# EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZERS AND SEED RATE ON GROWTH AND YIELD OF TWO UPLAND RICE (*ORYZA SATIVA* L) CULTIVARS.


**BY**

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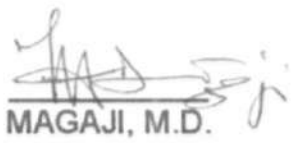

**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY.**


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**APRIL, 1994.**

## DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree.



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## CERTIFICATION

This thesis entitled *"Effects of Nitrogen and Phosphorus Fertilizers and Seed rate on Growth and Yield of Two Upland Rice (Oryza sativa L.) Cultivars"* by Magaji, Muhammed Danyaro meets the regulations governing the award of the degree of Doctor of Philosophy of the Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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## DEDICATION

This thesis is dedicated to my late parents Aishah A. Magaji and Alhaji Muhammadu Magaji. May their souls rest in perfect peace. Amin.

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**M.D. Magaji.**

**ABSTRACT**

Field experiments were conducted at the Fadama Farm of Usmanu Danfodiyo University, Sokoto for three consecutive years during 1990-92 rainy seasons. The objective of the investigation was to study the effects of nitrogen, phosphorus and seed rates on two upland rice cultivars with a view to arriving at an optimum combination rates of these factors for optimum paddy yield.

The analyzed data revealed that the cultivar Ex-China was significantly superior to ITA 257 in both total and ear-bearing tiller number/unit area, but almost at par with each other in panicle length. ITA 257 was, however, found to be significantly taller and therefore more susceptible to lodging than Ex-China, especially at high nitrogen rates. The latter was found to be of longer duration than the former. In terms of grain number/ear and seed weight, ITA 257 was superior. Also, in view of ITA's tall stature, it tended to produce more straw than its counterpart, in spite of Ex-China's higher tillering ability. Ex-China turned out to be higher paddy yielding than ITA 257.

The results also indicated that nitrogen significantly affected most of the growth parameters and paddy yield components, notably tillering, panicle length and plant height. But, in general, the nutrient had no significant effect on time to flowering and maturity. The nutrient aggravated lodging, especially in the relatively taller cultivar, ITA 257. Nitrogen also promoted grain number/ear significantly in most years, but, on the whole, it showed no significant effect on seed weight. It also affected both the straw and paddy yields significantly, but increasing the rates had

an adverse effect on grain:straw ratio. Seed rate, either alone, or in interaction with nitrogen or phosphorus also increased most of the parameters examined, but mainly up to 75 kg seed/ha beyond which competition set in. However, lodging and 1000-seed weight were not significantly affected by increasing seed rates. Grain:straw ratio was also little affected by this factor. Phosphorus showed no significant effects on tillering, time to flowering and maturity, straw weight, and grain:straw ratio. However, increasing levels of this nutrient significantly increased panicle length in two out of the three seasons, and in respect of lodging, there was a lower incidence of it with increasing phosphorus rate in only one season. An increase in the phosphorus levels also increased paddy yield in only one season.

Polynomial responses to nitrogen and seed rates were, in general, linear, indicating that paddy yield would continue to increase beyond the ranges of the factors tried in this experiment. With regards to phosphorus, however, the response was either inconclusive, or quadratic.

Correlation studies revealed that number of ear-bearing tillers/unit area was the single most important paddy yield contributing component, in view of its significant positive correlation with the yield throughout the conduct of the trials. Thus, the other two paddy yield components, i.e., number of grains/ear and seed weight were adjunct to it.

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CHAPTER 1

# INTRODUCTION

Rice (*Oryza sativa* L.), is said to be the most important cereal crop of the world. It is the staple food of half of the world's population. It was estimated that rice occupied about 150m ha with a total production of about 520m tonnes of paddy, of which over 90 percent was in South-East Asia (IRRI, 1991). In terms of area and production, rice in Africa is relatively small, being only 3.4% of the total world rice land contributing about 2.0% to total production (Lowe *et al.*, 1988). Of the world's total rice land area, only about 19m ha was found to be upland, with 12m ha in Asia, 6.7m ha in Latin America and 2.5m ha in Africa. Most of the upland rice in Africa was said to be found in West Africa, where it occupies about 1.54m ha (about 61 percent) of the upland rice hectarage in the continent. In Nigeria, about 55 percent of the paddy land is upland, making it the third most important paddy producer in Africa after Malagacy and Cote d 'I Voire (Arradeau, 1983).

Uptil mid 1960s, Nigeria was a net exporter of rice. However, due to oil boom in the 1970s, and the availability of cheaper and better quality rice in the international market, as well as the county's strong currency, Nigeria's rice imports rose from US $ 0.19m in 1970 to about US $ 214m in 1979 (WARDA, 1981). It was estimated that at the current per capita consumption of rice of about 20 kg/annum, Nigeria would need to produce about 2.16 m tonnes of rough rice by

the year 1990 in order to feed her increasing population. In order to accomplish that task, the country needed to raise her local production by about 20 percent/annum ( Idachaba, 1985; IRRI, 1991).

Rice for food has been used primarily as a whole grain which provides about 60 percent of the world's energy requirements. Rice bran has been found to be rich in oil and vitamin B. It is also said to be used for food, feed and in industry. Rice husk is used as fuel in rice mills and in building materials. Rice straw is a good livestock feed, especially if enriched with urea. It is also used for making hats, mats, ropes and for the manufacture of furfural (Ullah, 1983).

Although upland rice has occupied a significant hectarage in Nigeria, it has accounted for only about 25 percent of the total paddy production, in view of low yields (often less than 1 t/ha). Poor morpho-agronomic characteristics of the cultivars grown, poor mineral nutrition and inadequate agrotechniques are some of the most important factors contributing to the low yields (Norman, 1983).

Most of the research done to date on rice has been confined to lowland cultivars. Part of the attempts at self sufficiency in rice production in Nigeria should therefore aim at raising the yield of upland rice per unit land area, in view of the substantial hectarage available for this crop.

In view of the above, the objectives of this study were: i) to evaluate the performance of two upland rice cultivars (ITA 257 and Ex-China) at three levels each of seeding (30, 75 and 120 kg seed/ha), nitrogen (0, 45 and 90 kg N/ha) and phosphorus (0, 10 and 20 kg P/ha) respectively and ii) to find an optimum level of plant population that would give the maximum yield at an optimum combination of the nitrogen and phosphorus fertilizers.

CHAPTER 2

# REVIEW OF LITERATURE

Rice is very sensitive to lack of nutrients. It absorbs large quantities of nutrients during the growing season of which nitrogen, phosphorus and potassium are most essential. Because of this, rice is said to be a 'soilminer' or 'impoverisher'. Shortage of essential elements, especially nitrogen impairs grain yield. Of course, large amounts of nitrogen cause excessive tillering and undesirable vegetative growth; prolongs the growing period and increases the percentage of spikelet sterility; decreases seed weight and increases rice susceptibility to pests and diseases, thus impairing grain yield (Konokhova, 1985).

Rice benefits much from phosphorus, a deficiency of which causes metabolic disturbances in the plant, resulting in abnormal plant growth by narrowing the leaf blade and arresting root development. It also delays tillering and results in a small-sized panicle.

Response to potassium by the plant is often not as marked as for nitrogen and phosphorus, because of its presence usually in good amounts in rice soils. According to Jacquot and Courtois (1987), potassium enables water to be saved up in plant tissues and confers some resistance to lodging and increase resistance

to disease. It also increases the size and weight of the grain. Its deficiency leads to poor tillering, delays growth and can lead to death of leaves. It has also been reported that potassium increased grain yield and drymatter production significantly, but response to it varied from one cultivar to another and from season to season (Fageria *et al.*, 1990).

Besides nitrogen, phosphorus and potassium, other essential elements like Ca and S as well as micronutrients like B, Cl, Fe, Cu, Zn, Mo, and Mn are also important in rice plant development, because they are the constituents of the plant enzymes that govern the biochemical processes during plant life. The role of zinc in rice performance has particularly recieved alot of attention. Pande and Nayak (1974) have shown that the yield of grain and straw, number of ear-bearing tillers, plant height, panicle length, number of grains/panicle and 1000-seed weight increased with zinc application. Manganese has also been shown to increase paddy yield (Pillai, 1967).

Seeding rates in rice would depend on plant type, soil moisture and nutrient status, anticipated fertilizer practice, method of sowing and agro-climatic conditions of the area. Rice is however so flexible that it responds to seeding up to 700 plants/$m^2$ .

## 2.1 Nitrogen

Nitrogen is the major limiting nutrient element determining rice growth and yield, and hundreds of field experiments in all parts of the world where rice is grown have demonstrated that increases in yield almost always resulted when nitrogen was added (Lindt, 1953; Ishuzuka, 1965; Matsushima, 1965; Grist, 1975; Patrick *et al.*, 1983 and Mae, 1986). Leaf yellowing, poor growth, small leaf area and thinning of the rice culm are symptoms associated with nitrogen deficiency in paddy plants.

### 2.1.1 Effect of Nitrogenous Fertilizer on Growth

Murata and Matsushima (1980) reported that both the emergence and development of tiller primordia were greatly influenced by the nitrogen content of the plant, and the number of total tillers was found to be strongly correlated ($r = 0.96$) with the nitrogen content of the plant. Matsushima (1965) found that basal dressing and top-dressing of nitrogen just after plant establishment increased large and strong tillers and consequently increased grain yield. Lee and Ota (1971) observed that nitrogen top-dressing at booting or heading stage promoted the photosynthetic activity of the leaves thereby temporarily arresting leaf senescence. Alam and Azmi (1989) also reported an increase in plant height with increase in nitrogen. Salem *et al.* (1989) found that the time to 50% heading and to maturity

were delayed with added nitrogen levels. Salem *et al.* (1989) also reported increased predisposition to lodging with increase in nitrogen top-dressing. According to Park (1989), high nitrogen rates tended to decrease grain:straw ratio while increasing biomass.

### 2.1.2 Nitrogen and Yield Components

Fertilizer nitrogen has been shown to increase the number of ear-bearing tillers/$m^2$, especially when applied at necknode differentiation stage of the rice plant (Matsuo, 1965). According to Wada *et al.* (1986), the number of grains/panicle was found to be directly proportional to the nitrogen content of the plant during the period in which spikelet number was mostly determined.

Seed weight was also found to increase with increasing nitrogen content in the plant during the ripening stage (Matsuo, 1965). Murata and Matsushima (1980) reported that top-dressing nitrogen at the reduction division stage of the rice plant enlarged hull size, thus increasing the weight of the potential caryopsis. At full heading stage, nitrogen top-dressing was reported to increase grain number/panicle and to encourage the development of the kernel (Matsushima, 1965; 1976). According to Mukherjee and Prabhakar (1980), top-dressing nitrogen at the ripening stage helped to promote synthesis and mobilization of nutrients to the developing grain.

### 2.1.3 Effects of Rate of Nitrogen on Growth and Yield

Many subsistence farmers who grow upland rice do not generally apply fertilizer even though most upland rice areas are deficient in nitrogen. The response of upland rice to fertilizer nitrogen has been found to be variable depending on the cultivar grown and the prevailing soil and climatic conditions. In Nigeria, differences in rainfall has been found to influence nitrogen response of rice (IITA, 1985).

In Ghana, Takyi (1971) found that 67 kg N/ha gave good grain yields, while Dartey and Halm (1977) reported 45 kg N as being optimum. In Bangladesh, Jashin *et al.* (1984) found that applying 60 kg N/ha to an upland cultivar BR9 produced the highest paddy yield. Martins *et al.* (1984) have shown that maximum economic response was obtained by applying 90 kg N/ha. In India, Kumar and Sharma (1980) reported 60 kg N/ha as being the economic optimum level for an early-maruring, rainfed rice cultivar; while Khatua and Sahoo (1983) reported 76 kg N/ha for high yielding, short-duration cultivars maturing in 75 to 104 days. Singh and Modgal (1979) recommended 61 kg N/ha for drymatter accumulation at all stages of crop growth. Dixit and Singh (1979) reported increased yields of rainfed rice with increase in nitrogen levels with 80 kg/ha giving the highest grain yield, while Singh *et al.* (1981) obtained the highest grain yield at 50 kg N/ha. Ram *et al.* (1987) found that paddy yield of upland cultivar, Ratna was significantly

increased by increasing nitrogen rates from 20 - 60 kg/ha. At 80kg N/ha grain yield decreased.

In the Philippines, farmers have been reported to apply 60kg N/ha to traditional uplands and to get about 3 t/ha of paddy (De Datta and Ross, 1975). De Datta (1970) reported the highest grain yield ever in the Philippines, of 6.2 t/ha with a fertilizer-responsive semi-dwarf cultivar, IR5 with 60 kg N/ ha. In Peru, Sanchez (1972) found 30 kg N/ha as the optimum with IR4-2.

At Nsukka, Enyi (1964) reported a significant nitrogen response by upland rice. Oyedokun and Sobulo (1977) found that 30 kg N/ha was optimum for improved cultivars in South-west Nigeria. Fagade (1979) reported that 20 - 30 kg N/ha was optimum for a traditional cultivar FARO II (OS6); higher rates led to lodging. At Onne, for ITA 117 and ITA 307, 40kg N/ha was found sufficient to obtain maximum grain yields (IITA, 1985). At Ibadan, the paddy yield of ITA 257 was found to be significantly increased by the application of nitrogen at 80 kg/ha. On the other hand, at Ikenne, grain yields of ITA 235 and ITA 257 were increased by the application of only 40 kg N/ha and higher rates did not increase yields (IITA 1985).

### 2.1.4 Differential Response of Varieties to N levels

Of the various nonclimatic factors affecting nitrogen response in rice, plant type is of particular importance. The importance of improved plant type for obtaining high yields under upland conditions was demonstrated for the first time by IRRI (1967). Earlier workers (De Geus, 1957; Grist, 1965; Beachell and Evatt, 1961) had indicated that the *japonica* cultivars were superior to the *indicas* in terms of nitrogen response and grain yield. They observed that the majority of *indicas* were adapted to relatively low dressings of nitrogen; high quantities usually resulted in lodging and consequent loss of crop, while *japonicas* responded to higher nitrogen rates. However, later findings by De Datta *et al.* (1968), Chandler (1969), Jana and De Datta (1971), Purseglove (1972), De Datta and Malabuyoc (1976) clearly demonstrated that rice varieties with improved plant type, whether *indica or japonica* race, respond to higher levels of nitrogen. De Datta *et al.* (1968), De Datta and Malabuyoc (1976), further observed that most of the traditional tall rice cultivars lodged at certain growth stage and yielded best when 30 - 60 kg N/ha was applied; while modern-day semi-dwarf and dwarf genotypes produced progressively higher yields and responded to higher nitrogen rates. Thus, they concluded that short stature and culm length were important in obtaining high yields. Similar observations were also made by workers in Nigeria (Oyedokun and Sobulo, 1977; Fagade, 1979; IITA, 1985).

Various reasons have been advanced for the differential nitrogen response by paddy varieties. Tanaka *et al.* (1959) attributed the low efficiency of nitrogen utilization by *indicas* to their high soluble-nitrogen to protein-nitrogen ratios at the reproductive stage, culminating in decreased number of filled grains/panicle and weight of 1000-grains. Cultivars with short and stiff straw, shorter maturation period and little time lag between their active vegetative and reproductive phases have been reported to respond to higher doses of nitrogen (Purseglove, 1972). Again, the low response cultivars have been shown to have luxuriant nitrogen consumption at their early vegetative growth, leading to a large increase in height, dry weight, tillering and leaf area, resulting in mutual shading (Tanaka, 1965). Yamada (1959), Baba (1961), Mahapatra *et al.* (1966) also opined that *indicas* were less efficient in converting nitrogen to grain than *japonicas*.

General recommendations of nitrogen to upland rice in Nigeria have been 20 - 40 kg N/ha for tall, lodging cultivars and 40 - 70 kg N/ha for short, nonlodging varieties, the rate varying with agroecological zone (Anon., 1989).

### 2.1.5 Varietal Response to Varying Seed rates and N Rates

Nitrogen and plant population are important factors in determining rice yields. High yields of rice are usually obtained by increasing nitrogen application and by dense planting. Varietal differences in the response to nitrogen and

spacing, or both, have been observed in rice. (Matsuo, 1965) reported that most varieties adapted to dense planting were also adaptable to heavy nitrogen fertilization. It was found that with the application of heavy nitrogen, growth was accelerated and leaves grew thick. With dense planting, leafiness was found to increase. In both cases, competetion for light at the late growth stage became severe because of excess vegetative growth (Matsuo, 1965).

Heavy fertilization is usually compensated for by sparse planting, and less nitrogen fertilization by dense planting. Low nitrogen response cultivars which absorb large amounts of nitrogen at their early growth stages and increase the leaf area per unit of nitrogen content with heavy manuring have characteristics which decrease the effect of dense planting on yield. On the other hand, high nitrogen response cultivars have morphological and physiological characteristics which promote the effect of dense planting on yield under heavy fertilization (Matsuo, 1965).

It has also been found that of the higher tillering cultivars which respond less to plant population, there were those which have short culms and respond highly to nitrogen, and those which are tall and less responsive to nitrogen. Again, of the low-tillering cultivars which respond highly to spacing, are those that are tall and less responsive to nitrogen and the short group which are highly responsive to nitrogen (Matsuo, 1965). Thus, as pointed out by Yoshida (1983), an optimum

planting density that maximizes spikelet number varies with the tillering capacity *and cultivar and with nitrogen application.*

## 2.2 Phosphorus

### 2.2.1 Effect of Phosphorus on Growth and Yield

Phosphorus has been reported to be required by the rice plant throughout its growing period and the need has been found to increase with growth, with the greatest uptake during the late boot and heading periods in view of high demands for water and nutrients at these times (Raju, 1976). Phosphorus has been shown to stimulate root development and tillering, to hasten maturity and to give a higher feeding value to the rice plant (Purseglove, 1979). Murata and Matsushima (1980) reported a close correlation between phosphorus level and tillering, with no tillering taking place when the phosphorus content of the mother stem was below 0.25 percent. Sicar and Sen (1941) observed that progressive phosphate deficiency could lead to reduction in plant height and tillering. According to Jacquot and Courtois (1987), phosphorus has been found to have a favourable effect on earliness. Gupta and Gautam (1988) reported a significant increase in panicle number/unit area, grains/panicle and grain yield with phosphorus application.

### 2.2.2 Effects of Rates of Phosphorus on Growth and Yield

It has been shown that the effect of phosphorus on rice varied primarily with the soil and agroclimatic conditions of a place, but also with the expected yield level (Raju, 1979). Generally, it has been observed that 1 kg of phosphorus was required to produce 200 kg of drymatter in rice, and about 2/3 of the absorbed phosphorus was utilized in the production of panicles (Raju, 1979). Upland rice has been shown to respond more to phosphate application than lowland rice, because in the latter, flooding has been found to increase the availability of phosphorus (Davide, 1965; Ponnamperuma, 1975).

Phosphorus has frequently been reported to give increased yields of upland rice, but in some cases it has failed to show any response (Grist, 1978; Rao and Rao, 1991). Phosphorus deficiency has been reported to be common in upland paddy soils, especially in oxisols, and ultisols in Brazil, West Africa, and some parts of South-East Asia, where the soils have been found to have low available phosphorus and high phosphorus fixation capacity.

In the Philippines, in two out of every four experiments conducted in farmers' fields yields of IR5 were found to be more than 1 t/ha higher with addition of 13 - 26 kg P/ha applied (De Datta and Ross, 1975), but PCARR (1977) recommended 18 kg P/ha . In India, modern semidwarf cultivars have been found

to remove 16 - 18 kg P/ha (Singh and Modgal, 1978; Pande and Tilak, 1970; Mahapatra and Shrivastava, 1983). In Brazil, Fageria *et al.* (1982) found that phosphorus was the most limiting after water. They observed increased drymatter and number of tillers/unit area with the application of 20 - 40 kg P/ha. On extremely acid soils of Llanos Orientales (Brazil), Sanchez and Leal (1979) found that paddy yields were more than doubled with the application of 33 kg P/ha. However, they found no positive response to P on river-bottom soils.

In Malaysia, Dunsmore (1970) found that 27 kg P/ha was optimum for grain yield. In Nigeria, Enyi (1968) observed lack of response to P for upland tradltional cultivar Agbede. However, IITA (1982) reported significant response to added P in pot and greenhouse experiments.

### 2.2.3 Effect of N x P on Growth and Yield.

According to Davide (1965), Raju (1976), adequate phosphorus in the soil was essential to nitrogen uptake. A low phosphorus supply has been reported to suppress early nitrogen uptake and to prevent the synthesis of protein from nitrogenous materials; while plentiful supply promoted early growth (Fujiwara 1965).

In the Punjab (India), Baddesha and Maskina (1985) have shown that application of N and P together increased grain yield 30 percent more than applying nitrogen alone, implying that nitrogen fertilizer alone was not sufficient to maximize rice yield. Nayak (1984) reported increased paddy yields with increasing levels of N and $P_2O_5$ at 30, 60, 90 and 120 kg/ha in the ratios 1:1, 2:1, 3:1 4:1. He observed that nitrogen and phosphorus in the ratios 1:1 and 2:1 were significantly superior to the others. Tackchandani *et al.* (1987) also reported significant increases in yields with increasing N x P rates with the cultivar, 'Ratna'. In Ghana, Takyl (1971), however, could not detect a significant interaction between N & P on African upland rice in a savanna location. However, he found 47:14 kg N:P/ha as the best combination. At Baukwu-Manga (Ghana), Dartey and Halm (1977) also found that the optimum N & P rate was 45 and 29 kg/ha , but no significant N x P interaction was observed.

In India, 40 kg each of N & P have been recommended for upland rice, while in Thailand the use of 60 to 80 kg of N and 16 - 20 kg P/ha has been found to give 2 to 3 t/ha of paddy. Singh *et al.* (1989) found that number of days to 50% heading and maturity were slightly reduced by N x P application compared with nitrogen alone, and that number of panicles/$m^2$, 1000-kernel weight were also increased with application of 60 kg N and 20 kg P/ha rather than nitrogen alone. Rafey *et al.* (1989) also reported increased panicle length, number of grains/panicle and 1000-seed weight with N x P application.

### 2.2.4 Variety x Phosphorus and Paddy Yield

The response of upland rice to phosphorus depends mainly on the soil type, but varietal differences have also been reported. In India, Singh and Modgal (1978) found that modern semidwarf rices removed 16 kg P/ha of which about 60 percent was translocated to the grain. Pande and Tilak (1970), Mahapatra and Shrivastava (1983) found that short duration (100 - 110 day) upland cultivars responded to upto 18 kg P/ha. Lal *et al.* (1982) reported large variations in rice uptake in 19 upland genotypes grown in eastern Uttar Pradesh (India). The quantities ranged from 7.6 - 11 kg P/ha. In Brazilian upland conditions, Malavolta and Filho (1983) found that the quantity necessary to produce 1 ton of paddy varied from 5 - 15 kg/ha with IR8 requiring the least amount, and IAC 47 the highest. Substantial differences in response to phosphorus have also been found between lowland and upland rices (Raju, 1979; Ponnamperuma 1975; Kumbhar and Sonar, 1980).

## 2.3 Seedrate

### 2.3.1 Effect of Seed rate in General

Seed rate of upland rice has been reported to be less studied than that of lowland rice although it affects plant competition for light, water, nutrients and space (De Datta and Ross, 1975). It has been observed that the number of tillers

and the number of panicles per square metre in a rice population are largely a function of the planting density (Fagade and De Datta, 1971), and grain yield has been shown to increase with the number of plants per unit area as long as there is space in the cultivated field. According to Matsuo (1965), when plant density exceeds an optimum level, competition among plants for light and nutrients becomes severe. Consequently, plant growth slows down, and the grain yield decreases. With increase in plant density, the growth of the rice plant is checked and the number of tillers, plant height, and the number of total spikelets per panicle and the total number of spikelets per unit area increase, with the result that grain yield per unit area increases (Matsuo, 1965). When plant density is increased to some limit, competition amongst plants becomes severe at the late stage of growth, leading to mutual shading and reduced assimilation due to high respiration (Matsuo, 1965).

### 2.3.2 Effects of Rate of Seeding on Growth and Yield

An optimum planting density that maximizes spikelet number varies with the tillering capacity of a cultivar but also with spacing and planting methods. In India, the Indian council for Agricultural Research (ICAR) found that 80 kg seed/ha was the optimum for drilled upland rice (ICAR, 1981). Pillai (1981 and 1982) recommended 70 - 90 kg/ha for dibbling or drilling at 15 - 20 cm row spacing. Maurya and Vaish (1986) reported increase in grain yields from 2.27 to 3.43 t/ha

with increasing seed rate from 44 - 88 kg/ha. The highest yield was obtained by drilling.

In the Philippines, Clarete and Mabbayad (1978) recommended 70-90 kg seed/ha at 30 cm row spacing. At IRRI, the highest grain yield, 5.8 t/ha was obtained with IR8 at 80 kg seed/ha at 15-30 cm row spacing (IRRI, 1967; De Datta *et al.* 1974). In Thailand, Songmuang *et al.* (1983) found the optimum seed rate to be 62 kg/ha. Schiller and Dogkeaw (1978) found that 15 - 60 kg seed/ha at 15 - 45 cm hill spacing or band seeding did not affect grain yield and grain size in northern Thailand.

In Latin America, seedrate ranged from 40 - 60 kg/ha when drilled (International Rice Testing Programme for Latin America, 1979). Pedroso and Mariot (1980) recorded increased grain yield with increasing seedrate from 106-150 kg/ha at 31 and 18 cm row spacing respectively. They observed that the number of panicles per square metre was higher at the higher plant density, but 1000-grain weight was lower. Sobral and Oliveira (1987) obtained the highest grain yield at a row spacing of 34 cm with 45 - 60 kg seed/ha. In Nigeria, Kehinde (1986) obtained the highest grain yield with FARO II (OS6) at 45 kg seed/ha, higher rates led to lodging.

### 2.3.3 Differential Response of Varieties to Seed rate

Among other things, seeding rate depends upon the cultivar planted. Generally, increase in yield by dense planting has been found to be greater in the panicle-weight cultivars than in the panicle-number types and tall, leafy cultivars have been shown to be planted at low density than semidwarfs (Matsuo, 1965). In Nigeria, dense planting of tall cultivars has been found to increase lodging (Oyedokun and Sobulo, 1977). At Ikenne (South-West Nigeria), yields of rice cultivars LAC 23, ITA 173, and ADNY 11 were found to decrease at high planting densities; while yields of ITA 118, ITA 141 and ITA 235 increased (IITA, 1982).

CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Experimental Site

Three rainfed trials were conducted during 1990 - 92 rainy seasons at Sokoto, in the Usmanu Danfodiyo University (UDUS) Fadama Farm. Sokoto is located in the Sudan Savanna Ecological Zone of Nigeria ($13^0$ 09' N; $5^0$ 18' E) and the University is about 15km north of the city. The soils of the site were analyzed to be loamy sand with about 90% sand (range 86-96%). Soil pH was acidic-neutral ranging from 5.3 - 7.1 in 0.01M $CaCl_2$ and 5.7 - 7.4 in 1:1 $H_20$. The soil was very low in total-N content (0.03 - 0.06%), very low in organic-C, low to moderate in C.E.C. (8.2 - 10.4 meq/100g soil). It was also low to medium in Base Saturation (34 - 57%), but suprisingly fair in available-P (0.9 - 1.6 ppm). The soil was found to be fair in Exchangeable Bases comprising of Potassium, Ca+Mg and Sodium (Appendix A).

## 3.2 Climatic Conditions

The number of rainy days in the three experimental seasons were observed to be 40, 34 &35 days during 1990, '91 and '92 rainy seasons, respectively with

an annual rainfall of 623, 454 and 594 mm, respectively (Appendix B). Both the total rainfall and its distribution pattern in 1990 was relatively better compared with other years. The Temperature and Relative Humidity were also normal for the long range averages (Appendix C). Solar radiation was fairly high ranging from 17 - 26kw/$m^2$ during the period of the trial (Appendix D).

### 3.3 Treatments and Experimental Design

In all the trials, the treatments consisted of three seed rates (30, 75 and 120 kg/ha) combined with three levels of nitrogen (0,45 and 90 kg/ha) as the main plot treatments and three levels of phosphorus (0,10 and 20 kg P/ha) combined with two upland rice cultivars (ITA 257 and Ex-China) in the subplots in a split-plot design replicated three times. Phosphorus was applied as basal dressing as per the treatment to each plot and incorporated into the soil. Nitrogen was applied in 2-equal splits at the time of planting and four weeks after planting as side dressing. The phosphorus was applied through single superphosphate (18% $P_2O_5$) and nitrogen as Calcium Ammonium Nitrate (CAN) (26% N). Gross and net plot sizes were (6 x 2 M) and (6 x 1.5 M) consisting of eight and six rows respectively.

### 3.4 Description of the Varieties

#### 3.4.1 ITA 257

This upland rice variety originated from International Rice Research Institute (IRRI), Los Banos (Philippines). It was introduced into Nigeria through International Institute of Tropical Agriculture (IITA), Ibadan (Nigeria) from which it derived its name. It is a medium duration variety maturing in 90 - 100 days after sowing. The panicles are well exerted with a relatively high number of grains/panicle. Its seeds are bold (seed weight = 27 g/1000) and are nonshattering. This latter characteristic of the variety is favoured by those who transport it to long distances before threshing; whereas farmers who thresh on the farm do not like the variety.

#### 3.4.2 Ex-China

This rice variety, also known as FARO 15, could be grown both under lowland and upland conditions. It came to Nigeria from the Peoples' Republic of China by unconventional route via Sokoto State Government in the early eighties. Since then, the variety has been widely cultivated by Sokoto/Kebbi State farmers amongst whom it is very popular. It is late maturing ripening within 115-120 days after sowing. It has straw-coloured kernels shorter but wider than those of ITA 257 and the seeds shatter, especially if harvested late.

### 3.5 Cultural Practices

#### 3.5.1 Land Preparation

The experimental sites were ploughed twice at an interval of about 15 days. The plots were levelled manually and the main plots were demarcated with high levees in order to minimize nitrogen drift from one main plot to another.

#### 3.5.2 Sowing

The rice seeds, which had been soaked in water the night before, were sown in drills 30 cm apart as per the rates of the treatments. The experiments were sown on 10, 17 and 5 July in 1990, ' 91 and ' 92 rainy seasons, respectively.

#### 3.5.3 Weeding

The paddy crop was weeded three times. Weeds were kept under control by initially applying a pre-emergent herbicide 'Ronstar' at the rate of 4 l/ha. It was followed by two hand weedings as and when necessary.

### 3.5.4 Harvesting

The crop was harvested at maturity when the entire plants turned golden brown and the rachilla have dried. The variety ITA 257, irrespective of the treatment, was always the first to ripen and was harvested about 15 days earlier than Ex-China. Harvesting was done with the help of sickle as close to the ground as possible. The total above-ground biomass was bundled in sheaves and threshing was done after 3 days. The grain and straw were weighed and the former air dried to a constant weight at a moisture content of about 14%.

## 3.6 Observations

### 3.6.1 Total Tiller Count (/$m^2$)

At boot leaf stage, the number of total tillers was recorded from 2 samples of 50 cm of row and total tillers/$m^2$ was calculated therefrom.

### 3.6.2 Number of Ear-bearing Tillers (/$m^2$)

At harvest, the number of ear-bearing tillers/metre of row was counted from 2 samples from which the total number/$m^2$ was calculated.

### 3.6.3 Days to 50% Flowering (DFF)

This is the period of time from sowing to the stage when about 50% of the plants in a plot treatment have flowered.

### 3.6.4 Days to Maturity (DM)

Days to maturity was the time from sowing to the stage when more than 90% of the paddy has matured.

### 3.6.5 Lodging

Just before harvesting, the number of rows in each treatment that lodged was recorded and expressed in percentage.

### 3.6.6 Length of Panicle (cm)

The length of the panicle of ten randomly tagged plants was measured from the base of the inflorescence to the tip of the tallest spikelet.

### 3.6.7 Plant Height at Maturity (cm)

Plant height was measured at maturity from ground level to the tip of the tallest panicle, excluding awns, if any, from 10 randomly tagged plants as described in International Rice Testing Programme (IRRI, 1980).

### 3.6.8 Number of Grains/Ear

From a sample of 10 randomly tagged plants in each plot, grains were threshed and counted. Mean number/panicle was worked out therefrom.

### 3.6.9 1000-Seed Weight (g)

This was determined by weighing 3 samples of 250 seeds from each plot's yield and 1000-seed weight was arrived at from these.

### 3.6.10 Paddy Yield (t/ha)

This was the weight of cleaned and dried grain harvested from the net plot area of each treatment expressed in tons/ha at about 14% moisture content.

### 3.6.11 Straw Yield (t/ha)

Weight of straw was recorded immediately after threshing of individual treatments and the final weight was recorded after allowing the straw to attain constant weight in the field.

### 3.6.12 Grain:Straw Ratio

This was obtained by dividing the weight of grain of each net plot with its corresponding straw weight.

### 3.6.13 Data Analysis

The data were analyzed using Analysis of Variance (ANOVA) in a Microcomputer Statistical Programme (MSTAT) (MSU, 1985). The treatment means were separated using Duncan's Multiple Range Test (DMRT) in the same programme. Linear correlation between the variables under trial were examined using correlation/regression procedures (MSU, 1985). Polynomials of the first and second order for the different levels of the factors under trial with respect to grain yield were also examined as described by Little and Hills (1978) and Gomez and Gomez (1986).

## CHAPTER 4

# RESULTS

### 4.1 Total Tillers, 1990

Mean number of total tillers (/$m^2$) as affected by seed rate, variety, nitrogen and phosphorus during 1990 rainy season is shown in Table 1, while their corresponding analysis of variance is shown in Appendix E1. Analyzed data showed that mean differences due to variety and nitrogen were both significant at 1% level; while differences due to seed rate and phosphorus were not significant.

Variety x seed rate interaction was also found to be significant at 5% level. With regard to nitrogen levels, it was found that total tiller number increased with increase in nitrogen level from control to 45 kg/ha. A further increase from 45 - 90 kg/ha left the tiller number statistically unchanged. The variety Ex-China produced a significantly higher number of tillers per unit area than ITA 257.

With regard to seed rate x variety interaction, when both paddy cultivars were examined at each seeding rate, it was found that in case of ITA 257, tiller number increased significantly with increase in seed rate from 30 - 75 kg/ha; while the difference between 75 and 120 kg/ha was not significant. In case of Ex-China, the tiller number remained statistically similar across the seeding rates, although

Table 1. Mean number of total tillers of paddy (/m$^2$) as affected by Seed rate, Variety, Nitrogen and Phosphorus during 1990 rainy season.

| Seed kg/ha | Varieties | | | N (kg/ha) | Total tillers | P (kg/ha) | Total tillers |
|---|---|---|---|---|---|---|---|
| | ITA 257 | Ex-China | Mean | | | | |
| 30 | 592 c | 934 a | 763 a | 0 | 684 b | 0 | 749 a |
| 75 | 730 b | 897 a | 814 a | 45 | 804 a | 10 | 783 a |
| 120 | 724 b | 821 ab | 772 a | 90 | 861 a | 20 | 817 a |
| SE ± | 63.4 | | | SE± | 42 | SE± | 63.4 |
| Sig. | * | | | Sig. | ** | Sig. | ns |
| Mean | 682 b | 884 a | | | | | |
| SE ± | 36.6 | | | | | | |
| Sig. | ** | | | | | | |

NS *, ** - not significant and significant at 5 and 1% levels, respectively. Means followed by the same letter within a treatment group either amongst marginal means, or those within the first order of interaction are not different statistically by DMRT at 5% level.

Table 2. Mean number of total tillers of paddy (/m$^2$) as affected by nitrogen, seed rate, phosphorus and variety during 1991 rainy season.

| N (kg/ha) | Total tillers | Seed (kg/ha) | Total tillers | P (kg/ha) | Total tillers | Varieties | Total tillers |
|---|---|---|---|---|---|---|---|
| 0 | 438 b | 30 | 474 a | 0 | 481 a | ITA 257 | 415 b |
| 45 | 532 a | 75 | 490 a | 10 | 502 a | Ex-China | 583 a |
| 90 | 527 a | 120 | 532 a | 20 | 514 a | | |
| SE± | 28.8 | SE± | 28.8 | SE± | 18.9 | SE± | 15.5 |
| Sig. | ** | | ns | | ns | | ** |

NS & * , ** - not significant and significant. at 5 & 1% levels, respectively.

Means followed by the same letter within a treatment group are not different statistically by DMRT at 5% level.

there was a trend of decrease in tiller number with increase in seed rate. Considering both varieties at each level of seed, the data revealed that Ex-China had a significantly higher number of total tillers across the rates except at the highest rate wherein the cultivars were at par. No other first or higher order of interaction was found to have a significant effect on total tillers.

### 4.2 Total Tillers, 1991

Mean number of total tillers (/$m^2$) of paddy as affected by nitrogen, seed rate, phosphorus and variety during 1991 rainy season is shown in Table 2, while their corresponding analysis of variance is shown in Appendix E2. Analysis of the data showed that of the factors under trial, mean differences due to varieties and nitrogen were both significant at 1% level; while those due to seed rate and phosphorus were not significant. The data revealed that total tiller number in this season increased significantly with increase in nitrogen from control to 45 kg, but the difference between 45 and 90 kg N/ha was not significant. Amongst the varieties, Ex-China produced a significantly higher number of tillers than ITA 257. None of the interactions was found to be significant.

### 4.3 Total Tillers, 1992

Mean number of total tillers ($m^2$) of rice as affected by nitrogen, seed rate

Table 3. Mean number of total tillers (/m$^2$) as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1992 rainy season.

| N (kg /ha) | Total tillers | Seed rate (kg/ha) | Total tillers | P (kg /ha) | Total tillers | Varieties | Total tillers |
|---|---|---|---|---|---|---|---|
| 0 | 695 a | 30 | 728 a | 0 | 720 a | ITA 257 | 683 a |
| 45 | 715 a | 75 | 752 a | 10 | 720 a | Ex-China | 747 a |
| 90 | 735 a | 120 | 665 b | 20 | 705 a | | |
| SE± | 16.1 | SE± | 16.1 | SE± | 22.5 | SE± | 18.4 |
| Sig. | ns | SE | ** | SE | ns | SE | ns |

NS & ** - not significant and significant. at 1% level, respectivefy.

Means followed by the same letter within a treatment group are not different statistically by DMRT at 5% level.

Table 4. Mean number of ear-bearing tillers (/m$^2$) as affected by Variety, Seed rate, Nitrogen and Phosphorus during 1990 rainy season.

| | Seed rate | | | | N (kg /ha) | Ears | P (kg /ha) | Ears |
|---|---|---|---|---|---|---|---|---|
| Vars | 30 | 75 | 120 | Mean | | | | |
| ITA 257 | 443c | 497ab | 498ab | 479a | 0 | 458a | 0 | 476a |
| Ex-China | 529a | 493a-c | 469bc | 497a | 45 | 493a | 10 | 496a |
| | | | | | 90 | 514a | 20 | 493a |
| SE± | | 24.7 | | 14.3 | SE± | 22.2 | SE± | 17.5 |
| Sig. | | ** | | ns | Sig. | ns | Sig. | ns |
| Mean | 486a | 495a | 484a | | | | | |
| SE± | | 22.2 | | | | | | |
| Sig. | | ns | | | | | | |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter within a treatment group either amongst marginal means,or those within the first order of interaction are not different statistically by DMRT at 5% level.

and phosphorus levels, and varieties is shown in Table 3 , and the corresponding analysis of variance in Appendix E3. The total tiller number was significantly affected by seed rates ($P < 0.05$), but not by nitrogen, phosphorus or varieties. Increasing seed rates from 30 - 75 kg did not significantly affect the mean tiller number/unit area, but both levels produced significantly higher number of tillers than 120 kg seed/ha.

None of the first order of interactions was found to be significant, but of the second order of interactions, nitrogen x seed rate x phosphorus was significant at the 5% level. A combination of 90 kg N, 75 kg Seed and 10 kg/ha P was found to be the best combination tested in total tiller production. No other interactions produced any significant effect on the tiller number.

### 4.4 Ear-bearing Tillers, 1990

Mean number of ear-bearing tillers (/$m^2$) of paddy as affected by variety, seed rate, nitrogen and phosphorus during 1990 rainy season is shown in Table 4, and their corresponding analysis of variance is presented in Appendix E4. Analysis of the data revealed that none of the factors under trial was found to have a significant effect on the number of ear-bearing tillers/unit area.

Seed rate x variety interaction was found to be significant at 1% level. When

looked at each seed rate, it was found that the varieties were similar across the rates except at 30 kg seed/ha wherein Ex-China produced a significantly higher number of ears/unit area than ITA 257. When each variety was considered across the seed rates, it was noted that in case of ITA 257, the ear number increased with increase in seeding rate from 30 - 75 kg/ha, beyond which there was no further increase in the ear-bearing tillers. In the case of Ex-China, ear number decreased with each increase in seed rate, but only the difference between 30 and 120 kg/ha seed rates was statistically significant. No other interactions of either the first or higher order was found to be significant in this trial.

### 4.5 Ear-bearing Tillers, 1991.

Mean number of ear-bearing tillers/$m^2$ of paddy as affected by nitrogen, seed rate, variety and phosphorus during 1991 rainy season is shown in Table 5, while their corresponding analysis of variance is shown in Appendix E5. Analysis of the data showed that mean differences in the ear number due to nitrogen, seed rate and variety were significant at 1, 5 and 1 percent levels respectively. However, phosphorus means were not found to vary significantly. The data further revealed that an increase in nitrogen from control to 45 kg/ha significantly increased ear number/unit area. A further increase in the level from 45 - 90 kg decreased the number, but not significantly. The ear number also increased when the seed rate was raised from 30 - 75 kg/ha, with a further increase leaving the number

Table 5. Mean number of ear-bearing tillers of paddy (/m$^2$) as affected by Nitrogen, Seed rate, Variety and Phosphorus during 1991 rainy season.

| N (kg/ha) | Seed rate (kg/ha) | | | Varieties | | Mean | P (kg/ha) | Ears |
|---|---|---|---|---|---|---|---|---|
| | 30 | 75 | 120 | ITA 257 | Ex-China | | | |
| 0 | 254d | 321c | 382ab | 262d | 377b | 319b | 0 | 356a |
| 45 | 372a-c | 414a | 382ab | 315c | 464a | 389a | 10 | 362a |
| 90 | 343bc | 400a | 381ab | 277cd | 472a | 375a | 20 | 366a |
| SE± | | 23.5 | | SE± | 19.7 | 13.6 | SE ± | 13.9 |
| Sig. | | * | | Sig. | * | ** | Sig. | ns |
| Mean | 323b | 378a | 382a | 285b | 438a | | | |
| SE± | | 13.6 | | | 11.4 | | | |
| Sig. | | ** | | | ** | | | |

NS, * & ** - not significant and significant at 5 and 1% levels, respectively.

Means followed by the same letter in a treatment group either amongst marginal means, or within the first order of interaction are not different statistically by DMRT at 5% level.

Table 6. Mean number of ear-bearing tillers of paddy (/m$^2$) as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1992 rainy season.

| N (kg/ha) | Ears | Seed rate (kg/ha) | Ears | P (kg/ha) | Ears | Varieties | Ears |
|---|---|---|---|---|---|---|---|
| 0 | 313a | 30 | 277b | 0 | 315a | ITA 257 | 297b |
| 45 | 319a | 75 | 342a | 10 | 316a | Ex-China | 354a |
| 90 | 346a | 120 | 359a | 20 | 347a | | |
| SE± | 8.6 | SE± | 8.6 | SE± | 8.4 | SE± | 6.8 |
| Sig. | ** | Sig. | ** | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not different statistically by DMRT at 5% level.

statistically the same. The cultivar Ex-China was found to produce a significantly higher number of ears/unit area than ITA 257.

Nitrogen x seed rate interaction was also found to be significant at 1% level. When the seed rate was considered at varying nitrogen levels, the data showed that with the exception of the highest seed rate of 120 kg/ha, there was a significant increase in ear number/unit area when the nitrogen level was raised from 0 - 45 kg/ha, but a further increase in N to 90 kg/ha did not significantly change the number of ears. In case of 120 kg seed/ha, the ear number remained the same at all levels of nitrogen tested. When each level of nitrogen was examined at varying seed rates, it was found that in case of control N, the ear number increased significantly progressively at all seed rates, but in case of 45 N/ha, the ear number remained the same across the seeding rates. In case of 90 kg N/ha, the ear number increased significantly with increasing seed rate from 30 - 75 kg/ha, but a further increase led to a decrease in the ear number, though not significantly.

Nitrogen x variety interaction was also found to be significant at 5% level. When both varieties were considered across nitrogen levels, the data showed that in both cultivars the ear number increased when the nitrogen level was raised from 0 - 45 kg with a further increase in the nutrient leaving the number statistically unchanged. When both cultivars were examined at each nitrogen

level, it was discovered that Ex-China was superior to ITA 257 significantly at all levels of nitrogen. No other first order or higher order interaction was found to be significant.

### 4.6 Ear-bearing Tillers, 1992

Mean number of ear-bearing tillers (/m$^2$) of paddy as affected by nitrogen, seed rate and phosphorus levels, and varieties during 1992 rainy season is presented in Table 6, and their corresponding analysis of variance in Appendix E6. The differences in means due to seed rates and varieties were both significant at 1% level. The differences in means due to nitrogen and phosphorus, however, could not attain the level of significance. 30 kg seed rate/ha resulted in significantly lower number of ears/unit area than the other levels, and the difference between 75 and 120 kg seed/ha was not significant. The variety Ex-China produced a significantly higher number of ears/unit area than ITA 257.

The second order interaction of nitrogen x seed rates x phosphorus was also found to be significant at 5% level. In general, the seed rate of 75 kg/ha in combination with either 45 kg N or the highest level of P (20 kg/ha) resulted in higher number of ear-bearing tillers/unit area. No first order interactions, the third order, or others of the second order were found to have any significant effect on the number

of ear-bearing tillers/unit area.

### 4.7 Ear-bearing Tillers Combined over 1990-92 Seasons

Mean number of ear-bearing tillers (/$m^2$) of paddy as affected by nitrogen, seed rate, phosphorus and variety during 1990-92 is shown in Table 7, while their corresponding analysis of variance is presented in Appendix E7. According to analyzed data, mean differences due to nitrogen, seed rate and variety were all highly significant at 1% level. Phosphorus means were however not significantly different. The analysis revealed that increase in nitrogen from 0 - 45 kg/ha significantly increased the number of ear-bearing tillers/unit area,but the difference between the second and the third level was not significant. Similarly, the ear number increased significantly with increased seeding only up to 75 kg seed/ha beyond which the increase was not significant. With regard to the paddy cultivars, Ex-China produced a significantly higher number of ears than ITA 257. None of the interactions between the factors under trial had any significant effect on the ear number.

### 4.8 Days to 50% Flowering, 1990

Mean number of days to 50% flowering in paddy as affected by variety, seed

Table 7. Mean number of ear-bearing tillers (/$m^2$) of paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1990 - 92 rainy seasons.

| N (kg /ha) | Ears | Seed rate (kg/ha) | Ears | P (kg /ha) | Ears | Varieties | Ears |
|---|---|---|---|---|---|---|---|
| 0 | 363b | 30 | 361b | 0 | 382a | ITA 257 | 354b |
| 45 | 401a | 75 | 405a | 10 | 391a | Ex-China | 429a |
| 90 | 411a | 120 | 408a | 20 | 402a | | |
| SE± | 10.2 | SE± | 10.2 | SE± | 9.3 | SE± | 7.6 |
| Sig. | ** | Sig. | ** | Sig. | ** | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter(s) within a treatment group are not different *statistically by DMRT at 5% level.*

Table 8. Mean number of days to 50% flowering (DF) in paddy as affected by Variety, Seed rate, Phosphorus and Nitrogen during 1990 rainy season.

| | Seed rate (kg/ha) | | | P (kg/ha) | | | Mean | N (kg/ha) | DF |
|---|---|---|---|---|---|---|---|---|---|
| Vars. | 30 | 75 | 120 | 0 | 10 | 20 | | | |
| ITA 257 | 69b | 66c | 61d | 67c | 66cd | 64d | 66cd | 0 | 69a |
| Ex-China | 72a | 72a | 70ab | 72ab | 70b | 73a | 72a | 45 | 68a |
| SE± | | 1.3 | | | 1.2 | | | 90 | 68a |
| Sig. | | ** | | | * | | | SE± | 1.0 |
| | | | | | | | | Sig. | ns |
| Mean | 71a | 69a | 66b | 70a | 68a | 69a | | | |
| SE± | | 1.0 | | | 0.9 | | | | |
| Sig. | | ** | | | ns | | | | |

NS, * & ** - not significant and significant at 5 and 1 % levels, respectively.

Means followed by the same letter(s) amongst the marginal ones and those within the first order of interaction are not different statistically by DMRT at 5% level.

rate, phosphorus and nitrogen during 1990 is shown in Table 8, while their corresponding analysis is shown in Appendix E8. According to the analyzed data, mean differences due to variety and seed rate were both found to be significant at 1% level; while the effects of nitrogen and phosphorus were found to be non significant. Amongst the varieties, Ex-China took a significantly longer period to flower than ITA 257. Ripenness to flower was not hastened significantly by increase in seed rate from 30 - 75, but the latter two flowered significantly later than plants sown at 120 kg/ha.

Seed rate x variety interaction was found to be significant at 1% level. When examined at varying seed rates, the results indicated that Ex-China flowered at a significantly later time than ITA 257 at all the seed rates tested. When each of the varieties was considered at each seed rate, it would be seen that in case of ITA 257, there was a significant progressive decrease in flowering time with increase in the rate of seeding, but in case of Ex-China, time to flowering was not significantly affected by seed rate.

Phosphorus x variety interaction was also found to be significant at 5% level. At each P level when both cultivars were examined, it was found that ITA 257 flowered in a significantly shorter period than Ex-China at all P levels, but when each cultivar was considered, in case of ITA 257, it was found that flowering was

significantly delayed when P was not applied than at 20 kg P/ha was given. Thus, the difference between the control and 10 kg P/ha was not significant and similarly so between 10 and 20 kg P/ha. In case of Ex-China, the difference in the time to flowering between control P and 10 kg P/ha was not significant, but the third P rate of 20 kg/ha was significantly later than the second rate. No other interaction was found to be significant.

### 4.9 Days to 50% Flowering, 1991

Mean number of days to 50% flowering in paddy as affected by nitrogen, seed rate, phosphorus and variety during 1991 rainy season is presented in Table 9, while their analysis of variance is shown in Appendix E9. According to the analysis, mean differences due to nitrogen, seed rate and variety were all highly significant at 1% level. Phosphorus means were not significantly different, however.The data has shown that increase in nitrogen from 0 - 45 kg/ha tended to decrease time to flowering significantly, but a further increase showed no significant change in the period. Increased seeding had a similar effect on time to flowering with that of nitrogen. With regard to the varieties, ITA 257 flowered in a significantly shorter period than Ex-China.

Nitrogen x seed rate interaction was also found to be significant at 1% level.

Table 9. Mean number of days to 50% flowering (DF) as affected by Seed rate, Nitrogen, Varieties and Phosphorus during 1991rainy season.

| Seed rate (kg/ha) | Nitrogen (kg/ha) | | | Varieties | | Mean | P (kg/ha) | DF |
|---|---|---|---|---|---|---|---|---|
| | 0 | 45 | 90 | ITA 257 | Ex-China | | | |
| 30 | 67a | 65b | 65b | 64b | 68a | 66a | 0 | 65a |
| 75 | 65b | 65b | 65b | 63b | 67a | 65b | 10 | 65a |
| 120 | 65b | 64b | 65b | 62b | 67a | 65b | 20 | 65a |
| SE± | SE± | 0.3 | | SE± | 0.2 | 0.3 | SE± | 0.3 |
| Sig. | | ** | | | ** | ** | Sig. | ns |
| Mean | 66a | 65b | 65b | 63b | 67a | | | |
| SE± | SE± | 0.3 | | SE± | 0.2 | | | |
| Sig | | ** | | | ** | | | |

NS & ** - not significant and significant at 1%, respectively.

Means followed by the letter within a treatment group either amongst marginal means or within the first order of interaction are not different statistically by DMRT at 5% level.

Table 10. Mean number of days to 50% flowering (DF) in paddy as affected by Variety, Seed rate, Phosphorus and Nitrogen during 1992 rainy season.

| Vars. | Seed rate (kg/ha) | | | Phosphorus(kg/ha) | | | Mean | N (kg/ha) | DF |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 75 | 120 | 0 | 10 | 20 | | | |
| ITA 257 | 73ab | 68b | 60c | 70bc | 68c | 63d | 67b | 0 | 72a |
| Ex-China | 77a | 78a | 73ab | 76a | 74ab | 78a | 76a | 45 | 72a |
| SE± | | 2.4 | | | 2.4 | | 1.4 | 90 | 71a |
| Sig. | | * | | | * | | ** | SE± | 1.8 |
| Mean | 75a | 73a | 67b | 73a | 71a | 71a | | Sig. | ns |
| SE± | | 1.8 | | | 1.7 | | | | |
| Sig. | | ** | | | ns | | | | |

NS, * & ** - not significant and significant at 5 and 1% levels respectively.
Means followed by the letter within a treatment group either amongst marginal means or within the first order of interaction are not different statistically by DMRT at 5% level.

At the same nitrogen level, when the seed rate was varied, the data revealed that at control N, the period to flowering decreased significantly with increase in seeding, while at both 45 and 90 kg N/ha, the period was attained about the same time irrespective of the seed rate. When each seed rate was examined at varying nitrogen levels, it was found that at 30 kg/ha, time to flowering was reached significantly later at control N than at the two higher N levels of 45 and 90 kg/ha, which did not differ amongst themselves. However, at both 75 and 120 kg seed/ha, the length of time to flowering remained the same across the nitrogen levels.

Seed rate x variety interaction was also found to be significant at 1% level. At the same seed rate when the paddy cultivars were examined, Ex-China was found to flower significantly later than ITA 257 at all the seed rates tested. When each variety was considered in relation to the seed rates, in case of ITA 257 there was a significant reduction in flowering time as the seed rate was progressively increased from 30 - 120 kg/ha. In case of Ex-China, at 30 kg/ha time to flowering was found to be significantly delayed compared to the higher levels of 75 and 120 kg/ha, which in turn did not differ. No other interactions were found to affect flowering time significantly.

## 4.10 Days to 50% Flowering, 1992

Mean number of days to 50% flowering in paddy as affected by variety, seed rate, phosphorus and nitrogen during 1992 rainy season is shown in Table 10. Their corresponding analysis of variance is shown in Appendix E10. Analyzed data showed that differences in means due to variety and seed rate were significant at 1% level; while those due to nitrogen and phosphorus were not significant. The variety Ex-China flowered significantly later than ITA 257 and increase in seed rate from 30 - 75 kg/ha did not significantly change the time to the attainment of 50% flowering, but the two seeding rates significantly delayed flowering than at 120 kg seed/ha.

Variety x seed rate interaction was found to be significant at 5% level. Considering each variety at varying rates of seeding, it was found that in case of ITA 257, flowering was reached about the same time at both 30 and 75 kg seed/ha, with a significant decrease in the period when the seed rate was increased from 75 to 120 kg/ha. However, in case of Ex-China, the flowering period was statistically the same across seeding rates. When both varieties were examined at each seed rate, it was clear that except at 30 kg seed wherein the cultivars were similar, Ex-China took a significantly longer period than ITA 257 to attain 50% flowering across the seed rates.

Phosphorus x variety interaction was also found to be significant at 5% level. At each P level when the varieties were examined, Ex-China flowered significantly later than ITA 257 across phosphorus levels. Considering each variety at the varying P levels revealed a trend similar to that between seed rate x varieties. No other first order or other higher interactions were found to have a significant effect on flowering time in this season.

### 4.11 Days to Maturity, 1990

Mean number of days to maturity in paddy as affected by nitrogen, seed rate, phosphorus and variety during 1990 rainy season is shown in Table 11; while their corresponding analysis of variance is presented in Appendix E11. Analyzed data showed that of the factors under trial, only mean difference due to varieties was significant at 1% level. The effects of nitrogen, seed rate and phosphorus were not significant. Amongst the varieties, Ex-China matured significantly later than ITA 257.

Of the interactions, nitrogen x seed rate x variety was found to be highly significant ($p < 0.01$). Ex-China at 0 Kg N, 120 kg seed or 45 kg N, 30 kg seed or 45 kg N, 120 kg seed/ha took the longest period to maturity. No other interactions were found to be significant.

Table 11. Mean number of days to maturity (DTM) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1990 rainy season.

| N (kg/ha) | DTM | Seed rate (kg/ha) | DTM | P (kg/ha) | DTM | Varieties | DTM |
|---|---|---|---|---|---|---|---|
| 0 | 105a | 30 | 107a | 0 | 106a | ITA 257 | 100b |
| 45 | 106a | 75 | 105a | 10 | 105a | Ex-China | 110a |
| 90 | 104a | 120 | 105a | 20 | 105a | | |
| SE± | 1.2 | SE± | 1.2 | SE± | 0.8 | SE± | 0.6 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | ** |

NS & ** - Not significant and significant at 1%, respectively.

Means followed by the letter within a treatment group are not different statistically by DMRT at 5% level.

Table 12. Mean number of days to maturity (DTM) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1991 rainy season.

| N (kg/ha) | DTM | Seed rate (kg/ha) | DTM | P (kg/ha) | DTM | Varieties | DTM |
|---|---|---|---|---|---|---|---|
| 0 | 116a | 30 | 116a | 0 | 115a | ITA 257 | 109b |
| 45 | 114a | 75 | 114ab | 10 | 114a | Ex-China | 121a |
| 90 | 114a | 120 | 113b | 20 | 115a | | |
| SE± | 1.2 | SE± | 1.2 | SE± | 0.9 | SE± | 0.8 |
| Sig. | ns | Sig. | * | Sig. | ns | Sig. | ** |

NS, * & ** - not significant and significant at 5 and 1%, respectively.

Means followed by the letter within a treatment group are not different statistically by DMRT at 5% level.

### 4.12 Days to Maturity, 1991

Mean number of days to maturity in paddy as affected by nitrogen, seed rate, phosphorus and variety during 1991 rainy season is shown in Table 12; while their corresponding analysis of variance is shown in Appendix E12. Analysis of the data revealed that the mean number of days to maturity due to seed rate and variety were significant at 5 and 1% levels respectively, but neither nitrogen nor phosphorus were found to affect the time significantly. Increasing the seed rate from 30 - 75 kg/ha did not affect the time to maturity significantly. Similarly, the difference in the time between 75 and 120 kg/ha was not significant. However, plants sown at 30 kg/ha matured significantly later than those sown at 120 kg/ha. Ex-China ripened significantly later than ITA 257. None of the interactions was found to have a significant effect on the ripening period.

### 4.13 Days to Maturity, 1992

Mean number of days to maturity in paddy as affected by nitrogen, seed rate, phosphorus and variety during 1992 rainy season is presented in Table 13 and their corresponding analysis of variance is shown in Appendix E13. The analyzed data showed that means due to seed rate and variety were both significant at 1% level; while those due to nitrogen and phosphorus were not significant. In case of seed

Table 13. Mean number of days to maturity (DTM) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1992 rainy season.

| N (kg/ha) | DTM | Seed rate (kg/ha) | DTM | P (kg/ha) | DTM | Varieties | DTM |
|---|---|---|---|---|---|---|---|
| 0 | 94a | 30 | 96a | 0 | 94a | ITA 257 | 91b |
| 45 | 94a | 75 | 94ab | 10 | 93a | Ex-China | 97a |
| 90 | 94a | 120 | 92b | 20 | 94a | | |
| SE± | 1.0 | SE± | 1.0 | SE± | 0.9 | SE± | 0.7 |
| Sig. | ns | Sig. | ** | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter(s) in a treatment group are not statistically different by DMRT at 5% level.

Table 14. Mean plant height at maturity (cm) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1990 rainy season.

| N (kg/ha) | Height (cm) | Seed rate (kg/ha) | Height (cm) | P (kg/ha) | Height (cm) | Varieties | Height (cm) |
|---|---|---|---|---|---|---|---|
| 0 | 66.04b | 30 | 69.91a | 0 | 68.76a | ITA 257 | 76.80a |
| 45 | 70.00a | 75 | 68.96a | 10 | 70.19a | Ex-Chi. | 61.40b |
| 90 | 71.30a | 120 | 68.46a | 20 | 68.39a | | |
| SE± | 0.768 | SE± | 0.647 | SE± | 0.768 | SE± | 0.530 |
| Sig. | ** | Sig. | ** | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

rates, the period to maturity did not change with increase in seeding from 30 - 75 kg/ha, but the lowest rate of 30 kg/ha delayed the attainment of maturity significantly when compared to the highest rate of 120 kg/ha. With regard to the varieties, Ex-China ripened significantly later than ITA 257. None of the interactions was found to be significant.

### 4.14 Plant Height at Maturity, 1990

Mean plant height (cm) of rice as affected by nitrogen and phosphorus levels, seed rate and varieties is shown in Table 14; while their corresponding analysis of variance is shown in Appendix E14. Analysis of the data revealed that mean plant height due to nitrogen and varieties were significant both at the 1% level. The means due to phosphorus levels and seed rates were however not significant. Increase in nitrogen level from 0 - 45 kg produced significantly taller plants, but a further increase from 45 - 90 kg did not significantly change the plant height. The variety ITA 257 was found to be significantly taller than Ex-China. Neither the first, second nor the third order of interactions had any significant effect on plant height in this season.

### 4.15 Plant Height at Maturity, 1991

Mean plant height (cm) of rice as affected by variety, nitrogen, phosphorus

Table 15. Mean plant height at maturity (cm) of paddy as affected by Variety, Nitrogen, Phosphorus and Seed rate during 1991 rainy season.

| | Nitrogen (kg/ha) | | | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|---|---|---|
| Varieties | 0 | 45 | 90 | 0 | 10 | 20 | |
| ITA 257 | 76.26a | 78.19a | 75.59a | 77.04a | 74.67a | 78.33a | 76.68a |
| Ex-China | 53.15c | 65.78b | 75.26a | 63.26c | 69.00b | 61.93c | 64.73b |
| SE± | | 1.504 | | | 1.504 | | 0.868 |
| Sig. | | ** | | | * | | ** |
| Mean | 64.70b | 71.98a | 75.43a | 70.15a | 71.83a | 70.13a | |
| SE± | | 1.393 | | | 1.063 | | |
| Sig. | | ** | | | ns | | |

| Seed rate (kg/ha) | | |
|---|---|---|
| 30 | 75 | 120 |
| 70.17a | 71.76a | 70.19a |
| SE± | | 1.393 |
| Sig. | | ns |

NS, * & ** - not significant and significant at 5 and 1% levels, respectively.

Means followed by the same letter(s) in a treatment group either amongst marginal ones or within the first order of interaction are not statistically different by DMRT at 5% level.

and seed rates during 1991 rainy season is shown in Table 15; while their corresponding analysis of variance is shown in Appendix E15. The mean plant height due to nitrogen and varieties were significant at 1 and 5% levels respectively, but differences in means due to seed rates and phosphorus were not significant statistically. The data showed that increasing the nitrogen level from 0 - 45 kg/ha significantly increased plant height but a further increase from 45 - 90 kg N/ha did not bring about a significant change in the height. ITA 257 produced significantly taller plants than Ex-China.

*Nitrogen x variety interaction was also found to be highly significant* ($P < 0.01$). When the same variety was considered at varying levels of nitrogen, in case of ITA 257, plant height remained statistically similar at all levels of nitrogen. In the case of Ex-China, however, the plant height progressively increased significantly with each increase in nitrogen level from 0 - 90 kg/ha. When the varieties were considered at the same level of nitrogen, ITA 257 was found to be significantly taller at all levels of nitrogen except at the highest level of 90 kg N/ha, at which the varieties were statistically at par.

Phosphorus x variety interaction was also found to be statistically significant at the 5% level. At the same level of P when the varieties were considered, ITA 257 produced significantly taller plants than Ex-China at all levels of phosphorus.

When the variety was considered at varying levels of P, plant height did not vary significantly in case of ITA 257, but in case of Ex-China, there was a significant increase in height when the phosphorus level was raised from 0 - 10 kg. However, the difference between the control and 20 kg P was not significant. No other first order or second order interactions were found to be significant. The third order interaction was also not significant statistically.

### 4.16 Plant Height at Maturity, 1992

Mean plant height (cm) of rice as affected by seed rate, nitrogen, phosphorus and varieties during 1992 rainy season is shown in Table 16, and their corresponding analysis of variance is shown in Appendix E16. The means due to nitrogen, phosphorus and varieties were not statistically significant; while the means due to seed rates were significant at the 5% level. The rice plants sown at 30 kg/ha were found to be tallest with higher levels of seed significantly reducing the height.

Nitrogen x seed rate interaction was significant at the 5% level. When the seed rates were considered at the same level of nitrogen, at 90 kg N, mean plant height at all levels of seed were statistically at par. At 45 kg N, the tallest plants were produced at the highest seed rate of 120 kg/ha; while those produced at 30

Table 16. Mean plant height at maturity (cm) of paddy as affected by Variety, Nitrogen, Phosphorus and Seed rate during 1992 rainy season.

| Seed rate (kg/ha) | Nitrogen (kg/ha) 0 | 45 | 90 | Mean | P (kg /ha) | Ht. | Vars. | Ht. |
|---|---|---|---|---|---|---|---|---|
| 30 | 95.72a | 92.06bc | 93.44a | 93.74a | 0 | 91.24a | ITA 257 | 92.2a |
| 75 | 96.56e | 90.44b-d | 93.39a | 90.13c | 10 | 92.82a | Ex-Chi. | 91.8a |
| 120 | 89.94c-e | 93.28a | 93.06ab | 92.09b | 20 | 91.91a | | |
| SE± | | 0.933 | | 0.539 | SE± | 0.763 | SE± | 0.623 |
| Sig. | | * | | * | Sig. | ns | Sig. | ns |
| Mean | 90.74a | 91.93a | 93.30a | | | | | |
| SE± | | 0.639 | | | | | | |
| Sig. | | ns | | | | | | |

NS & * - not significant and significant at 5 % level, respectively.

Means followed by the same letter(s) in a treatment group either amongst marginal ones or within the first order of interaction are not statistically different by DMRT at 5% level.

Table 17. Mean percentage of lodged plants (/plot) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1990 rainy season.

| N (kg/ha) | Lodging | Seed rate (kg/ha) | Lodging (%) | P (kg/ha) | Lodging | Vars. | Lodging |
|---|---|---|---|---|---|---|---|
| 0 | 5.3a | 30 | 6.1a | 0 | 8.5a | ITA 257 | 13.9a |
| 45 | 10.6a | 75 | 10.1a | 10 | 7.3a | Ex-Chi. | 3.8b |
| 90 | 10.6a | 120 | 10.4a | 20 | 10.8a | | |
| SE± | 2.52 | SE± | 2.52 | SE± | 1.9 | SE± | 1.55 |
| Sig | ns | Sig. | ns | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group either amongst marginal ones or within the first order of interaction are not statistically different by DMRT at 5% level.

and 75 kg of seed were statistically at par. At the control level of N, the plants sown at 30 kg/ha were significantly taller than those sown at the higher seed rates of 75 and 120 kg/ha, and the latter two were found to be at par. No other first order interactions were found to be significant and neither the second nor the third order of interactions were statistically significant.

### 4.17 Lodging, 1990

Mean percentage of lodged plants in paddy as affected by nitrogen, seed rate, phosphorus and variety during 1990 rainy season is shown in Table 17; while their analysis of variance is shown in Appendix E17. Analysis of the data showed that with the exception of varieties whose difference was significant at 1% level, all the other factors under trial were not significant. Of the varieties, ITA 257 proved to be significantly more susceptible to lodging than Ex-China. None of the interactions was found to have any significant effect on lodging in this season.

### 4.18 Lodging, 1991

Mean percentage of lodged plants of paddy as affected by nitrogen, seed rate, phosphorus and variety during 1991 rainy season is shown in Table 18, and their corresponding analysis of variance in Appendix E18. Analyzed data revealed

Table 18. Mean number of lodged plants (/plot) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1991 rainy season.

| N (kg/ha) | Lodging (%) | Seed rate (kg/ha) | Lodging (%) | P (kg/ha) | Lodging (%) | Vars. | Lodging (%) |
|---|---|---|---|---|---|---|---|
| 0 | 6.7a | 30 | 7.7a | 0 | 10.2a | ITA 257 | 16.2a |
| 45 | 12.4a | 75 | 11.1a | 10 | 8.1a | Ex-Chi. | 1.6b |
| 90 | 7.6a | 120 | 7.9a | 20 | 8.3a | | |
| SE± | 3.50 | SE± | 3.50 | SE± | 2.80 | SE± | 2.30 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

Table 19. Mean number of lodged plants (/plot) in paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1992 rainy season.

| N (kg/ha) | Lodging (%) | Seed rate (kg/ha) | Lodging (%) | P (kg/ha) | Lodging (%) | Vars. | Lodging (%) |
|---|---|---|---|---|---|---|---|
| 0 | 4.4a | 30 | 4.7a | 0 | 13.2a | ITA 257 | 12.3a |
| 45 | 9.1a | 75 | 8.7a | 10 | 7.1b | Ex-Chi. | 5.4b |
| 90 | 13.0a | 120 | 13.2a | 20 | 6.2b | | |
| SE± | 3.90 | SE± | 3.90 | SE± | 2.30 | SE± | 1.90 |
| Sig. | ns | Sig. | ns | Sig. | ** | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

that with respect to this parameter, only mean difference due to variety was significant at 1% level, with ITA 257 being more significantly lodged than Ex-China. Nitrogen, seed rate and phosphorus had no significant effect on lodging in this trial. Also, none of the interactions had any significant effect on lodging.

### 4.19 Lodging, 1992

Mean percentage of lodged paddy plants as affected by nitrogen, seed rate, phosphorus and variety during 1992 rainy season is presented in Table 19, while their analysis of variance is shown in Appendix E19. The analyzed data showed that mean percentage differences of lodged plants due to nitrogen and seed rate were not significant, but those due phosphorus and variety were all highly significant ($p < 0.01$). With regard to phosphorus, a significantly higher percentage of plants lodged in treatments without the nutrient than in those treated to it. The difference between treatments fertilized with 10 and 20 kg P/ha was however not significant. The variety ITA 257 lodged significantly more than Ex-China. None of the interactions was found to significantly affect lodging.

### 4.20 Panicle Length, 1990

Mean panicle length (cm) of rice as affected by nitrogen and phosphorus

Table 20. Mean length of paddy panicle (cm) as affected by Nitrogen, Phosphorus, Seed rate, and Variety during 1990 rainy season.

| N (kg /ha) | Panicle Length (cm) | P (kg /ha) | Panicle Length (cm) | Seed rate (kg/ha) | Panicle Length (cm) | Vars. | Panicle Length (cm) |
|---|---|---|---|---|---|---|---|
| 0 | 18.70b | 0 | 19.82a | 30 | 20.50a | ITA 257 | 19.50a |
| 45 | 19.96a | 10 | 19.67a | 75 | 19.46b | Ex-Chi. | 19.80a |
| 90 | 20.37a | 20 | 19.57a | 120 | 19.07b | | |
| SE± | 0.178 | SE± | 0.168 | SE± | 0.178 | SE± | 0.140 |
| Sig | ** | Sig. | ns | Sig. | ** | Sig. | ns |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

Table 21. Mean length of paddy panicle (cm) as affected by Nitrogen, Phosphorus, Seed rate, and Variety during 1991 rainy season.

| N (kg /ha) | Panicle Length (cm) | P (kg /ha) | Panicle Length (cm) | Seed rate (kg/ha) | Panicle Length (cm) | Vars. | Panicle Length (cm) |
|---|---|---|---|---|---|---|---|
| 0 | 20.44a | 0 | 19.98b | 30 | 20.59a | ITA 257 | 20.50a |
| 45 | 20.43a | 10 | 20.74a | 75 | 19.96b | Ex-Chi. | 20.40a |
| 90 | 20.52a | 20 | 20.67a | 120 | 20.83a | | |
| SE± | 0.162 | SE± | 0.145 | SE± | 0.162 | SE± | 0.120 |
| Sig. | ns | Sig. | * | Sig. | * | Sig. | ns |

NS & * - not significant and significant at 1% level, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

levels, seed rate and varieties during 1990 rainy season is shown in Table 20, and their corresponding analysis of variance is presented in Appendix E20. Analysis of the data revealed that means due to nitrogen and seed rate were significant both at the 1% level; while those of phosphorus and varieties were not significant. It was found that increasing the nitrogen levels from 45 - 90 kg N/ha did not significantly change the panicle length, but the two levels produced significantly larger panicles than the control. With regard to the seed rates, plants sown at 30 kg/ha produced significantly larger panicles than those sown either at 75 or 120 kg of seed/ha; the latter two were found to be at par however. None of the first, second or third order of interactions was found to be significant.

### 4.21 Panicle Length, 1991

Mean panicle length (cm) of rice as affected by nitrogen and phosphorus levels, seed rate and varieties during 1991 rainy season is shown in Table 21; while their corresponding analysis of variance is shown in Appendix E21. The means of the length of the panicles due to seed rates and phosphorus levels were found to be statistically significant at the 5% level; while those due to nitrogen and varieties were not significant. In case of seed rates, 30 and 120 kg of seed produced significantly larger panicles than those sown at 75 kg/ha, but the two former rates did not differ significantly. Increasing the phosphorus levels from 0 -

10 kg also significantly increased the panicle length, but a further increase from 10 - 20 kg P left it unchanged.

S x P x V interaction was found to be significant at the 1% level. 30 kg seed and 10 kg P gave the largest panicles (21.89 cm) for ITA 257 and 30 kg seed and 20 kg P was best for Ex-China. The third order of interaction was also significant at the 5% level. The other interactions were not found to affect panicle length significantly.

**4.22 Panicle Length, 1992**

Mean length of panicles (cm) of rice as affected by phosphorus and nitrogen levels, seed rate and varieties during the 1992 rainy season is shown in Table 22; while their corresponding analysis of variance is shown in Appendix E22. Means of the lengths of the panicles due to phosphorus levels were significant at 5% level and those due to varieties at the 1% level. The means due to nitrogen and seed rates were not found to be significant. Phosphorus at 0 and 20 kg/ha produced panicles of similar size that were both significantly longer than those at 10 kg P. The variety Ex-China produced significantly longer panicles than those of ITA 257.

*Nitrogen x phosphorus interaction was found to be significant at the 1%*

Table 22. Mean length of paddy panicle (cm) as affected by Phosphorus, Nitrogen, Seed rate, and Variety during 1992 rainy season.

| | Nitrogen (kg/ha) | | | Mean | Seed rate (kg/ha) | Pan-'cle (cm) | Vars. | Pan-'cle (cm) |
|---|---|---|---|---|---|---|---|---|
| P(kg/ha) | 0 | 45 | 90 | | | | | |
| 0 | 21c | 23a | 26a | 22.3a | 30 | 22.3a | ITA 257 | 21b |
| 10 | 22b | 21c | 22b | 21.6b | 75 | 22.0b | Ex-Chi. | 23a |
| 20 | 23a | 22b | 23a | 22.4a | 120 | 22.0b | | |
| SE± | | 0.31 | | 0.18 | SE± | 0.20 | SE± | 0.15 |
| Sig. | | ** | | * | Sig. | * | Sig. | ** |
| Mean | 22a | 22a | 23a | | | | | |
| SE± | | 0.20 | | | | | | |
| Sig. | | ns | | | | | | |

Table 23. Mean number of grains/ear as affected by Nitrogen, Phosphorus, Seed rate, and Variety during 1990 rainy season.

| N (kg/ha) | Grains (/ear) | Seed rate | Grains (/ear) | P (kg/ha) | Grains (/ear) | Varieties | Grains (/ear) |
|---|---|---|---|---|---|---|---|
| 0 | 98.3b | 30 | 111.7a | 0 | 103.4a | ITA 257 | 125.5a |
| 45 | 106.5a | 75 | 100.3b | 10 | 104.5a | Ex-China | 82.9b |
| 90 | 107.9a | 120 | 100.5b | 20 | 104.7a | | |
| SE± | 1.85 | SE± | 1.85 | SE± | 1.67 | SE± | 1.46 |
| Sig. | * | Sig. | ** | Sig. | ** | Sig. | ** |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.

Means followed by the same letter in a treatment group amongst the marginal means and those within the first order of interaction are not statistically different by DMRT at 5% level.

level. When phosphorus rates were considered at the same level of nitrogen, at the control level of N, panicle size increased significantly with each increase in phosphorus level from 0 - 20 kg/ha. At 45 kg N, panicle length decreased significantly from 0 - 10 kg/ha and then increased from 10 - 20 kg/ha. At the highest level of N of 90 kg/ha, panicle size at 0 and 20 kg P were at par, but the two were found to produce larger panicles than those at 10 kg P. When the nitrogen rates were examined at different levels of phosphorus, it became clear that at control P, panicle size increased significantly as the nitrogen level was raised from 0 - 45 kg, but the panicles at 45 and 90 kg N were found to be similar in size. At both 10 and 20 kg P, plants treated to 0 and 90 kg N were at par, but produced significantly larger panicles than those to which 45 kg N was applied. The third order of interaction was also found to be significant at the 5% level. The other interactions were not significant.

### 4.23 Grains/Ear, 1990

The mean number of grain/ear as affected by nitrogen, seed rate phosphorus and varieties during 1990 rainy season is shown in Table 23, and their corresponding analysis of variance in Appendix E23. The grain number/ear was significantly affected by nitrogen at the 5% level and by Seed rates and varieties both at the 1% level. The means due to phosphorus were not statistically

significant. With regard to nitrogen, there was no significant difference between 45 and 90 kg N, but these two levels resulted in significantly higher grain number/ear than the control. In the case of seed rates, 30 kg of seed/ha gave significantly higher number of grains/ear than both 75 and 120 kg of seed; while the latter two were at par. The variety Ex-China produced significantly less number of grains/ear than ITA 257. None of the first, second or third order interactions were found to significantly affect the grain number.

### 4.24 Grains/Ear, 1991

Mean number of grains/panicle of rice as affected by nitrogen seed rate phosphorus and varieties during 1991 rainy season is shown in Table 24; while their corresponding analysis of variance is presented in Appendix E24. Analysis of the data revealed that amongst the treatments, only the differences between the varieties was significant ($P < 0.01$). The variety ITA 257 produced a significantly higher number of grains/ear than Ex-China. Seed rate x nitrogen and nitrogen x phosphorus interactions were, however found to be both significant at the 5% level.

At the same level of nitrogen when seed rates were examined, it was evident that at control N the difference in grain number between 30 and 75 kg and 75 and 120 kg/ha were not significant, but plants sown at 120 kg seed produced

Table 24. Mean number of grains/ear as affected by Nitrogen, Phosphorus, Seed rate, and Variety during 1991 rainy season.

| | Seed rate (kg/ha) | | | P (kg/ha) | | | Mean |
|---|---|---|---|---|---|---|---|
| N (kg/ha) | 30 | 75 | 120 | 0 | 10 | 20 | |
| 0 | 81.4bc | 88.6ab | 96.72a | 82.9cd | 84cd | 88.9a | 88.9a |
| 45 | 92.9a | 97.9a | 76.89b-e | 88.2bc | 94.2ab | 85.3bc | 89.2a |
| 90 | 86.0bc | 77.6b-d | 74.9c-f | 84.7bc | 80.2cd | 73.6cd | 79.5a |
| SE± | | 3.96 | | SE± | 3.63 | | 2.29 |
| Sig. | | * | | Sig. | * | | ns |
| Mean | 86.8a | 88.0a | 82.9a | | | | |
| SE± | | 2.29 | | | | | |
| Sig. | | ns | | | | | |

| Varieties | Grains (/ear) |
|---|---|
| ITA 257 | 92.8a |
| Ex-China | 79.0b |
| SE± | 1.70 |
| Sig. | * |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.

Means followed by the same letter(s) in a treatment group amongst the marginal means and those within the first order of interaction are not statistically different by DMRT at 5% level.

a significantly higher number of grains/ear than those sown at 30 kg/ha. At 45 kg N, again raising the seed rate from 30 - 75 kg left the grain number unchanged statistically, but both levels resulted in significantly more grains than 120 kg seed/ha; while at 90 kg N the grain number was similar across the seeding rates. When the various nitrogen levels were considered at each seed rate the data revealed that at 30 kg seed, the increase in the number of grains/ear from 0 - 45 kg N was significant, but there was a significant decrease in the number as the nitrogen rate was raised from 45 - 90 kg/ha. Both 0 and 90 kg N/ha produced ears with a similar number of grains at the 30 kg seed rate. At 75 kg seed, the grain number at control and 45 kg N was statistically the same, but a further increase in N rate from 45 - 90 kg led to a decrease in the number. Again, the grain numbers at the control and 90 kg N were found to be at par. At 120 kg seed, grain number significantly decreased with increase in nitrogen from 0 - 45 kg, but a further increase from 45 - 90 kg N left it unchanged.

Viewing nitrogen rates at each phosphorus level also showed that at 0 kg P, the grain number/ear across the nitrogen rates was similar. At 10 kg P, the number increased significantly with increasing N from 0 - 45 kg and then decreased significantly with a further increase from 45 - 90 kg N; while both 0 and 90 kg N resulted in similar grain numbers. At 20 kg P, the number significantly decreased with nitrogen enrichment from 0 - 45 kg and then remained the same

with a further increase from 45-90 kg. When P rates were varied at each N level, the data showed that at control N, grain number at 0 and 10 kg P was similar, but significantly increased from 10 - 20 kg/ha, but at 45 kg and 90 kg N, the number was statistically the same across P rates. No other interactions were found to be significant.

### 4.25 Grains/Ear, 1992

Mean number of grains/ear of rice as affected by nitrogen, seed rate phosphorus and varieties during 1992 rainy season in shown in Table 25, and their corresponding analysis of variance is shown in Appendix E25. Statistical analysis of the data showed that only means due to the varieties were significant ($P < 0.01$). None of the other treatments was found to be significant. The variety ITA 257 produced significantly more grains/ear than Ex-China. None of the interactions of any order was found to be significant.

### 4.26 Grains /Ear Combined over 1990-92 Seasons

Mean number of grains per ear of rice as affected by N and P levels, seed rates and varieties during 1990-1992 rainy seasons is shown in Table 26, and their corresponding analysis of variance is shown in Appendix E26. Results of the

Table 25. Mean number of grains/ear as affected by Nitrogen, Seed rate, Phosphorus, and Variety during 1992 rainy season.

| N (kg/ha) | Grains (/ear) | Seed rate (kg/ha) | Grains (/ear) | P (kg/ha) | Grains (/ear) | Varieties | Grains (/ear) |
|---|---|---|---|---|---|---|---|
| 0 | 124.5a | 30 | 135.6a | 0 | 126.3a | ITA257 | 133.8a |
| 45 | 127.4a | 75 | 125.6a | 10 | 129.0a | Ex-Chi. | 122.3b |
| 90 | 132.3a | 120 | 123.0a | 20 | 128.9a | | |
| SE± | 3.79 | SE± | 3.79 | SE± | 2.39 | SE± | 1.95 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.
Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

Table 26. Mean number of grains/ear as affected by Nitrogen, Phosphorus, Seed rate, and Variety during 1990 - 1992 rainy seasons.

| | Phosphorus (kg/ha) | | | Mean | Seed rate (kg/ha) | Grains (/ear) | Vars. | Grains (/ear) |
|---|---|---|---|---|---|---|---|---|
| N (kg/ha) | 0 | 10 | 20 | | | | | |
| 0 | 99b | 102ab | 111a | 104a | 30 | 112a | ITA257 | 117a |
| 45 | 109a | 110a | 105ab | 108a | 75 | 104b | Ex-Ch. | 95b |
| 90 | 108ab | 106ab | 104ab | 106a | 120 | 102b | | |
| SE± | | 2.0 | | 1.8 | SE± | 1.1 | SE± | 1.3 |
| Sig. | | * | | ns | Sig. | ** | Sig. | ** |
| Mean | 104a | 106a | 107a | | | | | |
| SE± | | 1.1 | | | | | | |
| Sig. | | ns | | | | | | |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.
Means followed by the same letter(s) in a treatment group either amongst marginal means or those within the first order of interaction are not statistically different by DMRT at 5% level.

analysis of the data revealed that differences in the means of grain number/ear due to nitrogen and phosphorus were not significant; while those due to varieties and seed rates were highly significant ($P < 0.01$). Nitrogen x phosphorus interaction was also significant at 5% level. With respect to seed rates, grain number was found to decrease significantly with increase in seeding from 30 - 75 kg/ha and plants sown at 75 and 120 kg/ha produced statistically similar grain numbers/ear. The cultivar ITA 257 consistently proved superior to Ex-China in the grain number/ear.

With respect to N x P interaction, when nitrogen levels were examined at each P rate, the data showed at control P, grain number/ear significantly increased when N was raised from 0 - 45 kg/ha, but a further increase from 45 - 90 kg N did not bring about a significant change in the number. At both 10 and 20 kg P, the grain number remained the same across N levels. Examining each N rate at varying P levels revealed that at control N, the differences between 0 and 10 and between 10 and 20 kg P/ha were not significant, but the grain number at 20 kg P was found to be significantly larger than at 0 P. At 45 and 90 kg N, the grain number was statistically unaffected across P levels.

### 4.27 1000-Seed Weight, 1990

Mean seed weight (g) of rice as affected by nitrogen, varieties, seed rate and phosphorus during 1990 rainy season is shown in Table 27; while their corresponding analysis of variance is shown in Appendix E27. The differences in the means due to nitrogen, phosphorus and seed rates were found to be non significant, but the difference in variety means was found to be highly significant ($p < 0.01$). N x V interaction was also significant at the 5% level. The variety ITA 257 produced significantly heavier seeds than Ex-China.

With regard to the N x V interaction, when the same nitrogen level was examined for the two varieties under study, ITA 257 produced heavier seeds than Ex-China at all levels of nitrogen. When the variety was studied for the different levels of nitrogen, in the case of ITA 257, 45 kg N produced significantly heavier seeds than both the control and 90 kg N/ha. In case of Ex-China, control N resulted in significantly heavier seeds than either 45 or 90 kg N/ha. No other first order, second or the third order interaction was found to be significant.

### 4.28 1000-Seed Weight, 1991

Mean weight of 1000-seeds (g) of rice as affected by nitrogen, seed rate

Table 27. Mean 1000-seed weight (g) of paddy as affected by Nitrogen, Variety, Seed rate, and Phosphorus during 1990 rainy season.

| N (kg/ha) | Varieties | | Mean | Seed rate (kg/ha) | 1000-seed wt. (g) | P (kg/ha) | 1000-seed wt (g) |
|---|---|---|---|---|---|---|---|
| | ITA 257 | Ex-Chi. | | | | | |
| 0 | 29.0b | 23.6c | 26.3a | 30 | 26.2a | ITA257 | 26.1a |
| 45 | 29.6a | 23.0d | 26.3a | 75 | 26.1a | Ex-Chi. | 26.1a |
| 90 | 28.9b | 22.8d | 25.9a | 120 | 26.2a | | |
| SE± | 0.165 | | 0.116 | SE± | 0.116 | SE± | 0.106 |
| Sig. | * | | ns | Sig. | ns | Sig. | ns |
| Mean | 29.2a | 23.2b | | | | | |
| SE± | 0.095 | | | | | | |
| Sig. | ** | | | | | | |

Table 28. Mean 1000-seed weight (g) of paddy as affected by Nitrogen, Seed rate, Phosphorus and Variety during 1991 rainy season.

| N (kg/ha) | 1000-seed wt.(g) | Seed rate (kg/ha) | 1000-seed wt. (g) | P (kg/ha) | 1000-seed wt. (g) | Vars. | 1000-seed wt. (g) |
|---|---|---|---|---|---|---|---|
| 0 | 26.3a | 30 | 26.7a | 0 | 27.0a | ITA 257 | 29.0a |
| 45 | 27.1a | 75 | 26.5a | 10 | 26.7a | Ex-Chi. | 24.6b |
| 90 | 27.0a | 120 | 27.2a | 20 | 26.7a | | |
| SE± | 0.297 | SE± | 0.297 | SE± | 0.222 | SE± | 0.181 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | ** |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.
Means followed by the same letter in a treatment group either amongst marginal means or those within the first order of interaction are not statistically different by DMRT at 5% level.

and phosphorus levels, and varieties during 1991 rainy season is shown in Table 28, and their corresponding analysis of variance in Appendix E28. The mean seed weight was not significantly affected by nitrogen, phosphorus or seed rates, but varieties produced a highly significant effect ($P < 0.01$). The variety ITA 257 produced heavier seeds than Ex-China. None of the first, second or third order interactions was found to have a significant effect on the seed weight.

### 4.29 1000-Seed Weight, 1992

Mean weight of 1000-seed (g) of rice as affected by nitrogen and phosphorus levels, seed rate and varieties during 1992 rainy season is shown in Table 29, and their corresponding analysis of variance in Appendix E29. Analyzing the data statistically revealed that neither nitrogen nor seed rates produced significant effects on seed weight, but phosphorus levels and variety were significant at the 5 and 1% levels respectively. In case of phosphorus, increasing the level from 0 - 10 kg produced significantly heavier seeds, but a further increase from 10 - 20 kg significantly reduced the seed weight. ITA 257 produced significantly larger seeds than Ex-China. None of the interactions of the first, second or third order was significant.

Table 29. Mean 1000-seed weight (g) of paddy as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1992 rainy season.

| N (kg/ha) | 1000-seed wt (g) | P (kg/ha) | 1000-seed wt(g) | Seed rate (kg/ha) | 1000-seed wt(g) | Varieties | 1000-seed wt(g) |
|---|---|---|---|---|---|---|---|
| 0 | 29.02a | 0 | 28.65b | 30 | 28.96a | ITA 257 | 29.27a |
| 45 | 28.48a | 10 | 29.07a | 75 | 28.49a | Ex-Chi. | 28.13b |
| 90 | 28.60a | 20 | 28.38b | 120 | 28.65a | | |
| SE± | 0.150 | SE± | 0.130 | SE± | 0.130 | SE± | 0.110 |
| Sig. | ns | Sig. | * | Sig. | ns | Sig. | ** |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

Table 30. Mean 1000-seed weight (g) of paddy as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1990 - 1992 rainy season.

| N (kg/ha) | 1000-seed wt (g) | P (kg/ha) | 1000-seed wt(g) | Seed rate (kg/ha) | 1000-seed wt(g) | Varieties | 1000-seed wt(g) |
|---|---|---|---|---|---|---|---|
| 0 | 27.2a | 0 | 27.1a | 30 | 27.3a | ITA 257 | 29.1a |
| 45 | 27.3a | 10 | 27.3a | 75 | 27.0a | Ex-Chi. | 25.3b |
| 90 | 27.2a | 20 | 27.2a | 120 | 27.4a | | |
| SE± | 0.14 | SE± | 0.09 | SE± | 0.09 | SE± | 0.08 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | ns |

NS - not significant at 5% level.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

### 4.30 Mean 1000-Seed Weight Combined over 1990-92 Seasons

Means of 1000-seed weight (g) of rice as affected by the N, P, seed rates and varieties during 1990 - 1992 seasons are shown in Table 30, and their corresponding analysis of variance is shown in Appendix E30. Analyzing the data statistically revealed that of the factors under trial only the difference in means due to the rice cultivars was statistically significant ($P < 0.01$). ITA 257 consistently produced significantly heavier seeds than Ex-China.

### 4.31 Straw Weight, 1990

Mean weight of straw (t/ha) of rice as affected by nitrogen and phosphorus levels, seed rates and varieties during 1990 rainy season is shown in Table 31. Their corresponding analysis of variance in shown in Appendix E31. The mean straw weights were not significantly affected by nitrogen and seed rates, but they were significantly affected by phosphorus and varieties both at the 1% level. It was found that increasing levels of phosphorus from control to 10 kg reduced straw weight significantly, and a further increase from 10 - 20 kg produced significantly more straw, but 0 and 20 kg P/ha were statistically similar.

Nitrogen x phosphorus interaction was also significant at the 1% level. At

Table 31. Mean weight of paddy straw (t/ha) as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1990 rainy season.

| N (kg/ha) | Phosphorus (kg/ha) | | | Seed rate (kg/ha) | | | Varieties | | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 75 | 120 | ITA 257 | Ex-Ch | |
| 0 | 2.2c | 2.3c | 2.2c | 2.1c | 2.1c | 2.5a | 2.2b | 2.3b | 2.2a |
| 45 | 2.4c | 2.1d | 2.8a | 2.6a | 2.4b | 2.1c | 2.5a | 2.3b | 2.4a |
| 90 | 2.6b | 2.3c | 2.3c | 2.5a | 2.1c | 2.3b | 2.6a | 2.2b | 2.4a |
| SE± | | 0.04 | | | 0.06 | | | 0.04 | 0.03 |
| Sig. | | ** | | | ** | | | | ** |
| Seed rate (kg/ha | | | | | | | | | |
| 30 | 2.4a | 2.2b | 2.4a | | | | 2.3c | 2.5a | |
| 75 | 2.5a | 2.0d | 2.3b | | | | 2.5a | 2.1e | |
| 120 | 2.1c | 2.3b | 2.5a | | | | 2.4b | 1.9d | |
| Mean | 2.4a | 2.2b | 2.4a | 2.4a | 2.3a | 2.3a | 2.4a | 2.2b | |
| SE± | | 0.03 | | | 0.03 | | | 0.02 | |
| Sig. | | ** | | | ns | | | ** | |

NS & ** - not significant and significant at 1% level, respectively.
Means followed by the same letter in a treatment group either amongst marginal means or those within the first order of interaction are not statistically different by DMRT at 5% level.

Table 32. Mean weight of straw (t/ha) of paddy as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1991 rainy season.

| N (kg/ha) | Straw wt(t/ha) | Seed rate (kg/ha) | Straw wt(t/ha) | P (kg/ha) | Straw wt t/ha | Variety | Straw wt (t/ha) |
|---|---|---|---|---|---|---|---|
| 0 | 3.5b | 30 | 3.7b | 0 | 4.0a | ITA 257 | 4.5a |
| 45 | 4.6a | 75 | 4.7a | 10 | 4.5a | Ex-Chi. | 4.1b |
| 90 | 4.7a | 120 | 4.4a | 20 | 4.3a | | |
| SE± | 0.12 | SE± | 0.12 | SE± | 0.18 | SE± | 0.15 |
| Sig. | ** | Sig. | ** | Sig. | ns | Sig. | * |

NS, * & ** - not significant and significant at 5 and 1% levels, respectively.
Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

the same phosphorus level, in case of control P, increasing nitrogen level from 45 - 90 kg/ha gave a significantly higher amount of straw, but the difference between the control and 45 kg N was not significant. At 10 kg P increasing the nitrogen from 0 - 45 kg resulted in a significant decrease in the weight of straw, but a further increase in N level from 45 - 90 kg/ha produced significantly more straw, but not significantly different from that at control N. At 20 kg P straw weight significantly increased from 0 - 45 kg of N and then decreased significantly from 45 - 90 kg of N/ha. Again, 0 and 90 kg N were found to be at par.

Nitrogen x seed rate interaction was also significant ($P < 0.01$). When considered at the same seed rate, increasing the nitrogen level from 0 - 45 kg/ha led to a significant increase in straw weight except at the highest seed rate of 120 kg, at which the straw weight significantly decreased. A further increase in nitrogen from 45 - 90 kg increased straw weight significantly only at the highest seed rate. At 30 kg seed there was no significant difference in straw weight between 45 and 90 kg N/ha. At 75 kg seed/ha the straw weight decreased significantly when N level was increased from 45 to 90 kg/ha.

Nitrogen x variety interaction was also significant ($P < 0.01$). When considered at the same nitrogen level for both varieties, ITA 257 produced significantly more straw than Ex-China at all levels of N except at the control.

When the same variety was considered at varying levels of nitrogen, in case of ITA 257, the straw weight increased significantly from control to 45 kg N/ha, with a further increase from 45 - 90 kg N leaving the straw weight unchanged. In case of Ex-China, however, the straw weight was unchanged at all levels of nitrogen.

Seed rate x phosphorus interaction was also found to be significant at the 1% level. When considered at the same seed rate,in case of 30 and 75 kg of seed, increasing phosphorus level from 0 - 10 caused a significant decrease in straw weight, but a further increase from 10 - 20 kg P gave rise to a significantly higher straw weight. At the highest seed rate of 120 kg/ha mean straw weight increased progressively as P level was raised from 0 - 20 kg/ha.

Interaction between seed rate and variety was also significant at the 1% level. At all levels of seed rate except 30 kg, ITA 257 produced significantly more straw than Ex-China. When the same variety was considered at varying levels of seed, in case of ITA 257 straw weight was highest at 75 kg of seed compared with the other two levels, but in case of Ex-China, significantly more straw was produced at 30 kg of seed than at the subsequent higher rates.

The second order interactions of N x S x V, N x P x V and S x P x V were also found to be significant all at the 1% level. It was found that the following

combinations gave the highest straw weight: 45 kg N, 30 kg seed for ITA 257 and 90 kg N and 30 kg of seed for Ex-China; 45 kg N and 20 kg P for both varieties; 75 kg of seed and 0 kg P for ITA 257 and 30 kg of seed and 20 kg P for Ex-China respectively. The third order of interaction was also significant at the 1% level.

### 4.32 Straw Weight, 1991

Mean weight of straw (t/ha) of rice as affected by nitrogen, seed rate, phosphorus and varieties during 1991 rainy season is shown in Table 32; while the corresponding analysis of variance is shown in Appendix E32. Analysis of the data has shown that differences in the means due to nitrogen and seed rates were significant both at the 1% level, and the difference in the means due to varieties was significant at the 5% level. The means due to phosphorus levels were however not significant. Increasing levels of nitrogen from 0 - 45 kg produced a significantly higher yield of straw, but the difference between 45 and 90 kg N was not significant. Similarly, increasing the seed rate from 30 - 75 kg significantly increased straw weight, but the difference between the second and the third rates of 75 & 120 kg/ha was not significant. With regard to the varieties, ITA 257 produced significantly more straw than Ex-China. None of the first, second or the third order interactions were found to be significant.

### 4.33 Straw Weight, 1992

Mean weight of straw (t/ha) of rice as affected by nitrogen and seed rate, varieties and phosphorus during 1992 rainy season is shown in Table 33, and the corresponding analysis of variance in Appendix E33. Means due to nitrogen, seed rates, varieties and phosphorus were all found to be significant at the 1% level. Straw weight was progressively and significantly increased with each successive increase in N level from 0 to 90 kg/ha. The difference in the straw weight with increase in seed rate from 75 - 120 was not significant, but the latter two were both significantly higher than 30 kg seed. Ex-China produced a significantly higher yield of straw than ITA 257 only in this season.

Nitrogen x Seed rate interaction was also found to be significant at 5% level. When viewed across seed rates, at control N, straw yield did not differ between 30 and 75 kg seed/ha, but both were significantly lower than at 120 kg seed/ha. At 45 and 90 kg N, straw weight was significantly increased with seeding rate from 30 - 75 kg/ha, but a further increase from 75 - 120 did not bring about a significant change. When the seed rate was examined at varying N levels, at 30 kg/ha straw yield did not differ significantly across N rates. At 75 kg seed, the increase in straw yield was significant with each increase in N rate from 0 to 90 kg/ha. At 120 kg seed, straw yield was highest at the highest N rate of 90 kg N, but the

Table 33. Mean weight of paddy straw (t/ha) as affected by Nitrogen, Seed rate, Varieties and Phosphorus during 1992 rainy season.

| N (kg/ha) | Seed rate (kg/ha) 30 | 75 | 120 | Varieties ITA 257 | Ex-China | Mean | P (kg/ha) | Straw wt(t/ha) |
|---|---|---|---|---|---|---|---|---|
| 0 | 4.2e | 4.4e | 5.0c | 4.1c | 4.6c | 4.6c | 0 | 4.8b |
| 45 | 4.3de | 5.5c | 5.6bc | 4.3c | 6.0a | 5.1b | 10 | 5.1b |
| 90 | 4.6de | 6.2ab | 6.4ab | 5.5ab | 6.0a | 5.7a | 20 | 5.7a |
| SE± | | 0.15 | | SE± | 0.13 | 0.09 | SE± | 0.09 |
| Sig. | | * | | | ** | ** | Sig. | ** |
| Vars. | | | | | | | | |
| ITA257 | 3.5d | 4.7c | 5.6ab | | | | | |
| Ex-Ch. | 5.3b | 6.0a | 5.7ab | | | | | |
| Mean | 4.4b | 5.4a | 5.7a | 4.6b | 5.6a | | | |
| SE± | | 0.08 | | 0.07 | | | | |
| Sig. | | ** | | ** | | | | |

Table 34. Mean paddy yield (t/ha) as affected by Seed rate, Phosphorus, Nitrogen, and Varieties during 1990 rainy season.

| Seed rate (kg/ha) | Paddy yield | P (kg/ha) | Paddy yield | N (kg/ha) | Varieties ITA 257 | Ex-China | Mean |
|---|---|---|---|---|---|---|---|
| 30 | 1.92b | 0 | 2.13a | 0 | 1.77c | 1.70c | 1.73b |
| 75 | 2.08ab | 10 | 2.08a | 45 | 2.11b | 2.44a | 2.28a |
| 120 | 2.31a | 20 | 2.09a | 90 | 2.40a | 2.20b | 2.30a |
| SE± | 0.053 | SE± | 0.042 | SE± | 0.060 | | 0.053 |
| Sig. | * | Sig. | ns | Sig. | * | | ** |
| | | | | Mean | 2.09a | 2.11a | |
| | | | | SE± | 0.035 | | |
| | | | | Sig. | ns | | |

NS, * & ** - not significant and significant at 5 and 1% levels, respectively.
Means followed by the same letter in a treatment group either amongst marginal means or those within the first order of interaction are not statistically different by DMRT at 5% level.

difference between 0 and 45 kg N was not statistically significant.

Nitrogen x variety interaction was also found to be highly significant ($P < 0.01$). At the same N rate when both varieties were considered, Ex-China out-yielded ITA 257 at both 0 and 45 kg N/ha but at 90 kg N they were found to be at par. Viewing each variety across the N rates, it was observed that in case of ITA 257 straw yield at 90 kg N/ha and was significantly higer than those at 0 and 45 kg N which were statistically similar. In case of Ex-China there was a significant increase in the yield of the straw from 0 - 45 kg N, but at the higher rates of 45 and 90 kg/ha the straw yields did not differ significantly.

Seed rate x variety interaction was also found to be significant at 1% level. At both 30 and 75 kg seed/ha Ex-China out-yielded ITA 257 significantly, but at 120 kg seed straw yield for the two varieties were similar. When examined across the seed rates there was a progressive and significant increase in straw yield from 30 - 120 kg/ha in the case of ITA 257, but in case of Ex-China, a significant increase in straw yield was observed only from 30 - 75 kg seed/ha.

Seed rate x phosphorus x variety interaction was also found to be significant at the 5% level, 120 kg seed and 20 kg P/ha being the best combination for ITA 257; while for Ex-China 75 kg seed and 20 kg P/ha was found to be the best.

Their corresponding straw weights were 4.89 and 5.55 t/ha respectively. The third order interaction of N x S x P x V was also significant at the 1% level.

### 4.34 Grain Yield, 1990

Mean grain yield of paddy (t/ha) as affected by seed rate and phosphorus levels, nitrogen and varieties during 1990 rainy season is shown in Table 34, and their corresponding analysis of variance in Appendix E34. Analysis of the data revealed that seed rates and nitrogen were significant at the 5% and 1% levels respectively, whereas phosphorus and varieties were not significant. The paddy yield was not significantly affected when seed rate was increased from 30 - 75 kg/ha, or from 75 to 120 kg/ha, but the difference in between 30 and 120 kg seed rates was significant. In case of nitrogen levels, the paddy yield was significantly increased when the nutrient was increased from control to either 45 or 90 kg/ha. The difference between 45 and 90 kg N was not significant.

Nitrogen x variety interaction was also found to be significant at the 5% level. At 45 kg N, Ex-China yielded significantly higher than ITA 257, and the reverse was the case at 90 kg N/ha. There was no difference in the yields of the two varieties at 0 level of N. When the same variety was examined at varying levels of nitrogen, in case of ITA 257, each increase in nitrogen significantly

increased paddy yield, but in case of Ex-China, 45 kg N/ha yielded higher than both the control and 90 kg N/ha. The difference in yield between 0 and 90 kg N/ha was also significant. Other interactions were not found to be significant.

### 4.35 Grain Yield, 1991

Mean grain yield of paddy (t/ha) as affected by nitrogen and seed rate phosphorus and varieties during the 1991 rainy season is shown in Table 35, and their corresponding analysis of variance is shown in Appendix E35. Analyzing the data statistically revealed that the differences in means due to nitrogen and phosphorus levels were significant at the 5 and 1% levels respectively. The differences in the means due to seed rates and varieties, however were not found to be significant. In case of nitrogen, control level resulted in significantly lower paddy yield than both 45 and 90 kg N/ha. The difference between the latter two were, however, not significant. With respect to phosphorus, 10 kg P resulted in the highest paddy yield followed by 20 kg, which was also higher than the control.

Seed rate x phosphorus x variety interaction was significant at the 1% level. For the variety Ex-China, 120 kg of seed and 10 kg P/ha gave the highest paddy yield and for ITA 257, 75 kg seed and 20 kg P/ha was found to be the best combination. No other second order interaction was significant, and neither the first

Table 35. Mean paddy yield (t/ha) as affected by Nitrogen, Seed rate, Phosphorus and Varieties during 1991 rainy season.

| N (kg/ha) | Paddy yield | Seed rate | Paddy yield | P (kg/ha) | Paddy yield | Vars. | Paddy yield |
|---|---|---|---|---|---|---|---|
| 0 | 1.31b | 30 | 1.37a | 0 | 1.36c | ITA 257 | 1.49a |
| 45 | 1.60a | 75 | 1.54a | 10 | 1.62a | Ex-Chi. | 1.46a |
| 90 | 1.51a | 120 | 1.51a | 20 | 1.44b | | |
| SE± | 0.038 | SE± | 0.038 | SE± | 0.032 | SE± | 0.026 |
| Sig. | * | Sig. | ns | Sig. | ** | Sig. | ns |

NS, * & ** - not significant and significant at 5 & 1% levels, respectively.

Means followed by the same letter in a treatment group are not statistically different by DMRT at 5% level.

Table 36. Mean paddy yield (t/ha) as affected by Nitrogen, Seed rate, Phosphorus and Varieties during 1992 rainy season.

| N (kg/ha) | Paddy yield | Seed rate | Paddy yield | P (kg/ha) | Paddy yield | Vars. | Paddy yield |
|---|---|---|---|---|---|---|---|
| 0 | 2.45b | 30 | 2.55a | 0 | 2.33c | ITA 257 | 2.19b |
| 45 | 2.82ab | 75 | 2.81a | 10 | 2.81b | Ex-Chi. | 3.32a |
| 90 | 2.99a | 120 | 2.90a | 20 | 3.13a | | |
| SE± | 0.071 | SE± | 0.109 | SE± | 0.071 | SE± | 0.126 |
| Sig. | ** | Sig. | ns | Sig. | ** | Sig. | ** |

NS & ** - not significant and significant at 1% level, respectively.

Means followed by the same letter(s) in a treatment group are not statistically different by DMRT at 5% level.

nor the third order interactions were significant.

### 4.36 Paddy Yield, 1992

Mean grain yield of paddy (t/ha) as affected by nitrogen, phosphorus, seed rate and varieties during 1992 rainy season is shown in Table 36, while their corresponding analysis of variance is shown in Appendix E36. Analyzed data revealed that differences in means due to nitrogen, seed rates and varieties were all highly significant ($P < 0.01$); while phosphorus means were not statistically different. Paddy yield at control and 45 kg N/ha were found to be at par. Similarly, the difference between 45 and 90 kg N/ha was not significant, but 90 kg N produced a significantly higher paddy yield than the control. In case of seed rates, the differences in paddy yield from 30 - 120 were progressively significant. The variety Ex-China gave significantly higher yield of paddy than ITA 257. No interaction was found to have a significant effect on paddy yield in this season.

### 4.37 Polynomial Responses

#### 4.37.1 Polynomial response to nitrogen

Analysis of variance for responses to nitrogen are presented in Appendices

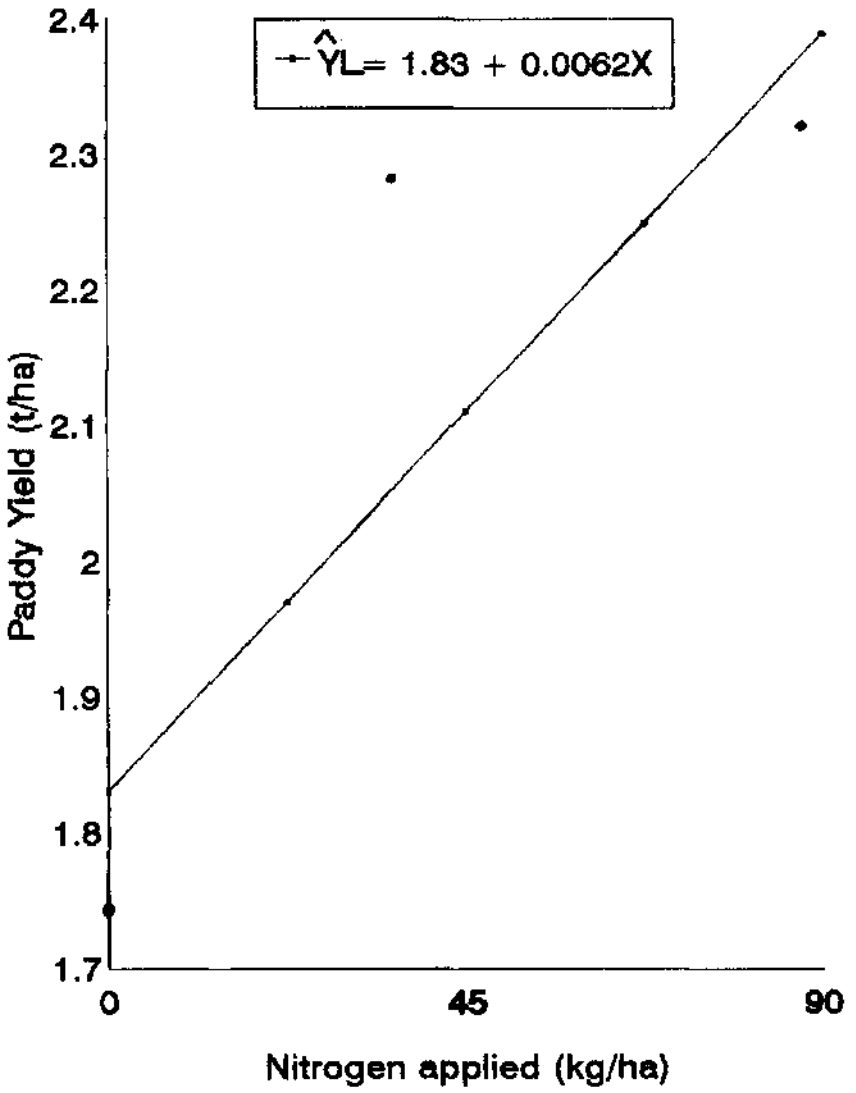



Figure 1. Polynomial response to N, 1990 rainy season

1 - 3 and 10. In 1990 rainy season, the response to nitrogen by paddy yield was best found to be linear because it was highly significant at 1% level. Quadratic response was found to be non significant (Figure 1). The respective functions were:

$$Y_l = 1.83 + 0.0062X$$

$$Y_q = 1.74 + 0.0178X - 0.000128X^2$$

In 1991, the relationship was found to be significant at 5% level with respect to both linearity and quadratic. However, since deviation from linearity was not significant while quadratic response was significant at 5% level, the best relationship between the parameters could be said to be linear (Figure 2) The respective functions were:

$$Y_l = 1.37 + 0.0022X$$

$$Y_q = 1.307 + 0.0106X - 0.0000938X^2$$

In 1992 rainy season, the linear relationship was hihgly significant at 1% level and the quadratic was not significant,but deviations from both were however not found to be significant (Figure 3). Thus, the best response in this trial could be described as linear. The following were the respective functions:

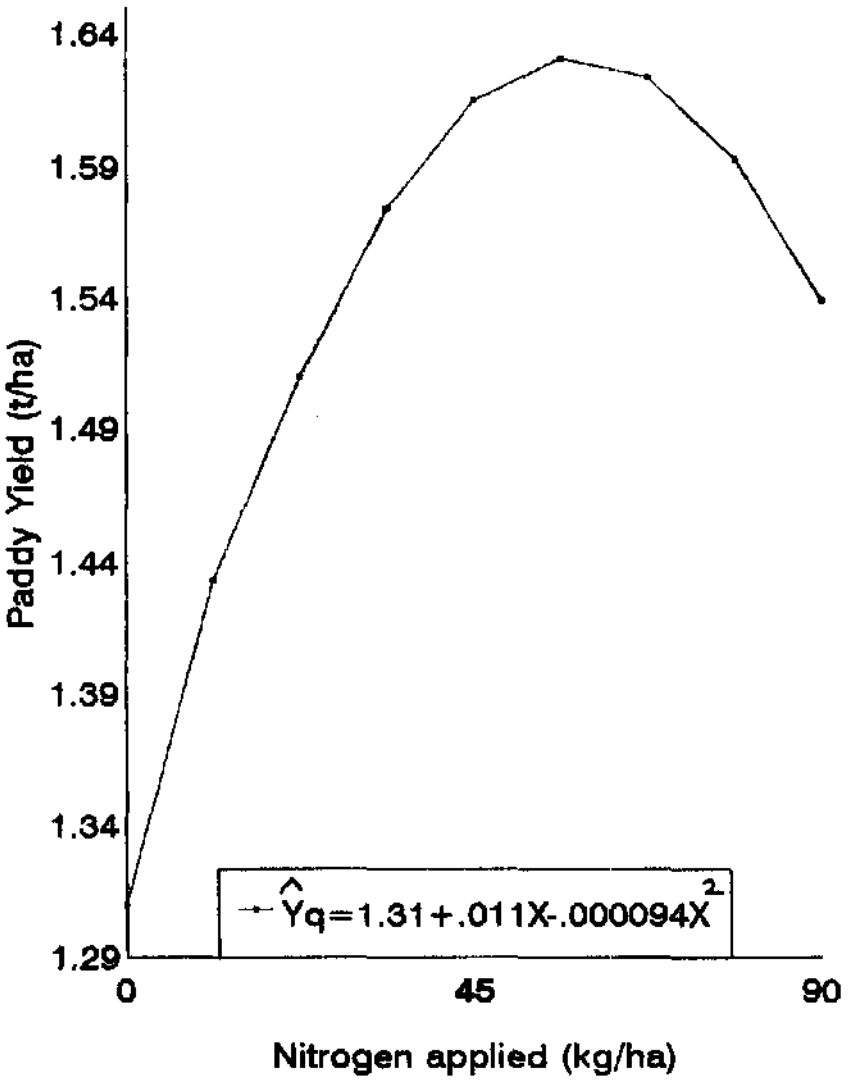



Figure 2. Polynomial response to N, 1991 rainy season

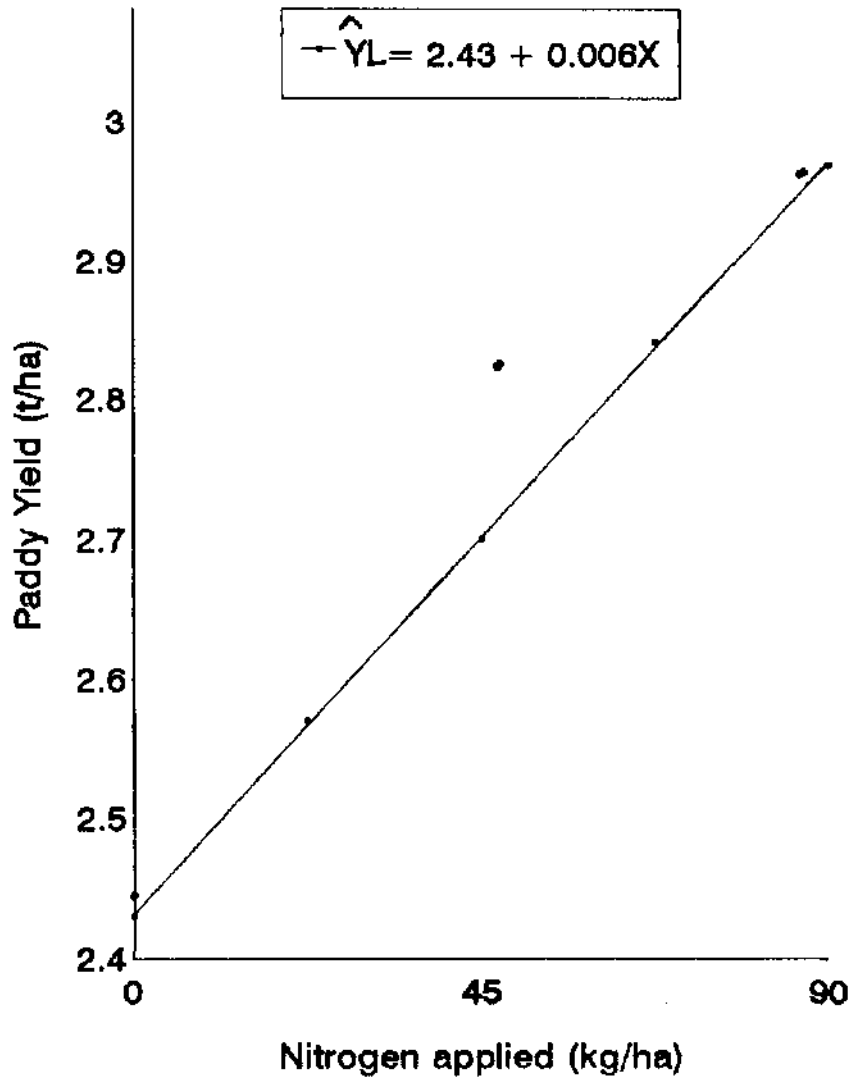



Figure 3. Polynomial response to N, 1992 rainy season

$$Y_l = 2.43 + 0.006X$$

$$Y_q = 2.45 + 0.0104X + 0.0000494X^2$$

### 4.37.2 Polynomial response to Phosphorus

Analysis of variace for responses to phosphorus are presented in Appendices 4 - 6 and 11. In 1990 rainy season, both linear and quadratic responses to P by the paddy yield as well as their deviations were found to be non significant (Figure 4). When this was examined in relation to soil reaction, it became obvious that due to the low pH (5.3) the response to P could not be seen to be manifested. The respective functions were:

$$Y_l = 2.08 + 0.0025X$$

$$Y_q = 2.14 - 0.0095X + 0.00035X^2$$

In 1991 season, the response relationship between Phosphorus and paddy yield was not significant in respect of linear response, but highly significant at 1% in respect of quadratic. Deviation from linearity was found to be highly significant, while deviation from quadratic was not significant (Figure 5). The following were the respective functions:

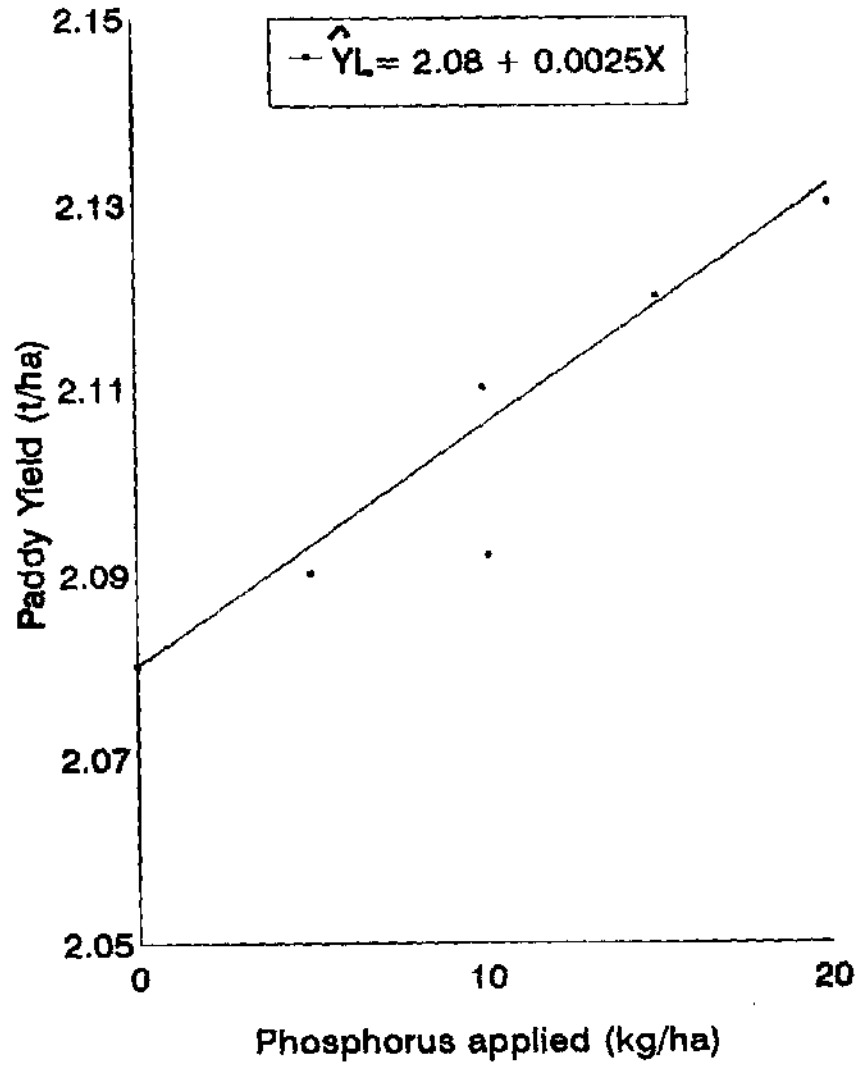



Figure 4. Polynomial response to P,1990 rainy season

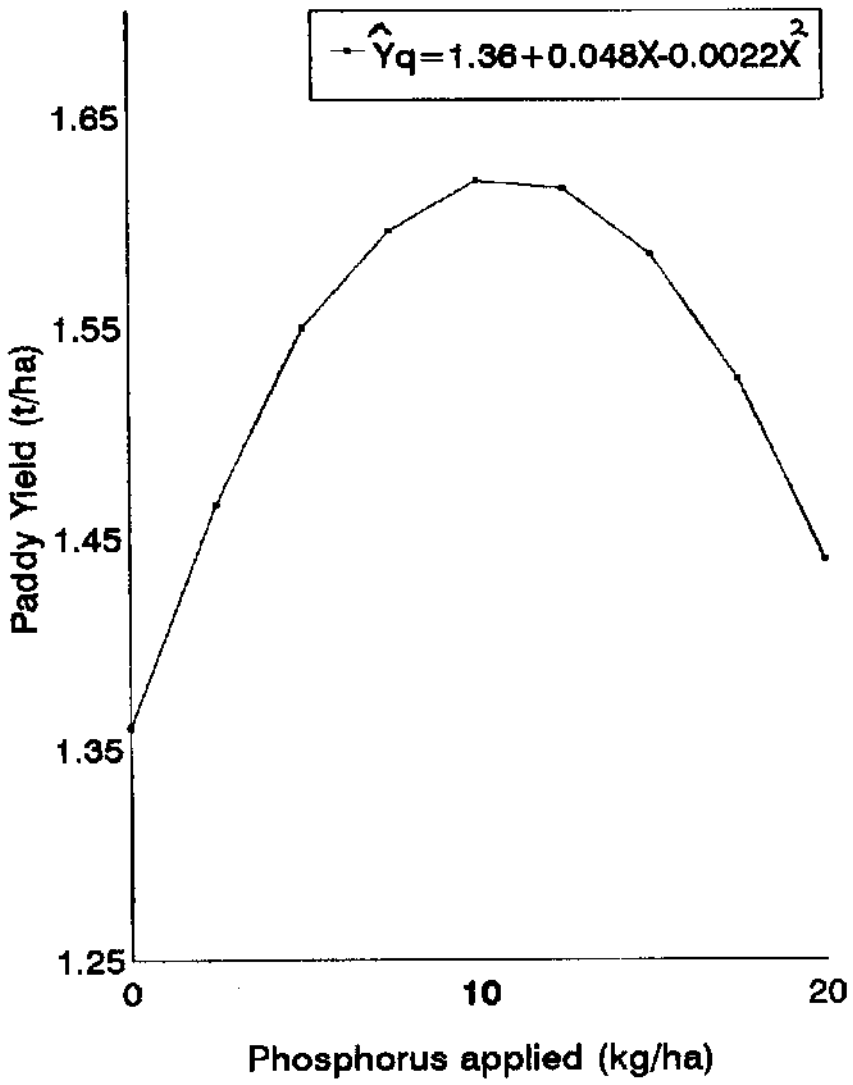



Figure 5. Polynomial response to P, 1991 rainy season

$$Y_l = 1.43 + 0.004X$$

$$Y_q = 1.36 + 0.048X - 0.0022X^2$$

In 1992, non of the polynomials was found to be significant nor were their deviations. (Figure 6). There was, however, a tendency to linearity. Therefore, the appropriate relationship could be linear. The respective functions were:

$$Y_l = 2.58 + 0.0175X$$

$$Y_q = 2.55 + 0.0345X + 0.00085X^2$$

### 4.37.3 Polynomial response to seed rate

Analysis variance for responses to seed rate are presented in Appendices 7 - 9 and 12. In 1990 season, the linear relationship between seed rate and paddy yield was found to be significant at 1% level; while quadratic response was not significant (Figure 7), indicating the best ralationship could be linear. The functions describing the relationships were:

$$Y_l = 1.90 + 0.0044X$$

$$Y_q = 1.88 + 0.0007X + 0.000025X^2$$

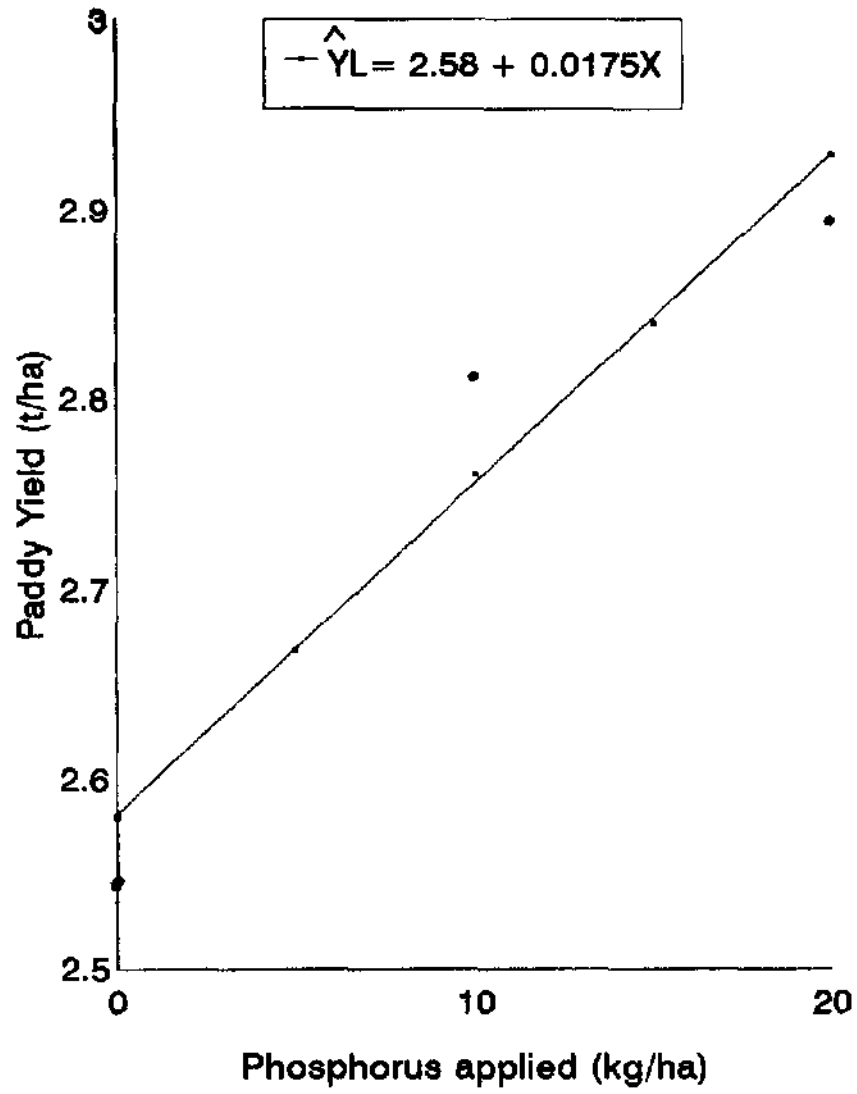



Figure 6. Polynomial response to P, 1992 rainy season

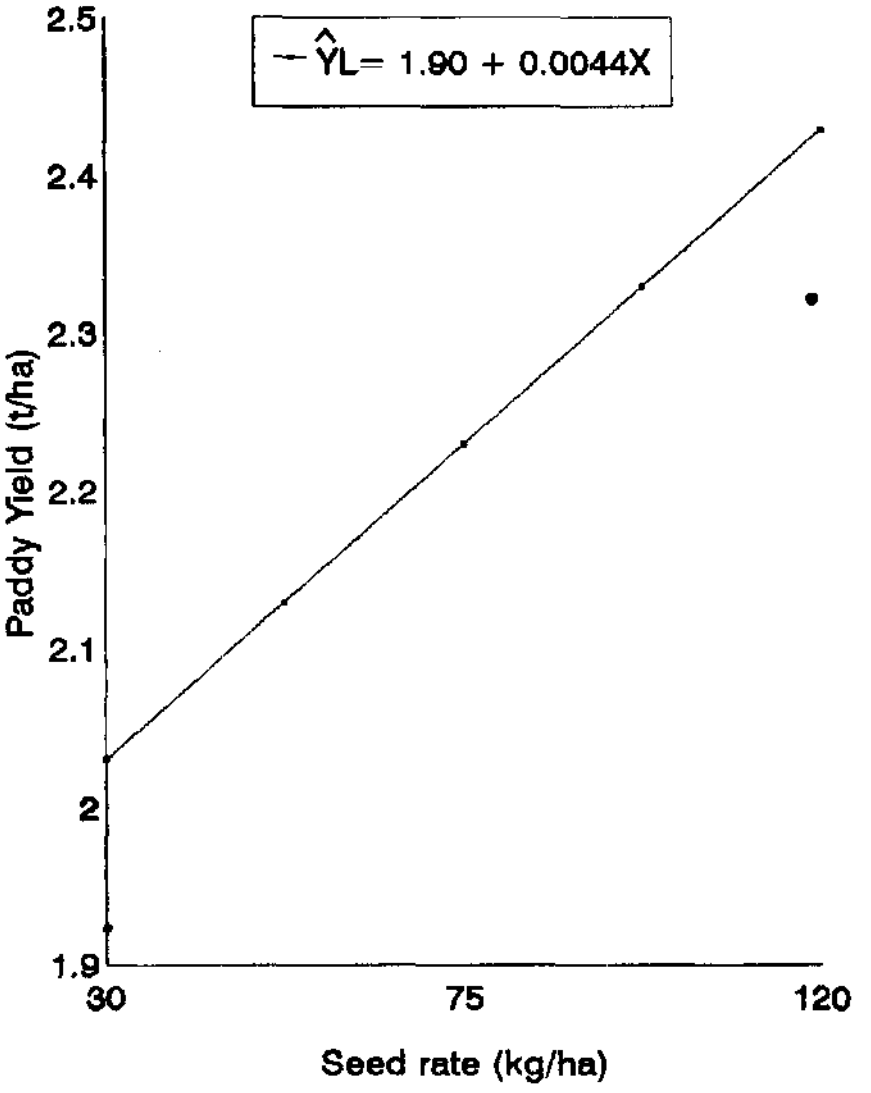



Figure 7. Polynomial response to Seed rate, 1990 rainy season

In 1991 rainy season, relationship between seed rate and paddy yield was not significant in respect of either linearity or quadratic nor were their deviations found to be significant (Figure 8). Tendency to linearity was however higher than quadratic. In view of this, it could be concluded that the appropriate response in this season was linear. The respective functions were:

$$Y_l = 1.35 + 0.00156X$$

$$Y_q = 1.14 + 0.00896X - 0.0000494X^2$$

*In 1992, the linear response was highly significant ($p < 0.01$) and deviation* from linearity was not significant. In case of quadratic, neither the response nor deviation from it was found to be significant (Figure 9). Thus, the response best fitting the relationship was linear. The following were the respective functions:

$$Y_l = 2.09 + 0.0089X$$

$$Y_q = 1.91 + 0.01484X - 0.000395X^2$$

### 4.38 Paddy yield combined over 1990-92 seasons

Mean grain yield (t/ha) of paddy as affected by nitrogen, phosphorus, seed rates and varieties during 1990 - 1992 rainy seasons is shown in Table 37, and

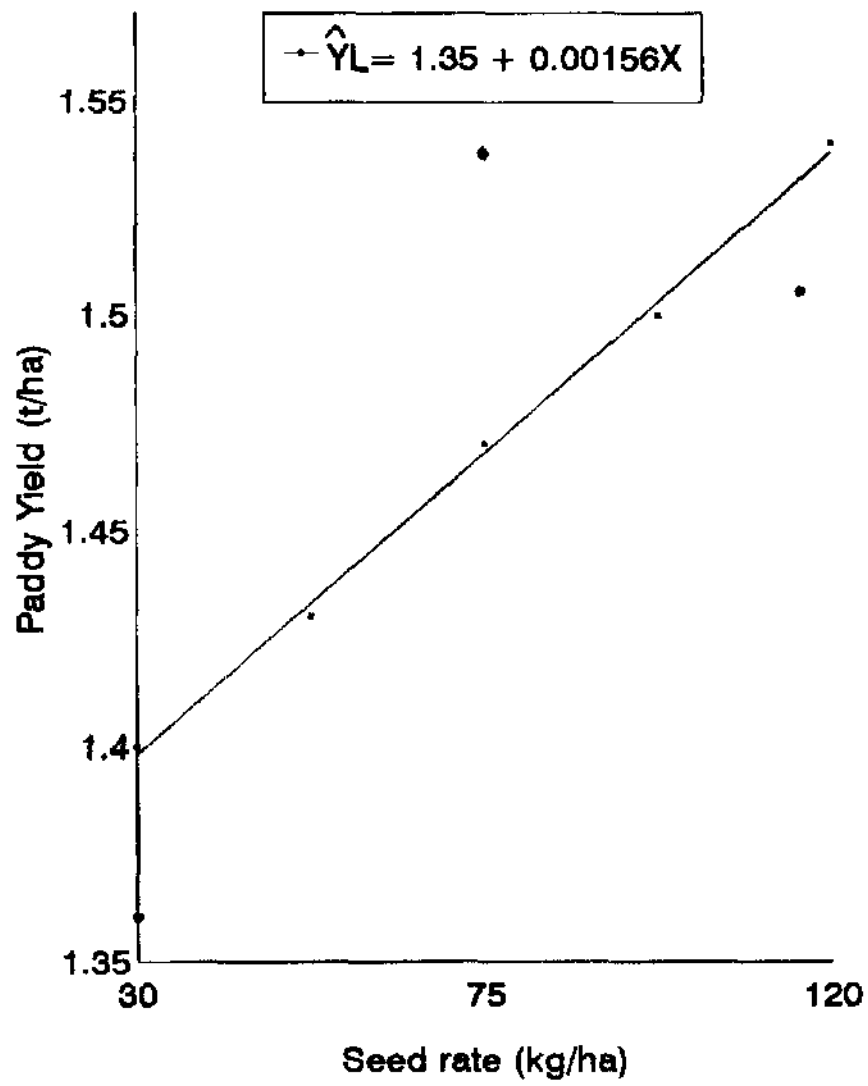



Figure 8. Polynomial response to Seed rate, 1991 rainy season

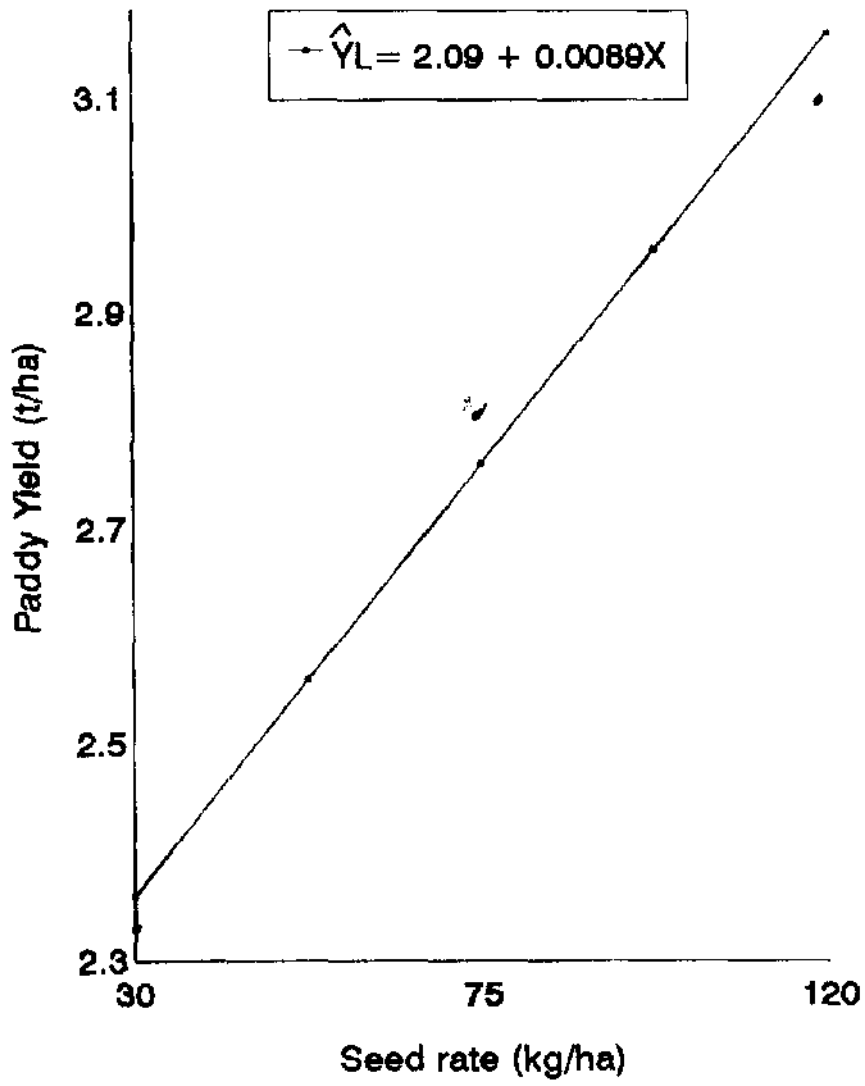



Figure 9. Polynomial response to Seed rate, 1992 rainy season

Table 37. Mean paddy yield (t/ha) as affected by Nitrogen, Phosphorus, Seed rate and Nitrogen during 1990 - 92 rainy season.

| N (kg/ha) | Paddy yield | P (kg/ha) | Paddy yield | Seed rate (kg/ha) | Paddy yield | Vars. | Paddy yield |
|---|---|---|---|---|---|---|---|
| 0 | 1.83b | 0 | 2.01a | 30 | 1.87c | ITA 257 | 1.93b |
| 45 | 2.23a | 10 | 2.17a | 75 | 2.14b | Ex-Chi. | 2.30a |
| 90 | 2.27a | 20 | 2.14a | 120 | 2.32a | | |
| SE± | 0.069 | SE± | 0.084 | SE± | 0.069 | SE± | 0.069 |
| Sig. | ** | Sig. | ns | Sig. | ** | Sig. | ** |

NS & * - not significant and significantat 1% level, respectively.

Means followed by the same letter in a treatment group are not different statistically by DMRT at 5% level.

their corresponding analysis of variance is presented in Appendix E37. Analysis of the data revealed that differences in the means due to nitrogen, seed rates and varieties were all highly significant at 1% level, but phosphorus means were statistically similar. Mean yields at 45 and 90 kg N were found to be similar, but were both significantly higher than at control N. In case of seed rates, paddy yield increased significantly across the rates from 30 - 120 kg/ha. Ex-China was, on the whole, found to be significantly higher paddy yielding variety than ITA 257.

### 4.38.1 Polynomial Response to N, P and Seed rate over 1990 - 92 Seasons

The combined yield response to nitrogen in respect of the experiment were found to be highly significant ($p < 0.01$) in respect of linearity and significant at 5% with respect to quadratic. Deviation from quadratic was highly significant; while deviation from linear response was not significant (Figure 10). In general, therefore, the best response could be said to be linear, since in two out of the three years of the experimentation, response to nitrogen had been linear. The respective functions were:

$$Y_l = 1.91 + 0.00489X$$

$$Y_q = 1.83 + 0.0129X - 0.000090X^2$$

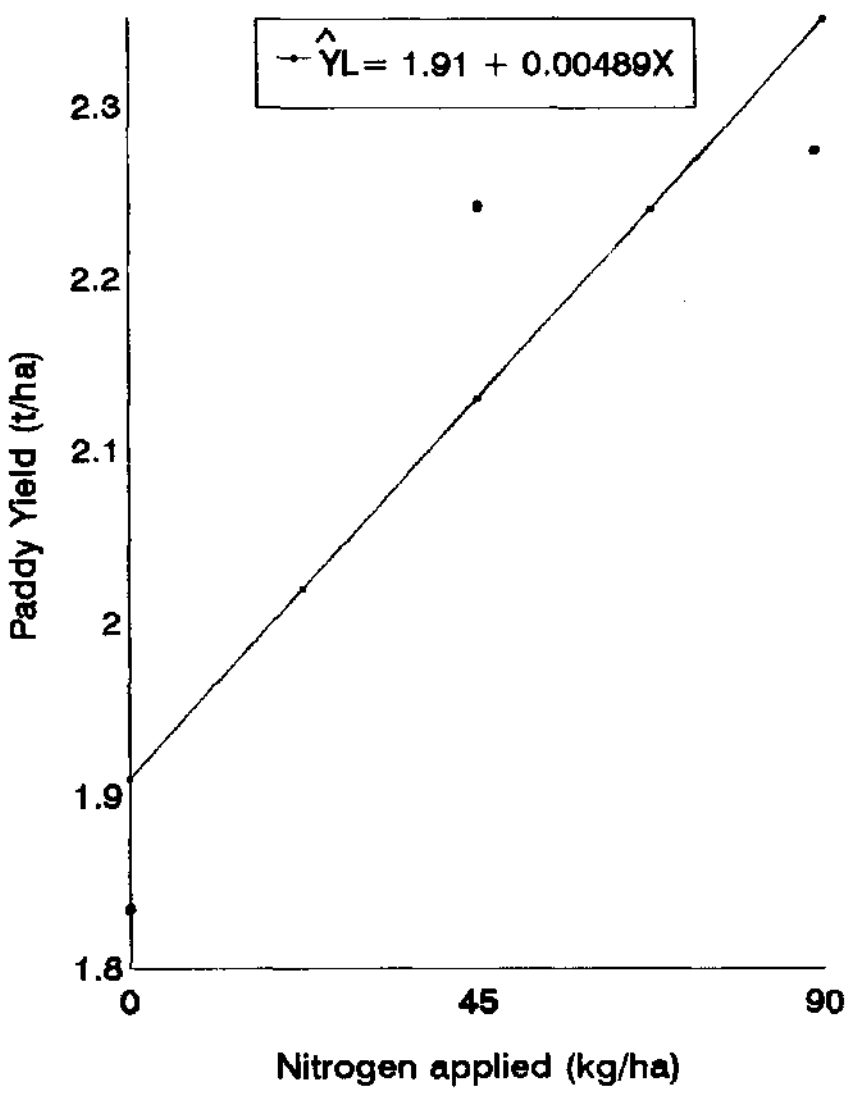



Figure 10. Polynomial response to N, 1990 - 92 rainy seasons

With respect to phosphorus, neither linear nor quadratic response was found to be significant. Deviations from them were also not found to be significant. Nevertheless, a close look at the figures revealed that the response tended more to quadratic than linearity (Figure 11). The respective functions were:

$$Y_l = 2.05 + 0.0065X$$

$$Y_q = 2.01 + 0.0255X - 0.00095X^2$$

With regard to seed rate, the linear response was found to be highly significant ($p < 0.01$) and deviation from it was not significant; while the quadratic response was not significant and deviation from it was highly significant over the seasons (Figure 12). As was the case with nitrogen, since response to seed rate in two out of three seasons was linear, this could similarly be said to be generally linear. The functions were:

$$Y_l = 1.74 + 0.0083X$$

$$Y_q = 1.64 + 0.0083X - 0.000022X^2$$

### 4.39 Correlation Studies

In 1990 cropping season, correlations between ear-bearing tillers, number

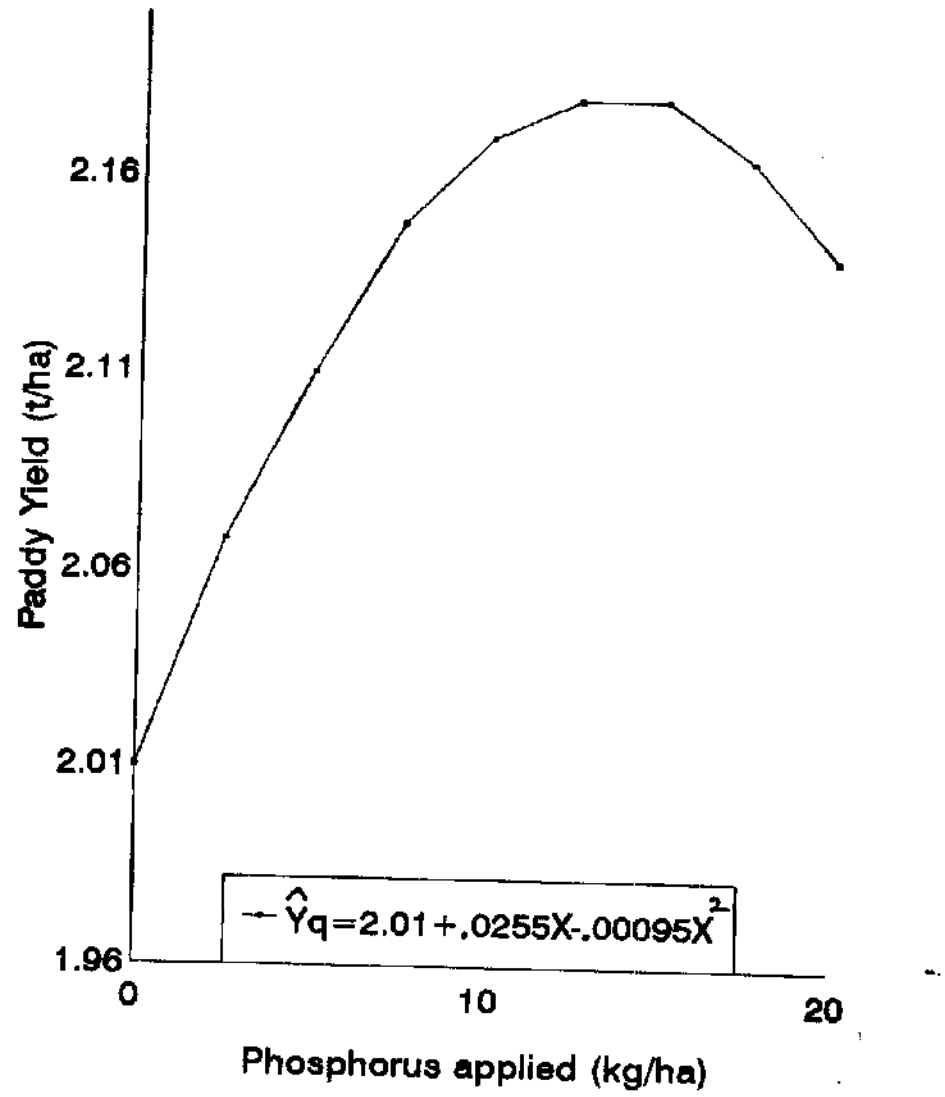



Figure 11. Polynomial response to P, 1990 - 92 rainy seasons

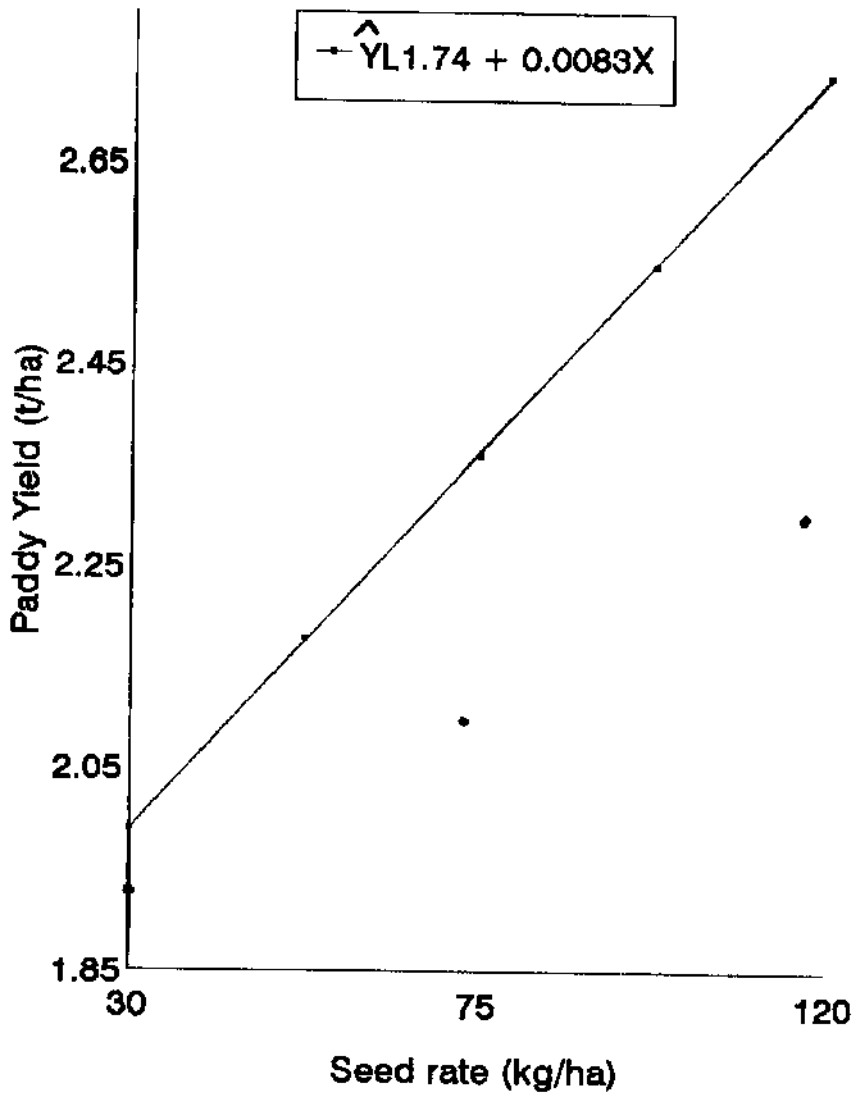



Figure 12. Polynomial response to Seed rate, 1990 - 92 rainy seasons

Table 38. Correlation coefficient matrices between yield and yield components and within the yield components as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1990 rainy season.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. Ear-bearing tillers/$m^2$ | 1.00 | | | |
| 2. Number of grains/ear | 0.09 ns | 1.00 | | |
| 3. 1000-seed weight | -0.03 ns | 0.435 ** | 1.00 | |
| 4. Paddy yield | 0.145 * | 0.068 ns | 0.064 ns | 1.00 |

NS, * & ** - not significant and significant at 5 and 1% level, respectively.

Table 39. Correlation coefficient matrices between yield and yield components and within the yield components as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1991 rainy season.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. Ear-bearing tillers/$m^2$ | 1.00 | | | |
| 2. Number of grains/ear | -0.234 ** | 1.00 | | |
| 3. 1000-seed weight | -0.398 ** | 0.214 ** | 1.00 | |
| 4. Paddy yield | 0.181 * | 0.019 ns | 0.096 ns | 1.00 |

NS, * & ** - not significant and significant at 5 and 1% level, respectively.

Table 40. Correlation coefficient matrices between yield and yield components and within the yield components as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1992 rainy season.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. Ear-bearing tillers/$m^2$ | 1.00 | | | |
| 2. Number of grains/ear | -0.067 ns | 1.00 | | |
| 3. 1000-seed weight | -0.195 * | 0.065 ns | 1.00 | |
| 4. Paddy yield | 0.336 ** | -0.103 ns | -0.275 ** | 1.00 |

NS, * & ** - not significant and significant at 5 and 1% level, respectively.

of grains/ear and 1000-seed weight and paddy yield were positive and in case of ear-bearing tillers, the relationship was significant at 5% level. Within the yield components, ear-bearing tillers/$m^2$ was positively correlated though not significantly with number of grains/ear. On the other hand, the number of tillers was negatively correlated with seed weight; while the number of grains/ear and seed weight were positively correlated and highly significant (Table 38).

In 1991 trial, the correlation between the yield components and the paddy yield was similar to that of the previous season. However, unlike in 1990, the number of ear-bearing tillers and number of grains/ear were negatively correlated and the correlation was highly significant ($p < 0.01$) as was also found to be the case between the former and seed weight. The correlation between the number of grains/ear and seed weight was negative and highly significant at 1% level (Table 39).

In 1992 growing season, only the correlation between the number of bearing tillers/$m^2$ and paddy yield was positive and highly significant ($p < 0.01$). Both the number of grains/ear and seed weight were negatively correlated with grain yield and in case of 1000-seed weight, the correlation was highly significant ($p < 0.01$). Amongst the yield components, the correlation between ear-bearing tiller number/unit area and number of grains/ear was negative, but not significant.

Similarly, the relationship between the former and seed weight was negative, but significant at 5% level; grain number/ear and seed weight were positively correlated but not significantly so (Table 40).

### 4.40 Grain:Straw ratio, 1990

Mean grain:straw ratio of rice as affected by N and P levels, seed rates and varieties during 1990 rainy season is shown in Table 41, and their corresponding analysis of variance in Appendix 41. Analysis of the data revealed that differences in the means of the grain-straw ratio due to nitrogen levels, Seed rates and Varieties were significant at 1%,5% and 1% levels respectively; while means due to phosphorus levels were not different statistically. The data has shown that increasing the N levels from 0 - 45 kg/ha significantly increased the grain-straw ratio, but a further increase from 45 - 90 kg N left the ratio statistically unchanged. With regard to the varieties, Ex-China had a significantly higher grain:straw ratio than ITA 257. With regard to seed rates, there was a significant increase in the grain-straw ratio when the rate was raised from 30 - 75 kg/ha, but the difference in the ratio between 75 and 120 kg/ha was not significant.

Nitrogen x Phosphorus interaction was significant at 5% level. At the same level of P when N rates were varied, it was found that at 0 kg P, grain-straw ratio

Table 41. Mean grain:straw ratio of paddy as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1990 rainy season.

| N (kg/ha) | Phosphorus (kg/ha) | | | Seed rate (kg/ha) | | | Mean |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 75 | 120 | |
| 0 | 0.45b-d | 0.42d | 0.44c | 0.43b-d | 0.46b-d | 0.41bc | 0.44b |
| 45 | 0.48a-c | 0.52a | 0.45bc | 0.42cd | 0.48b | 0.46bc | 0.48a |
| 90 | 0.48a-c | 0.49ab | 0.50b | 0.45b-d | 0.47b-d | 0.54a | 0.49a |
| SE | | 0.011 | | | 0.012 | | 0.007 |
| Sig. | | * | | | ** | | ** |

| Seed rate(kg/ha) | | | | Varieties | | Mean |
|---|---|---|---|---|---|---|
| | | | | ITA 257 | Ex-China | |
| 30 | 0.42d | 0.44cd | 0.44c | 0.44bc | 0.43c | 0.43b |
| 75 | 0.45b-d | 0.50ab | 0.47b-d | 0.44bc | 0.51a | 0.47a |
| 120 | 0.54a | 0.49a-c | 0.47b-d | 0.48b | 0.51a | 0.50a |
| SE± | | 0.011 | | | 0.009 | 0.500 |
| Sig. | | * | | | ** | * |
| Mean | 0.47a | 0.48a | 0.46a | 0.46b | 0.48a | |
| SE± | | 0.007 | | | 0.005 | |
| Sig. | | ns | | | * | |

| N (kg/ha) | | | |
|---|---|---|---|
| 0 | 0.45bc | 0.42c | 0.44b |
| 45 | 0.46bc | 0.51a | 0.48a |
| 90 | 0.47b | 0.51a | 0.49a |
| | | | 0.007 |
| SE | | 0.009 | |
| Sig. | | ** | |

NS, * & ** - not significant and significant at 5 and 1% levels respectively.
Means followed by the same letter(s) in a treatment group either amongst marginal means or within the first order of interaction are not statistically different by DMRT at 5% level.

did not differ statistically across N levels. At 10 kg P, an increase in N level from 0 - 45 kg/ha significantly raised the ratio, but a further increase from 45 - 90 kg N did not affect it significantly. At 20 kg P, significant differences were observed between the control and 90 kg N, there being no significant difference between the first two N levels. Varying the P levels at the same N rates, it was observed that at 0 kg N, there were no significant differences in grain-straw ratio at all levels of P. At 45 kg N, an increase in P level from 0 - 10 kg/ha did not affect the ratio, but raising the phosphorus rate from 10 to 20 kg P decreased it significantly. At 90 kg N, again, there were no differences in the ratios across the P rates.

Nitrogen x Seed rate interaction was also found to be significant at 1% level. At the same level of N, when the seed rates were varied, at 0 kg N, increase in seed rate from 30 - 120 kg did not affect the ratio significantly. At 45 kg N, the increase in grain-straw ratio between 30 and 75 kg seed/ha was significant, but a further increase from 75-120 kg left it unchanged. At 90 kg N/ha, however, only the grain-straw at 120 kg of seed was significantly higher than the other seed rates which were found to be at par. When the N rates were varied at the same level of seed rates, it was found that differences in the ratio were not significant at all levels of N at 30 and 75 kg seed/ha, but at 120 kg seed, increasing the N levels from 0 - 45 kg/ha did not significantly change the grain-straw, but the difference between 45 and 90 kg N was statistically significant in favour of the higher rate.

Nitrogen x Variety interaction was also significant at 1% level. At the same level of N when the varieties were examined, it was found that the variety Ex-China was significantly superior to ITA 257 at all N levels except the control. When the variety was held constant while varying the N levels, in case of ITA 257 there were no significant differences in the mean ratios at all levels of N. In case of Ex-China, however, increasing the N level from 0 - 45 kg/ha resulted in a significantly higher harvest index, but raising the level further from 45 - 90 kg/ha did not significantly affect the ratio.

Seed rate x variety interaction was also significant at 1% level and the responses were identical to those described for Nitrogen x Variety interaction.

Seed rate x Phosphorus interaction was also found to be significant at 5% level. At the same level of P when the seed rates were varied, at 0 kg P, mean grain-straw ratio did not differ significantly from 30 - 75 kg of seed/ha, but these levels were found to be significantly lower than the mean at 120 kg seed/ha. At 10 kg P, there was also a significant increase in the ratio by raising the seed rate from 30 - 75 kg of seed. However, the differences in the mean ratios between the 75 and 120 kg seed,as well as between the lowest and the highest seed rates were not significant statistically. At 20 kg P, the mean differences in the grain:straw at all seed rates were insignificant. Holding the seed rates constant while varying P

levels, it would be found that at 30 and 75 kg seed grain-straw did not differ significantly at all levels of P. At 120 kg seed, however, there was significant difference only between the control and 20 kg P, while the difference between the control and 10 kg P was not significant.

The second order interactions of N x P x V, S x P x V were found to be significant both at 5% level. With regard to NxPxV, the highest grain-straw ratio was obtained with a combination of 90 kg N and 20 kg P in case of Ex-China. For ITA 257, the best combination was 45 kg N and 10 kg P/ha. With respect to SxPxV interaction, for both ITA 257 and Ex-China 120 kg seed and 0 kg P resulted in the highest ratios. The two varieties did not significantly differ at this treatment. No other second and first order of interactions were found to be significant. The third order of interaction was also not significant.

### 4.41 Grain:Straw ratio, 1991

Mean grain:straw ratio of paddy as affected by N and P levels, Seed rates and Varieties during 1991 rainy season is shown in Table 42, and their corresponding analysis of variance in Appendix E42. Analysis of the data showed that only the difference in the means of grain-straw ratio due to varieties was significant at the 5% level. With respect to the varieties, Ex-China was found to

Table 42. Mean grain:straw ratio of paddy as affected by Nitrogen, Phosphorus, Seed rate and Variety during 1991 rainy season.

| N (kg/ha) | G:S ratio | P (kg/ha) | G:S ratio | Seed rate (kg/ha) | G:S ratio | Vars. | G:S ratio |
|---|---|---|---|---|---|---|---|
| 0 | 0.38a | 0 | 0.35a | 30 | 0.35a | ITA 257 | 0.34b |
| 45 | 0.34a | 10 | 0.36a | 75 | 0.37a | Ex-Chi. | 0.37a |
| 90 | 0.35a | 20 | 0.35a | 120 | 0.34a | | |
| SE± | 0.007 | SE± | 0.007 | SE± | 0.007 | SE± | 0.007 |
| Sig. | ns | Sig. | ns | Sig. | ns | Sig. | * |

NS & * - not significant and significant at 5% level, respectively.
Means followed by the same letter in a treatment group are not statitically different by DMRT at 5% level.

Table 43. Mean grain:straw ratio of paddy as affected by Variety, Seed rate, Phosphorus and Nitrogen during 1992 rainy season.

| | Seed rate (kg/ha) | | | Phosphorus (kg/ha) | | | |
|---|---|---|---|---|---|---|---|
| Vars. | 30 | 75 | 120 | 0 | 10 | 20 | Mean |
| ITA 257 | 0.33c | 0.31c | 0.30c | 0.30c | 0.33c | 0.31c | 0.31b |
| Ex-Chi. | 0.41b | 0.47a | 0.49a | 0.48a | 0.43b | 0.45ab | 0.46a |
| SE± | | 0.011 | | | 0.011 | | 0.007 |
| Sig. | | ** | | | * | | ** |
| Mean | 0.37a | 0.39a | 0.40a | 0.39a | 0.38a | 0.38a | |
| SE± | | 0.012 | | | 0.008 | | |
| Sig. | | ns | | | ns | | |
| | | | N (kg/ha) | | | | Mean |
| | | | 0 | 0.36ab | 0.40a | 0.42a | 0.39a |
| | | | 45 | 0.42a | 0.40a | 0.32b | 0.38a |
| | | | 90 | 0.39a | 0.37ab | 0.39a | 0.38a |
| | | | SE± | | 0.011 | | |
| | | | Sig. | | ** | | |

NS, * & ** - not significant and significant at 5 and 1% levels, respectively.
Means followed by the same letter(s) in a treatment group either amongst marginal means or those within the first order of interaction are not statistically different by DMRT at 5% level.

have a significantly higher grain-straw ratio than ITA 257.

N x S x P interaction was found to be significant at the 5% level.The highest grain-straw ratio of 0.46 was obtained with a combination of 0 kg N, 20 kg P and 120 kg of seed rate/ha. This combination , however, was statistically at par with 45 kg N, 75 kg of seed and 0 kg P per ha. Neither the first nor the third order of interactions were found to be significant. No other second order interaction was significant either.

**4.42 Grain:straw ratio, 1992**

Mean grain-straw ratio of paddy as affected by P and N levels, seed rates and varieties are shown in Table 43; while their corresponding analysis of variance is shown in Appendix E43. Results of analyzed data revealed that only means due to varieties were significantly different at 1% level. Means due to N, P and seed rates were insignificant. The variety Ex-China produced a significantly higher grain-straw ratio than ITA 257.

Seed rate x variety interaction was found to be significant at 1% level. When the varieties were considered at the same seed rate, it was found that Ex-China had significantly higher grain:straw ratio than ITA 257 at all seed the rates. When

the same variety was examined at the varying seed rates, in case of ITA 257, the mean grain-straw ratios were seen to be similar at all seeding rates, but in case of Ex-China, the ratios increased significantly with increase in seed rate from 30 - 75 kg/ha, with a further increase leaving the ratios statistically unchanged.

Phosphorus x variety interaction was also significant at 5% level. Examining each variety at varying P levels would reveal that in case of ITA 257 the grain:straw ratio did not differ across P levels. In the of Ex-China, there was a decrease in the ratio from 0 - 10 kg P/ha, which did not change with a further increase in P from 10 - 20 kg/ha. At the same level of P when the two varieties were examined, Ex-China had significantly higher grain-straw ratio at all P rates compared to ITA 257.

Phosphorus x nitrogen interaction was highly significant at 1% level. The means have shown that at the same level of P when N levels were considered, at 0 and 10 kg P/ha, mean grain-straw ratios did not differ at all N levels. At 20 kg P, the mean ratios at 0 and 90 kg N were statistically similar, but both were significantly higher than at 45 kg N/ha. At the same level of N when P levels were examined, the mean grain-straw ratios were statistically similar at 0 and 90 kg N/ha. At 45 kg N, there was no significant difference in the ratio between the control and 10 kg P, but the ratio decreased when P was raised from 10 - 20 kg/ha.

No other first order interactions and neither the second nor the third order were found to have significant effects on the parameter in this season.

## CHAPTER 5

# DISCUSSION

### 5.1 Effect of N, P and Seed rates on Growth and Paddy Yield

The superiority of Ex-China over ITA 257 in tillering could be attributed to the fact that the former is a *japonica* type cultivar with a high potential for tillering, while the latter is *indica* in nature with a limited tillering ability. Besides, Ex-China is a variety recommended for both upland and lowland cultivation and usually lowland cultivars tiller more than upland types. These findings conformed to similar observations by Chang *et al.* (1972), De Datta and Beachell (1972) who reported that upland paddy varieties, because of low level moisture regime in areas where they are grown, are panicle-heavy types due to limited tillering, while those with lowland habits are panicle-number types due to their high potential for tillering.

Even though tillering is, by and large, a varietal characteristic, plant environmental conditions, especially soil moisture and mineral nutrition play a significant role. Thus, the relatively higher tillering experienced in 1990 when compared with the other seasons was a result of better soil moisture status resulting from good rains at the time of tillering (Appendix B). Consequently, a significant response to

nitrogen was realized. Similar observations in support of this finding were made by Matsushima (1965), Murata and Matsushima (1980).

Lack of a significant response to phosphorus, inspite of favourable pH could be due to good amounts of the nutrient inherent in the soil. Again, fertilizer P has been more associated with other physiological processes in the paddy plant than tillering.

The general lack of significant response to seed rate *per se*' by tillering could be attributed to general limitations of moisture. However, the general trend whereby tillering increased with seeding rate up to a point (75 kg/ha) and then decreased as the rate increased to 120 kg/ha, was a result of competition for resources as the population built up. Some of the tillers were bound to wither and die in the process of competition. Significant variety x seed rate interaction in 1990 showed the responsiveness of low-tillering paddy variety ITA 257 to high population density when compared to Ex-China which responded relatively less to increased seeding. The reason was that competition in the former would begin later than in the latter due to difference in number of plants/unit area at any time. This observation was in support of Matsuo (1965) who found that higher tillering cultivars responded less to population density than low tillering ones.

Non significant difference between the varieties in the number of ear-bearing tillers in 1990 was as a result of drought which occurred at heading stage of Ex-China. At that time, ITA 257 being earlier maturing, had already headed and therefore suffered much less. In the subsequent seasons, the trend was similar to that of total tillers/unit area. The significant difference in ear number between the cultivars in the subsequent seasons was still expected since Ex-China had also a higher number of total tillers. Response to nitrogen at this stage was also similar to that of total tillering throughout the period of the trial, probably because proportionate numbers of total tillers died in both cultivars. Nitrogen x variety interaction in 1991 was a pointer to the varietal differences in nitrogen utilization between the varieties. ITA 257 being taller, would be expected to be less responsive to nitrogen than Ex-China which was generally shorter and therefore expected to be less prone to lodging at high nitrogen rates. This observation conformed to earlier findings by De Geus (1957), Grist (1965) and Beachell and Evatt (1961) who reported the superiority of *japonica* cultivars due to their relatively shorter culms over the *indicas* in response to nitrogen.

Significant seed rate x variety interaction in 1990 also supported the idea of differential varietal response to seeding rate. ITA 257 being a low tillering type responded more to increased seeding rate than Ex-China which is a panicle-number variety, in support of Matsuo (1965) that low-tillering paddy cultivars which

often responded less to nitrogen fertilization were more responsive to high seeding rates.

Significant nitrogen x seed rate interaction in 1991 indicated the strong interrelationship between population density and nitrogen nutrition. At low plant density, tillering would compensate for lack of adequate nutrition, but at high density, starvation would lead to death of tillers if nutrition is inadequate. That phenomenon could explain the general decrease in ear number/unit area beyond 75 kg seed/ha in that season. This situation could have been worsened by insufficient moisture at the time of heading as well as at the higher seed rate of 120 kg/ha at the highest nitrogen level of 90 kg/ha.

The general lack of a significant response to phosphorus throughout the conduct of the trial also followed a similar trend as in total tillers. In Nigeria, Enyi (1964) and elsewhere (Grist, 1978; Brady, 1974) reported similar incidences as was experienced in this trial.

The overall significant effect of nitrogen on ear-bearing tiller number confirmed the role played by this nutrient as a precursor of the building blocks for tiller development. The effect of seeding rate was also typical throughout the conduct of this trial. The significant difference between the cultivars in terms of

time taken to reach fifty percent flowering and maturity was mainly genetic and was little affected by mineral nutrition. The significant response to seed rate was, however, expected since increasing numbers would compete for resources for survival. Thus, beyond 75 kg seed/ha, stiff competition would ensure to shorten the crop's life span. Variety x seed rate interaction in 1990 and 1992 revealed the effect of population in shortening the life period of the crop as a result of competition. At low plant population, and especially with adequate nutrition, vegetative growth would be prolonged thereby elongating the phenological stages. At high density, the reverse would be the case due to competition. Resources would be exhausted soon and the plant's phasic development shortened. However, it could also be argued that sufficient nutrition could shorten the crop's life cycle by accelerating growth and consequently the plant's phasic development. This was evidenced in 1991 whereby increasing nitrogen rate significantly decreased time to maturity.

Significant difference between the paddy varieties with regard to lodging could be attributed to the significant difference in their culm length. ITA 257 being taller would be expected to be more susceptible to lodging than Ex-China. Even though the effect of nitrogen on lodging was not significant in any season, there was, as expected, a general increase in lodged plants as nitrogen rate was increased, as the nutrient tended to make plants succulent thereby weakening the

straw. Similarly, the general increase in lodging with increased seeding could have been as a result of feable culms resulting from mutual shading brought about by competition. With regard to phosphorus, in 1992, a significant decrease in lodged plants as the rate was increased was indicative of the role of the nutrient in helping to strengthen the plants' straw and thus help to resist lodging as was also reported by Brady (1974).

Throughout the trial period, ITA 257 was observed to be taller than Ex-China and significantly so in two out of the three seasons, i.e., 1990 and 1991. Crop height is more a genetic characteristic.

Significant increase in crop height due to increase in N rate up to 45 kg N/ha, probably resulted from the nutrient's role in boosting vegetative growth. This phenomenon was observed in the first two seasons. In the last season, the margin between the varieties was very narrow and therefore not significant.

The general nonsignificant effect of seed rate on plant height was expected because increasing the seed rate brought about competition between the plants and consequently checking their growth. However, there was a tendency of producing taller plants at 75 kg/ha. As with seed rates, there was a general increase in plant height with increasing P fertilization from control to 10 kg P/ha,

probably through its role in promoting root growth and therefore uptake of water and mineral salts. This observation is in conformity with the findings of Sicar and Sen (1941) that phosphorus increased plant height due to its role in root development.

Significant N x V interaction observed in 1991 further indicated the effect of nitrogen on plant height. ITA 257 being a relatively poor plant type in view of its tall stature, did not show significant response to the nutrient. There was pronounced lodging in this variety. On the other hand, Ex-China being relatively shorter responded to N by increasing in height significantly with increasing N level without much lodging. Varietal differences in response to N was demonstrated by several workers (IRRI, 1967; Chandler, 1969; Jana and De Datta, 1971 and De Datta and Malabuyoc, 1976).

Significant V x P interaction pointed to the differential response to P by the different cultivars. Ex-China being higher tillering, was more likely to have a more elaborate root system and so higher P extraction capacity than ITA 257.

Significant seed rate x nitrogen interaction in 1991 demonstrated that at low seed rate, the plants suffered little or no competition, for space, especially at the control N, because tillering was minimal, thus enabling the plants to express

themselves fully. With increased nutrition, tillering would likely check the plant height. As seed rate increased, competition between the plants for the nutrients at low level would again check their growth. Tillering, which eventually led to competition for space and mutual shading, would also check plant height at high levels of both seed rate and N.

The non significant varietal differences in panicle length in 1990 and 1991 rainy seasons, was an indication that the varieties are similar in this trait. Phosphorus and seed rate seemed to have more influence on panicle length than N levels, which showed significant effects only in 1990 season. The significant increase in panicle size with increase in nitrogen from 0 - 45 kg/ha in that season could be due to the nutrient's positive effect on overall plant height and in the formation of the panicle itself as well as the entire plant structure after the panicle has been formed. At low level of nitrogen nutrition both the size of the ear and the entire plant are expected to be small. Both structures would increase in size with improved level of the nutrient. Its limited uptake due to inadequate moisture in 1991 may be the reason for its non significant effect on panicle size in that season. The significant decrease in panicle size beyond 30 kg seed/ha in 1990 and 1992 seasons was due to population pressure which eventually checked plant performance. The indirect influence of phosphorus through root growth, leading to better resource utilization in the soil could have led to its significant effect on

panicle size in two out of the three seasons. The role of the nutrients on panicle size could be due to their indirect effects on overall plant height of the rice crop as reported by Patel (1967) who observed that there was a positive linear relationship between the parameters. As expected, seed rate and panicle length would be inversely related. There was a general reduction in panicle length as the seeding rate was increased due to increased competition.

Significant N x P interaction with respect to panicle length in 1992 season was probably due to improved phosphorus availability resulting from better moisture status.

Significant varietal differences with respect to grain number/ear was observed throughout the trial. Generally, ITA 257 produced a higher grain number than Ex-China. Water stress at heading time in 1990 was responsible for the marked reduction of the kernel number in Ex-China which is a longer duration variety. Significant nitrogen x seed rate interaction in 1991 indicated the direct relationship between these factors in relation to the parameter examined. At low level of mineral nutrition, high seed rate would result in increased grain number/ear. At moderate level, increased tillering would give rise to a larger number of grains/ear even at low seed rate. At the same level of nutrition, high seed rate would produce a large number of plants with small panicles due to

competition. Similarly, at low plant population and high level of plant food, panicle size would increase. However, as the population builds up, profuse tillering would be expected to check plant growth, with the result that plant size would decrease. These results were in conformity with Matsuo (1965) who observed that heavy N fertilization was usually compensated for by sparse planting, and less N fertilizer by dense planting. In this experiment, the balance between N and Seed rate seemed to have been struck at 45 kg N and 75 kg seed/ha (Table 24).

Significant N x P interaction was also indicative of the inter-dependence of the nutrients to influence the grain number/ear. At low nitrogen rates, high phosphorus levels probably encouraged the nutrient's uptake to promote grain number. At high nitrogen rates, for some reason, phosphorus uptake and consequently grain number decreased. This observation agreed with those of Davide (1965), Raju (1979), Baddesha and Maskina (1985) and Tackchandani *et al.* (1987) that the presence of P in the soil encouraged nitrogen uptake to increase upland paddy yield.

ITA 257 consistently produced significantly larger seeds than Ex-China in view of its being of an upland cultivar. Upland varieties have been noted to produce heavy seeds (Jana and De Datta, 1971; IRRI, 1973) than dual-purpose varieties of which Ex-China is typical. Although nitrogen nutrition has been shown

to increase the seed weight (Matsushima, 1965; Wada *et al.*, 1986), in this trial, no significant effect on this parameter was experienced. The general lack of significant effects of the factors under trial on seed weight was due, probably to the rigid nature of the grain resulting from its being enclosed tightly by the outer and inner glumes. Thus, it could not grow to a size greater than that permitted by the hull as observed by Murata and Matsushima (1980).

Overall superiority of ITA 257 over Ex-China in straw production could be attributed to the former's significantly longer stems and larger leaves. The crop height could therefore be responsible for the variation in straw yield in favour of ITA 257 as reported by Patel (1967) who found that plant height was strongly correlated with straw yield. The author further observed that plant height was 1.5 - 9 times more effective in raising straw yield per unit area than other traits.

In two out of three seasons (1991 and 1992), there were significant straw yield increases/unit area with rising N levels. Even in the other season (1990) there were slight increases in the straw yield with increase in N rates. Nitrogen as a building block in drymatter synthesis would be expected to increase straw weight through its effects on tillering and canopy height as reported in several studies (Patel, 1967; Park, 1989; Singh and Modgal, 1979). As with N, there was a general significant increase in straw weight when P levels were raised. The role of P in

straw yield was probably through its indirect effect on improved root development and its ability to strengthen canopy architecture. Lack of P in the soil was shown to reduce straw yield through a decrease in plant height and tillering (Sicar and Sen, 1941).

Significant nitrogen x seed rate interactions in 1990 and 1992 indicated that 45 kg N at 75 kg seed/ha culminated in the highest straw weight/unit area. Combinations of higher levels of both factors would be limited by moisture availability; while disproportionate combination would either be limited by nutrient and space availability or insufficient moisture. Significant nitrogen x variety interaction in 1990 showed that ITA 257 had a higher capacity to utilize nitrogen for straw production than Ex-China. Significant N x P interaction in 1990 alone showed the complementarity of the two nutrients to produce significantly higher yields of straw than their individual effects.

Significant seed rate x phosphorus effects showed 75 kg seed/ha and control P to be superior to other treatment combinations as reported by Chang *et al.* (1972) that P application alone did not increase straw yield.

Significant grain yield difference between the paddy varieties was experienced in only one season ( i.e., 1992). Paddy yield, like in other cereal

crops, is a function of the various yield contributing factors. According to Yoshida (1983), in rice, grain yield is a product of number of ears/$m^2$, number of grains/ear and seed weight. In the present investigation, it was observed that higher yield of Ex-China was mainly as a result of its higher ear-bearing tiller number/unit area. The size of the grain is more a genetic factor as attested to by several workers (Murata and Matsushima, 1980; Yoshida *et al.*, 1973; Yoshida, 1983). Therefore, rice grain yield has been shown to be mainly correlated with the number of ears/unit area and number of grains/ear. In this trial, the relative superiority of the paddy variety Ex-china over ITA 257 in grain yield was mainly due to the latter's higher number of ear-bearing tillers/unit area. ITA 257 was significantly better than Ex-China in terms of grain number/ear, but this yield component was not significantly correlated with grain yield throughout this trial (Tables 38 - 40). Seed weight has also been either non significantly related to, or negatively correlated with grain yield.

When each factor under trial was considered, nitrogen was found to be significant in all the seasons in increasing paddy yield through its strong influence on the yield components, particularly number of ear-bearing tillers/unit area. Nitrogen has been shown to be the major limiting nutrient in rice growth and yield and several trials have testified to that (Lindt, 1953; Ishizuka, 1965; Matsushima, 1965; Grist, 1975, Patrick *et al.*, 1983; Murata and Matsushima, 1980; Mae,

1986).

Throughout this trial, the significant increase in yield due to increase in N levels was from 0 - 45 kg/ha, with a further increase from 45 - 90 kg N resulting in a non significant increase in the yield, except in 1991 when there was a slight decrease. These results conformed to those of Dartey and Halm (1977) who reported 45 kg as optimum and Ram *et al.* (1987) who found the N range for satisfactory paddy yield of an upland variety (Ratna) of 20 - 60 kg/ha. According to them, grain yield decreased at 80 kg N/ha. In Peru, Sanchez (1972) found 30 kg N/ha as optimum for an upland cv. IR4-2. At Nsukka (Nigeria), Enyi (1964) reported a significant response to N by upland rice. Oyedokun and Sobulo (1977) reported that 30 kg N/ha was optimum; while Fagade (1979) reported that 20 - 30 kg N/ha was optimum for a traditional upland cv. 0S6, higher rates leading to lodging. At Onne, 40 kg N was found to be sufficient to obtain maximum grain yields for ITA 117 and ITA 307 (IITA, 1985). At Ikenne, N rates beyond 40 kg/ha did not increase the grain yields of ITA 235 and ITA 257 (IITA, 1985).

With the exception of 1991, response to P by grain yield in this trial has not been significant inspite of the soil's seemingly good P status. Grain yield response to P has been reported to be rather erratic, depending on soil type and agro-climatic conditions. In Nigeria, IITA (1982) reported significant response to P, but

Enyi (1968) observed lack of response by an upland rice cultivar 'Agbede.'

A critical analysis of seed rate used in this investigation revealed that 30 kg/ha did not produce adequate number of ears to give optimum yield. Seventy five kg of seed/ha has, however, given the maximum yield and with a further increase to 120 kg/ha, it was observed that due to competition, it did not produce adequate number of ears, number of grains/panicle and seed weight. Similar findings were reported by Maurya and Vaish (1986), Schiller and Dogkeaw (1978), Pillai (1981 and 1982), IRTPLA (1979), Sobral and Oliveira (1987), Songmuang *et al.*, (1983) and Kehinde (1986). In all those trials, grain yield increase was attributed to increase in the number of productive tillers/unit area.

Significant nitrogen x variety interaction was recorded in 1990. In this season, ITA 257 yielded highest at 90 kg/ha and Ex-China at 45 kg/ha inspite of the latter's better N response characteristics, notably its relatively shorter straw. Drought during the heading stage of this variety may have been responsible for this response.

## 5.2 Polynomial Responses

The generally significant linear response to paddy yield by nitrogen proved

that both cultivars were responsive to the nutrient and up to 90 kg N/ha. It is therefore concluded that there was still room to increase the yield by way of increasing nitrogen level. With respect to phosphorus, the lack of significant manifestation of neither polynomial was attributed to the soil's inherently fair P status. In 1992, the linear polynomial response to yield was likely due to favourable soil conditions brought about by better water retentivity resulting from its higher silt and clay contents.

The significant linear response to seed rate in both 1990 and 1992 was expected in view of relatively higher rainfall with fairly better distribution. This was in contrast to the quadratic response in 1991 when the crop was subjected to rainfall of shorter duration and poor distribution. The overall significant linear polynomial response to nitrogen in 1990-92 seasons was expected since linearity was established in two out of the three trials.

### 5.3 Effects of Seasons on Yield and Yield Components

As pointed out earlier in this discussion, paddy yield in rice is a product of ear number/unit area, number of grins/ear and seed weight, with the latter's relative contribution being small because it is genetic.

Significant differences in the mean paddy yields in the seasons could be due to differences in the agro-climatic conditions during the growing seasons, particularly rainfall, and their effects on the factors under trial. In 1991, paddy yield was limited by drought beyond August, thus adversely affecting grain-fill (24 g vs. 29 g/1000 in '90 and '92).

The significantly higher grain:straw ratio of Ex-China relative ITA 257 could be due to the former's better ability to allocate assimilates to the reproductive organs, once they have been formed, at the expense of the vegetative parts. On the other hand, ITA 257 may have expended alot of its photosynthates to its large vegetative structure which may have competed highly for sink with the reproductive structures. Thus, only a fraction went to the reproductive organs following their formation and beyond. Another reason could be that ITA 257 being bred for drought tolerance paid a penalty in form of yield loss. On the contrary, Ex-China has a relatively better plant architecture made up of shorter culms and smaller leaves.

Significant increase in the ratio due to nitrogen from 0 - 45 kg/ha was a reflection of the role of the nutrient in increasing grain yield at the expense of vegetative organs. At the highest N rate of 90 kg/ha, luxuriant vegetative growth would tend to suppress grain yield in favour of straw production. The general non

significant increase in grain:straw ratio due to seed rate could have been because of the plants' inherent regulatory mechanisms to strike a balance between straw and grain yield.

### 5.4 Correlation Studies

The significant positive correlation between ear-bearing tillers/$m^2$ and paddy yield in this trial was expected since grain yield has invariably been associated with the number of harvestable ears/unit area. The feeble relationship between number of grains/ear in 1990 and 1991 and its negative correlation with the grain yield in 1992 could have been due to the large number of tillers that reached maturity resulting in competition. Similarly, the non-significant positive relationship between seed weight and the paddy yield in the first two years of the experiment, and a highly negative one in 1992 season was indicative of the minor role grain size *per se*' plays as a yield component. These findings have agreed with those of other workers (Yadava *et al.*, 1989; Park, 1989; Reuben and Katuli, 1989; Sane, 1962) who reported that the number of panicles/unit area was the most important paddy yield component.

The positive, though non-significant correlation between tiller number and number of grains/ear in 1990 could be due to favorable growing conditions,

especially mineral nutrition and a relatively well distributed rainfall that season; while the highly significant negative correlation in 1991 could be attributed to less favorable season in view of the scanty rainfall compared with the other seasons (Appendix B). The negative relationship between tiller number and seed weight throughout the trial was due to the usual inverse relationship between grain number and grain size. Thus, the larger the panicle number/unit area the smaller the individual grain size would be, especially in the light of significant linear polynomial response to seed rate.

## CHAPTER 6

# SUMMARY AND CONCLUSIONS

Field experiments were conducted at the Fadama Farm of Usmanu Danfodiyo University, Sokoto for three consecutive years during 1990-92 rainy seasons. The objective of the investigation was to study the effects of nitrogen, phosphorus and seed rates on two upland rice cultivars with a view to arriving at an optimum combination rates of these factors for optimum paddy yield.

The treatments consisted of three seed rates (30, 75 & 120 kg/ha) combined with three rates of nitrogen (0, 45 & 90 kg/ha) as main plot treatments and two rice varieties (Ex-China and ITA 257) combined with three phosphorus levels (0, 10 & 20 kg P/ha) as subplot treatments. The treatments were arranged arranged in a split plot design with three replications. The analyzed data revealed that the cultivar Ex-China was significantly superior to ITA 257 in both total and ear-bearing tiller number/unit area, but almost at par with each other in panicle length. ITA 257 was, however, found to be significantly taller and therefore more susceptible to lodging than Ex-China, especially at high nitrogen rates. The latter was found to be of longer duration than the former. In terms of grain number/ear and seed weight, ITA 257 was superior. Also, in view of ITA's tall stature, it tended

to produce more straw than its counterpart, in spite of Ex-China's higher tillering ability. Ex-China turned out to be higher paddy yielding than ITA 257.

The results also indicated that nitrogen significantly affected most of the growth parameters and paddy yield components, notably tillering, panicle length and plant height. But, in general, the nutrient had no significant effect on time to flowering and maturty. The nutrient aggravated lodging, especially in the relatively taller cultivar, ITA 257. Nitrogen also promoted grain number/ear significantly in most years, but, on the whole, it showed no significant effect on seed weight. It also affected both the straw and paddy yields significantly, but increasing the rates had an adverse effect on grain:straw ratio. Seed rate, either alone, or in interaction with nitrogen or phosphorus also increased most of the parameters examined, but mainly up to 75 kg seed/ha beyond which competition set in. However, lodging and 1000-seed weight were not significantly affected by increasing seed rates. Grain:straw ratio was also little affected by this factor. Phosphorus showed no significant effects on tillering, time to flowering and maturity, straw weight, and grain:straw ratio. However, increasing levels of this nutrient significantly increased panicle length in two out of the three seasons, and in respect of lodging, there was a lower incidence of it with increasing phosphorus rate in only one season. An increase in the phosphorus levels also increased paddy yield in only one season.

Polynomial responses to nitrogen and seed rates were, in general, linear, indicating that paddy yield would continue to increase beyond the ranges of the factors tried in this experiment. With regards to phosphorus, however, the response was either inconclusive, or quadratic.

Correlation studies revealed that number of ear-bearing tillers/unit area was the single most important paddy contributing yield component, in view of its significant positive correlation with the yield throughout the conduct of the trials. Thus, the other two paddy yield components, i.e., number of grains/ear and seed weight were adjunct to it.

In conclusion, the paddy cultivar Ex-China, was found to be significantly superior to ITA 257 in grain yield because of the its higher tillering ability and also its better responsiveness to nitrogen nutrition resulting from its relatively better canopy architecture, inspite of ITA's higher grain number/ear and heavier seeds. It could also be concluded that under the prevailing conditions under which the rice cultivars were tried, higher paddy yields could be obtained under favourable circumstances by exceeding both the nitrogen and seed rates examined so far.

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**Appendix A. Physico-chemical properties of soils at Usmanu Danfodiyo University, Sokoto Fadama Farm, 1990 - 92 rainy season.**

| **Soil characteristics** | | | | | | |
|---|---|---|---|---|---|---|
| Season | 1990 | | 1991 | | 1992 | |
| Soil depth (cm) | 0-15 | 15-30 | 0-15 | 15-30 | 0-15 | 15-30 |
| **Soil characteristics** | | | | | | |
| Clay | 4.80 | 4.90 | 4.90 | 3.60 | 5.10 | 4.90 |
| Silt | 3.30 | 3.20 | 5.20 | 2.60 | 9.00 | 5.20 |
| Sand | 91.9 | 91.9 | 89.9 | 95.8 | 85.9 | 89.0 |
| Textural class | Loamy sand | | Loamy sand | | Loamy sand | |
| **Chemical composition** | | | | | | |
| pH in 1:1 $H_2O$ | 5.70 | 6.70 | 7.10 | 7.40 | 7.20 | 6.00 |
| pH in 0.01M $CaCl_2$ | 5.30 | 6.50 | 7.00 | 7.10 | 6.70 | 5.50 |
| Organic-C (%) | 0.09 | 0.08 | 0.14 | 0.14 | 0.11 | 0.13 |
| Available-P | 1.40 | 1.60 | 1.00 | 0.90 | 1.60 | 1.60 |
| Total-N | 0.04 | 0.04 | 0.06 | 0.03 | 0.06 | 0.05 |
| **Exchangeable Bases (meq/100g soil)** | | | | | | |
| Ca + Mg | 2.60 | 2.10 | 1.70 | 1.70 | 3.40 | 2.6 |
| K | 0.87 | 1.00 | 1.00 | 0.52 | 0.70 | 0.60 |
| Na | 0.50 | 0.60 | 0.59 | 0.53 | 0.53 | 0.48 |
| C.E.C. | 10.4 | 8.2 | 9.8 | 9.6 | 10.1 | 9.9 |
| **Base saturation (%)** | 43.8 | 57.0 | 44.8 | 42.6 | 50.0 | 34.0 |

Appendix B. 10-Day rainfall (mm) at Sokoto, 1990 - 92 seasons.

| Decade | | Rainfall (mm) 1990 | 1991 | 1992 |
|---|---|---|---|---|
| 1-10 | April | 0 | 0 | 0 |
| 11-20 | April | 0 | 0 | 0 |
| 21-30 | April | 0 | 0 | 0 |
| 1-10 | May | 0 | 7.50 | 0 |
| 11-20 | May | 5.75 | 0 | 0 |
| 21-31 | May | 7.50 | 0 | 0 |
| 1-10 | June | 47.00 | 3.30 | 1.30 |
| 11-20 | June | 4.50 | 16.20 | 12.00 |
| 21-30 | June | 56.25 | 56.10 | 22.30 |
| 1-10 | July | 40.25 | 39.80 | 85.10 |
| 11-20 | July | 44.00 | 15.50 | 8.90 |
| 21-31 | July | 57.75 | 43.80 | 29.90 |
| 1-10 | August | 79.50 | 96.40 | 129.00 |
| 11-20 | August | 82.25 | 102.00 | 57.40 |
| 21-31 | August | 100.50 | 29.70 | 104.60 |
| 1-10 | September | 15.50 | 38.50 | 83.60 |
| 11-20 | September | 37.00 | 12.25 | 47.80 |
| 21-30 | September | 33.25 | 0 | 12.50 |
| 1-10 | October | 12.25 | 0 | 0 |
| **Total** | | **623.25** | **453.55** | **594.15** |

Source: Sokoto Energy Research Centre, Usmanu Danfodiyo University, Sokoto.

Appendix C. Mean minimum and maximum temperature ($0^{C}$) and Relative Humidity (%) at Sokoto, 1990 - 92 rainy seasons.

| Variable | Temperature ($0^{C}$) | | | | | | Relative humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | | 1991 | | 1992 | | 1990 | 1991 | 1992 |
| | Min. | Max. | Min. | Max. | Min. | Max. | | | |
| January | 19.0 | 33.5 | 12.5 | 28.0 | 15.0 | 21.7 | 26 | 20 | 26 |
| February | 18.5 | 33.0 | 24.8 | 34.5 | 17.6 | 24.6 | 15 | 20 | 26 |
| March | 21.5 | 35.6 | 24.5 | 36.8 | 22.6 | 30.0 | 16 | 12 | 24 |
| April | 29.7 | 40.9 | 26.0 | 37.0 | 25.4 | 33.0 | 26 | 25 | 47 |
| May | 26.5 | 38.6 | 26.5 | 36.0 | 26.6 | 32.7 | 50 | 52 | 50 |
| June | 26.2 | 37.4 | 32.8 | 38.0 | 24.8 | 30.5 | 59 | 57 | 62 |
| July | 22.9 | 31.6 | 24.7 | 36.7 | 22.9 | 27.6 | 74 | 76 | 66 |
| August | 23.4 | 32.0 | 25.0 | 33.0 | 22.8 | 27.0 | 79 | 75 | 76 |
| September | 23.9 | 34.1 | 24.3 | 37.5 | 23.2 | 38.1 | 73 | 69 | 73 |
| October | 23.9 | 37.1 | 23.9 | 39.3 | 23.2 | 39.2 | 48 | 44 | 62 |
| November | 21.3 | 36.6 | 14.3 | 33.2 | 17.5 | 26.5 | 19 | 24 | 45 |
| December | 20.2 | 33.2 | 16.2 | 32.5 | 18.0 | 24.9 | 27 | 28 | 30 |

Source: Sokoto Energy Research Centre, Usmanu Danfodiyo University, Sokoto

**Appendix D. Mean monthly global radiation (kw/m$^2$ ) at Sokoto, 1990 - 92 rainy seasons.**

| | Global radiation (kw/m$^2$ ) | | |
|---|---|---|---|
| **Seasons** | **1990** | **1991** | **1992** |
| January | 21.7 | 20.9 | 20.0 |
| February | 26.0 | 25.4 | 23.0 |
| March | 26.4 | 24.3 | 25.0 |
| April | 27.4 | 24.0 | 24.8 |
| May | 24.3 | 23.8 | 22.0 |
| June | 25.5 | 23.0 | 20.0 |
| July | 19.5 | 15.8 | 20.6 |
| August | 21.5 | 21.1 | 17.0 |
| September | 23.0 | 23.0 | 22.7 |
| October | 24.7 | 21.4 | 25.1 |
| November | 23.8 | 21.8 | 23.4 |
| December | 20.6 | 19.4 | 19.1 |

Source: Sokoto Energy Research Centre, Usmanu Danfodiyo University, Sokoto

## APPENDIX E

Appendix E1. Analysis of variance for total tillers ($m^2$), 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 143882.75 | 71941.377 | 1.51 | 0.250 |
| Nitrogen | 2 | 877796.46 | 438898.228 | 9.22 | 0.002 |
| Seed rate | 2 | 77625.23 | 38812.673 | 0.82 | |
| N x S | 4 | 205295.88 | 51323.969 | 1.08 | 0.399 |
| Error (a) | 16 | 761791.47 | 47611.967 | | |
| Phosphorus | 2 | 126970.09 | 63485.043 | 1.17 | 0.315 |
| N x P | 4 | 272918.25 | 68229.562 | 1.26 | 0.293 |
| S x P | 4 | 99034.69 | 247758.673 | 0.46 | |
| N x S x P | 8 | 315901.53 | 39487.691 | 0.73 | |
| Variety | 1 | 1650542.62 | 1650542.62 | 30.37 | 0.000 |
| N x V | 2 | 190230.23 | 95115.117 | 1.75 | 0.179 |
| S x V | 2 | 428122.83 | 214061.414 | 3.94 | 0.022 |
| N x S x V | 4 | 340287.21 | 85071.802 | 1.57 | 0.190 |
| P x V | 2 | 58165.57 | 29082.784 | 0.54 | |
| N x P x V | 4 | 31681.14 | 7920.284 | 0.15 | |
| S x P x V | 4 | 153074.32 | 38268.580 | 0.70 | |
| N x S x Px V | 8 | 117165.09 | 14645.636 | 0.27 | |
| Error (b) | 90 | 4891852.44 | 54353.916 | | |

Appendix E2. Analysis of variance for total tillers ($m^2$), 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 203196.60 | 101598.302 | 4.53 | 0.027 |
| Nitrogen | 2 | 304712.98 | 152356.488 | 6.79 | 0.007 |
| Seed rate | 2 | 98271.27 | 49135.636 | 2.19 | 0.144 |
| N x S | 4 | 64231.14 | 16057.784 | 0.72 | |
| Error (a) | 16 | 358768.62 | 22423.039 | | |
| Phosphorus | 2 | 30537.05 | 15268.525 | 1.58 | 0.212 |
| N x P | 4 | 64053.80 | 16013.451 | 1.66 | 0.167 |
| S x P | 4 | 22871.62 | 5717.904 | 0.59 | |
| N x S x P | 8 | 41659.42 | 5207.427 | 0.54 | |
| Variety | 1 | 1147275.86 | 1147275.86 | 118.58 | 0.000 |
| N x V | 2 | 43778.01 | 21889.006 | 2.26 | 0.109 |
| S x V | 2 | 48260.16 | 24130.080 | 2.49 | 0.088 |
| N x S x V | 4 | 8373.58 | 2093.395 | 0.22 | |
| P x V | 2 | 9565.05 | 4782.525 | 0.49 | |
| N x P x V | 4 | 87342.02 | 21835.506 | 2.26 | 0.069 |
| S x P x V | 4 | 16352.43 | 4088.108 | 0.42 | |
| N x S x P x V | 8 | 122641.05 | 15330.131 | 1.58 | 0.140 |
| Error (b) | 90 | 870760.11 | 9675.112 | | |

Appendix E3. Analysis of variance for total tillers (/m$^2$), 1992.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 360175.16 | 180087.58 | 6.44 | 0.008 |
| Nitrogen | 2 | 44774.16 | 22387.08 | 0.80 | |
| Seed rate | 2 | 215543.90 | 107771.95 | 3.85 | 0.043 |
| N x S | 4 | 187934.91 | 46983.73 | 1.68 | 0.203 |
| Error (s) | 16 | 447436.95 | 27964.81 | | |
| Phosphorus | 2 | 8549.68 | 4274.84 | 0.08 | |
| N x P | 4 | 462867.80 | 115716.95 | 2.11 | 0.085 |
| S x P | 4 | 307671.51 | 76842.88 | 1.40 | 0.239 |
| N x S x P | 8 | 929529.79 | 116191.22 | 2.12 | 0.041 |
| Variety | 1 | 163020.50 | 163020.50 | 2.97 | 0.088 |
| N x V | 2 | 289441.59 | 144720.80 | 2.64 | 0.076 |
| S x V | 2 | 141975.26 | 70987.63 | 1.29 | 0.278 |
| N x S x V | 4 | 75960.59 | 18990.15 | 0.35 | |
| P x V | 2 | 36998.37 | 18499.19 | 0.34 | |
| N x P x V | 4 | 139759.48 | 34939.87 | 0.64 | |
| S x P x V | 4 | 28624.59 | 7156.15 | 0.13 | |
| N x S x P x V | 8 | 453604.78 | 56700.60 | 1.03 | |
| Error (b) | 90 | 4933791.22 | 54819.90 | | |

Appendix E4. Analysis of variance for ear-bearing tillers (/m$^2$), 1990.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 43020.01 | 21510.006 | 1.62 | 0.228 |
| Nitrogen | 2 | 86239.60 | 43119.802 | 3.25 | 0.065 |
| Seed rate | 2 | 3469.12 | 1734.562 | 0.13 | |
| N x S | 4 | 45229.32 | 11307.330 | 0.85 | |
| Error (s) | 16 | 212257.99 | 13266.124 | | |
| Phosphorus | 2 | 12610.98 | 6305.488 | 0.76 | |
| N x P | 4 | 30702.47 | 7675.617 | 0.93 | |
| S x P | 4 | 32757.17 | 8189.293 | 0.99 | |
| N x S x P | 8 | 35626.05 | 4453.256 | 0.54 | |
| Variety | 1 | 12658.17 | 12658.173 | 1.53 | 0.218 |
| N x V | 2 | 38087.75 | 19043.877 | 2.31 | 0.105 |
| S x V | 2 | 98433.64 | 49216.821 | 5.96 | 0.003 |
| N x S x V | 4 | 27747.99 | 6936.997 | 0.84 | |
| P x V | 2 | 3676.01 | 1838.006 | 0.22 | |
| N x P x V | 4 | 24823.95 | 6205.988 | 0.75 | |
| S x P x V | 4 | 47257.17 | 11814.293 | 1.43 | 0.230 |
| N x S x P x V | 8 | 55891.31 | 6986.414 | 0.85 | |
| Error (b) | 90 | 742811.33 | 8253.459 | | |

Appendix E5. Analysis of variance for ear-bearing tillers(/$m^2$), 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 128628.04 | 64313.019 | 12.89 | 0.000 |
| Nitrogen | 2 | 148809.93 | 74404.963 | 14.91 | 0.000 |
| Seed rate | 2 | 119143.59 | 59571.796 | 11.94 | 0.000 |
| N x S | 4 | 78223.37 | 19555.843 | 3.92 | 0.021 |
| Error (a) | 16 | 79852.85 | 4990.803 | | |
| Phosphorus | 2 | 2924.04 | 1462.019 | 0.28 | |
| N x P | 4 | 29959.48 | 7489.870 | 1.43 | 0.228 |
| S x P | 4 | 12451.48 | 3112.870 | 0.60 | |
| N x S x P | 8 | 12932.56 | 1616.569 | 0.31 | |
| Variety | 1 | 949135.80 | 949135.802 | 181.83 | 0.000 |
| N x V | 2 | 43053.38 | 21526.691 | 4.12 | 0.019 |
| S x V | 2 | 16620.09 | 8310.043 | 1.59 | 0.209 |
| N x S x V | 4 | 20743.17 | 5185.793 | 0.99 | |
| P x V | 2 | 13867.94 | 6933.969 | 1.33 | 0.270 |
| N x P x V | 4 | 13649.88 | 3412.469 | 0.65 | |
| S x P x V | 4 | 14546.40 | 3636.599 | 0.70 | |
| N x S x P x V | 8 | 32318.68 | 4039.835 | 0.77 | |
| Error (b) | 90 | 469786.44 | 5219.849 | | |

Appendix E6. Analysis of variance for ear-bearing tillers(/$m^2$), 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 58398.30 | 29199.2 | 3.70 | 0.047 |
| Nitrogen | 2 | 34087.10 | 17043.5 | 2.16 | 0.148 |
| Seed rate | 2 | 203566.4 | 101783.2 | 12.89 | 0.000 |
| N x S | 4 | 21182.8 | 5295.7 | 0.67 | |
| Error (a) | 16 | 126367.1 | 7897.9 | | |
| Phosphorus | 2 | 36246.8 | 18123.4 | 2.39 | 0.097 |
| N x P | 4 | 25358.8 | 6339.7 | 0.84 | |
| S x P | 4 | 40635.5 | 10158.9 | 1.34 | 0.260 |
| N x S x P | 8 | 124589.7 | 15573.7 | 2.05 | 0.048 |
| Variety | 1 | 131698.5 | 131698.5 | 17.40 | 0.000 |
| N x V | 2 | 9288.7 | 4644.3 | 0.61 | |
| S x V | 2 | 1008.0 | 504.0 | 0.07 | |
| N x S x V | 4 | 28376.8 | 7094.2 | 0.94 | |
| P x V | 2 | 4096.7 | 2048.3 | 0.27 | |
| N x P x V | 4 | 36839.9 | 9209.9 | 1.22 | 0.309 |
| S x P x V | 4 | 31248.4 | 7812.1 | 1.03 | 0.395 |
| N x S x P x V | 8 | 93484.6 | 11685.6 | 1.54 | 0.153 |
| Error (b) | 90 | 681319.2 | 7570.2 | | |

Appendix E7. Analysis of variance for ear-bearing tillers combined over 1990 - 92.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Repliaction | 2 | 14083 | 7041.5 | 0.13 | |
| Years | 2 | 2378549 | 1189274.7 | 21.53 | 0.007 |
| Error (a) | 4 | 220939 | 55234.8 | | |
| Nitrogen | 2 | 206037 | 103018.9 | 12.23 | 0.000 |
| N x Y | 4 | 64613 | 16153.4 | 1.92 | 0.122 |
| Seed rate | 2 | 222845 | 111422.7 | 13.23 | 0.000 |
| S x Y | 4 | 113285 | 28321.4 | 3.36 | 0.016 |
| N x S | 4 | 36298 | 9074.6 | 1.08 | 0.378 |
| N x S x Y | 8 | 108377 | 13547.2 | 1.61 | 0.147 |
| Error (b) | 48 | 404300 | 8422.9 | | |
| Phosphorus | 2 | 32444 | 16222.1 | 2.30 | 0.102 |
| P x Y | 4 | 21422 | 5355.7 | 0.76 | |
| N x P | 4 | 25415 | 6353.8 | 0.90 | |
| N x P x Y | 8 | 62757 | 7844.7 | 1.11 | 0.356 |
| S x P | 4 | 11349 | 2837.4 | 0.40 | |
| S x P x Y | 8 | 71031 | 8878.9 | 1.26 | 0.266 |
| N x S x P | 8 | 56159 | 7019.9 | 0.99 | |
| N x S x P x Y | 16 | 115881 | 7242.6 | 1.03 | 0.429 |
| V ariety | 1 | 692920 | 692920.2 | 98.11 | 0.000 |
| V x Y | 2 | 394931 | 197465.8 | 27.96 | 0.000 |
| N x V | 2 | 3818 | 1909.4 | 0.27 | |
| N x V x Y | 4 | 85088 | 21272.2 | 3.01 | 0.018 |
| S x V | 2 | 14748 | 7274.1 | 1.04 | 0.353 |
| S x V x Y | 4 | 100791 | 25197.8 | 3.57 | 0.007 |
| N x S x V | 4 | 18332 | 4583.1 | 0.65 | |
| N x S x V x Y | 8 | 58398 | 7299.8 | 1.03 | 0.410 |
| P x V | 2 | 13820 | 6910.1 | 0.98 | |
| P x V x Y | 4 | 7179 | 1794.9 | 0.25 | |
| N x P x V | 4 | 22456 | 5614.1 | 0.79 | |
| N x P x V x Y | 8 | 53616 | 6702.0 | 0.95 | |
| S x P x V | 4 | 80288 | 20072.2 | 2.84 | 0.024 |
| S x P x V x Y | 8 | 13166 | 1645.9 | 0.23 | |
| N x S x P x V | 8 | 51011 | 6376.4 | 0.90 | |
| N x S x P x V x Y | 16 | 128050 | 8003.1 | 1.13 | 0.324 |
| Error (c) | 270 | 1906983 | 7062.9 | | |

Appendix E8. Analysis of variance for days to 50% flowering, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 58.68 | 29.340 | 1.15 | 0.342 |
| Nitrogen | 2 | 7.86 | 3.932 | 0.15 | |
| Seed rate | 2 | 663.49 | 331.747 | 12.97 | 0.000 |
| N x S | 4 | 116.73 | 29.182 | 1.14 | 0.372 |
| Error (a) | 16 | 409.10 | 25.569 | | |
| Phosphorus | 2 | 62.27 | 31.136 | 1.49 | 0.231 |
| N x P | 4 | 11.40 | 2.849 | 0.14 | |
| S x P | 4 | 130.88 | 32.719 | 1.56 | 0.191 |
| N x S x P | 8 | 138.57 | 17.321 | 0.83 | |
| Variety | 1 | 1605.56 | 1605.556 | 76.64 | 0.000 |
| N x V | 2 | 65.44 | 32.722 | 1.56 | 0.215 |
| S x V | 2 | 252.33 | 126.167 | 6.02 | 0.003 |
| N x S x V | 4 | 48.78 | 12.194 | 0.58 | |
| P x V | 2 | 156.59 | 78.296 | 3.74 | 0.027 |
| N x P x V | 4 | 27.07 | 6.769 | 0.32 | |
| S x P x V | 4 | 68.19 | 17.046 | 0.81 | |
| N x S x P x V | 8 | 47.70 | 5.963 | 0.28 | |
| Error (b) | 90 | 1885.56 | 20.951 | | |

Appendix E9. Analysis of variance for days to 50% flowering, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 7.00 | 3.500 | 1.36 | 0.187 |
| Nitrogen | 2 | 35.15 | 17.574 | 9.34 | 0.002 |
| Seed rate | 2 | 48.26 | 24.130 | 12.82 | 0.000 |
| N x S | 4 | 39.15 | 9.787 | 5.20 | 0.007 |
| Error (a) | 16 | 30.11 | 1.882 | | |
| Phosphorus | 2 | 4.78 | 2.389 | 0.96 | |
| N x P | 4 | 2.52 | 0.630 | 0.25 | |
| S x P | 4 | 6.85 | 1.713 | 0.69 | |
| N x S x P | 8 | 10.30 | 1.287 | 0.52 | |
| Variety | 1 | 742.27 | 743.265 | 298.34 | 0.000 |
| N x V | 2 | 2.75 | 1.377 | 0.55 | |
| S x V | 2 | 34.31 | 17.154 | 6.89 | 0.001 |
| N x S x V | 4 | 18.06 | 4.515 | 1.81 | 0.133 |
| P x V | 2 | 2.23 | 1.117 | 0.45 | |
| N x P x V | 4 | 4.69 | 1.173 | 0.47 | |
| S x P x V | 4 | 12.36 | 3.090 | 1.24 | 0.299 |
| N x S x P x V | 8 | 10.49 | 1.312 | 0.53 | |
| Error (b) | 90 | 224.22 | 2.491 | | |

Appendix E10. Analysis of variance for days to 50% flowering, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 230.72 | 115.358 | 1.35 | 0.287 |
| Nitrogen | 2 | 16.09 | 8.043 | 0.09 | |
| Seed rate | 2 | 2146.53 | 1073.265 | 12.55 | 0.000 |
| N x S | 4 | 395.62 | 98.904 | 1.16 | 0.366 |
| Error (a) | 16 | 1367.95 | 85.479 | | |
| Phosphorus | 2 | 161.72 | 80.858 | 1.04 | 0.357 |
| N x P | 4 | 68.99 | 17.247 | 0.22 | |
| S x P | 4 | 366.43 | 91.608 | 1.18 | 0.325 |
| N x S x P | 8 | 474.86 | 59.358 | 0.76 | |
| Variety | 1 | 3271.51 | 3271.506 | 42.07 | 0.000 |
| N x V | 2 | 218.53 | 109.265 | 1.41 | 0.250 |
| S x V | 2 | 569.05 | 248.525 | 3.66 | 0.029 |
| N x S x V | 4 | 142.14 | 35.534 | 0.46 | |
| P x V | 2 | 664.98 | 332.488 | 4.28 | 0.016 |
| N x P x V | 4 | 76.54 | 19.136 | 0.25 | |
| S x P x V | 4 | 263.47 | 65.867 | 0.85 | |
| N x S x P x V | 8 | 115.46 | 14.432 | 0.19 | |
| Error (b) | 90 | 6998.00 | 77.756 | | |

Appendix E11. Analysis of variance for days to maturity, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 19.06 | 9.525 | 0.26 | |
| Nitrogen | 2 | 69.86 | 34.932 | 0.96 | |
| Seed rate | 2 | 127.75 | 63.877 | 1.75 | 0.206 |
| N x S | 4 | 111.36 | 27.840 | 0.76 | |
| Error (a) | 16 | 585.17 | 26.573 | | |
| Phosphorus | 2 | 56.01 | 28.006 | 1.73 | 0.183 |
| N x P | 4 | 50.10 | 12.525 | 0.77 | |
| S x P | 4 | 64.43 | 16.108 | 0.99 | |
| N x S x P | 8 | 137.01 | 17.127 | 1.06 | 0.100 |
| Variety | 1 | 3803.86 | 3803.858 | 234.73 | 0.000 |
| N x V | 2 | 28.60 | 14.302 | 0.88 | |
| S x V | 2 | 52.20 | 26.099 | 1.61 | 0.205 |
| N x S x V | 4 | 239.73 | 59.932 | 3.70 | 0.007 |
| P x V | 2 | 23.42 | 11.710 | 0.72 | |
| N x P x V | 4 | 78.40 | 19.599 | 1.21 | 0.312 |
| S x P x V | 4 | 83.25 | 20.812 | 1.28 | 0.282 |
| N x S x P x V | 8 | 24.72 | 3.090 | 0.19 | |
| Error (b) | 90 | 1458.44 | 16.205 | | |

Appendix E12. Analysis of variance for days to maturity, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 188.31 | 94.154 | 2.42 | 0.124 |
| Nitrogen | 2 | 272.23 | 136.117 | 3.50 | 0.054 |
| Seed rate | 2 | 281.12 | 140.562 | 3.61 | 0.050 |
| N x S | 4 | 169.36 | 42.340 | 1.09 | 0.395 |
| Error (a) | 16 | 622.69 | 38.918 | | |
| Phosphorus | 2 | 39.27 | 19.636 | 0.84 | |
| N x P | 4 | 29.32 | 7.330 | 0.31 | |
| S x P | 4 | 43.54 | 10.886 | 0.47 | |
| N x S x P | 8 | 20.86 | 2.608 | 0.11 | |
| Variety | 1 | 5820.01 | 5820.006 | 249.87 | 0.000 |
| N x V | 2 | 138.01 | 69.006 | 2.96 | 0.056 |
| S x V | 2 | 48.68 | 24.340 | 1.04 | 0.355 |
| N x S x V | 4 | 94.69 | 23.673 | 1.02 | 0.403 |
| P x V | 2 | 54.98 | 27.488 | 1.18 | 0.311 |
| N x P x V | 4 | 12.51 | 3.127 | 0.13 | |
| S x P x V | 4 | 45.40 | 11.349 | 0.49 | |
| N x S x P x V | 8 | 48.57 | 6.071 | 0.26 | |
| Error (b) | 90 | 2096.33 | 23.293 | | |

Appendix E13. Analysis of variance for days to maturity, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 120.04 | 60.019 | 2.37 | 0.125 |
| Nitrogen | 2 | 9.04 | 4.519 | 0.18 | |
| Seed rate | 2 | 376.70 | 188.352 | 7.43 | |
| N x S | 4 | 88.81 | 22.204 | 0.88 | |
| Error (a) | 16 | 405.41 | 25.338 | | |
| Phosphorus | 2 | 35.81 | 17.907 | 0.88 | |
| N x P | 4 | 69.04 | 17.259 | 0.85 | |
| S x P | 4 | 86.70 | 21.676 | 1.06 | 0.379 |
| N x S x P | 8 | 162.56 | 20.319 | 1.00 | |
| Variety | 1 | 1752.64 | 1753.636 | 85.94 | 0.000 |
| N x V | 2 | 97.83 | 48.914 | 2.40 | 0.096 |
| S x V | 2 | 54.83 | 27.414 | 1.34 | 0.266 |
| N x S x V | 4 | 116.54 | 29.136 | 1.43 | 0.231 |
| P x V | 2 | 15.94 | 7.969 | 0.39 | |
| N x P x V | 4 | 45.64 | 11.414 | 0.56 | |
| S x P x V | 4 | 126.65 | 31.664 | 1.55 | 0.194 |
| N x S x P x V | 8 | 138.75 | 17.344 | 0.85 | |
| Error (b) | 90 | 1836.56 | 20.406 | | |

Appendix E14. Analysis of variance for plant height at maturity, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 465.81 | 232.907 | 3.66 | 0.049 |
| Nitrogen | 2 | 810.81 | 405.407 | 6.36 | 0.009 |
| Seed rate | 2 | 58.11 | 29.056 | 0.46 | |
| N x S | 4 | 167.63 | 41.907 | 0.66 | |
| Error (a) | 16 | 1019.30 | 63.706 | | |
| Phosphorus | 2 | 97.15 | 48.574 | 1.07 | 0.345 |
| N x P | 4 | 57.15 | 14.287 | 0.32 | |
| S x P | 4 | 59.30 | 14.824 | 0.33 | |
| N x S x P | 8 | 227.85 | 28.181 | 0.63 | |
| Variety | 1 | 9645.06 | 9645.062 | 213.34 | 0.000 |
| N x V | 2 | 84.35 | 42.173 | 0.93 | |
| S x V | 2 | 32.83 | 16.414 | 0.36 | |
| N x S x V | 4 | 87.21 | 21.802 | 0.48 | |
| P x V | 2 | 63.38 | 31.191 | 0.69 | |
| N x P x V | 4 | 247.32 | 61.830 | 1.37 | 0.251 |
| S x P x V | 4 | 93.17 | 23.293 | 0.52 | |
| N x S x P x V | 8 | 315.68 | 39.460 | 0.87 | |
| Error (b) | 90 | 4068.89 | 45.210 | | |

Appendix E15. Analysis of variance for ear-bearing tillers(/$m^2$), 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 107.44 | 53.722 | 0.26 | |
| Nitrogen | 2 | 3236.33 | 1618.167 | 7.73 | 0.004 |
| Seed rate | 2 | 90.26 | 45.130 | 0.22 | |
| N x S | 4 | 422.07 | 105.519 | 0.50 | |
| Error (a) | 16 | 3350.00 | 209.375 | | |
| Phosphorus | 2 | 103.37 | 51.685 | 0.42 | |
| N x P | 4 | 222.07 | 55.519 | 0.45 | |
| S x P | 4 | 157.26 | 39.315 | 0.32 | |
| N x S x P | 8 | 364.07 | 45.509 | 0.37 | |
| Variety | 1 | 5784.10 | 5784.099 | 47.38 | 0.000 |
| N x V | 2 | 3506.31 | 1753.154 | 14.36 | 0.000 |
| S x V | 2 | 45.57 | 22.784 | 0.19 | |
| N x S x V | 4 | 645.36 | 161.340 | 1.32 | 0.268 |
| P x V | 2 | 846.31 | 423.154 | 3.47 | 0.035 |
| N x P x V | 4 | 371.06 | 92.765 | 0.76 | |
| S x P x V | 4 | 293.80 | 73.451 | 0.60 | |
| N x S x P x V | 8 | 416.49 | 52.062 | 0.43 | |
| Error (b) | 90 | 10987 | 122.088 | | |

Appendix E16. Analysis of variance for plant height at maturity, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 194.60 | 274.302 | 7.89 | 0.004 |
| Nitrogen | 2 | 176.64 | 88.321 | 2.82 | 0.089 |
| Seed rate | 2 | 352.98 | 176.488 | 5.63 | 0.014 |
| N x S | 4 | 494.69 | 123.673 | 3.95 | 0.020 |
| Error (a) | 16 | 501.40 | 31.337 | | |
| Phosphorus | 2 | 67.42 | 33.710 | 0.54 | |
| N x P | 4 | 68.14 | 17.034 | 0.27 | |
| S x P | 4 | 210.80 | 52.701 | 0.84 | |
| N x S x P | 8 | 417.98 | 52.247 | 0.83 | |
| Variety | 1 | 8.91 | 8.914 | 0.14 | |
| N x V | 2 | 267.60 | 133.802 | 2.13 | 0.124 |
| S x V | 2 | 154.60 | 77.302 | 0.297 | |
| N x S x V | 4 | 211.65 | 52.914 | 0.84 | |
| P x V | 2 | 36.09 | 18.043 | 0.29 | |
| N x P x V | 4 | 100.95 | 25.238 | 0.40 | |
| S x P x V | 4 | 103.62 | 25.904 | 0.41 | |
| N x S x P x V | 8 | 749.90 | 93.738 | 1.49 | 0.171 |
| Error (b) | 90 | 5654.00 | 62.822 | | |

Appendix E17. Analysis of variance for percent lodging, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 1412.98 | 706.488 | 4.15 | 0.035 |
| Nitrogen | 2 | 1053.90 | 526.951 | 3.09 | 0.073 |
| Seed rate | 2 | 624.37 | 312.186 | 1.83 | 0.192 |
| N x S | 4 | 232.99 | 58.247 | 0.34 | |
| Error (a) | 16 | 2727.08 | 170.443 | | |
| Phosphorus | 2 | 354.57 | 177.286 | 1.81 | 0.169 |
| N x P | 4 | 188.01 | 47.001 | 0.48 | |
| S x P | 4 | 390.61 | 97.652 | 1.00 | |
| N x S x P | 8 | 83.17 | 10.396 | 0.11 | |
| Variety | 1 | 4136.66 | 4136.659 | 42.21 | 0.000 |
| N x V | 2 | 318.26 | 159.132 | 1.62 | 0.202 |
| S x V | 2 | 369.62 | 198.309 | 2.02 | 0.138 |
| N x S x V | 4 | 298.79 | 74.698 | 0.76 | |
| P x V | 2 | 47.37 | 23.685 | 0.24 | |
| N x P x V | 4 | 474.42 | 118.604 | 1.21 | 0.312 |
| S x P x V | 4 | 462.04 | 115.502 | 1.20 | 0.309 |
| N x S x P x V | 8 | 1406.46 | 1 75.809 | 1.79 | 0.178 |
| Error (b) | 90 | 8820.18 | 98.002 | | |

Appendix E18. Analysis of variance for percent lodging, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 1263.23 | 631.616 | 1.86 | 0.187 |
| Nitrogen | 2 | 1013.35 | 506.676 | 1.49 | 0.254 |
| Seed rate | 2 | 404.49 | 202.246 | 0.60 | |
| N x S | 4 | 1175.08 | 293.770 | 0.87 | |
| Error (a) | 16 | 5424.43 | 339.027 | | |
| Phosphorus | 2 | 139.71 | 69.853 | 0.34 | |
| N x P | 4 | 970.73 | 242.683 | 1.17 | 0.327 |
| S x P | 4 | 438.10 | 109.526 | 0.53 | |
| N x S x P | 8 | 360.38 | 45.048 | 0.22 | |
| Variety | 1 | 8654.60 | 8654.602 | 41.85 | 0.000 |
| N x V | 2 | 608.45 | 304.225 | 1.47 | 0.235 |
| S x V | 2 | 1028.44 | 514.220 | 2.49 | 0.088 |
| N x S x V | 4 | 505.11 | 126.277 | 0.61 | |
| P x V | 2 | 95.77 | 47.887 | 0.23 | |
| N x P x V | 4 | 1592.50 | 398.126 | 1.93 | 0.113 |
| S x P x V | 4 | 582.32 | 145.580 | 0.70 | |
| N x S x P x V | 8 | 333.65 | 41.707 | 0.20 | |
| Error (b) | 90 | 18612.53 | 206.806 | | |

Appendix E19. Analysis of variance for percent lodging, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 3570.27 | 1783.137 | 4.32 | 0.031 |
| Nitrogen | 2 | 2010.45 | 1005.224 | 2.44 | 0.119 |
| Seed rate | 2 | 1924.43 | 962.214 | 2.33 | 0.129 |
| N x S | 4 | 681.15 | 170.289 | 0.41 | |
| Error (a) | 16 | 6604.16 | 412.760 | | |
| Phosphorus | 2 | 1577.64 | 788.819 | 5.56 | 0.005 |
| N x P | 4 | 453.65 | 113.413 | 0.80 | |
| S x P | 4 | 181.78 | 45.446 | 0.32 | |
| N x S x P | 8 | 967.97 | 120.997 | 0.85 | |
| Variety | 1 | 1929.45 | 1929.447 | 13.61 | 0.000 |
| N x V | 2 | 42.72 | 21.361 | 0.15 | |
| S x V | 2 | 160.69 | 80.343 | 0.57 | |
| N x S x V | 4 | 598.88 | 149.719 | 1.06 | |
| P x V | 2 | 13.96 | 6.980 | 0.05 | |
| N x P x V | 4 | 724.75 | 181.188 | 1.28 | 0.284 |
| S x P x V | 4 | 206.19 | 51.548 | 0.36 | |
| N x S x P x V | 8 | 1569.16 | 196.145 | 1.38 | 0.214 |
| Error (b) | 90 | 12761.63 | 141.796 | | |

Appendix E20. Analysis of variance for length of panicle, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 26.48 | 13.228 | 3.86 | 0.042 |
| Nitrogen | 2 | 81.53 | 40.765 | 11.91 | 0.000 |
| Seed rate | 2 | 58.68 | 29.340 | 8.57 | 0.002 |
| N x S | 4 | 29.21 | 7.302 | 2.13 | 0.123 |
| Error (a) | 16 | 54.77 | 3.423 | | |
| Phosphorus | 2 | 1.83 | 0.914 | 0.30 | |
| N x P | 4 | 5.40 | 1.349 | 0.45 | |
| S x P | 4 | 16.47 | 4.117 | 1.36 | 0.254 |
| N x S x P | 8 | 11.20 | 1.400 | 0.46 | |
| Variety | 1 | 2.99 | 2.989 | 0.99 | |
| N x V | 2 | 9.53 | 4.765 | 1.57 | 0.213 |
| S x V | 2 | 12.01 | 6.006 | 1.98 | 0.143 |
| N x S x V | 4 | 1.80 | 0.451 | 0.15 | |
| P x V | 2 | 0.35 | 0.173 | 0.06 | |
| N x P x V | 4 | 4.14 | 1.034 | 0.34 | |
| S x P x V | 4 | 6.77 | 1.691 | 0.56 | |
| N x S x P x V | 8 | 5.42 | 0.677 | 0.22 | |
| Error (b) | 90 | 272.78 | 3.031 | | |

Appendix E21. Analysis of variance for panicle length, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 20.33 | 10.167 | 3.59 | 0.051 |
| Nitrogen | 2 | 0.26 | 0.130 | 0.05 | |
| Seed rate | 2 | 21.81 | 10.907 | 3.85 | 0.043 |
| N x S | 4 | 11.37 | 2.843 | 1.00 | 0.434 |
| Error (a) | 16 | 45.33 | 2.833 | | |
| Phosphorus | 2 | 18.93 | 9.463 | 4.15 | 0.018 |
| N x P | 4 | 14.37 | 3.593 | 1.58 | 0.187 |
| S x P | 4 | 8.37 | 2.093 | 0.92 | |
| N x S x P | 8 | 103.33 | 12.917 | 5.67 | 0.000 |
| Variety | 1 | 1.04 | 1.043 | 0.46 | |
| N x V | 2 | 13.49 | 6.747 | 2.96 | 0.056 |
| S x V | 2 | 3.79 | 1.895 | 0.83 | |
| N x S x V | 4 | 20.73 | 5.182 | 2.28 | 0.067 |
| P x V | 2 | 3.72 | 1.858 | 0.82 | |
| N x P x V | 4 | 17.80 | 4.451 | 1.95 | 0.108 |
| S x P x V | 4 | 42.62 | 10.654 | 4.68 | 0.001 |
| N x S x P x V | 8 | 47.98 | 5.997 | 2.63 | 0.012 |
| Error (b) | 90 | 205.00 | 2.278 | | |

Appendix E22. Analysis of variance for paddy panicle, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 29.37 | 14.685 | 3.29 | 0.063 |
| Nitrogen | 2 | 17.33 | 8.667 | 1.94 | 0.175 |
| Seed rate | 2 | 34.48 | 17.241 | 3.86 | 0.042 |
| N x S | 4 | 21.85 | 5.463 | 1.22 | 0.339 |
| Error (a) | 16 | 71.41 | 4.463 | | |
| Phosphorus | 2 | 23.44 | 11.722 | 3.46 | 0.035 |
| N x P | 4 | 51.89 | 12.972 | 3.83 | 0.006 |
| S x P | 4 | 17.30 | 4.324 | 1.28 | 0.285 |
| N x S x P | 8 | 35.81 | 4.477 | 1.32 | 0.243 |
| Variety | 1 | 99.56 | 99.562 | 29.36 | 0.000 |
| N x V | 2 | 3.90 | 1.951 | 0.58 | |
| S x V | 2 | 17.27 | 8.636 | 2.55 | 0.083 |
| N x S x V | 4 | 5.43 | 1.358 | 0.40 | |
| P x V | 2 | 0.09 | 0.043 | 0.01 | |
| N x P x V | 4 | 8.73 | 2.182 | 0.64 | |
| S x P x V | 4 | 11.02 | 2.756 | 0.81 | |
| N x S x P x V | 8 | 55.49 | 6.937 | 2.05 | 0.049 |
| Error (b) | 90 | 305.22 | 3.391 | | |

Appendix E23. Analysis of variance for number of grains/ ear, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 365.64 | 182.821 | 0.50 | |
| Nitrogen | 2 | 3003.86 | 1501.932 | 4.08 | 0.036 |
| Seed rate | 2 | 4611.90 | 2305.951 | 6.27 | 0.009 |
| N x S | 4 | 3350.02 | 837.506 | 2.28 | 0.106 |
| Error (a) | 16 | 5887.25 | 367.953 | | |
| Phosphorus | 2 | 56.01 | 26.006 | 0.09 | |
| N x P | 4 | 1206.91 | 301.728 | 1.00 | 0.408 |
| S x P | 4 | 1931.77 | 482.941 | 1.61 | 0.179 |
| N x S x P | 8 | 1950.53 | 243.816 | 0.81 | |
| Variety | 1 | 73813.36 | 73813.358 | 245.72 | 0.000 |
| N x V | 2 | 322.23 | 1 61.117 | 0.54 | |
| S x V | 2 | 21.53 | 10.765 | 0.04 | |
| N x S x V | 4 | 433.21 | 108.302 | 0.36 | |
| P x V | 2 | 187.57 | 93.784 | 0.31 | |
| N x P x V | 4 | 183.95 | 45.988 | 0.15 | |
| S x P x V | 4 | 1464.21 | 366.052 | 1.22 | |
| N x S x P x V | 8 | 1551.94 | 193.992 | 0.65 | |
| Error (b) | 90 | 27035.78 | 300.398 | | |

Appendix E24. Analysis of variance for number of grain/ ear, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 4451.44 | 2225.722 | 3.94 | 0.040 |
| *Nitrogen* | 2 | 3308.93 | 1654.464 | 2.93 | 0.082 |
| Seed rate | 2 | 789.93 | 393.963 | 0.70 | |
| N x S | 4 | 6864.93 | 1716.231 | 3.04 | 0.048 |
| Error (a) | 16 | 9036.11 | 564.757 | | |
| Phosphorus | 2 | 56.15 | 28.074 | 0.04 | |
| N x P | 4 | 5471.81 | 1367.954 | 2.89 | 0.026 |
| S x P | 4 | 1864.59 | 466.148 | 0.98 | |
| N x S x P | 8 | 7697.00 | 962.125 | 2.03 | 0.051 |
| Variety | 1 | 7660.47 | 7660.469 | 16.18 | 0.016 |
| N x V | 2 | 468.16 | 234.089 | 0.49 | |
| S x V | 2 | 1778.12 | 889.062 | 1.88 | 0.158 |
| N x S x V | 4 | 3343.47 | 835.867 | 1.77 | 0.142 |
| P x V | 2 | 1937.98 | 968.988 | 2.05 | 0.135 |
| N x P x V | 4 | 2816.51 | 704.127 | 1.49 | 0.212 |
| S x P x V | 4 | 1777.65 | 444.414 | 0.94 | |
| N x S x P x V | 8 | 4926.98 | 615.872 | 1.30 | 0.253 |
| Error (b) | 90 | 42603.78 | 473.375 | | |

Appendix E25. Analysis of variance for number of grains/ ear, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 12982.09 | 6491.043 | 4.06 | 0.037 |
| Nitrogen | 2 | 1534.09 | 767.043 | 0.48 | |
| Seed rate | 2 | 4945.20 | 2472.599 | 1.55 | 0.243 |
| N x S | 4 | 5415.80 | 1353.951 | 0.85 | |
| Error (a) | 16 | 25579.36 | 1598.710 | | |
| Phosphorus | 2 | 227.42 | 113.710 | 0.18 | |
| N x P | 4 | 5713.36 | 1428.340 | 2.32 | 0.062 |
| S x P | 4 | 2366.69 | 591.673 | 0.96 | |
| N x S x P | 8 | 5748.64 | 718.580 | 1.17 | 0.328 |
| Variety | 1 | 5213.340 | 5213.340 | 8.45 | 0.004 |
| N x V | 2 | 1927.94 | 963.969 | 1.56 | 0.215 |
| S x V | 2 | 1996.90 | 998.451 | 1.62 | 0.203 |
| N x S x V | 4 | 1992.99 | 498.247 | 0.81 | |
| P x V | 2 | 1843.94 | 921.969 | 1.49 | 0.229 |
| N x P x V | 4 | 2994.17 | 748.543 | 1.21 | 0.310 |
| S x P x V | 4 | 2484.54 | 621.136 | 1.01 | 0.408 |
| N x S x P x V | 8 | 7061.68 | 882.710 | 1.43 | 0.194 |
| Error (b) | 90 | 55506.56 | 616.740 | | |

Appendix E26. Analysis of variance for number of grains/ear combined over 1990 - 92 seasons.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Repliaction | 2 | 544.97 | 272.484 | 0.06 | |
| Years | 2 | 139297.78 | 69648.891 | 15.03 | 0.013 |
| Error (a) | 4 | 18541.84 | 4635.459 | | |
| Nitrogen | 2 | 1218.77 | 609.385 | 0.76 | |
| N x Y | 4 | 5669.96 | 1417.490 | 1.77 | 0.149 |
| Seed rate | 2 | 8043.02 | 4021.508 | 5.03 | 0.010 |
| S x Y | 4 | 2823.27 | 705.817 | 0.88 | |
| N x S | 4 | 5817.09 | 1454.274 | 1.82 | 0.140 |
| N x S x Y | 8 | 8849.73 | 1106.217 | 1.38 | 0.228 |
| Error (b) | 48 | 38396.20 | 799.921 | | |
| Phosphorus | 2 | 200.99 | 100.496 | 0.22 | |
| P x Y | 4 | 62.59 | 15.647 | 0.03 | |
| N x P | 4 | 5505.86 | 1376.465 | 3.02 | 0.018 |
| N x P x Y | 8 | 6081.34 | 760.167 | 1.67 | 0.105 |
| S x P | 4 | 1412.80 | 353.200 | 0.78 | |
| S x P x Y | 8 | 3450.62 | 431.328 | 0.95 | |
| N x S x P | 8 | 5681.65 | 710.206 | 1.56 | 0.136 |
| N x S x P x Y | 16 | 7672.16 | 479.510 | 1.05 | 0.400 |
| V ariety | 1 | 59357.29 | 59357.286 | 130.44 | 0.000 |
| V x Y | 2 | 25951.73 | 12975.866 | 28.51 | 0.000 |
| N x V | 2 | 412.40 | 206.200 | 0.45 | |
| N x V x Y | 4 | 1414.08 | 353.521 | 0.78 | |
| S x V | 2 | 1455.51 | 727.755 | 1.60 | 0.203 |
| S x V x Y | 4 | 1855.49 | 463.872 | 1.02 | 0.397 |
| N x S x V | 4 | 3473.64 | 868.409 | 1.91 | 0.109 |
| N x S x V x Y | 8 | 2184.92 | 273.115 | 0.60 | |
| P x V | 2 | 2187.66 | 1093.829 | 2.40 | 0.092 |
| P x V x Y | 4 | 2617.01 | 654.252 | 1.44 | 0.221 |
| N x P x V | 4 | 1452.97 | 363.243 | 0.80 | |
| N x P x V x Y | 8 | 3894.25 | 486.781 | 1.07 | 0.384 |
| S x P x V x Y | 8 | 5461.59 | 455.133 | 1.00 | 0.449 |
| N S x P x V | 8 | 5329.04 | 444.086 | 0.98 | |
| N x S x P x V x Y | 16 | 6858.59 | 571.549 | 1.26 | 0.244 |
| Error (c) | 270 | 122865.67 | 455.058 | | |

Appendix E27. Analysis of variance for 1000-seed weight, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 6.30 | 3.148 | 2.17 | 0.146 |
| Nitrogen | 2 | 7.37 | 3.687 | 2.55 | 0.109 |
| Seed rate | 2 | 0.42 | 0.210 | 0.15 | |
| N x S | 4 | 4.79 | 1.198 | 0.83 | |
| Error (a) | 16 | 23.14 | 1.448 | | |
| Phosphorus | 2 | 2.93 | 1.466 | 1.00 | |
| N x P | 4 | 2.61 | 0.652 | 0.44 | |
| S x P | 4 | 11.91 | 2.977 | 2.03 | 0.097 |
| N x S x P | 8 | 15.30 | 1.912 | 1.30 | 0.253 |
| Variety | 1 | 1465.27 | 1465.270 | 996.92 | 0.000 |
| N x V | 2 | 9.57 | 4.786 | 3.26 | 0.043 |
| S x V | 2 | 1.70 | 0.852 | 0.58 | |
| N x S x V | 4 | 15.80 | 3.950 | 2.69 | 0.036 |
| P x V | 2 | 9.00 | 4.498 | 3.06 | 0.051 |
| N x P x V | 4 | 1.05 | 0.262 | 0.18 | |
| S x P x V | 4 | 5.74 | 1.435 | 0.98 | |
| N x S x P x V | 8 | 10.27 | 1.283 | 0.87 | |
| Error (b) | 90 | 132.28 | 1.470 | | |

Appendix E28. Analysis of variance for 1000-seed weight, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 14.35 | 7.174 | 0.75 | |
| Nitrogen | 2 | 21.42 | 10.709 | 1.12 | 0.349 |
| Seed rate | 2 | 13.24 | 6.618 | 0.70 | |
| N x S | 4 | 8.30 | 2.074 | 0.22 | |
| Error (a) | 16 | 152.31 | 9.520 | | |
| Phosphorus | 2 | 2.35 | 1.173 | 0.22 | |
| N x P | 4 | 20.73 | 5.182 | 0.98 | |
| S x P | 4 | 23.16 | 5.790 | 1.09 | 0.366 |
| N x S x P | 8 | 15.69 | 1.961 | 0.37 | |
| Variety | 1 | 757.99 | 757.990 | 142.74 | 0.000 |
| N x V | 2 | 5.30 | 2.651 | 0.50 | |
| S x V | 2 | 3.46 | 1.731 | 0.33 | |
| N x S x V | 4 | 3.76 | 0.941 | 0.18 | |
| P x V | 2 | 1.16 | 0.817 | 0.15 | |
| N x P x V | 4 | 22.30 | 5.574 | 1.05 | 0.386 |
| S x P x V | 4 | 9.53 | 2.382 | 0.45 | |
| N x S x P x V | 8 | 13.95 | 1.744 | 0.33 | |
| Error (b) | 90 | 477.94 | 5.310 | | |

Appendix E29. Analysis of variance for 1000-seed weight, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 1.94 | 0.970 | 0.41 | |
| Nitrogen | 2 | 8.63 | 4.314 | 1.82 | 0.194 |
| Seed rate | 2 | 6.27 | 3.134 | 1.32 | 0.294 |
| N x S | 4 | 7.28 | 1.819 | 0.77 | |
| Error (a) | 16 | 37.97 | 2.373 | | |
| Phosphorus | 2 | 13.02 | 6.512 | 3.35 | 0.039 |
| Variety | 1 | 52.54 | 52.543 | 27.03 | 0.000 |
| N x P | 4 | 3.99 | 0.997 | 0.51 | |
| S x P | 4 | 4.84 | 1.209 | 0.62 | |
| P x V | 2 | 1.24 | 0.622 | 0.32 | |
| N x V | 2 | 1.09 | 0.544 | 0.28 | |
| S x V | 2 | 4.37 | 2.186 | 1.12 | 0.329 |
| N x S x P | 8 | 17.86 | 2.233 | 1.15 | 0.339 |
| N x S x V | 4 | 10.46 | 2.614 | 1.35 | 0.259 |
| N x P x V | 4 | 11.43 | 2.859 | 1.47 | 0.217 |
| N x P x V | 4 | 1.85 | 0.462 | 0.24 | |
| N x S x P x V | 8 | 10.22 | 1.278 | 0.66 | |
| Error (b) | 90 | 174.92 | 1.944 | | |

Appendix E30. Analysis of variance for 1000-seed weight combined over 1990-92 seasons.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Repliaction | 2 | 17.62 | 8.812 | 1.46 | 0.334 |
| Years | 2 | 2724.11 | 1362.053 | 435.18 | 0.000 |
| Error (a) | 4 | 24.14 | 6.035 | | |
| Nitrogen | 2 | 1.88 | 0.938 | 0.16 | |
| N x Y | 4 | 4.70 | 1.176 | 0.38 | |
| Seed rate | 2 | 9.03 | 4.515 | 1.61 | 0.209 |
| S x Y | 4 | 7.85 | 1.963 | 0.63 | |
| N x S | 4 | 3.85 | 0.962 | 0.34 | |
| N x S x Y | 8 | 24.08 | 3.010 | 0.96 | |
| Error (b) | 48 | 134.36 | 2.799 | | |
| Phosphorus | 2 | 1.20 | 0.600 | 0.21 | |
| P x Y | 4 | 18.35 | 4.587 | 1.47 | 0.212 |
| N x P | 4 | 7.74 | 1.936 | 0.69 | |
| N x P x Y | 8 | 13.42 | 1.678 | 0.54 | |
| S x P | 4 | 24.12 | 6.030 | 2.15 | 0.088 |
| S x P x Y | 8 | 14.85 | 1.857 | 0.59 | |
| N x S x P | 8 | 12.70 | 1.587 | 0.57 | |
| N x S x P x Y | 16 | 20.91 | 1.307 | 0.42 | |
| V ariety | 1 | 4.08 | 4.078 | 1.30 | |
| V x Y | 2 | 111.83 | 55.915 | 17.87 | 0.000 |
| N x V | 2 | 0.83 | 0.415 | 0.13 | |
| N x V x Y | 4 | 45.98 | 11.495 | 3.67 | 0.006 |
| S x V | 2 | 4.59 | 2.294 | 0.73 | |
| S x V x Y | 4 | 8.00 | 2.000 | 0.64 | |
| N x S x V | 4 | 5.32 | 1.329 | 0.42 | |
| P x V | 2 | 3.19 | 1.595 | 0.51 | |
| P x V x Y | 4 | 7.44 | 1.861 | 0.59 | |
| N x P x V | 4 | 10.59 | 2.647 | 0.85 | |
| N x P x V x Y | 8 | 20.76 | 2.595 | 0.83 | |
| S x P x V | 4 | 8.04 | 2.009 | 0.64 | |
| S x P x V x Y | 8 | 19.59 | 2.449 | 0.78 | |
| N x S x P x V | 8 | 9.88 | 1.235 | 0.39 | |
| N x S x P x V x Y | 16 | 39.79 | 2.487 | | |
| Error (c) | 270 | 845.06 | 3.130 | | |

Appendix E31. Analysis of variance for straw weight, 1990.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.11 | 0.054 | 0.54 | |
| Nitrogen | 2 | 0.44 | 0.221 | 2.31 | 0.131 |
| Seed rate | 2 | 0.41 | 0.207 | 2.16 | 0.147 |
| N x S | 4 | 4.62 | 1.155 | 12.09 | 0.000 |
| Error (a) | 16 | 1.53 | 0.096 | | |
| Phosphorus | 2 | 0.98 | 0.488 | 8.6 | 0.000 |
| N x P | 4 | 2.99 | 0.747 | 13.16 | 0.000 |
| S x P | 4 | 2.45 | 0.613 | 10.81 | 0.000 |
| N x S x P | 8 | 2.01 | 0.251 | 4.42 | 0.000 |
| Variety | 1 | 0.63 | 0.633 | 11.16 | 0.000 |
| N x V | 2 | 1.72 | 0.861 | 15.18 | 0.000 |
| S x V | 2 | 2.58 | 1.292 | 22.76 | 0.000 |
| N x S x V | 4 | 1.59 | 0.399 | 7.00 | 0.000 |
| P x V | 2 | 0.30 | 0.152 | 2.67 | 0.074 |
| N x P x V | 4 | 2.67 | 0.667 | 11.76 | 0.000 |
| S x P x V | 4 | 2.94 | 0.736 | 12.97 | 0.000 |
| N x S x P x V | 8 | 1.61 | 0.202 | 3.55 | 0.001 |
| Error (b) | 90 | 5.11 | 0.057 | | |

Appendix E32. Analysis of variance for straw weight, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.21 | 0.104 | 0.08 | |
| Nitrogen | 2 | 36.95 | 18.476 | 8.46 | 0.000 |
| Seed rate | 2 | 22.86 | 11.429 | 13.67 | 0.003 |
| N x S | 4 | 7.93 | 1.982 | 1.47 | 0.258 |
| Error (a) | 16 | 21.62 | 1.351 | | |
| Phosphorus | 2 | 4.13 | 2.065 | 2.81 | 0.065 |
| N x P | 4 | 4.26 | 1.064 | 1.45 | 0.225 |
| S x P | 4 | 2.36 | 0.589 | 0.80 | |
| N x S x P | 8 | 3.25 | 0.406 | 0.55 | |
| Variety | 1 | 4.68 | 4.678 | 6.36 | 0.013 |
| N x V | 2 | 2.81 | 1.406 | 1.91 | 0.153 |
| S x V | 2 | 1.83 | 0.913 | 1.24 | 0.293 |
| N x S x V | 4 | 1.17 | 0.294 | 0.40 | |
| P x V | 2 | 1.64 | 0.818 | 1.11 | 0.333 |
| N x P x V | 4 | 0.29 | 0.072 | 0.10 | |
| S x P x V | 4 | 2.51 | 0.627 | 0.85 | |
| N x S x P x V | 8 | 10.05 | 1.256 | 1.71 | 0.107 |
| Error (b) | 90 | 66.21 | 0.736 | | |

Appendix E33. Analysis of variance for straw weight, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 8.60 | 4.301 | 6.47 | 0.008 |
| Nitrogen | 2 | 30.33 | 15.163 | 22.80 | 0.000 |
| Seed rate | 2 | 38.14 | 19.071 | 28.68 | 0.000 |
| N x S | 4 | 7.95 | 1.988 | 2.99 | 0.050 |
| Error (a) | 16 | 10.64 | 0.665 | | |
| Phosphorus | 2 | 9.06 | 4.530 | 6.32 | 0.002 |
| N x P | 4 | 0.63 | 0.157 | 0.22 | |
| S x P | 4 | 0.52 | 0.131 | 0.18 | |
| N x S x P | 8 | 9.25 | 1.156 | 1.61 | 0.131 |
| Variety | 1 | 33.87 | 33.866 | 47.28 | 0.000 |
| N x V | 2 | 7.31 | 3.656 | 5.10 | 0.007 |
| S x V | 2 | 15.68 | 7.839 | 10.94 | 0.000 |
| N x S x V | 4 | 0.98 | 0.245 | 0.34 | |
| P x V | 2 | 0.37 | 0.186 | 0.26 | |
| N x P x V | 4 | 0.25 | 0.062 | 0.09 | |
| S x P x V | 4 | 7.49 | 1.873 | 2.61 | 0.040 |
| N x S x P x V | 8 | 22.36 | 2.794 | 3.90 | 0.000 |
| Error (b) | 90 | 64.47 | 0.716 | | |

Appendix E34. Analysis of variance for paddy yield, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 6.40 | 3.20 | 10.64 | 0.001 |
| Nitrogen | 2 | 8.85 | 4.42 | 14.71 | 0.000 |
| Seed rate | 2 | 3.48 | 1.74 | 5.79 | 0.012 |
| N x S | 4 | 2.64 | 0.66 | 2.20 | 0.115 |
| Error (a) | 16 | 4.81 | 0.30 | | |
| Phosphorus | 2 | 0.08 | 0.04 | 0.29 | |
| N x P | 4 | 0.49 | 0.12 | 0.63 | |
| S x P | 4 | 0.34 | 0.08 | 0.43 | |
| N x S x P | 8 | 1.69 | 0.21 | 1.09 | 0.375 |
| Variety | 1 | 0.02 | 0.02 | 0.08 | |
| N x V | 2 | 1.62 | 0.81 | 4.18 | 0.018 |
| S x V | 2 | 0.53 | 0.27 | 1.38 | 0.256 |
| N x S x V | 4 | 0.16 | 0.21 | | |
| P x V | 2 | 0.14 | 0.07 | 0.37 | |
| N x P x V | 4 | 0.60 | 0.15 | 0.77 | |
| S x P x V | 4 | 1.83 | 0.46 | 2.37 | 0.058 |
| N x S x P x V | 8 | 1.29 | 0.16 | 0.83 | |
| Error (b) | 90 | 17.43 | 0.19 | | |

Appendix E35. Analysis of variance for paddy yield, 1991

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.28 | 0.138 | 0.87 | |
| Nitrogen | 2 | 1.90 | 0.951 | 6.01 | 0.110 |
| Seed rate | 2 | 0.83 | 0.413 | 2.61 | 0.104 |
| N x S | 4 | 1.40 | 0.349 | 2.21 | 0.114 |
| Error (a) | 16 | 2.53 | 0.158 | | |
| Phosphorus | 2 | 1.66 | 0.828 | 7.57 | 0.000 |
| N x P | 4 | 0.66 | 0.166 | 1.51 | 0.204 |
| S x P | 4 | 0.56 | 0.141 | 1.28 | 0.282 |
| N x S x P | 8 | 1.33 | 0.166 | 1.52 | 0.160 |
| Variety | 1 | 0.04 | 0.04 | 0.37 | |
| N x V | 2 | 0.16 | 0.080 | 0.73 | |
| S x V | 2 | 0.09 | 0.043 | 0.39 | |
| N x S x V | 4 | 0.30 | 0.074 | 0.68 | |
| P x V | 2 | 0.06 | 0.029 | 0.27 | |
| N x P x V | 4 | 0.47 | 0.119 | 1.09 | 0.368 |
| S x P x V | 4 | 1.59 | 0.399 | 3.65 | 0.008 |
| N x S x P x V | 8 | 1.66 | 0.207 | 1.89 | |
| Error (b) | 90 | 9.84 | 0.109 | | |

Appendix E36. Analysis of variance for paddy yield, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.36 | 0.182 | 0.41 | |
| Nitrogen | 2 | 6.60 | 3.302 | 7.52 | 0.004 |
| Seed rate | 2 | 14.13 | 7.065 | 16.08 | 0.000 |
| N x S | 4 | 1.33 | 0.332 | 0.76 | |
| Error (a) | 16 | 7.09 | 0.439 | | |
| Phosphorus | 2 | 2.99 | 1.497 | 1.43 | 0.243 |
| N x P | 4 | 0.34 | 0.084 | 0.08 | |
| S x P | 4 | 0.93 | 0.232 | 0.22 | |
| N x S x P | 8 | 7.58 | 0.947 | 0.91 | |
| Variety | 1 | 41.47 | 41.466 | 39.72 | 0.000 |
| N x V | 2 | 1.77 | 0.885 | 0.85 | |
| S x V | 2 | 0.95 | 0.474 | 0.45 | |
| N x S x V | 4 | 6.95 | 1.737 | 1.66 | 0.165 |
| P x V | 2 | 0.19 | 0.096 | 0.09 | |
| N x P x V | 4 | 1.89 | 0.472 | 0.45 | |
| S x P x V | 4 | 0.88 | 0.221 | 0.21 | |
| N x S x P x V | 8 | 3.51 | 0.438 | 0.42 | |
| Error (b) | 90 | 93.951 | 1.044 | | |

Appendix E37. Analysis of variance for paddy yield combined over 1990-92 seasons.

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 2.36 | 1.182 | 1.01 | 0.410 |
| Years | 2 | 107.81 | 53.907 | 46.10 | 0.000 |
| Error (a) | 4 | 4.68 | 1.169 | | |
| Nitrogen | 2 | 15.23 | 7.617 | 25.43 | 0.000 |
| N x Y | 4 | 2.13 | 0.531 | 1.78 | 0.149 |
| Seed rate | 2 | 13.36 | 6.681 | 22.32 | 0.000 |
| S x Y | 4 | 5.08 | 1.269 | 4.24 | 0.005 |
| N x S | 4 | 0.21 | 0.052 | 0.17 | |
| N x S x Y | 8 | 5.16 | 0.645 | 2.16 | 0.048 |
| Error (b) | 48 | 14.37 | 0.299 | | |
| Phosphorus | 2 | 1.91 | 0.952 | 2.12 | 0.121 |
| P x Y | 4 | 2.82 | 0.705 | 1.57 | 0.182 |
| N x P | 4 | 0.66 | 0.165 | 0.37 | |
| N x P x Y | 8 | 0.83 | 0.104 | 0.23 | |
| S x P | 4 | 1.02 | 0.256 | 0.57 | |
| S x P x Y | 8 | 0.80 | 0.100 | 0.22 | |
| N x S x P | 8 | 2.10 | 0.262 | 0.58 | |
| N x S x P x Y | 16 | 8.50 | 0.531 | 1.18 | 0.280 |
| V ariety | 1 | 13.51 | 13.513 | 30.10 | 0.000 |
| V x Y | 2 | 28.01 | 14.004 | 31.19 | 0.000 |
| N x V | 2 | 0.51 | 0.235 | 0.57 | |
| N x V x Y | 4 | 3.04 | 0.759 | 1.69 | 0.152 |
| S x V | 2 | 0.14 | 0.071 | 0.16 | |
| S x V x Y | 4 | 1.43 | 0.357 | 0.79 | |
| N x S x V | 4 | 2.10 | 0.525 | 1.17 | 0.325 |
| N x S x V x Y | 8 | 3.30 | 0.663 | 1.48 | 0.165 |
| P x V | 2 | 0.18 | 0.090 | 0.20 | |
| N P x V | 4 | 0.21 | 0.054 | 0.12 | |
| N x P x V x Y | 4 | 1.65 | 0.413 | 0.92 | |
| S x P x V | 8 | 1.31 | 0.164 | 0.36 | |
| S x P x V x Y | 4 | 0.90 | 0.225 | 0.50 | |
| N x S x P x V | 8 | 3.41 | 0.426 | 0.95 | |
| N x S x P x V x Y | 16 | 4.71 | 0.294 | 0.66 | |
| Error (c) | 270 | 121.22 | 0.449 | | |

Appendix E41. Analysis of variance for grain:straw ratio, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.12 | 0.059 | 12.27 | 0.000 |
| Nitrogen | 2 | 0.10 | 0.051 | 10.63 | 0.001 |
| Seed rate | 2 | 0.11 | 0.056 | 11.68 | 0.000 |
| N x S | 4 | 0.12 | 0.030 | 6.28 | 0.003 |
| Error (a) | 16 | 0.08 | 0.005 | | |
| Phosphorus | 2 | 0.01 | 0.004 | 0.77 | |
| N x P | 4 | 0.05 | 0.012 | 2.56 | 0.043 |
| S x P | 4 | 0.06 | 0.014 | 3.06 | 0.020 |
| N x S x P | 8 | 0.05 | 0.006 | 1.27 | 0.279 |
| Variety | 1 | 0.03 | 0.027 | 5.71 | 0.018 |
| N x V | 2 | 0.05 | 0.027 | 5.80 | 0.004 |
| S x V | 2 | 0.05 | 0.026 | 5.44 | 0.005 |
| N x S x V | 4 | 0.04 | 0.009 | 1.92 | 0.114 |
| P x V | 2 | 0.00 | 0.001 | 0.29 | |
| N x P x V | 4 | 0.05 | 0.012 | 2.62 | 0.039 |
| S x P x V | 4 | 0.05 | 0.014 | 2.88 | 0.027 |
| N x S x P x V | 8 | 0.04 | 0.006 | 1.17 | 0.328 |
| Error (b) | 90 | 0.43 | 0.005 | | |

Appendix E42. Analysis of variance for grain:straw ratio, 1990

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.11 | 0.054 | 9.99 | 0.001 |
| Nitrogen | 2 | 0.06 | 0.030 | 5.54 | 0.140 |
| Seed rate | 2 | 0.02 | 0.012 | 2.23 | 0.139 |
| N x S | 4 | 0.01 | 0.003 | 0.56 | |
| Error (a) | 16 | 0.09 | 0.005 | | |
| Phosphorus | 2 | 0.00 | 0.001 | 0.09 | |
| N x P | 4 | 0.03 | 0.007 | 0.87 | |
| S x P | 4 | 0.02 | 0.005 | 0.55 | |
| N x S x P | 8 | 0.17 | 0.022 | 2.64 | 0.110 |
| Variety | 1 | 0.05 | 0.047 | 5.68 | 0.019 |
| N x V | 2 | 0.04 | 0.019 | 2.33 | 0.102 |
| S x V | 2 | 0.03 | 0.015 | 1.88 | 0.158 |
| N x S x V | 4 | 0.00 | 0.001 | 0.07 | |
| P x V | 2 | 0.02 | 0.009 | 1.12 | 0.329 |
| N x P x V | 4 | 0.02 | 0.006 | 0.73 | |
| S x P x V | 4 | 0.02 | 0.004 | 0.50 | |
| N x S x P x V | 8 | 0.09 | 0.012 | 1.42 | 0.197 |
| Error (b) | 90 | 0.74 | 0.003 | | |

Appendix E43. Analysis of variance for grain:ratio, 1992

| Source of variation | DF | SS | MS | F Value | Prob. |
|---|---|---|---|---|---|
| Replication | 2 | 0.03 | 0.160 | 1.10 | 0.357 |
| Nitrogen | 2 | 0.01 | 0.004 | 0.27 | |
| Seed rate | 2 | 0.02 | 0.010 | 0.72 | |
| N x S | 4 | 0.04 | 0.009 | 0.61 | |
| Error (a) | 16 | 0.23 | 0.014 | | |
| Phosphorus | 2 | 0.00 | 0.002 | 0.32 | |
| N x P | 4 | 0.11 | 0.028 | 1.08 | |
| S x P | 4 | 0.02 | 0.005 | 0.72 | |
| N x S x P | 8 | 0.09 | 0.011 | 1.56 | 0.147 |
| Variety | 1 | 0.77 | 0.769 | 110.39 | 0.000 |
| N x V | 2 | 0.01 | 0.004 | 0.61 | |
| S x V | 2 | 0.08 | 0.042 | 6.09 | 0.000 |
| N x S x V | 4 | 0.03 | 0.007 | 1.04 | 0.391 |
| P x V | 2 | 0.04 | 0.022 | 3.22 | 0.044 |
| N x P x V | 4 | 0.02 | 0.006 | 0.80 | |
| S x P x V | 4 | 0.03 | 0.006 | | |
| N x S x P x V | 8 | 0.06 | 0.008 | 1.09 | 0.379 |
| Error (b) | 90 | 0.63 | 0.078 | | |

## APPENDIX F

Appendix F 1, a. Polynomial Response to N, 1990

| N (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 1.74 | 1.83 | 1.74 |
| 45 | 2.28 | 2.11 | 2.29 |
| 90 | 2.31 | 2.39 | 2.31 |

Appendix F 1, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Nitrogen | 2 | 8.85 | 4.42 | 10.64 ** |
| Linear | 1 | 8.46 | 8.46 | 28.11 ** |
| Deviation from Linearity | 1 | 0.93 | 0.93 | 3.09 ns |
| Quadratic | 1 | 0.39 | 0.39 | 1.33 ns |
| Deviation from Quadratic | 1 | 0.02 | 0.02 | 0.09 ns |
| Error | 16 | 4.81 | 0.30 | |

NS & ** - not significant and significant at 1% level, respectively.

Appendix F 2, a. Polynomial Response to N, 1991

| N (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 1.31 | 1.37 | 1.31 |
| 45 | 1.60 | 1.47 | 1.60 |
| 90 | 1.51 | 1.57 | 1.50 |

Appendix F 2, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Nitrogen | 2 | 1.90 | 0.95 | 6.01 * |
| Linear | 1 | 0.87 | 0.87 | 5.51 * |
| Deviation from Linearity | 1 | 1.03 | 1.03 | 6.52 * |
| Quadratic | 1 | 1.05 | 1.05 | 6.65 * |
| Deviation from Quadratic | 1 | 0.01 | 0.01 | 0.01 * |
| Error | 16 | 2.53 | 0.16 | |

NS & * - not significant and significant at 5% level, respectively.

Appendix F 3, a. Polynomial Response to N, 1992

| N (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 2.45 | 2.43 | 2.45 |
| 45 | 2.82 | 2.70 | 2.82 |
| 90 | 2.99 | 2.97 | 2.99 |

Appendix F 3, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Nitrogen | 2 | 6.60 | 3.30 | 7.52 * |
| Linear | 1 | 6.38 | 6.38 | 14.35 ** |
| Deviation from Linearity | 1 | 0.15 | 0.15 | 0.34 ns |
| Quadratic | 1 | 0.30 | 0.30 | 0.68 ns |
| Deviation from Quadratic | 1 | 0.00 | 0.00 | 0.00 ns |
| Error | 16 | 7.03 | 0.44 | |

NS, * & ** - not significant and significant at 5& 1% levels, respectively.

Appendix F 4, a. Polynomial Response to P, 1990

| P (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 2.13 | 2.08 | 2.13 |
| 10 | 2.08 | 2.33 | 2.08 |
| 20 | 2.09 | 2.58 | 2.09 |

Appendix F 4, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Phosphorus | 2 | 0.08 | 0.04 | 0.20 ns |
| Linear | 1 | 0.05 | 0.05 | 0.26 ns |
| Deviation from Linearity | 1 | 0.04 | 0.04 | 0.18 ns |
| Quadratic | 1 | 0.02 | 0.02 | 0.11 ns |
| Deviation from Quadratic | 1 | 0.03 | 0.03 | 0.13 ns |
| Error | 90 | 17.46 | 0.1? | |

NS - not significant.

Appendix F 5, a. Polynomial Response to P, 1991

| P (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 1.36 | 1.43 | 1.36 |
| 10 | 1.62 | 1.47 | 1.62 |
| 20 | 1.44 | 1.51 | 1.44 |

Appendix F 5, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Phosphorus | 2 | 1.66 | 0.83 | 7.6? * |
| Linear | 1 | 0.14 | 0.14 | 1.28 ns |
| Deviation from Linearity | 1 | 0.71 | 0.71 | 6.61 * |
| Quadratic | 1 | 1.41 | 1.41 | 12.04 ** |
| Deviation from Quadratic | 1 | 0.00 | 0.00 | 0.00 ns |
| Error | 90 | 9.84 | 0.11 | |

NS, * &** - not significant and significant at 5 & 1% levels, respectively.

Appendix F 6, a. Polynomial Response to P, 1992

| P (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 2.55 | 2.58 | 2.55 |
| 10 | 2.81 | 2.76 | 2.81 |
| 20 | 2.90 | 2.93 | 2.90 |

Appendix F 6, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Phosphorus | 2 | 2.99 | 1.50 | 1.43 ns |
| Linear | 1 | 2.68 | 2.68 | 2.58 ns |
| Deviation from Linearity | 1 | 0.09 | 0.09 | 0.09 ns |
| Quadratic | 1 | 0.22 | 0.22 | 0.21 ns |
| Deviation from Quadratic | 1 | 0.10 | 0.10 | 0.09 ns |
| Error | 90 | 93.95 | 1.04 | |

NS - not significant.

Appendix F 7, a. Polynomial Response to Seed rate, 1990

| Seed rate (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 30 | 1.92 | 2.03 | 1.92 |
| 75 | 2.08 | 2.23 | 2.08 |
| 120 | 2.31 | 2.43 | 2.31 |

Appendix F 7, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Seed rate | 2 | 3.48 | 1.74 | 5.80 * |
| Linear | 1 | 3.33 | 3.33 | 11.40 ** |
| Deviation from Linearity | 1 | 1.07 | 1.07 | 3.57 ns |
| Quadratic | 1 | 0.04 | 0.04 | 0.13 ns |
| Deviation from Quadratic | 1 | 1.03 | 1.03 | 3.43 ns |
| Error | 16 | 4.82 | 0.30 | |

NS, * & ** - not significant and significant at 1% levels respectively.

Appendix F 8, a. Polynomial Response to Seed rate, 1991

| Seed rate (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 30 | 1.37 | 1.40 | 1.37 |
| 75 | 1.54 | 1.47 | 1.54 |
| 120 | 1.51 | 1.54 | 1.51 |

Appendix F 8, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Seed rate | 2 | 0.83 | 0.41 | 2.63 ns |
| Linear | 1 | 0.43 | 0.43 | 2.69 ns |
| Deviation from Linearity | 1 | 0.50 | 0.50 | 3.12 ns |
| Quadratic | 1 | 0.29 | 0.29 | 1.81 ns |
| Deviation from Quadratic | 1 | 0.21 | 0.21 | 1.31 ns |
| Error | 16 | 2.53 | 0.16 | |

NS - not significant.

Appendix F 9, a. Polynomial Response to Seed rate, 1992

| Seed rate (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 30 | 2.33 | 2.36 | 2.32 |
| 75 | 2.81 | 2.76 | 2.80 |
| 120 | 3.13 | 3.16 | 3.12 |

Appendix F 9, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Seed rate | 2 | 14.13 | 7.07 | 16.08 ** |
| Linear | 1 | 12.95 | 13.95 | 31.78 ** |
| Deviation from Linearity | 1 | 0.09 | 0.09 | 0.20 ns |
| Quadratic | 1 | 0.19 | 0.19 | 0.13 ns |
| Deviation from Quadratic | 1 | 0.00 | 0.00 | 0.00 ns |
| Error | 16 | 7.03 | 0.44 | |

NS & ** - not significant and significant at 1% level, respectively.

Appendix F 10, a. Polynomial Response to N, 1990 - 92

| N (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 1.83 | 1.91 | 1.83 |
| 45 | 2.23 | 2.13 | 2.23 |
| 90 | 2.27 | 2.35 | 2.26 |

Appendix F 10, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Nitrogen | 2 | 15.23 | 7.61 | 25.46 ** |
| Linear | 1 | 4.23 | 4.23 | 14.10 ** |
| Deviation from Linearity | 1 | 0.50 | 0.50 | 1.67 ns |
| Quadratic | 1 | 0.95 | 0.95 | 3.17 ns |
| Deviation from Quadratic | 1 | 8.95 | 8.95 | 29.80 ** |
| Error | 48 | 14.37 | 0.30 | |

NS & ** - not significant and significant at 1% level, respectively.

Appendix F 11, a. Polynomial Response to P, 1990 - 92

| P (kg/ha) | Paddy yield (kg/ha) | | |
|---|---|---|---|
| | Observed | Expected | |
| | | Linear | Quadratic |
| 0 | 2.01 | 2.05 | 2.01 |
| 10 | 2.17 | 2.12 | 2.17 |
| 20 | 2.14 | 2.18 | 2.14 |

Appendix F 11, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Phosphorus | 2 | 1.90 | 0.95 | 2.12 ns |
| Linear | 1 | 0.37 | 0.37 | 0.82 ns |
| Deviation from Linearity | 1 | 0.12 | 0.12 | 0.27 ns |
| Quadratic | 1 | 0.26 | 0.26 | 0.58 ns |
| Deviation from Quadratic | 1 | 1.53 | 1.53 | 3.40ns |
| Error | 270 | 1.22 | 0.45 | |

NS - not significant.

Appendix F 12, a. Polynomial Response to Seed rate, 1990 - 92

| Seed rate | Paddy yield (kg/ha) | | |
|---|---|---|---|
| (kg/ha) | Observed | Expected | |
| | | Linear | Quadratic |
| 30 | 1.87 | 1.99 | 1.87 |
| 75 | 2.14 | 2.36 | 2.14 |
| 120 | 2.32 | 2.74 | 2.32 |

Appendix F 12, b. Analysis of Variance

| Source of Variation | DF | SS | MS | F value |
|---|---|---|---|---|
| Seed rate | 2 | 13.36 | 6.68 | 22.32 ** |
| Linear | 1 | 4.43 | 4.43 | 14.77 ** |
| Deviation from Linearity | 1 | 0.03 | 0.03 | 0.10 ns |
| Quadratic | 1 | 0.06 | 0.06 | 0.20 ns |
| Deviation from Quadratic | 1 | 8.90 | 8.90 | 29.67 ** |
| Error | 48 | 14.37 | 0.30 | |

NS & **- not significant and significant at 1% level, respectively.