution of dry matter by this treatment.

<u>Content and Uptake of Potassium</u>

The results presented in Tables 21(a) to 21(f) and Fig.19 indicated that increased application of fertilisers resulted in increased potash content of the plant at all stages of growth and in grain at harvest. The increase was observed to be significant at all stages of growth.

The content of the nutrient was found to increase from tillering upto flowering, though at harvest it showed a considerable decline. Increased content of potassium with increased supply of the nutrient can be expected. Sadanandan et al. (1969) found that the percentage content and uptake of potassium significantly increased with higher doses of potassium. Similar results have also been obtained by Agarwal (1978). Increased application of nitrogen is also found to increase the plant potassium content as is evident from the research findings of Sadayappan and Kolandaiswamy (1974). Agarwal (1978) reported that increase in the rates of applied phosphorus upto 60 kg P_2O_5/ha increased the potassium content in the plant. Rice plants absorb more potassium than nitrogen and phosphorus, and the absorption occurs even at the later stages of growth. This fact, combined with the split application of the nutrient must have resulted in the increased accumulation of the nutrient in the plant even at heading and flowering stages.

The grain potassium content was also found to be significantly influenced by increased fertiliser application. Singh et al. (1976) observed that potassium content in the grain increased with increased application of the nutrient, owing to the greater absorption and translocation.

As indicated by Tables 24(a) to 24(e) and Fig.20 the uptake of potassium was significantly higher with increased application of the nutrient at all growth stages. This is in agreement with the findings of Singh et al. (1976) and Singh and Jaiprakash (1979), according to which the application of higher amounts of potassium increased its uptake significantly.

The wider plant spacings were observed to give higher plant and grain potassium contents. This may again be attributed to the nutrient competition between plants in the closer spacings, as in the case of nitrogen and phosphorus.

With regard to uptake, significant influence of spacing was noticed at all stages. At all stages, the spacing of 10 cm x 10 cm was seen to reign over the others. This was mainly due to the fact that the same spacing produced the highest dry matter at all growth stages. The result obtained here is a consequences to this.

E. Soil Analysis

1. Residual Nutrient Status of the Soil

Chemical analysis of the soil, the results of which are presented in Tables 25,26 and 27 indicated that the residual nutrient status of the soil did not show any significant fluctuation under the influence of the various fertiliser levels, spacings and their combinations. This was in spite of the variation in the rate of application of the nutrients in the various treatments. The reason might be that the experimental soil, being sandyloam with an open texture, lost a good portion of the added fertilisers through leaching and poor fixation.

F. Economics of Production

The Table 28 on economics of production indicated that the highest profit was obtained with 80:40:40 kg/ha NPK in combination with 10 cm x 10 cm spacing. This was due to the high yield of grain and straw obtained in this treatment. The lowest net profit was obtained in the case of treatment l_1s_1 (50:25:25 kg/ha NPK with 10 cm x 5 cm spacing) because of the low yield of grain and straw.

With regard to the benefit:cost ratio, it was seen that this was highest in treatment l_2s_3 (60:30:30 kg/ha NPK with 15 cm x 10 cm spacing). In other words, in this treatment, the amount obtained in return for each rupee invested was higher than in other treatments. But the net profit in treatment l_2s_3(60:30:30 kg/ha NPK with 15 cm x 10 cm spacing) was lower than in l_4s_2(80:40:40 kg/ha NPK with 10 cm x 10 cm spacing), where the profit was highest. This may be due to the higher yields of grain and straw obtained in latter case. From the benefit:cost point of view, the treatment l_2s_3(60:30:30 kg/ha NPK with 15 cm x 10 cm spacing) seemed to be ideal.

G. Correlation Studies

The results (Table 29) showed that the grain yield was significantly and positively correlated with dry matter production. Similar positive correlations between grain yield and dry matter production were reported by Muthswamy et al (1973b), Sahu and Murty (1975) and Rai and Murty (1979).

The results revealed that the uptake of nitrogen, phosphorus and potash by the crop at harvest were significantly and positively correlated with grain yield. This corroborates the findings of Muthuswamy et al.(1973b), Rai and Murty (1979) and Iruthayaraj and Morachan (1980), that nitrogen, phosphorus and potash uptake were highly correlated with grain yield.

It was further noticed that the uptake of nitrogen, phosphorus and potash were positively and significantly correlated with protein yield and dry matter production. This can be due to the increased uptake of the major nutrients which in turn resulted in more dry matter production.

SUMMARY

SUMMARY

An investigation was undertaken at the Rice Research Station, Kaymkulam, during the second crop season of 1981-82 to find out the effect of different levels of fertilisers (50:25:25 kg/ha NPK, 60:30:30 kg/ha NPK, 70:35:35 kg/ha NPK and 80:40:40 kg/ha NPK) and different spacings (10 cm x 5 cm, 10 cm x 10 cm, 15 cm x 10 cm, and 20 cm x 10 cm) on growth and yield of rice variety, Mashuri. The experiment was laid out as a 4 x 4 factorial experiment in randomised block design, with three replications. The results of the study are summarised below.

1. The different levels of fertilisers and the different spacings had significant effect on plant height at all the five stages of crop growth with the highest level of the fertiliser and the widest spacing recording the maximum height. The treatment combinations also influenced plant height significantly and the treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the tallest plants at all growth stages.

2. The number of tillers per hill at all stages of growth increased significantly with increase in levels

of fertilisers and increase in spacings, with the highest fertiliser level and the widest spacing recording the maximum number. The influence of treatment combinations was significant only at flowering and harvest stages, when treatment l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) gave the highest value.

3. Fertiliser levels progressively and significantly influenced the number of leaves produced per hill. The influence of the different spacings and their combinations with levels of fertilisers were also significant. The highest value was registered by fertiliser level 80:40:40 kg/ha NPK, spacing 20 cm x 10 cm and treatment combination l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing)

4. Leaf area index and drymatter production were markedly influenced by fertiliser levels, spacings and their combinations. Highest values for both aspects were obtained with 80:40:40 kg/ha NPK. Spacing 10 cm x 5 cm and treatment combination l_4s_1 (80:40:40 kg/ha NPK with 10 cm x 5 cm spacing) gave the highest leaf area index, whereas spacing 10 cm x 10 cm and treatment combination l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing)

gave the highest dry matter production.

5. Number of productive tillers per hill was significantly influenced by fertiliser levels, spacings and their combinations. Highest value was given by 80:40:40 kg/ha NPK. Number of productive tillers per hill was highest with 20 cm x 10 cm spacing and treatment combination l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing).

6. Length of the panicle, weight of the panicle, number of spilelets per panicle and number of filled grains per panicle increased significantly with increases in the fertiliser levels and spacings. Treatment combination l_4s_4 (80:40:40 kg/ha NPK with 20 cm x 10 cm spacing) recorded the maximum value in all four cases.

7. The different fertiliser levels, spacings and their combinations failed to produce any significant influence on the percentage sterility.

8. Thousand grain weight was progressively and significantly increased by increasing fertiliser levels. The different spacings and their combinations failed to

evoke any significant influence here.

9. The different fertiliser levels, spacings and their combinations significantly increased grain and straw yields. Fertiliser level 80:40:40 kg/ha NPK, spacing 10 cm x 10 cm and treatment combination l_4s_2 (80:40:40 kg/ha NPK with 10 cm x 10 cm spacing) gave the maximum yield of grain and straw.

10. Higher levels of fertilisers had significant influence with respect to grain:straw ratio and harvest index. The different spacings and their combinations with fertiliser levels also influenced significantly the grain: straw ratio and harvest index.

11. The grain protein content was significantly and progressively increased with increasing fertiliser levels and spacings. The treatment combinations failed to produce any significant influence on this aspect.

12. Effect of fertiliser levels in increasing the nitrogen, phosphorus and potash contents of plants and grain was significant at all stages of growth with the highest contents being recorded by 80:40:40 kg/ha NPK. The different

spacings also influenced the plant and grain nutrient contents significantly with 20 cm x 10 cm giving the maximum values.

13. Uptake of nitrogen, phosphorus and potash increased significantly with increase in fertiliser levels. The various spacings also influenced the nutrient uptake significantly.

14. There was no significant influence on the available nitrogen, phosphorus and potash content of the soil after the experiment, with different fertiliser levels, spacings and their combinations.

15. Grain yield was significantly and positively correlated with dry matter production and the uptake of nitrogen, phosphorus and potash. Also the correlations of dry matter production and of protein yield with nitrogen, phosphorus and potash uptake were significant and positive.

16. The maximum net profit of Rs.3656.03 was obtained with 80:40:40 kg/ha NPK in combination with 10 cm x 10 cm

spacing, while the maximum benefit:cost ratio was obtained with 60:30:30 kg/ha NPK in combination with 15 cm x 10 cm spacing.

From the above study it can be concluded that for getting the maximum net profit from paddy variety, Mashuri, fertiliser doses of 80:40:40 kg/ha NPK in combination with spacing of 10 cm x 10 cm is required during the second crop season in the Onattukara tract.

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* Originals not seen.

APPENDICES

APPENDIX I

Meteorological data duuring the crop season, 1981-82

Standard weeks	Dates	Total rainfall mm	Maximum temperature oC	Minimum temperature oC	R.H.% forenoon	R.H% afternoon
34	Aug.20 - Aug.26	133.4	29.9	22.9	96	70
35	Aug.26 - Sept 2	13.4	30.6	23.9	94	70
36	Sept 3 - Sept 9	142.4	30.5	23.8	96	74
37	Sept 10- Sept16	126.8	29.3	23.3	97	77
38	Sept 17- Sept23	243.1	29.2	23.8	95	86
39	Sept 24- Sept30	0.8	31.5	24.2	95	66
40	Oct. 1- Oct. 7	8.2	31.6	23.4	96	61
41	Oct. 8- Oct.14	23.6	31.2	23.7	95	64
42	Oct. 15- Oct.21	54.8	32.1	24.3	95	68
43	Oct. 22- Oct.28	90.6	30.1	23.9	93	74
44	Oct. 29- Nov. 4	147.6	29.4	23.1	96	71
45	Nov. 5 - Nov.11	32.0	30.0	23.5	95	73
46	Nov. 12- Nov.18	123.4	31.6	24.0	94	67
47	Nov. 19- Nov.25	Nil	31.5	23.1	95	62
48	Nov. 26- Dec. 2	8.0	30.6	23.1	95	69
49	Dec. 3- Dec. 9	10.1	32.0	22.6	95	63
50	Dec. 10- Dec.16	Nil	32.0	21.1	93	51
51	Dec. 17- Dec.23	Nil	32.2	22.4	92	50
52	Dec. 24- Dec.30	Nil	33.1	19.8	91	47
53	Dec. 31- Jan. 6	Nil	33.5	20.5	89	43

APPENDIX I (Contd.)

Average values for meteorological observations for five years 1976-77 to 1980-81

Standard weeks	Dates		Total rainfall mm	Maximum temperature °C	Minimum temperature °C	R.H.% forenoon	R.H.% afternoon
34	Aug.20	- Aug. 26	34.44	30.05	24.03	95.10	71.8
35	Aug.27	- Sept. 2	20.02	31.48	23.62	95.00	66.20
36	Sept.3	- Sept. 9	35.25	31.35	23.98	94.50	65.75
37	Sept.10	- Sept.16	24.40	31.13	23.70	95.00	67.50
38	Sept.17	- Sept.23	22.05	31.30	23.75	92.75	67.50
39	Sept.24	- Sept.30	56.63	30.75	24.00	93.00	71.00
40	Oct. 1	- Oct. 7	41.53	31.18	23.78	94.75	67.25
41	Oct. 8	- Oct. 14	48.73	31.68	24.23	94.75	69.25
42	Oct. 15	- Oct. 21	39.37	31.50	24.15	95.25	70.75
43	Oct. 22	- Oct. 28	146.33	31.28	23.85	95.00	70.00
44	Oct. 29	- Nov. 4	175.75	31.65	23.63	95.75	70.50
45	Nov. 5	- Nov. 11	66.28	31.13	23.70	94.50	67.50
46	Nov. 12	- Nov. 18	102.78	31.40	23.63	95.25	68.50
47	Nov. 19	- Nov. 25	18.10	32.03	23.20	94.25	63.25
48	Nov. 26	- Dec. 2	17.50	32.13	22.95	94.00	60.25
49	Dec. 3	- Dec. 9	19.95	32.88	22.48	92.50	56.50
50	Dec. 10	- Dec. 16	23.75	32.60	22.55	92.00	58.25
51	Dec. 17	- Dec. 23	4.00	33.00	21.85	91.75	52.50
52	Dec. 24	- Dec. 30	16.98	32.43	21.95	91.00	52.50
53	Dec. 31	- Jan. 6	2.45	33.25	21.15	90.00	46.75

APPENDIX II

Abstract of analysis of variance table for height of the plant, number of tillers per hill and number of leaves per plant at tillering, panicle initiation, heading, flowering and harvest stages.

	Source				
	Block	l	s	l x s	Error
df	2	3	3	9	30
Mean Square					
Height of the plant at tillering stage	0.808	36.53*	29.96*	13.72*	1.29
Height of the plant at panicle initiation stage	0.064	45.38*	150.34*	69.55*	0.619
Height of the plant at heading stage	0.337	56.48*	491.09*	67.26*	1.59
Height of the plant at flowering stage	1.44	307.14*	381.87*	73.72*	2.18
Height of the plant at harvest	0.993	355.37*	385.36*	35.72*	2.23
Number of tillers per hill at tillering stage	1.21	13.3*	14.46*	1.05	1.21
Number of tillers per at panicle initiation stage	0.303	19.92*	30.95*	0.539	1.271
Number of tillers per hill at heading stage	0.33	24.24*	26.34*	0.345	1.26
Number of tillers per hill at flowering stage	0.000108	22.88*	17.08*	0.175*	0.026
Number of tillers per hill at harvest	0.00161	9.81*	15.6*	1.21*	0.049
Number of leaves per hill at tillering stage	0.0595	20.32*	5.16*	0.596*	0.226
Number of leaves per hill at panicle initiation stage	0.123	45.53*	16.13*	13.25*	0.605
Number of leaves per hill at heading stage	0.0901	56.77*	192.89*	11.63*	0.438
Number of leaves per hill at flowering stage	0.151	117.18*	224.41*	12.47*	0.441
Number of leaves per hill at harvest	1.220	35.64*	99.99*	0.968	0.540

APPENDIX III

Abstract of analysis of various table for leaf area index and dry matter production at tillering, panicle initiation, heading flowering and harvest stages.

	Source				
	Block	l	s	l x s	Error
df	2	3	3	9	30
Mean Square					
LAI at tillering stage	0.19	3.34*	5.96*	1.83*	0.117
LAI at panicle initiation stage	0.0602	2.99*	8.13*	3.94*	0.127
LAI at heading stage	0.047	2.42*	42.10*	18.26*	0.091
LAI at flowering stage	0.451	3.59*	23.37*	2.91*	0.121
Dry matter production at tillering stage	237.86	18694.19*	38228.8*	1816.0*	253.02
Dry matter production at panicle initiation stage	1325.88	57584.89*	47253.2*	1224.56	558.87
Dry matter production at heading stage	276.36	133725.38*	1205905.5*	7062.67*	1429.54
Dry matter production at flowering stage	629.18	3599237.09*	2662749.67*	466019.78*	777.82
Dry matter production at harvest	490.28	3327939.26*	1528748.52*	280943.84*	1036.87

* Significant at 0.05 level

APPENDIX IV

Abstract of analysis of variance table for number of productive tillers per hill, length and weight of the panicle, number of spikelets and filled grains per panicle, percentage sterility and thousand grain weight

	Source				
	Block	l	s	l x s	Error
df	2	3	3	9	30
Mean Square					
Number of productive tiller per hill	0.0037	3.17*	8.01*	1.33*	0.00165
Length of the panicle	0.0028	2.29*	1.35*	3.21*	0.053
Weight of the panicle	0.00018	0.124*	1.49*	0.0649*	0.0015
Number of spikelets per panicle	61.63	600.04*	66.51*	98.57*	21.52
Number of filled grains per panicle	66.86	361.09*	42.49	75.50*	21.09
Percentage sterility	3.404	3.83	3.30	5.47	3.85
Thousand grain weight	1.505	6.16*	1.37	0.23	1.46

* Significant at 0.05 level.

APPENDIX V

Abstract of analysis of variance table for grain and straw yield, grain: straw ratio, harvest index, protein content of grain and content of nitrogen in plants at tillering, panicle initiation, heading, flowering and harvest stages.

	Source				
	Block	l	s	lxs	Error
df	2	3	3	9	30
<u>Mean square</u>					
Grain yield	576.36	447307.77*	493977.87*	2695.52*	621.65
Straw yield	527.71	366055.57*	1683495.31*	13613.84*	1031.85
Grain:straw ratio	0.000027	0.00592*	0.000858*	0.000202*	0.000045
Harvest index	0.288	59.75*	7.27*	2.24*	0.267
Protein content of grain	0.0042	4.29*	2.27*	0.180	0.206
Nitrogen content in plants at tillering stage	0.0058	0.30*	0.104*	0.039*	0.0118
Nitrogen content in plants at panicle initiation stage	0.112	0.502*	0.628*	0.0742	0.0974
Nitrogen content in plants at heading stage	0.0252	0.253*	0.339*	0.0181	0.0149
Nitrogen content in plants at flowering stage	0.00461	0.121*	0.0482*	0.0285	0.016
Nitrogen content in grain at harvest	0.00012	0.1109*	0.059*	0.0046	0.0052
Nitrogen content in plants at harvest	0.00063	0.0096*	0.0059*	0.0008	0.00087

* Significant at 0.05 level

APPENDIX VI

Abstract of analysis of variance table for content of phosphorus and potash in plant at tillering , panicle initiation, heading, flowering and harvest stages.

	Source				
	Block	l	s	lxs	Error
df	2	3	3	9	30
Mean Square					
Phosphorus content at tillering stage	0.00017	0.0124*	0.00092*	0.0002*	0.000089
Phosphorus content at panicle initiation stage	0.00007	0.0225*	0.00329*	0.00176*	0.00007
Phosphorus content at heading stage	0.0063	0.031*	0.016*	0.00503	0.0052
Phosphorus content at flowering stage	0.00043	0.0038*	0.0018*	0.00015	0.00008
Phosphorus content in grain at harves	0.00011	0.0154*	0.0009*	0.0004*	0.00018
Phosphorus content in plant at harvest	0.000019	0.0036*	0.0013*	0.0001	0.000085
Potash content at tillering stage	0.000081	0.087*	0.0084*	0.0003	0.00016
Potash content at panicle initiation stage	0.00027	0.055*	0.0035*	0.00028	0.00052
Potash content at heading stage	0.00031	0.067*	0.004*	0.00047	0.00027
Potash content at flowering stage	0.00046	0.029*	0.0063*	0.00036	0.00021
Potash content in grain at harvest	0.000102	0.0373*	0.0043*	0.00057*	0.00015
Potash content in plant at harvest	0.000077	0.0332*	0.0119*	0.00087*	0.00012

*Significant at 0.05 level.

APPENDIX VII

Abstract of analysis of variance table for uptake of nitrogen and phosphorus at tillering, panicle initiation, heading, flowering and harvest stages.

	Source				
	Block	l	s	lxs	Error
df	2	3	3	9	30
Mean Square					
Uptake of nitrogen at tillering stage	0.614	39.87*	4.53*	1.92*	0.728
Uptake of nitrogen at panicle initiation stage	75.53	418.03*	279.60*	39.86	54.92
Uptake of nitrogen at heading stage	59.16	866.77*	560.69*	54.63	36.13
Uptake of nitrogen at flowering stage	18.50	1891.53*	63.75	262.54*	70.62
Uptake of nitrogen at harvest	22.95	366.19*	51.30*	28.63*	11.11
Uptake of phosphorus at tillering stage	0.0065	1.41*	0.23*	0.027*	0.0067
Uptake of phosphorus at panicle initiation stage	0.053	22.85*	1.34*	0.97*	0.048
Uptake of phosphorus at heading stage	1.45	56.7*	23.84*	1.07*	0.15
Uptake of phosphorus at flowering stage	0.206	103.72*	18.20*	4.89*	0.328
Uptake of phosphorus at harvest	0.123	73.03*	10.22*	2.89*	0.498

* Significant at 0.05 level.

APPENDIX VIII

Abstract of analysis of variance table for uptake of potash at tillering, panicle initiation, heading, flowering and harvest stages and for available nitrogen, phosphorus and potassium content in soil after the experiment.

	Source				
	Block	l	s	lxs	Error
df	2	3	3	9	30
Mean Square					
Uptake of potash at tillering stage	0.071	15.51*	7.15*	0.486*	0.061
Uptake of potash at panicle initiation stage	0.378	82.92*	8.70*	0.73	0.47
Uptake of potash at heading stage	0.321	331.40*	283.19*	1.57	0.73
Uptake of potash at flowering stage	0.965	1812.1*	642.25*	126.52*	0.933
Uptake of potash at harvest	0.210	1529.01*	201.82*	60.02*	0.776
Available nitrogen in soil after the experiment	7.33	0.69	0.39	0.11	1.51
Available phosphorus in soil after the experiment	0.84	0.78	0.49	0.20	1.70
Available potassium in soil after the experiment	8.71	3.94	2.74	4.98	4.68

* Significant at 0.05 level.

SPACING-CUM-FERTILISER INVESTIGATION ON RICE VARIETY, MASHURI, IN THE ONATTUKARA TRACT

By

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ABSTRACT OF A THESIS
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ABSTRACT

With a view to investigate the influence of different fertiliser levels, spacings and their combinations on the growth and yield of rice variety, Mashuri, in the sandy loam tracts of Onattukara, an experiment was conducted at the Rice Research Station, Kayamkulam, during the second crop season of the year, 1981-82. The response of the variety to four fertiliser levels (50:25:25, 60:30:30, 70:35:35 and 80:40:40 kg/ha NPK), four spacings (10 cm x 5 cm, 10 cm x 10 cm, 15 cm x 10 cm and 20 cm x 10 cm) and their various combinations was studied.

The experiment was laid out in randomised block design, as a 4 x 4 factorial experiment with three replications.

The study revealed that height of the plant number of tillers per hill and number of leaves per hill at all stages of crop growth significantly increased with increasing doses of fertilisers and spacings. Leaf area index and dry matter production were markedly influenced by fertiliser levels, spacings and their combinations at all stages studied.

The yield and yield attributes were significantly influenced by the treatments. The maximum grain yield of 2918.26 kg/ha was recorded with a fertiliser dose of 80:40:40 kg/ha NPK and spacing of 10 cm x 10 cm. The fertiliser levels, spacings and their combinations had significant effect on the protein content of grain.

Studies on chemical composition and uptake of nutrients showed that the content and uptake of nitrogen, phosphorus and potash significantly increased with increase in fertiliser levels. The different spacings and their combinations with fertilisers also substantially influenced the content and uptake of these nutrients.

Positive and significant correlations were noticed between grain yield and dry matter production, and between grain yield and uptake of nitrogen, phosphorus and potash. Dry matter production at harvest and protein yield were significantly correlated with the uptake of nitrogen, phosphorus and potash.

The maximum net profit of Rs.3656.03 was obtained with 80:40:40 kg/ha NPK in combination with 10 cm x 10 cm spacing. However, considering the benefit:cost ratio, 60:30:30 kg/ha NPK in combination with 15 cm x 10 cm spacing gave the maximum value.

Table 28 (contd.)

1	2	3	4	5	6	7
l_4s_1	6733.86	267.20	3903.00	4170.20	2563.66	1.61
l_4s_2	7535.23	267.20	3612.00	3879.20	3656.03	1.94
l_4s_3	6621.37	267.20	3030.00	3297.20	3324.17	2.01
l_4s_4	6385.86	267.20	3030.00	3297.20	3088.66	1.94

Treatments:

l_1s_1 - 50:25:25 kg/ha NPK with 10cm x 5cm spacing
l_1s_2 - 50:25:25 kg/ha NPK with 10cm x 10cm "
l_1s_3 - 50:25:25 " " " 15cm x 10cm "
l_1s_4 - 50:25:25 " " " 20cm x 10cm "

l_2s_1 - 60:30:30 " " " 10cm x 5 cm "
l_2s_2 - 60:30:30 " " " 10cm x 10cm "
l_2s_3 - 60:30:30 " " " 15cm x 10cm "
l_2s_4 - 60:30:30 " " " 20cm x 10cm "

l_3s_1 - 70:35:35 kg/ha NPK with 10cm x 5cm spacing
l_3s_2 - 70:35:35 kg/ha NPK with 10cm x 10cm "
l_3s_3 - 70:35:35 " " " 15cm x 10 cm "
l_3s_4 - 70:35:35 " " " 20cm x 10cm "

l_4s_1 - 80:40:40 " " " 10cm x 5 cm "
l_4s_2 - 80:40:40 " " " 10cm x 10cm "
l_4s_3 - 80:40:40 " " " 15cm x 10cm "
l_4s_4 - 80:40:40 " " " 20cm x 10cm "

Price of 1 kg grain - Rs.1.52
" 1 kg straw - Rs.0.50
" 1 kg urea - Rs.2.40
" 1kg superphosphate - Rs.0.55
" 1 kg MOP - Rs.1.33

Labour charges per day for men - Rs.16.05
Labour charges per day for women - Rs.14.55