NITROGEN ECONOMY THROUGH INCORPORATION OF AZOLLA IN RICE

BY

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Thesis
Submitted in partial fulfilment of
requirement for the Degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

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Vellayani, Trivandrum

1981

DECLARATION

I hereby declare that this thesis entitled "Nitrogen economy through incorporation of Azolla in rice" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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31st March 1981.

CERTIFICATE

Certified that this thesis, entitled "Nitrogen economy through incorporation of Azolla in rice", is a record of research work done independently by Shri. JAIKUMARAN, U. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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ACKNOWLEDGEMENT

I consider it a pleasure and privilege to unveil my heartfelt gratitude and deep sense of indebtedness to Dr. C. Sreedharan, Professor of Agronomy and Chairman of my Advisory Committee, for his masterly guidance, consistant inspiration, healthy criticism and unwearing help rendered throughout the course of this study and preparation of this thesis.

My sincere thanks are also due to Prof. U. Mohammed Kunju, Prof. R. Raveendran Nair, and Associate Prof. Dr. P.Padmaja, Members of my advisory committee for their valuable suggestions, constructive criticism and constant encouragement extended to me from time to time during the course of my work.

I am thankful to Shri. T.P. George, Special Officer (Agricultural Engineering) and Shri. T.F. Kuriakose, Associate Professor (Agronomy) for their whole hearted help and encouragements extended to me for the successful conduct of the experiment at Agronomic Research Station, Chalakudy.

Facilities provided for chemical analysis work at the College of Horticulture, Vellanikkara by the former Associate Dean, Dr. P.C. Sivaraman Nair and Associate Professor (Agronomy) Dr. R. Vikraman Nair and that for the statistical analysis work by the late Prof. E.J. Thomas and Assistant Professor Shri. M.P. Abdurazak are gratefully acknowledged.

I express my sincere gratitude to all the staff members of the Agronomic Research Station, Chalakudy and Department of Agronomy and to my beloved friends for their tireless co-operation and enthusiastic help rendered from time to time for my research activities.

Dr. N. Sadanandan, Dean, Faculty of Agriculture is also gratefully acknowledged for providing adequate facilities for the timely completion of the work.

I am also indebted to the Kerala Agricultural University for the award of a fellowship for the period of my course work and allowing me to take up this project on a part time basis.

31/3/1981

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INTRODUCTION

I. INTRODUCTION

Though India is in a comfortable situation in the production of food grains at present, the brightness of her future is shadowed by the mounting population growth. It is estimated that towards the close of this century the country has to double her production to maintain the present satisfactory situation on the food front. Statistics tabled by Swaminathan (1980) give us little scope for increasing the area under cultivation as a way of increasing production.

While reviewing the position in Kerala, it can be seen that the State is not self-sufficient in the production of our staple grain, even at present. About half of the requirement is met through imports from neighbouring States.

The one and only way to step up production under the prevailing situation in India and particularly in Kerala is to increase productivity per unit area per unit time by resorting to intensive cultivation, for which high level fertilizer application is often needed. But intensive fertilizer use is a high cost technology especially in the prevailing situation of soaring prices of inputs and low prices of outputs. This situation is further aggravated by the day-to-day petroleum energy crisis and the widening gap between domestic consumption and indigenous production of fertilizer nutrients, which can escalate prices of fertilizers from time to time. More over, the low efficiency of fertilizer nutrients like nitrogen, which seldom goes beyond 50% (Chaudhuri, 1980) is another set back in this regard and this condition is further worsened in sandy textured soils.

Hence a relevant and low cost technology with high efficiency, which can serve as a substitute to high cost fertilizer intensive technology and can sustain the same level of production, has become an important need.

In this connection "Integrated Nutrient Supply System" is a very good proposition (Pillai and Vamadevan, 1978) in which a balanced and combined application of organics and inorganics is resorted to in achieving high efficiency and better economy.

Package of Practices Recommendation of Kerala Agricultural University (Anon, 1978a) suggests application of five tonnes of organic manure (farm yard manure) along with inorganic N. But at present, farm yard manure has become a very costly input in Kerala which may cost about Rs. 125-150 per tonne. In addition to this, the availability of farm yard manure is rather limited for rice production. But application of organics is very important to manipulate soils, especially those of a coarse texture, in order to increase productivity. In this connection it is to be remembered that in Kerala there is a vast stretch of sandy soil in which rice is commonly cultivated. So an effective and low cost substitute for organic N has become very essential.

Azolla has already been identified as a potential source of bio-nitrogen for rice culture in countries like Vietnam, China, Philippines, Thailand, SriLanka and California. Besides as a supplemental source of N, Azolla incorporation has been found to be more useful in sandy soils because of its slow releasing effect, thereby reducing the losses through percolation (Sawatdee et al., 1978).

Azolla is not an alien plant to India and is commonly seen in several parts of the country (Singh, 1977a). Several investigations have also been conducted at Cuttack (CRRI), Tamil Nadu and Hyderabad (AICRIP) to exploit its potentiality in rice culture.

In Kerala also, Azolla is commonly found in many parts of the State during wet season. But it is seldom utilised in rice culture because of lack of proper knowledge regarding its utility. Research investigations about its suitability, feasibility and potentiality in rice culture have not so far been conducted in this State.

Considering all these facts, a project on "Nitrogen economy through incorporation of Azolla in rice" was proposed with the following objectives:

1. To investigate the effect of basal incorporation of Azolla on growth and yield of rice,

2. To assess the saving of nitrogen by incorporation of Azolla,

3. To study the relative efficiency of Azolla incorporation in the first and second crop seasons,

4. To evaluate the importance of Azolla as an alternate cheap source of organic N for rice crop.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The investigation "Nitrogen economy through incorporation of Azolla in rice" was carried out with the objectives of studying the effect of basal incorporation of Azolla on growth and yield of rice and to assess the saving of nitrogen through its incorporation. Review pertaining to the investigation is given herein.

I. Azolla

1.1. A general description

Azolla is a genus of water fern with worldwide distribution (Moore, 1969). The genus term 'Azolla' derived from two greek words; 'AZO' meaning 'to dry' and 'OLLYO' meaning 'to kill', thereby self-explaining that the fern is killed by drying (Lumpkin and Plucknett, 1980). Different vernacular names such as water velvet, mosquito fern etc., assigned to Azolla in different countries have been recounted by Lumpkin and Plucknett (1980) in their comprehensive review on Azolla.

According to taxonomic classification, Azolla belongs to the order 'Salviniales' and recently the monotypic family 'Azollaceae' has been assigned to this genus (Konar and Kapoor, 1974).

The genus Azolla has got six living species, classified primarily on the basis of reproductive organs and, with different geographic distribution (Svenson, 1944; Moore, 1969; Lumpkin and Plucknett, 1980). Azolla pinnata is the species found in most of the Asiatic countries (Svenson, 1944). It is utilized as a green manure crop especially in China (Lumpkin, 1977), Philippines (Watanabe et al., 1977), Thailand (Sawatdee and Seetanun, 1979) and Vietnam (Talley and Rains, 1980). Azolla pinnata is also the species found common in India in shallow ditches, ponds and in places of stagnant water (Rao, 1936; Srivastava and Tandon, 1951; Loyal, 1958; Gopal, 1967; Sweet and Hills, 1971; Singh, 1977a).

Azolla harbours the blue green algae Anabaena azollae which lives in the cavities of upper lobes of Azolla leaves as a symbiont and fixes atmospheric nitrogen (Oes, 1913; Bortels, 1940; Ashton and Walmsley, 1976; Peters, 1977; Singh, 1977b; Kannaiyan, 1979; Lumpkin and Plucknett, 1980; Venkataraman, 1980). The fern has got an exponential growth rate of different magnitudes depending upon the species and environmental conditions (Lumpkin and Plucknett, 1980). Hence the Azolla-Anabaena system offers a potential source of biological nitrogen and organic manure especially for wet rice cultivation.

1.ii. Composition of Azolla

Several reports have been published on the chemical composition of Azolla. Moore (1969) reviewed the reports on nutrient concentration in Azolla from which it could be learnt that the water content in fresh material of Azolla varied between 92.8% to 93.6% and nitrogen, phosphorus and potassium content varied between 3.37% and 4.75%, 0.12% and 0.79% and 0.80% and 6.52% respectively, on dry matter basis. A report from Cuttack showed that N, P and K content in Azolla on dry matter basis ranged between 4-6%, 0.5-0.9% and 2-6% respectively (Anon, 1976). Watanabe et al. (1977) observed that Azolla contained 3 to 5% N on dry weight basis and 0.1 to 0.2% on fresh weight basis. While reviewing the different reports of Singh (1977c,d; 1978a; 1978b) from Cuttack, it was observed that Azolla analysed 4 to 6% N, 0.5 to 0.9% P and 2 to 6% K on dry matter basis and 85-95% moisture. The same analysis was also got by Arunachalam (1980).

Jayapragasam and Raj (1980) on analysing the samples of *Azolla pinnata* collected from different locations in Tamil Nadu found that the dry matter per cent of Azolla varied from 4.1 to 5.7 and nitrogen content between 2.44 to 2.98.

From a study tour, Venkataraman (1980) recorded that commonly cultivated species of *Azolla imbricata* in China contained 3.08 to 4.12% N, 0.16% P_2O_5 and 0.18% K_2O on dry weight basis. Lumpkin and Pluckett (1980) has also reviewed the reports on elemental analysis of Azolla. Hence, it can be concluded that the nutrient composition of

Azolla varies depending upon the species and environmental conditions.

1. iii. Utilization of Azolla in rice culture

Azolla has been utilised as a green manure crop especially for rice cultivation, in some of the South-Eastern Asian countries. Saubert (1949) reported that Azolla was a traditional part of rice culture and rotation in Asia where it was known to increase paddy production. Management practices to crop Azolla as a bio-source of nitrogen for rice has already been developed and practised in Vietnam (Dap, 1967; Thuyet and Tuan, 1973). Moore (1969), in his review on Azolla, has brought out different reports on uses and potentialities of Azolla as a green manure in different parts of the Globe.

Peters (1977) suggested that the Azolla-Anabaena association could be offered, either as a water weed or a beneficial organism with agronomic significance, depending upon its location. Talley et al. (1977) while referring to the possibility of application of Azolla species in California rice culture, pointed out that, this depended upon whether significant nitrogen transfer could occur from Azolla to rice while it was grown together with rice and whether Azolla could fix significant amount of nitrogen when grown as green manure crop.

In order to encourage year-round cultivation of

Azolla with rice in paddy fields, new technical measures combined with paired narrow rows technique have been introduced in China in 1975 (Liu, 1979). Lumpkin (1977) observed that a domesticated variety of Azolla known as "Vietnam Azolla" was grown throughout the year in the Kwangtung Province of China. According to Venkataraman (1980), Azolla, as a green manure crop for rice was known to chinese peasants a century ago. Lumpkin and Pluckmett (1980) reported that Azolla was a part of rice culture in Vietnam and China centuries ago.

Singh, from a series of trials conducted at CRRI Cuttack, (1977a, b, c, d, e; 1978a, 1978 b, 1979) has explored the potential of Azolla utilization in Indian rice culture. Kannaiyan (1979) suggested an extensive survey on strains of Azolla suitable to Tamil Nadu.

All these reports clearly indicate the scope of utilization of Azolla as a source of nitrogen and organic matter in rice culture.

I. iv. <u>Techniques of Azolla utilization in rice fields.</u>

Several techniques of Azolla utilization have been reported.

In order to release nitrogen from Azolla, death of the plants was found to be essential. Otherwise only 2% of the nitrogen in the Azolla blanket was released (Saubert, 1949). When more than one layer of Azolla mat was formed, the lower layer died and decayed enabling the release of nitrogen (Gopal, 1967).

Singh (1977d, 1977e) observed that basal incorporation of Azolla was found better for higher yields of rice in the Kharif season. Unincorporation was equally good in the Rabi season, provided Azolla decayed in the field.

Liu (1979) reported that paired narrow row planting of rice in China encouraged dual culturing of Azolla with rice which produced higher yields.

According to Sawatdee and Seetanum (1979) effect of Azolla incorporation in rice after transplanting was equivalent to unincorporation wherein Azolla was inoculated before or after transplanting.

Singh (1979) recorded increased grain yields in rice when the fern was grown simultaneously with rice, or separately and then incorporated after a month of planting.

Arunachalam (1980) observed that incorporation of Azolla basally or unincorporation after inoculation produced similar yield of rice. Natarajan et al. (1980) found that basal incorporation of Azolla increased rice yield which was higher than dual cropping in which Azolla was incorporated 30 days after planting.

From a study on residual effect of Azolla, Subudhi and Singh (1980) inferred that unincorporation of Azolla registered lower grain yield than basally incorporated Azolla. But straw yield was higher in unincorporated plots.

According to Venkataraman (1980), two croppings and incorporation of Azolla at 15 days intervals either prior to planting or subsequent to planting are prevalent in China, of which the latter is found to be very popular.

A nitrogen isotope study conducted at IRRI showed that Azolla placed on surface soil lost 66% of N, floating Azolla with some plants still alive after 6 weeks lost 40% of N whereas direct incorporation resulted only in 33% loss which confirmed the efficiency of Azolla nitrogen after soil incorporation (Anon, 1978b).

Hence, among the different methods of application, basal incorporation of Azolla at the time of transplanting can be considered to be more effective.

II. Effect of Azolla on growth and yield of rice

II.1. Growth

Reports showing effect of Azolla on growth and growth attributes of rice are very meagre.

Singh (1977e, 1978a) observed increase in plant height and tiller number when one layer of Azolla equivalent to 10 t/ha was incorporated. Natarajan et al. (1980) reported that there was only a marginal increase in these attributes due to incorporation of Azolla basally or after 30 days of planting, either alone or in combination with inorganic nitrogen.

Subudhi and Singh (1980) observed higher tillering in Azolla incorporated plots.

II. ii. Effect on yield and yield attributes

(a) Yield attributes

Kulasooriya and de Silva (1977) reported that Azolla applied in combination with urea increased filled grains per panicle over urea application alone, thereby showing the possibility of reducing sterility through Azolla incorporation.

An experiment conducted at Cuttack in the Rabi season revealed that Azolla incorporation @ 10 t/ha increased the number of panicles/sq m and weight of panicle/sq m in varieties IR 8 and Supriya (Singh, 1977d).

(b) Yield

Several workers have reported about the response of Azolla incorporation on rice.

Studies conducted at Cuttack revealed that Azolla incorporation @ 10-12 t/ha significantly increased rice yields.(Singh, 1977d). Azolla incorporation gave 12%, 28%, 24% and 25% increase in grain yield in varieties IR 8, Supriya, Vani and CR 1005 respectively during Kharif season whereas in Rabi season, 38% and 41% increase was recorded in varieties IR 8 and Kalinga respectively (Singh, 1978a). Increase in straw yield was upto the level of 47%. He further observed that combined application of Azolla @ 10 t/ha with 30 or 50 kg N/ha recorded equivalent yields produced by 60 or 80 kg N applied alone.

Srinivasan (1977) observed that incorporation of Azolla increased grain yield of rice by 19.1%. Talley et al. (1977) got higher rice yields to the extent of 112% over the no nitrogen control when Azolla filiculoides amounting to 60 kg N/ha was incorporated. Further increase to the level of 216% was obtained when Azolla was grown along with a standing crop of rice in addition to the above incorporation.

Watanabe et al. (1977) obtained a 12% increase in grain yield through Azolla incorporation in which 15 kg N/ha was supplied by a fully grown cover of Azolla.

An experiment conducted by Sawatdee et al. (1978) in the sandy soils of Thailand revealed that incorporation of about 11.5 t/ha of Azolla recorded a grain yield of 3.5 t/ha. Unincorporation, though producing 18.5 t/ha of fresh matter of Azolla in the field, could give only 2.6 t/ha grain which was equal to no nitrogen control.

Results of experiment conducted by Govindarajan et al. (1979, 1980) indicated that the combined application of Azolla with fertiliser recorded higher grain yields over fertiliser nitrogen alone and this increase was comparable to that of an application of 25 kg N/ha.

Sawatdee and Seetanum (1979) opined that incorporation of 15-18 tonnes of Azolla 20 days after transplanting recorded an yield of 3.5-3.7 t of grains/ha which was equivalent to that from 37.5 kg fertilizer nitrogen.

Sundaram et al. (1979) observed that incorporation of Azolla at the time of transplanting or first weeding with 75% recommended dose of N gave higher grain yield than application of 100% N alone.

From experiments conducted at Agricultural College and Research Institute, Madurai, Arunachalam (1980) inferred that inoculation or incorporation of Azolla before or after transplanting increased both grain and straw yields. Incorporation of one crop of Azolla gave an yield equivalent to 30 kg N/ha.

Natarajan et al. (1980) reported that incorporation of Azolla @ 10 t/ha increased rice yield in all the varieties and seasons they tried.

Natarajan and Sadayappan (1980) observed that incorporation of 6 t of Azolla per hectare significantly increased rice yields. This was markedly better than inoculation of 2 t/ha of Azolla which was incorporated later at the time of first weeding.

Srinivasan (1980a) concluded that Azolla inoculated @ 3 t/ha at the time of transplanting, and incorporated 15 days after gave yields comparable to that of 25 kg N/ha. He further observed that yield response of rice to Azolla incorporation was upto 60 t/ha (1980b).

Subudhi and Singh (1980) reported that incorporation of 10 tonnes of Azolla per hectare increased rice yields by

40% over control. They also obtained significant residual effect for Azolla applied in the previous season.

According to Talley and Rains (1980), incorporation of Azolla to supply 40 kg N/ha gave equivalent yield as that from a same quantity of inorganic nitrogen. At 93 kg N level, only 70% increase was obtained over the same level of inorganic nitrogen.

AICRIP trials revealed that Azolla incorporation increased rice yields particularly in North-Eastern tracts of India (Pillai et al., 1980).

But Pillai and Vamadevan (1978) did not get significant increase through incorporation of Azolla.

From the reports mentioned above, it can be concluded that Azolla incorporation can significantly benefit in increasing rice yields.

III. Effect of Azolla on soil properties

Azolla incorporation in rice fields can provide organic matter to the soil (Singh, 1977a). Roychoundhary et al. (1979) observed that Azolla applied as dead (dry) organic matter had no effect on improvement of soil aggregates.

Arunachalam (1980) reported that higher total and available N, organic carbon and available P was recorded in Azolla treated plots. Data published by Subudhi and Singh (1980) showed marginally higher organic carbon content in Azolla treated plots.

Experimental results of 422 tests conducted in China showed that organic matter increased from 1.54 to 1.59% with no change in N content and a slight decrease in phosphate status; due to Azolla incorporation (Venkataraman, 1980).

IV. Effect of Azolla on saving of nitrogen

Lab investigations by Saubert (1949) indicated that as much as 313 kg N/ha/yr could be made available through Azolla cultivation. Moore (1969), after reviewing the reports hitherto, concluded that over a period of 3 to 4 months, 100-160 kg N/ha could be assimilated by Azolla of which half of the quantity was derived from the atmosphere.

At IRRI, 22 crops of Azolla harvested over a period of 335 days supplied as much as 465 kg N/ha derived from 8 t of dry matter and this was nearly comparable to the nitrogen fixation of a forage legume (Anon., 1978b; Watanabe et al., 1980).

At CRRI, Cuttack, an annual production of 331 t of green material containing about 840 kg N/ha/yr could be made available in rice cultivation (Singh, 1979).

Kellar and Goldman (1979) reported an annual fixation of 164 kg N/ha/yr by Azolla filiculoides in the littoral zone of a small eutrophic lake in New Zealand.

According to Watanabe (1977) Azolla grown in field plots for 20-30 days could accumulate 24 kg N/ha.

Several workers (Anon., 1976; Singh, 1977b, c; Anon., 1978c; ~~Singh, 1978c~~; Singh, 1978a, b; Watanabe, 1978; Subudhi and Singh, 1980) reported that one layer of Azolla weighing 8-15 t of green matter per hectare could be produced within a period of 8-20 days. This supplied 30-50 kg N per hectare which was comparable to the same quantity of fertilizer nitrogen.

Talley et al. (1977) found that growing a crop of Azolla filiculoides containing 60 kg N/ha appeared technically feasible. Talley and Rains (1980) suggested that 50% of N requirement for rice in California could be supplied by one fallow season crop of Azolla. It was also observed that the effect of Azolla on rice yield was comparable to that of inorganic nitrogen on equivalent N basis.

Watanabe et al. (1977) reported that from a field fully covered with Azolla, rice yields equivalent to 15 kg N/ha was harvested.

Experiments conducted at Cuttack showed that combined application of chemical nitrogen @ 30-50 kg N/ha + 10-12 t/ha of Azolla produced rice yield equivalent to that from 50-60 and 70-80 kg N/ha as chemical N alone. Hence, by way of incorporation of 10-12 tonnes of Azolla, 30 kg N/ha could be saved. Still higher benefits were also obtained through combined application (Singh, 1977d, 1978a). The same trend has also been reported by Arunachalam (1980).

An yield response equivalent to 37.5 kg inorganic N/ha through Azolla incorporation has been observed by Sawatdee et al. (1978), and Sawatdee and Seetanum (1979).

Sundaram et al. (1979) observed that yield obtained from 75% recommended dose of N with Azolla was equal to 100% N alone thereby a saving of 25% chemical N was obtained. Same trend was recorded by Govindarajan et al. (1979, 1980) also. Srinivasan (1980a) observed that 25 kg N/ha could be saved when Azolla was inoculated @ 3 t/ha and incorporated 15 days after planting. Natarajan et al. (1980) also recorded 25% saving of nitrogen when Azolla was used along with graded levels of N.

According to Natarajan and Sadayappan (1980), 6 t/ha of Azolla incorporated basally was comparable to urea nitrogen applied at 35.1 and 17.4 kg/ha in the Kharif and Rabi seasonsrespectively. When Azolla was combined with 25 kg N/ha, the equivalent values were 44.8 and 28 kg N/ha. Inoculation of 2 t/ha of Azolla and incorporation at the time of weeding equalled to 15.1 and 15.2 kg/ha of N respectively in the Kharif and Rabi seasons.

All these reports clearly indicate that Azolla incorporation can save a substantial quantity of nitrogen and it can be used as supplemental source of N to rice crop.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The experiment "Nitrogen economy through incorporation of Azolla in rice" was conducted to find out the effect of Azolla on growth and yield of rice and to assess the saving of nitrogen through incorporation of Azolla. The materials and methods adopted for investigation are given below.

1. Experimental site

The trial was conducted at the Agronomic Research Station, Chalakudy: the Station situated at 10°20' North and 76°20' East and at an altitude of 3.25 metres above mean sea level.

1.1. Soil

The trial was carried out in Block No.VIIC during the first crop season and Block No.VIIB during the second crop season. The soil type of the field was sandy loam comprising 77-84% sand, 4-12% silt and 7-11% clay; bulk density varied between 1.2-1.71 g/cc.

Soil in Block No.VIIC and VIIB contained 0.0149 and 0.0243 per cent of total N, 31.69 and 39.47 ppm of available P, 23.42 and 34.17 ppm of exchangeable K, 0.3 and 0.4 per cent of organic carbon respectively.

2. Climate

In general, the Station receives high rainfall during the South West Monsoon and moderate showers during the

North East Monsoon. Data pertaining to weekly rainfall, mean minimum and maximum temperatures and mean evaporation for the last four years recorded at the meteorological observatory of the station during the cropping season are presented in Appendix I. These data correspond to standard weeks starting from 2nd July (starting of the 27th week) to 4th February of the next year (closing date of the 5th week), the period in which the trial was conducted.

The abstract of these data is given in the Table 1.

Table 1. Abstract of weather data for the cropping season.

Weather	Mean values of cropping season	
	For the last four years (1976-'77 - 1979-'80)	For the cropping period (1979-'80)
Total rainfall	2052.6 mm	2021.5 mm
Maximum temperature	31.3°C	31.4°C
Minimum temperature	23°C	22.8°C
Evaporation	0.341 cm	0.337 cm

Total rainfall, mean maximum and minimum temperatures and mean pan evaporation during the cropping period (1979-'80) and corresponding average values of the same for the last four years (1976-'80) are graphically represented in Fig.1.

From these data, it was found that weather conditions

FIG. 1. WEATHER CONDITIONS DURING THE CROPPING PERIOD (1979-80) CORRESPONDING AVERAGES FOR THE LAST FOUR YEARS (1976-77 - 1979-80)

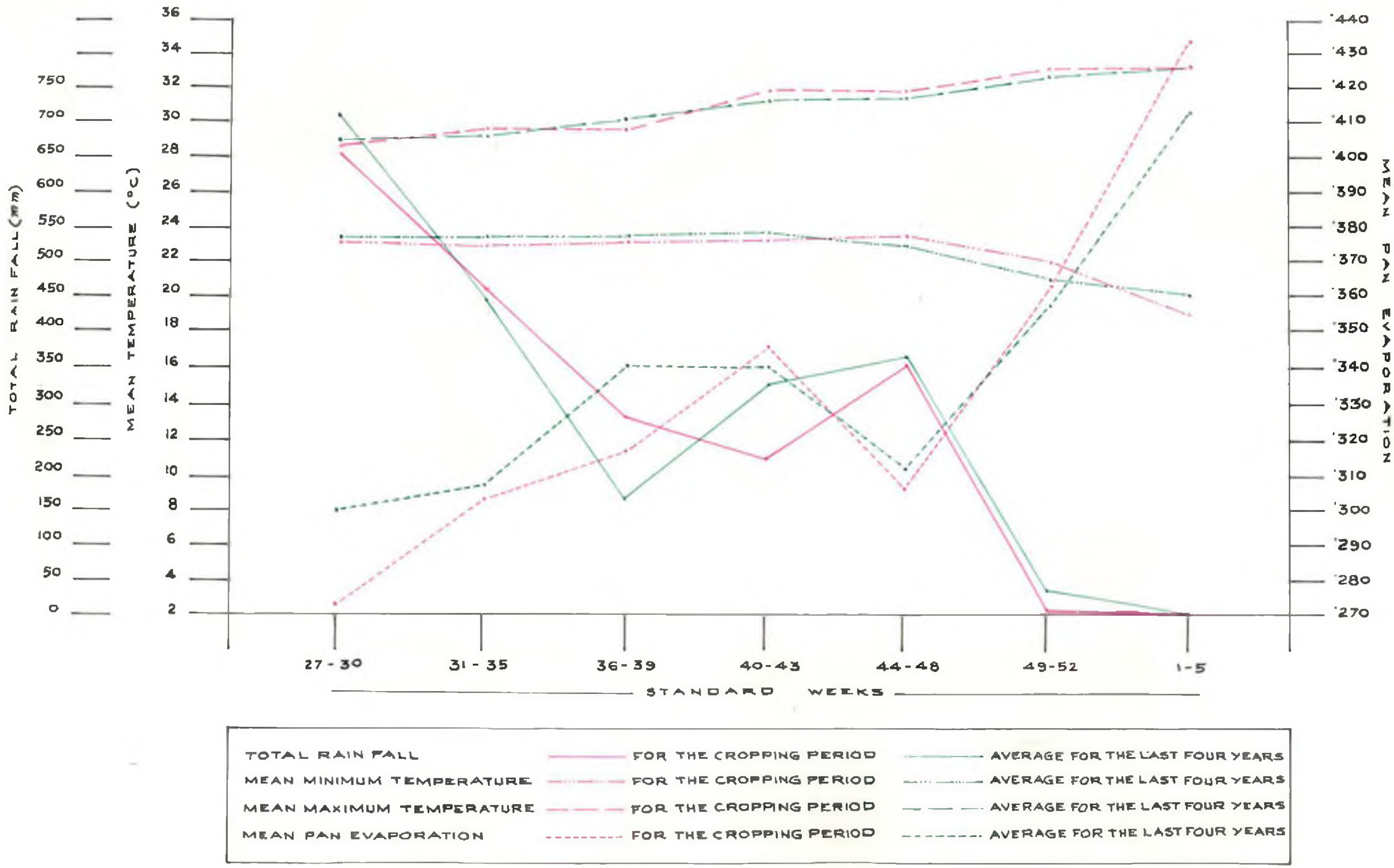
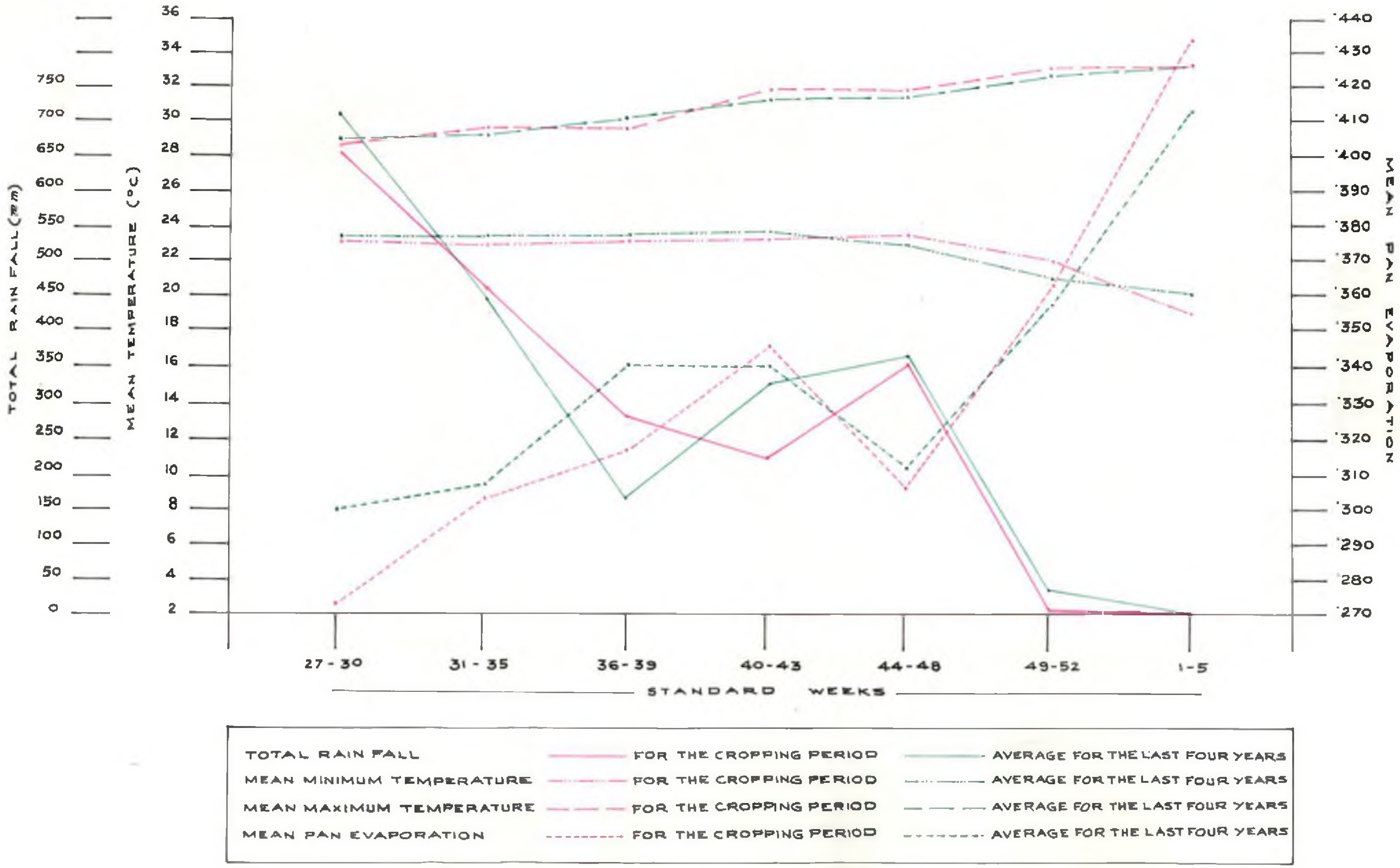


FIG. 1. WEATHER CONDITIONS DURING THE CROPPING PERIOD (1979-'80) CORRESPONDING AVERAGES FOR THE LAST FOUR YEARS (1976-'77 - 1979-'80)



during the period of investigation were normal.

3. Season

The experiment was conducted during the year 1979-80 in the first and second crop seasons.

The first crop was transplanted on 9th July, 1979 and harvested on October 18th, 1979 with a duration of 101 days in the main field. The second crop transplanted on 3rd November, 1979, matured within 89 days of planting and was harvested on 30th January, 1980.

4. Cropping history

In field No.VIIC, the previous crop raised was bulk sesamum whereas bulk paddy was raised in field No.VIIB prior to the experimental crop.

5. Materials

5.1. Variety

The variety Jaya was selected for the investigation. It is a medium duration, photo-insensitive variety released from All India Co-ordinated Rice Improvement Project at Hyderabad. The duration of the variety varies between 120-125 days in Kerala.

5.2. Manures and fertilisers

Farm yard manure applied to the field involving the concerned treatment contained 41 per cent moisture, 0.56 per cent total N, 0.32 per cent total P and 0.45 per cent total K.

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

5.3. Azolla

Azolla pinnata was the species used for incorporation in the plots of concerned treatments. It analysed 92% moisture, 2.8% total N, 0.23% total P and 2.05% total K.

6. Methods

6.1. Treatments

T_1	-	Control without N and Azolla
T_2	-	Recommended dose of N alone
T_3	-	Farm yard manure @ 5 t/ha + recommended dose of N
T_4	-	Azolla 5 t/ha without N
T_5	-	Azolla 5 t/ha + recommended dose of N
T_6	-	Azolla 5 t/ha + 50% of recommended dose of N
T_7	-	Azolla 5 t/ha + 75% of recommended dose of N
T_8	-	50% of recommended dose of N alone
T_9	-	75% of recommended dose of N alone

Ninety kg N/ha was applied as the recommended dose, being the recommendation for medium duration varieties under Kerala conditions.

6.2. Design and layout

The experiment was laid out in the Randomised Block

Design with three replications and nine treatments. Hence, there were 27 plots altogether. Layout of the experiment is given in Fig.2.

6.3. Spacing and plot size

Spacing	-	20 cm x 15 cm
Plot size		
Gross	-	5 m x 4.05 m
Net	-	3.8 m x 3.45 m

6.4. Details of field cultivation

The package of practices recommendations (Anon., 1978a) were closely observed while field culturing the experimental crops.

The main field was ploughed, puddled and levelled before planting. Twenty five day old seedlings were planted at two seedlings per hill. Gap filling was done on the seventh day after planting.

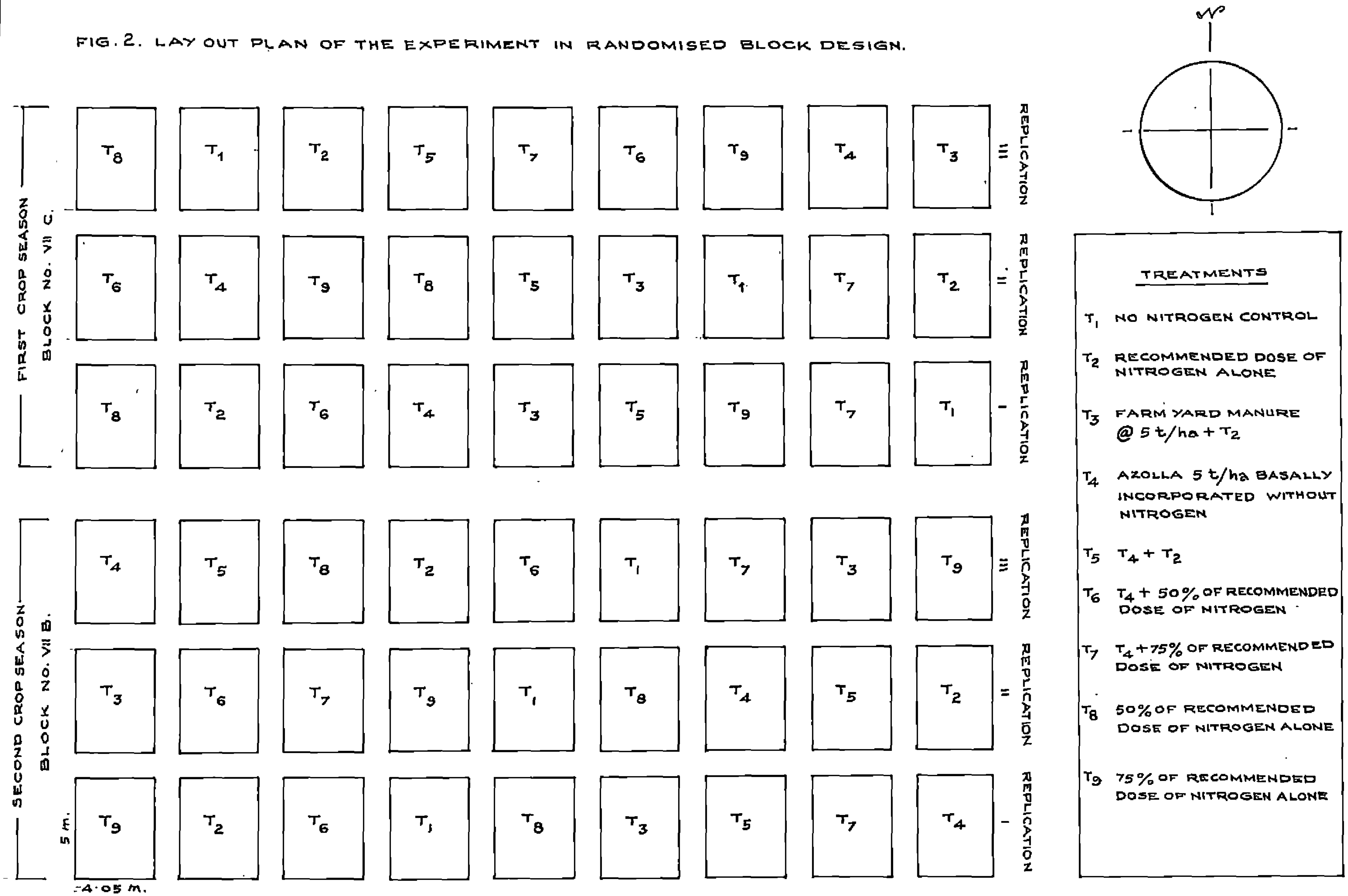
One hand weeding was given 30 days after planting.

Continuous five cm submergence was maintained in the field after planting upto ten days before harvest.

6.4.1. Application of fertilisers and lime

Nitrogen as per the treatment and uniform quantity of 67.5 kg/ha of K_2O were applied in four equal splits, being the recommendation for sandy soils. These were applied at the planting, early tillering, necknode differentiation and early reduction division stages.

FIG. 2. LAY OUT PLAN OF THE EXPERIMENT IN RANDOMISED BLOCK DESIGN.



A uniform quantity of 45 kg/ha of P_2O_5 was applied to all plots entirely as basal.

All plots received a uniform quantity of lime applied in two splits: first as basal @ 350 kg/ha and another 250 kg/ha applied 30 days after planting.

6.4.2. Incorporation of farm yard manure and Azolla

Sun dried and well powdered farm yard manure was incorporated along with final ploughing in the respective treatment plots.

Azolla was multiplied in plots of uniform fertility outside the experimental area and collected. After draining the excess water, fresh Azolla was applied and incorporated along with final ploughing in the respective treatment plots.

6.4.3. Plant protection

Plant protection measures were undertaken as and when needed.

6.4.4. Harvest

The crop was harvested after a period of 101 days and 89 days after planting respectively in the first and second crop seasons.

7. Observations recorded

7.1. Biometric observations

For periodical observations, three sample units of two hill x two hill were randomly selected in each plot as suggested by Gomez (1972) and the following observations were recorded.

a. Height of the plant

Height of the plant was recorded from the base of the plant to the tip of the top-most leaf at the early tillering, maximum tillering and panicle initiation stages. At flowering and harvest, height from the base to the tip of tallest panicle was taken.

b. Number of tillers

Total number of tillers of all the 12 hills at early tillering, maximum tillering and harvest was recorded and the number of tillers/sq.m was worked out.

c. Percentage of productive tillers

This was computed using the data obtained on the number of tillers at maximum tillering stage and harvest.

d. Leaf area index

Leaf area index was calculated by adopting the method suggested by Gomez (1972). Four sample hills were uprooted from the area earmarked for the same and leaves were removed from plants for measuring leaf area. Leaf area was computed using the constant 0.75 and was recorded at the stage of flowering.

e. Yield attributes

e.1. Number of panicles/sq.m

Total number of panicles occupied in the 12 hills selected was counted and panicles/sq.m was computed.

e.2. Number of filled grains/panicle

Centre panicles from all the 12 hills were threshed and number of filled grains (f), number of unfilled grains (u) and weight of filled grains (w) were determined.

The rest of the panicles from all the 12 hills were also threshed and number of unfilled grains (U) and weight of filled grains(W) were assessed.

From these data, number of filled grains per panicle was calculated using the formula given below (Gomez, 1972).

$$\text{Number of filled grains/panicle} = \frac{f}{w} \times \frac{W+w}{P}$$

Where P is total number of panicles from all the 12 hills.

e.3. 1000 grain weight

From the values obtained for calculating the number of filled grains per panicle, 1000 grain weight was calculated and adjusted to 14% moisture using the formula given below.

$$\text{1000 grain weight} = \frac{100-M}{86} \times \frac{w}{f} \times 1000$$

Where M is the moisture content of filled grains.

e.4. Weight of panicle

All the panicles from the 12 hills were weighed and weight per panicle was calculated.

e.5. Length of panicle

The middle panicle of each hill was measured for its length and mean length was found out.

f. Dry weight of grain

Dry weight of grain was recorded for the net harvested area, weight adjusted to 14% moisture and expressed as yield per hectare.

g. Dry weight of straw

Straw harvested from the net plot was uniformly dried in sun light, weighed and expressed as yield per hectare.

h. Harvest index

Harvest index was worked out by dividing the weight of grain per hectare with the sum total yield of dry weight of grain and straw per hectare.

i. Percentage of filling

$$\frac{\text{Dry weight of grain}}{\text{Dry weight of grain + dry weight of half filled and unfilled grain}} \times 100$$

was the formula adopted to compute percentage of filling.

7.2. Chemical analysis

7.2.1. Plant analysis

(a) Total N

Total nitrogen content of grain and straw was analysed adopting Microkjeldahl digestion method as suggested by Jackson (1967).

(b) Total P

Total P content of grain and straw was determined through triple acid extraction (9:2:1: HNO_3:H_2SO_4:$HClO_4$) and thereafter estimating colorimetrically by developing vanadomolybdophosphoric acid yellow colour.

(c) Total K

Potassium content of grain and straw was assessed through triple acid extraction and thereafter reading in EEL flame photometer.

(d) Uptake of N, P and K

N, P or K content of grain and straw was multiplied with respective yields and values thus obtained added together to get uptake of N, P or K at harvest.

7.2.2. Soil analysis

Soil samples were drawn from the field prior to planting and immediately after harvest and dried in the shade before analysing.

(a) Total N

Total nitrogen was estimated using Microkjeldahl digestion method as suggested by Jackson (1967).

(b) Available P

Available P was estimated by extracting with Bray No.1 solution and thereafter developing chloromolybdic acid blue colour and reading in Klett-Summerson photoelectric colorimeter (Jackson, 1967).

(c) Available K

Available K was leached with one normal neutral Ammonium acetate solution and estimated using Flame photometer.

(d) Organic carbon

Oxidisable organic carbon was determined by using the Walkley and Black method quoted by Hesse (1971).

7.3. Other observations

(a) C N ratio

Ratio of Walkley Black value of organic carbon to total nitrogen content of soil was calculated and this has been expressed as C N ratio.

(b) Response curve

Regression of yield on the quantity of nitrogen applied alone or in combination with Azolla was worked out to study the response curve. The optimum quantity of N required to produce maximum yield, either alone or in combination with Azolla, was also computed.

(c) Correlation coefficients

Simple correlation among yield of grain and yield components, viz., number of panicle per sq.m., number of filled grains per panicle and 1000 grain weight was worked out.

(d) Average response ratio and apparent N recovery

Average response ratio under inorganic N application alone or in combination with Azolla was calculated using the formula

$$\text{Response ratio} = \frac{\text{Grain yield of the treatment} - \text{Grain yield of the control}}{\text{Inorganic N applied in the treatment}}$$

Average apparent N recovery was also worked out by adopting the formula suggested by Pillai and Vamadevan (1978).

$$\text{i.e. Apparent N recovery} = \frac{\text{Uptake of N in the treatment} - \text{Uptake of N in the control}}{\text{Inorganic N applied in the treatment}} \times 100$$

8. <u>Statistical analysis</u>

Statistical analysis was done using the analysis of variance technique for Randomised Block Design as suggested by Panse and Sukhatme (1978).

RESULTS

IV. RESULTS

Observations recorded were statistically analysed seasonwise and also by pooling the data of both seasons. Results obtained are presented below with mean values in Tables 2 to 16 and analysis of variance in Appendices II to X.

I. Growth

I.1. Height of plants

Data on mean height of plants taken at different stages of growth are presented in Table 2 and analysis of variance in Appendix II.

At early tillering stage, the results obtained showed that there was no significant difference between the treatments in the second crop season, eventhough significant variation was observed in the 1st crop season. Analysis of mean data also showed that height was not influenced by the treatments at early tillering stage. At panicle initiation stage, application of farm yard manure with full dose of N(T_3) recorded significantly superior height in both the seasons. But in the second crop season, this was on par with application of full dose of N with Azolla (T_5) which recorded maximum height. Application of 75% N either alone (T_9) or in combination with Azolla (T_7) was found to be equally influencing the height as that of application of

Table 2. Height of the plants (cm) at different stages of growth.

Treatments	Early tillering			Panicle initiation			Flowering			Harvest		
	First crop	Second crop	Mean	First crop	Second drop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	42.09	47.03	44.56	50.64	52.17	51.40	73.95	60.72	67.34	73.77	61.79	67.79
T_2: 100% N alone	43.13	48.42	45.76	62.05	57.94	59.99	79.38	61.25	70.32	78.80	64.50	71.65
T_3: FYM+100% N	47.28	49.58	48.43	67.33	59.75	63.54	80;41	66.64	73.52	80.13	67.11	73.62
T_4: Azolla alone	42.79	45.22	44.01	54.02	51.28	52.65	70.67	59.51	65.09	70.53	61.83	66.18
T_5:Azolla+100% N	41.92	49.23	45.58	59.33	61.41	60.37	76.79	67.78	72.29	76.15	67.05	71.60
T_6: Azolla+50% N	43.31	50.06	46.68	56.55	56.64	56.60	75.46	62.56	69.01	74.65	64.58	69.62
T_7: Azolla+75% N	42.17	47.22	44.70	60.66	57.61	59.13	79.01	63.44	71.23	78.09	65.08	71.99
T_8: 50% N alone	40.77	47.34	44.06	55.33	55.47	55.40	72.70	62.25	67.47	72.01	63.53	67.77
T_9: 75% N alone	45.05	47.36	46.21	61.48	57.22	59.35	75.58	61.34	68.46	74.43	64.47	69.45
C.D. (0.05)	1.44	NS	NS	2.56	3.45	4.57	3.47	4.80	2.85	3.54	NS	2.72

100 per cent nitrogen alone (T_2).

From the analysis of variance of the pooled data of both the seasons, it was revealed that the treatment x season interaction was not significant at the stages of flowering and harvest. Mean data on height at both the stages showed an identical trend. Application of farm yard manure in combination with full dose of N (T_3) recorded significantly superior height. But application of full dose of nitrogen either alone (T_2) or in combination with Azolla (T_5) and application of 75 per cent N with Azolla (T_7) were found to be on par with T_3. It was also noted that the treatments T_9, T_8, and T_4 gave lower height than these four treatments.

I.2. <u>Number of tillers</u>

Mean values of number of tillers per square metre at early tillering stage and maximum tillering stage are given in Table 3 and analysis of variance in Appendix III.

From the analysis of variance of combined data, it was revealed that the treatment x season interaction was not significant at both stages.

At early tillering stage, analysis of mean data showed that the application of full dose of nitrogen with farm yard manure (T_3) produced significantly higher number of tillers than all the other treatments except T_2 and T_7. Application of higher levels of nitrogen at 75 per cent or

Table 3. Number of tillers per sq.m at different stages of growth.

Treatments	Early tillering			Maximum tillering		
	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	224.31	216.38	220.64	282.31	225.98	254.31
T_2: 100% N alone	299.97	273.97	286.97	349.63	311.97	330.63
T_3: FYM + 100% N	325.30	270.64	297.97	395.63	365.63	380.63
T_4: Azolla alone	252.97	218.64	235.64	321.30	235.31	278.31
T_5: Azolla + 100% N	284.97	254.64	269.97	399.63	367.63	383.63
T_6: Azolla + 50% N	273.97	248.64	266.97	381.63	312.97	347.30
T_7: Azolla + 75% N	292.97	260.31	276.64	334.97	366.65	350.96
T_8: 50% N alone	278.64	251.97	265.31	334.30	319.30	326.63
T_9: 75% N alone	294.30	256.31	275.31	361.63	334.30	347.97
C.D. (0.05)	19.00	NS	22.33	15.67	76.66	37.66

100 per cent either alone or in combination with Azolla recorded higher tillering than that of lower levels.

Analysis of mean data of maximum tillering stage indicated that application of 100% N with Azolla (T_5) registered maximum number of tillers followed by combined application of 100% N with farm yard manure (T_3) and these were significantly superior to application of 100% N alone (T_2).

I. 3. Leaf area index

Data on leaf area index at flowering are given in Table 4 and analysis of variance in Appendix III.

From the variance ratio test of the treatment x season interaction of combined data, it was seen that the treatment x season interaction was not significant. Mean data showed that the treatments which received maximum N such as T_3 and T_2 recorded significantly higher leaf area. Incorporation of Azolla in combination with application of 75% N (T_7) or 100% N (T_5) also recorded higher leaf area index and these were on par with that of T_3 and T_2.

II. Post harvest observations

II. 1. Percentage of productive tillers

Mean values of percentage of productive tillers at harvest are presented in Table 5(a) and analysis of variance in Appendix IV.

Analysis of variance of combined data showed that the treatment x season interaction was not significant.

Table 4. Leaf area index at flowering.

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	1.094	1.237	1.166
T_2: 100% N alone	1.828	1.981	1.904
T_3: FYM + 100% N	1.925	1.869	1.897
T_4: Azolla alone	1.365	1.079	1.222
T_5: Azolla + 100% N	1.544	1.827	1.686
T_6: Azolla + 50% N	1.294	1.699	1.496
T_7: Azolla + 75% N	1.580	1.908	1.744
T_8: 50% N alone	1.387	1.710	1.549
T_9: 75% N alone	1.569	1.488	1.528
C.D. (0.05)	0.298	0.501	0.280

Table 5(a). Percentage productive tillers at harvest.

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	69.20	75.84	72.52
T_2: 100% N alone	68.50	66.50	67.50
T_3: FYM + 100% N	58.97	67.84	63.41
T_4: Azolla alone	66.22	76.61	71.42
T_5: Azolla + 100% N	58.65	67.09	62.87
T_6: Azolla + 50% N	61.61	68.76	65.19
T_7: Azolla + 75% N	63.73	73.64	68.69
T_8: 50% N alone	66.81	63.21	65.01
T_9: 75% N alone	69.52	63.75	66.64
C.D. (0.05)	NS	NS	6.85

From the mean data it was seen that the plots which received more N tended to reduce percentage of productive tillers. Maximum percentage of productive tillers was recorded in the control plot (T_1) closely followed by Azolla alone incorporated plot (T_4).

II.2. Yield components

Data on yield components such as number of panicles per square metre, number of filled grains per panicle and 1000 grain weight are presented in Table 5(b) and analysis of variance in Appendix IV.

(a) Number of panicles/square metre

In the first crop season, application of full dose of nitrogen alone (T_2) registered maximum number of panicles which was significantly superior to all other treatments, but on par with application of 75% nitrogen alone (T_9). Higher levels of nitrogen supplied through the treatments T_3 and T_5 and lower levels of nitrogen supplied through T_6 and T_8 recorded significantly lower panicle production than T_2.

In the second crop season, combined application of Azolla with 75% N (T_7) produced maximum number of panicles, closely followed by T_3, which were significantly superior to application of 100% N alone (T_2). Application of Azolla along with 100% N also was on par with T_7 and T_3. The treatments T_2, T_9, T_6 and T_8 recorded lower number of panicles. In general, it was seen that nitrogen in

Table 5(b) Yield components.

Treatments	Number of panicles per sq.m			Number of filled grains per panicle			1000 grain weight (g)		
	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	180.33	161.00	170.67	39.98	40.62	40.30	26.91	19.93	23.42
T_2: 100% N alone	275.00	227.67	251.33	40.99	42.15	41.57	24.51	25.44	24.97
T_3: FYM+100% N	216.67	269.66	242.67	54.46	46.48	50.47	24.80	25.37	25.09
T_4: Azolla alone	206.33	183.33	195.00	35.11	37.65	36.38	26.29	22.54	24.42
T_5: Azolla+100% N	245.33	254.33	250.00	33.27	43.44	38.36	26.72	26.90	26.81
T_6: Azolla+50% N	229.67	214.33	222.00	38.34	49.17	43.76	24.59	22.77	23.68
T_7: Azolla+75% N	228.67	270.00	250.33	45.32	37.41	41.37	25.85	25.03	25.44
T_8: 50% N alone	238.67	202.33	220.67	37.89	49.57	43.73	23.37	24.99	24.18
T_9: 75% N alone	250.33	212.33	231.33	37.65	44.07	40.86	26.32	24.89	25.61
C.D. (0.05)	25.30	40.00	NS	7.93	8.27	NS	NS	3.82	NS

combination with Azolla has given higher panicles than the corresponding levels of nitrogen alone.

(b) Number of filled grains per panicle

In the first crop season, full dose of nitrogen applied along with farm yard manure (T_3) produced significantly higher number of filled grains per panicle, followed by T_7. In the second crop season, 50% N applied either alone (T_8) or in combination with Azolla (T_6) recorded maximum filled grains. However, all the other treatments also performed almost in the same manner as that of these two treatments (T_8 and T_6).

(c) 1000 grain weight

In general, different treatments had no effect on 1000 grain weight. However, in the second crop season, application of full dose of N with Azolla (T_5) registered maximum test weight, closely followed by the treatments T_2, T_3 and T_7.

II. 3. Length of panicle

Mean values of length of panicle are given in Table 6 and analysis of variance in Appendix V.

From the analysis of variance of combined data, it was seen that the treatment x season interaction was not significant.

Mean data showed that only marginal variation was observed between the treatments. However, the treatment T_3 recorded maximum length.

Table 6. Length and weight of the panicle at harvest.

Treatments	Length of panicle (cm)			Weight of panicle (g)		
	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	20.09	19.53	19.81	1.340	1.373	1.360
T_2: 100% N alone	20.24	20.21	20.22	1.330	1.675	1.500
T_3: FYM + 100% N	21.49	20.87	21.18	1.640	1.866	1.760
T_4: Azolla alone	19.74	19.38	19.56	1.210	1.359	1.290
T_5: Azolla + 100% N	20.46	21.13	20.80	1.200	1.897	1.550
T_6: Azolla + 50% N	20.50	20.16	20.33	1.250	1.700	1.480
T_7: Azolla + 75% N	20.00	19.90	19.95	1.410	1.572	1.490
T_8: 50% N alone	20.86	20.60	20.73	1.150	1.837	1.490
T_9: 75% N alone	20.95	20.79	20.87	1.310	1.667	1.490
C.D.(0.05)	0.92	NS	0.77	0.160	0.228	NS

Table 7. Percentage of filling.

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	89.42	85.23	87.33
T_2: 100% N alone	85.14	88.18	86.66
T_3: FYM + 100% N	87.91	88.84	88.38
T_4: Azolla alone	83.44	86.60	85.02
T_5: Azolla + 100% N	82.26	87.65	84.96
T_6: Azolla + 50% N	84.21	87.78	86.00
T_7: Azolla + 75% N	91.78	88.94	90.36
T_8: 50% N alone	84.59	89.29	86.94
T_9: 75% N alone	91.21	87.88	89.54
C.D. (0.05)	2.87	NS	NS

II. 4. Weight of panicle

Data on weight of panicle are presented in Table 6 and analysis of variance in Appendix V.

In the first crop season, full dose of nitrogen applied along with farm yard manure (T_3) recorded maximum weight which was superior to all the other treatments. In the second crop season, application of full dose of nitrogen along with Azolla (T_5) registered maximum weight.

II. 5. Percentage of filling

Mean values of percentage of filling are given in Table 7 and analysis of variance in Appendix V.

In the first crop season, application of 75% N along with Azolla (T_7) produced higher percentage of filling than all other treatments, except those of 75% N applied alone (T_9) and no nitrogen control (T_1). In the second crop season, the treatments did not differ significantly. However, the treatments T_3, T_2, T_7 and T_8 recorded higher filling percentage.

II. 6. Yield

(a) Yield of grain

Mean grain yield data are presented in Table 8 and analysis of variance in Appendix VI.

In the first crop season, application of 75% nitrogen with Azolla (T_7) recorded significantly higher yield than all the other treatments which was comparable only to the

Table 8. Yield of grain (kg/ha).

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	2124	1515	1819
T_2: 100% N alone	2758	2838	2798
T_3: FYM + 100% N	2990	3078	3034
T_4: Azolla alone	2220	1539	1880
T_5: Azolla + 100% N	2540	2838	2689
T_6: Azolla + 50% N	2528	2573	2551
T_7: Azolla + 75% N	2886	3078	2982
T_8: 50% N alone	2194	2405	2300
T_9: 75% N alone	2625	2574	2599
C.D. (0.05)	210	247	510

full dose of nitrogen applied either alone (T_2) or in combination with farm yard manure (T_3). The treatment (T_5) was significantly inferior to all these treatments.

In the second crop season, T_7 recorded maximum yield, followed by treatments T_3, T_2 and T_5. These four treatments were on par with each other and significantly superior to all the other treatments.

In both the seasons, application of 50% N with Azolla (T_6) tended to produce as much grains as that of application of 75% N alone (T_9).

(b) Yield of straw

Mean yield of straw in different treatments is given in Table 9 and analysis of variance in Appendix VI.

In the first crop season, application of full dose of N with farm yard manure (T_3) produced maximum yield of straw closely followed by the treatments T_5 and T_2 which were significantly superior to all the other treatments. The treatment T_7 recorded significantly lower straw yield than T_3, T_5 and T_2.

In the second crop season, T_5 recorded maximum straw yield which was significantly superior to T_2. The treatments T_7 and T_3 closely followed T_5 in straw production and were on par with each other.

II. 7. Harvest index

Mean values of harvest index are given in Table 10 and analysis of variance in Appendix VI.

Table 9. Yield of straw (kg/ha).

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	2506	1162	1834
T_2: 100% N alone	4486	2506	3496
T_3: FYM + 100% N	4632	2696	3664
T_4: Azolla alone	3542	1111	2327
T_5: Azolla + 100% N	4617	3033	3825
T_6: Azolla + 50% N	3899	2131	3015
T_7: Azolla + 75% N	4127	2727	3427
T_8: 50% N alone	3738	2133	2935
T_9: 75% N alone	4084	2547	3315
C.D.(0.05)	319	434	492

Table 10. Harvest index

Treatments	First crop	Second crop	Mean
T_1: No N (Control)	0.4590	0.5660	0.5123
T_2: 100% N alone	0.3800	0.5309	0.4556
T_3: FYM + 100% N	0.3930	0.5339	0.4633
T_4: Azolla alone	0.3850	0.5815	0.4834
T_5: Azolla + 100% N	0.3550	0.4858	0.4206
T_6: Azolla + 50% N	0.3940	0.5478	0.4709
T_7: Azolla + 75% N	0.4120	0.5318	0.4719
T_8: 50% N alone	0.3700	0.5309	0.4503
T_9: 75% N alone	0.3910	0.5026	0.4470
C.D. (0.05)	0.0310	0.0535	0.0297

Analysis of variance of pooled data showed that treatment x season interaction was not significant. Mean data indicated that control plot recorded maximum value of harvest index. However, among other treatments remarkable variation was not observed.

III. Chemical analysis studies

III. 1. N, P and K content of grain

Data on N, P and K content of grain are presented in Table 11 and analysis of variance in Appendix VII.

a. N content:

In the first crop season, application of full dose of N either alone (T_2) or in combination with farm yard manure (T_3) increased the 'N' content of grain significantly over other treatments. This was closely followed by T_5. However, in the second crop season different treatments did not influence the 'N' content.

b. P content:

In both the seasons total P content of grain was not affected by the treatments.

c. K content:

Eventhough in the second crop season, the K content of grain was influenced by the treatments, appreciable variation was not noticed between the treatments in the first crop season as well as in the combined data.

Table 11. N, P and K content of grain (per cent).

Treatments	N			P			K		
	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	0.835	1.027	0.931	0.3222	0.3263	0.3243	0.2250	0.3750	0.300
T_2: 100% N alone	1.041	0.947	0.999	0.3307	0.3143	0.3225	0.1750	0.3667	0.271
T_3: FYM + 100% N	1.069	0.887	0.978	0.3263	0.3512	0.3388	0.1750	0.3750	0.275
T_4: Azolla alone	0.947	0.938	0.943	0.3471	0.3307	0.3389	0.1670	0.4083	0.288
T_5: Azolla + 100% N	0.961	0.952	0.957	0.3471	0.3185	0.3328	0.1920	0.2750	0.233
T_6: Azolla + 50% N	0.789	0.989	0.889	0.3345	0.3225	0.3285	0.2080	0.3500	0.279
T_7: Azolla + 75% N	0.793	0.905	0.849	0.3346	0.3767	0.3556	0.2000	0.4250	0.313
T_8: 50% N alone	0.784	0.994	0.889	0.3553	0.3222	0.3388	0.2080	0.3833	0.296
T_9: 75% N alone	0.919	1.064	0.992	0.3595	0.3345	0.3470	0.1920	0.3333	0.263
C.D.(0.05)	0.063	NS	NS	NS	NS	NS	NS	0.074	NS

III. 2. N, P and K content of straw

Mean values of N, P and K content of the straw are presented in Table 12 and analysis of variance in Appendix VIII.

(a) N content

In the first crop season, application of full dose of N with Azolla (T_5) recorded higher N content. But treatments T_8, T_7, T_6 and T_9 were on par with this. The treatments T_3 and T_2 recorded lowest N content.

In the second crop season, though application of 75% N alone (T_9) recorded maximum N content, the treatments T_3, T_7, T_5 and T_6 were statistically equal to T_9.

(b) P content

Though the application of 50% N with Azolla (T_6) recorded maximum P content in the first crop season, which was on par with T_2, T_8, T_4 and T_5, influence of treatments was not evidenced in the second crop season and also in the combined data.

(c) K content

Eventhough the treatments differed significantly in the second crop season, much variation was not observed between treatments in the first crop season as well as in the combined analysis.

III. 3. N P K uptake

Data on uptake of N, P and K are given in Table 13

Table 12. N, P and K content of straw (per cent).

Treatments	N			P			K		
	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	0.546	0.611	0.579	0.1502	0.1442	0.1472	1.125	2.142	1.633
T_2: 100% N alone	0.485	0.607	0.546	0.1876	0.1569	0.1723	1.242	2.067	1.654
T_3: FYM + 100% N	0.537	0.784	0.660	0.1570	0.1837	0.1704	1.142	2.125	1.633
T_4: Azolla alone	0.607	0.583	0.595	0.1837	0.1339	0.1588	1.255	2.092	1.658
T_5: Azolla + 100% N	0.737	0.705	0.721	0.1837	0.1771	0.1804	1.325	1.975	1.650
T_6: Azolla + 50% N	0.658	0.705	0.681	0.2048	0.1602	0.1825	1.233	2.258	1.746
T_7: Azolla + 75% N	0.658	0.765	0.712	0.1669	0.1637	0.1653	1.217	2.142	1.680
T_8+ 50% N alone	0.700	0.588	0.644	0.1840	0.1504	0.1672	1.292	2.242	1.767
T_9: 75% N alone	0.625	0.803	0.714	0.1602	0.1637	0.1619	1.192	1.867	1.529
C.D. (0.05)	0.129	0.104	NS	0.0222	NS	NS	NS	0.188	NS

and analysis of variance in Appendix IX.

(a) N uptake

In the first crop season, application of full dose of N with Azolla (T_5) or farm yard manure (T_3) resulted in maximum uptake which was significantly superior to all other treatments. This was followed by T_2 and T_7.

In the second crop season, significantly maximum uptake was recorded when 75% N was applied along with Azolla (T_7) and this was statistically on par with application of full dose of N with Azolla (T_5) or farm yard manure (T_3).

(b) P uptake

In the first crop season, combined application of Azolla either with full dose of N (T_5) or with 75% N (T_7) resulted in high uptake of P. This was on par with application of full dose of N either alone (T_2) and in combination with farm yard manure (T_3).

In the second crop season, application of 75% N with Azolla (T_7) recorded maximum uptake which was significantly superior to all the other treatments except T_3 and T_5.

(c) K uptake

In the first crop season, application of full dose of nitrogen in combination with Azolla (T_5) recorded maximum uptake which was superior to all the other treatments except T_2. Treatments T_3 and T_7 ranked next to these two treatments.

Table 13. N, P and K uptake at harvest (kg/ha).

Treatments	N			P			K		
	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	31.44	22.64	27.04	10.61	6.61	8.61	33.05	30.59	31.82
T_2: 100% N alone	50.41	42.18	41.30	17.49	12.83	15.16	60.43	62.19	61.31
T_3: FYM + 100% N	56.84	48.46	52.65	17.06	15.77	16.42	57.34	69.30	63.32
T_4: Azolla alone	42.54	20.90	31.72	14.22	6.54	10.38	47.05	29.67	38.36
T_5: Azolla + 100% N	58.41	48.28	53.35	17.30	14.41	15.86	66.05	68.31	67.18
T_6: Azolla + 50% N	45.56	40.43	42.99	16.25	11.70	13.97	53.43	56.97	55.20
T_7: Azolla + 75% N	50.04	48.76	49.40	16.54	16.06	16.30	55.98	70.80	63.39
T_8: 50% N alone	43.34	36.48	39.91	14.66	10.92	12.79	52.82	59.01	55.91
T_9: 75% N alone	49.65	47.69	48.67	15.84	12.78	14.31	53.69	56.00	54.85
C.D.(0.05)	5.70	6.24	8.56	1.44	1.52	3.00	7.32	10.46	13.25

In the second crop season, incorporation of Azolla with 75% N (T_7) registered maximum uptake. This was significantly superior to all the other treatments, but was statistically on par with T_3, T_5 and T_2.

III. 4. Soil analysis

Mean values of total N, organic carbon (Walkley and Black value), C:N ratio, available P and exchangeable K in the soil after cropping are presented in Table 14(a) and 14(b) and analysis of variance in Appendix X(a) and (b).

(a) Total N

Total nitrogen content of the soil after cropping did not vary due to different treatments in both the seasons. However, in the second crop season the treatments which received higher doses of nitrogen such as T_2, T_5 and T_7 recorded numerically higher N content.

(b) Organic carbon

Though the significantly lowest value of organic carbon content was recorded in the control plot (T_1) during the first crop season, different treatments did not have any influence during the second crop season.

(c) C:N ratio

In general, C N ratio of the soil was not affected by different treatments, though in the second crop season, significantly higher ratio was recorded in the control plot (T_1).

Table 14(a). Soil analysis data after cropping.

Treatments	Total N (per cent)			Organic carbon (per cent)			C N ratio		
	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	0.0369	0.0331	0.0350	0.170	0.580	0.375	4.95	17.65	11.41
T_2: 100% N alone	0.0409	0.0504	0.0456	0.350	0.500	0.425	8.95	10.63	9.79
T_3: FYM+100% N	0.0372	0.0453	0.0412	0.380	0.500	0.440	10.34	11.23	10.79
T_4: Azolla alone	0.0331	0.0414	0.0373	0.350	0.540	0.445	10.57	13.74	12.16
T_5: Azolla+100% N	0.0426	0.0509	0.0468	0.470	0.530	0.500	11.22	10.74	10.98
T_6: Azolla + 50% N	0.0520	0.0434	0.0477	0.480	0.570	0.525	9.63	13.44	11.53
T_7: Azolla + 75% N	0.0439	0.0471	0.0455	0.450	0.530	0.490	10.60	11.47	11.03
T_8: 50% N alone	0.0480	0.0448	0.0464	0.420	0.600	0.510	8.99	13.68	11.33
T_9: 75% N alone	0.0481	0.0471	0.0476	0.430	0.560	0.495	9.12	12.35	10.73
C.D.(0.05)	NS	NS	0.0088	0.14	NS	NS	NS	3.45	NS

Table 14(b). Soil analysis after cropping.

Treatments	Available P (ppm)			Exchangeable K (ppm)		
	First crop	Second crop	Mean	First crop	Second crop	Mean
T_1: No N (Control)	40.39	48.82	44.60	14.33	21.75	18.04
T_2: 100% N alone	43.15	49.89	46.52	20.50	23.67	22.08
T_3: FYM + 100% N	43.58	47.44	45.51	22.33	10.92	16.63
T_4: Azolla alone	49.89	48.82	49.36	20.67	13.67	17.17
T_5: Azolla + 100% N	45.29	40.54	42.92	26.00	18.00	22.00
T_6: Azolla + 50% N	51.12	43.61	47.36	25.83	13.00	19.42
T_7: Azolla + 75% N	36.55	46.98	41.77	17.83	14.33	16.08
T_8: 50% N alone	44.53	42.53	43.53	14.83	12.33	13.58
T_9: 75% N alone	40.54	41.19	40.86	26.16	13.58	19.88
C.D. (0.05)	NS	NS	NS	NS	6.64	NS

(d) Available P

Available P content of the soil did not vary significantly due to treatments in both the seasons.

(e) Exchangeable K

Treatments had little influence on exchangeable K content of the soil, though in the second crop season, the plot which received full dose of 'N' (T_2) recorded high 'K' content.

DISCUSSION

V. DISCUSSION

The objectives of the present investigations are to bring out the effect of Azolla incorporation on growth and yield of rice and to assess the saving of nitrogen. The results obtained are discussed below.

I. Growth

I.1. Height

The results presented in Table 2 show that at early tillering stage, a clear trend is not evidenced from the treatments.

At flowering and harvest stages, the treatment which received 75% N in combination with Azolla gives a height equal to that of 100% N applied either alone or in combination with Azolla or farm yard manure.

The results indicate that when full dose of nitrogen is applied, addition of farm yard manure or Azolla does not have any remarkable effect on height. The nitrogen content of Azolla or farm yard manure is released slowly (Sawatdee et al., 1978; Chandler Jr., 1979). In the case of Azolla, availability of its nitrogen to a single crop is about 70% (Watanabe, 1977; Watanabe et al., 1977) and farm yard manure releases only 30% of its nitrogen in a single season (Allison, 1973). But inorganic nitrogen will be readily and easily taken up by the plant. Hence, when sufficient nitrogen is applied in the inorganic form, the plant utilises the same more readily than from these organic sources which are only gradually mineralised. Such a situation has been observed by Koyama and Miamorichand (1973) also. This might have resulted in the lack of significant response to Azolla or farm yard manure at higher nitrogen level. The results are in agreement with that reported by Natarajan et al. (1980).

Results also show that when Azolla is applied in combination with 75% nitrogen, the increase in height observed equals to that of 100% nitrogen applied either alone or in combination with Azolla or farm yard manure. This shows that if inorganic nitrogen is not sufficient, the plant tends to take up some nitrogen from Azolla. Similar result of beneficial effect of combined application of Azolla with inorganic nitrogen has been reported by Singh (1978a).

I.2. Number of tillers

Results on tillering presented in Table 3, reveal that at early tillering stage higher levels of nitrogen, either alone or in combination with Azolla or farm yard manure, record higher tillering than that of lower levels.

Tillering in rice plant increases as nitrogen level increases (Kalyanikutty and Morachan, 1974; Gopalaswamy and Raj, 1977). Tillering increases with growth reaching a maximum at maximum tillering stage. Though the quantity of nitrogen supplied in different treatments varies, sufficient nitrogen supply might have been ensured to all the treatments to produce the same level of tillering at early tillering stage.

At maximum tillering stage, combined application of full dose of nitrogen either with Azolla (T_5) or farm yard manure (T_3) produces more tillering than an application of 100% N alone (T_2).

As growth advances from early tillering to maximum tillering, nitrogen supplying capacity of different treatments differ considerably. The nitrogen content in Azolla or farm yard manure is getting released and can be taken up by the plant. The crop also received two splits of total inorganic nitrogen as per treatment before maximum tillering stage. These ensure maximum nitrogen availability in the treatments T_3 and T_5 than the other treatments and might have enabled them to produce maximum tillering at this stage.

Results illustrated by Fig. 3 further indicates that, in general, combined application of Azolla with inorganic nitrogen increases tillering over inorganic nitrogen alone at each level. Similar increase in tillering due to Azolla incorporation has been observed by Singh (1978a) and Subudhi and Singh (1980).

FIG. 3. TILLERS AT MAXIMUM TILLERING STAGE AND PANICLES AT HARVEST.

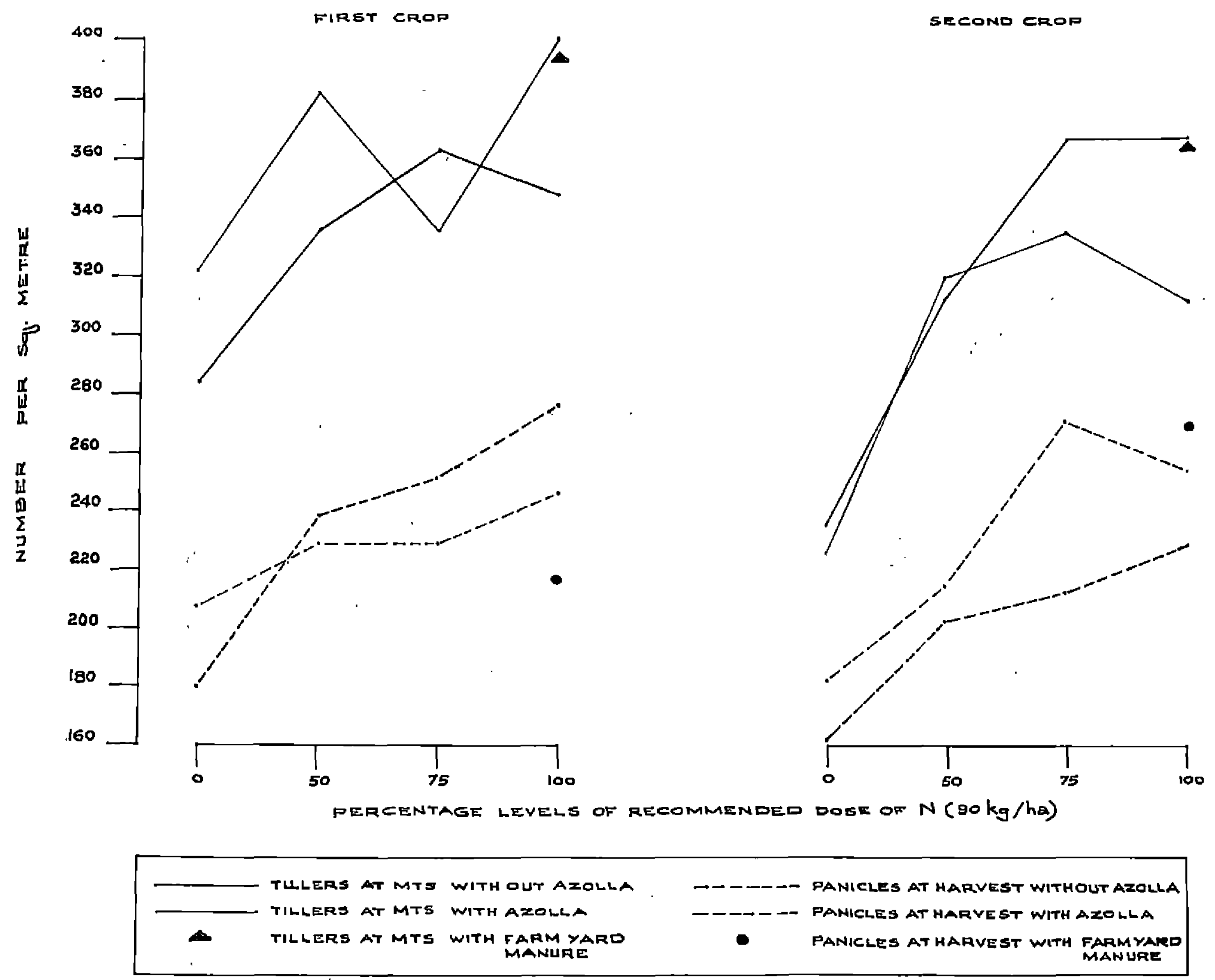
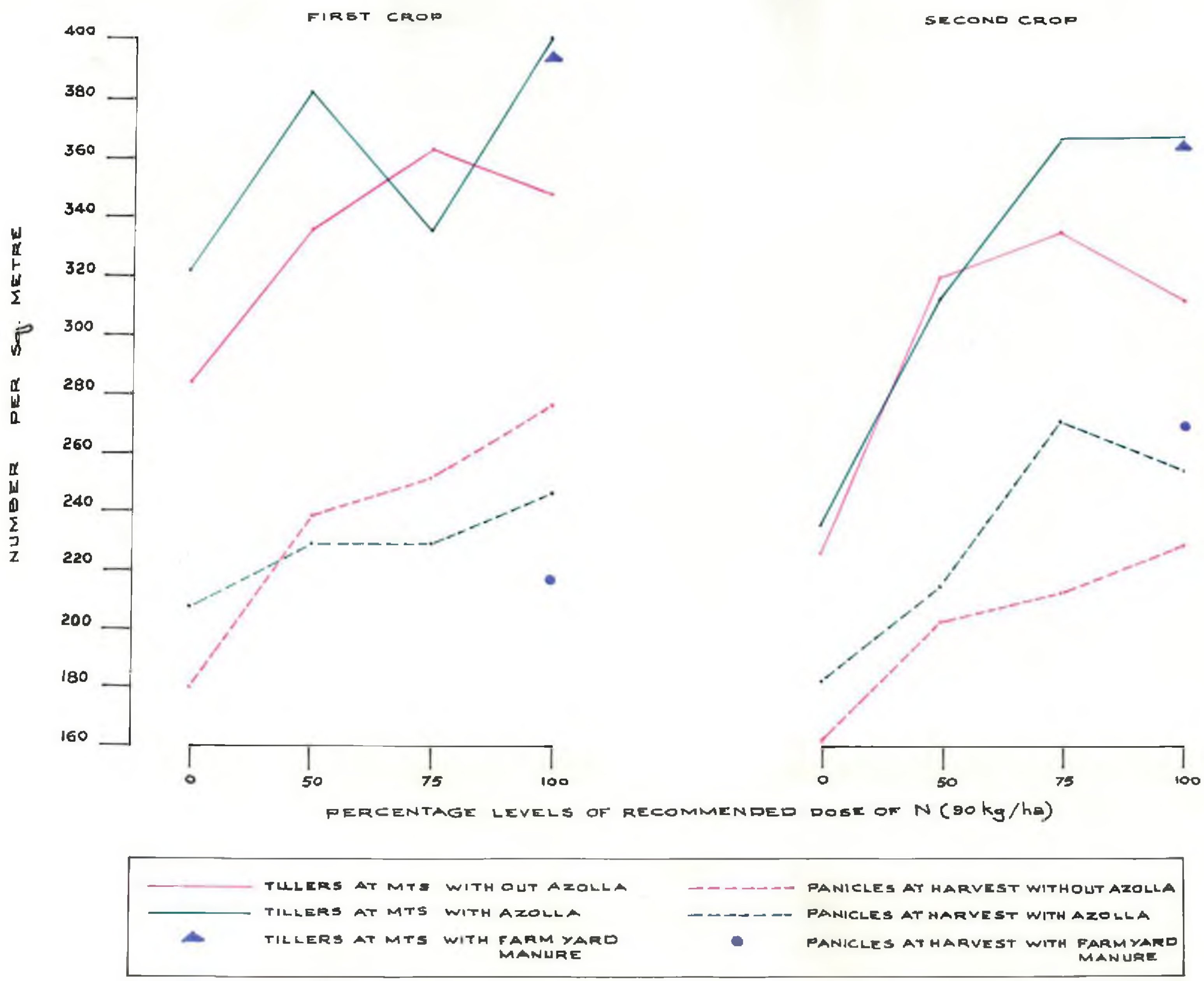


FIG. 3. TILLERS AT MAXIMUM TILLERING STAGE AND PANICLES AT HARVEST



I. 3. Leaf area index

It is to be noted particularly that the values of leaf area index are low compared to that generally observed for rice plants. This is due to low tillering and low height generally noticed in sandy soils of the area.

Leaf area index at flowering presented in Table 4 indicates that application of full dose nitrogen alone and in combination with Azolla or farm yard manure record maximum values. Application of 75% nitrogen with Azolla also gives the same index.

Several reports have shown that leaf area index increased with nitrogen levels (Perumal and Rao, 1974; Rao et al., 1974a; Palit et al., 1976). Height of the plant continues to increase until flowering time, mainly because of an increase in leaf length (Ishizuka, 1971). Results obtained for LAI closely follow the trend observed in the height. Hence the increase in leaf length might have influenced the leaf area index.

II. Post harvest observations

II.1. Percentage of productive tillers

Results are presented in Table 5(a) which indicate that higher levels of nitrogen tend to reduce percentage of productive tillers.

It is already seen from the discussion on tillering that N at higher levels increased tiller production at maximum tillering stage. The results presented in Table 5(b) and Fig.3 also indicate that higher panicle number is recorded in accordance with higher levels of nitrogen application. This may be due to the conversion of more number of tillers into panicles in these treatments. But in the case of low nitrogen levels, most of the tillers produced at maximum tillering stage is converted into panicles by restricting the production of number of unproductive tillers, because of reduced nitrogen availability.

When higher levels of nitrogen are applied, there is a proportionate increase in the number of unproductive tillers, which in turn reduces the percentage of productive tillers in these treatments.

Similar observations have been reported by Nair (1976).

II. 2. Yield components

(a) Number of panicles per square metre

As revealed from Table 5(b) and Fig. 3, there is a progressive increase in panicle production with increasing levels of nitrogen application. In the first crop season, maximum panicles are produced by the treatment receiving full dose of nitrogen alone. The treatment receiving full dose of nitrogen with Azolla or farm yard manure has recorded lower panicle production.

Increase in panicle production per square metre in accordance with increasing nitrogen levels is a general trend in rice culture (Subbiah and Morachan, 1974; Subbiah et al., 1977; Raju, 1978).

When rice is grown in a constantly flooded condition, the differences in nitrogen response between rainy and dry seasons are associated mainly with solar radiation because the fluctuation in other climatic factors is small (De Datta, 1970). The first crop season is characterised by cloudy nature of weather, high rainfall and low solar radiation (Appendix I, Fig.1; Yoshida, 1978). This favours more vegetative growth of the plant utilizing nitrogen supply, thereby producing higher number of unproductive tillers as indicated in Table 5(a). The fertilizer use efficiency has also been reported to be comparatively low in the first crop season (Racho and De Datta, 1968). When farm yard manure or Azolla is applied along with full dose of nitrogen in this season more tillers are produced at maximum tillering stage resulting in more straw yield at harvest, as illustrated by Fig.3 and Fig.7. Fig. 3 further shows that the panicle production at 100% N alone is appreciably higher than that of 100% N with Azolla or farm yard manure. Eventhough more quantity of N is available in the latter treatments, they have recorded lower panicle production in the first crop season, consequent to the increased vegetative growth.

But during the second crop season, incorporation of Azolla along with inorganic nitrogen records higher number of panicles than application of inorganic nitrogen alone

(Fig. 3). Application of 75% N with Azolla (T_7) has registered maximum panicle production. When Azolla is incorporated with 100% N, there is a decrease in panicle number though it is not statistically significant. Application of farm yard manure with 100% N (T_3) has also recorded the same level of panicle production as that of the treatment (T_7). When 100% N alone is applied, the panicle production is significantly lower than that of T_3 and T_7. In the second crop season, productive efficiency of nitrogen is higher due to reduced losses and more solar radiation (Racho & De Datta, 1968). Azolla or farm yard manure can supply a substantial amount of nitrogen. This produces more number of tillers (Fig. 3) which is converted into panicles probably due to higher solar radiation available in the season. Beneficial effect of combined application of inorganic nitrogen with Azolla over application of nitrogen alone is noticed at every level. Singh (1977c, 1978a) has also observed an increase in panicle production due to Azolla incorporation.

There seems to be an optimum level of inorganic nitrogen for panicle production in the second crop season when applied in combination with Azolla. It is seen from Fig. 3 that the treatment 100% N with Azolla records a lower panicle number than 75% N with Azolla. However, these two treatments have recorded significantly higher tiller production than the corresponding level of inorganic

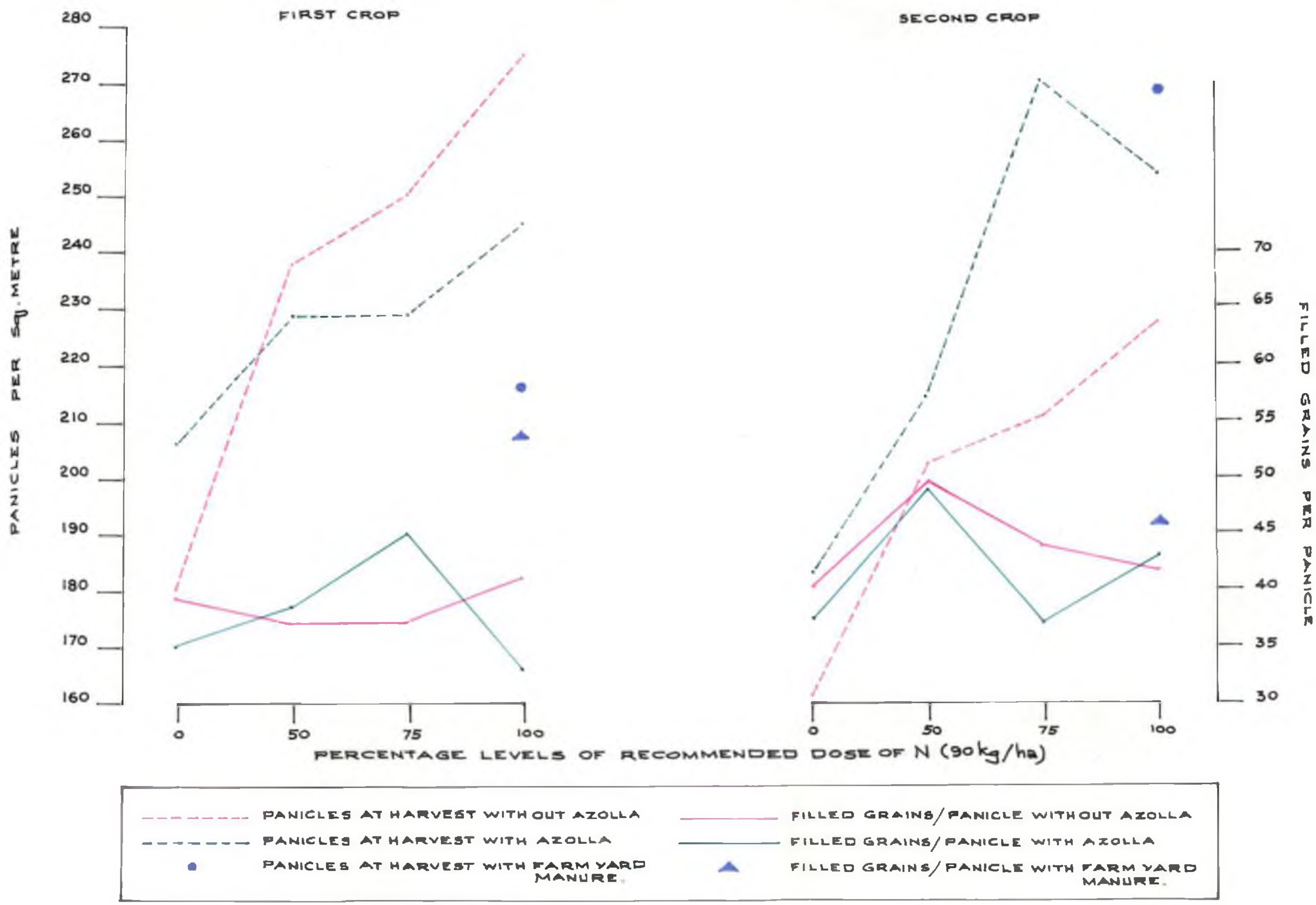
N alone, without much variation between these two levels. This shows that extra nitrogen applied over and above 75% nitrogen with Azolla has been utilised for producing unproductive tillers.

Further it can be seen that when 100% inorganic nitrogen is applied along with Azolla or farm yard manure or 75% N with Azolla, higher panicle production was noticed than application of 100% N alone. When inorganic nitrogen alone is applied, panicle production shows a linear trend. This reveals the importance of organic nitrogen in sandy soil. The inorganic N is not seen utilised properly even after 4 split applications. The plants might have to depend more on organic source of N for producing this important yield attribute. Beneficial effects of Azolla nitrogen in sandy soils have been noticed by Sawatdee et al. (1978).

(b) Number of filled grains per panicle

As indicated in Table 5(b) and Fig. 4, full dose of nitrogen applied along with farm yard manure (T_5) produced highest number of filled grain per panicle in the first crop season. 75% nitrogen applied along with Azolla also records a higher number. It has already been established that yield components, viz., panicle number and number of filled grains, exhibit a negative correlation among each other (Matsushima, 1976). Correlation coefficients given in Table 15 also show this negative relationship between number of filled grains and panicle number in the first

FIG. 4 PANICLES AND FILLED GRAINS PER PANICLE.



crop season. This is illustrated further in Fig. 4. In the case of panicle production, 100% nitrogen with farm yard manure produces a lower number per square metre. This is in turn might have reduced the number of spikelets produced per unit area. The higher quantity of photosynthates produced through increased nitrogen supply in this treatment might have helped to fill most of the sink. The same trend is also noticed in the treatment receiving Azolla with 75% nitrogen. It is also seen from Fig. 4 that the negative correlation between the panicle number and the number of filled grains starts from the 0 nitrogen level, when inorganic N alone is applied. When Azolla is incorporated with N, the number of filled grains increases proportionately with panicle production and the negative correlation is projected only at 100% N level. This indicates that Azolla incorporation may reduce unfilled grains, when applied along with nitrogen upto 75% N level. This is again supported by Fig. 5 on percentage of filling. These findings are in confirmity with the finding of Kulasooriya and de Silva (1977).

In the second crop season, the number of filled grains per panicle is maximum when 50% N is applied alone or in combination with Azolla. The other treatments also perform almost alike. Table 5(b) and Fig.4 reveal that when nitrogen is supplied upto 50% level either alone or in combination with Azolla, the filled grains increase proportionately with increase in panicle number. Such a proportionate increase is common in lower levels because of effective channelling of photosynthates to the spikelets which are produced in lesser number (Matsushima, 1976). But when nitrogen supply is increased beyond this level, the negative relationship as stated earlier comes into the picture (Fig. 4). But it is to be noted that solar radiation is high in the second crop season especially during the reproductive period as read from evaporation values presented in Appendix I. High solar energy during the reproductive phase might have helped the crop to enhance photosynthesis, which could be effectively channelled to fill the sink (Ishizuka, 1971; Sanchez, 1976; Yoshida, 1978). This might have resulted in lack of significant variation between the other treatments.

(c) <u>1000 grain weight</u>

As revealed from Table 5(b), thousand grain weight is not much influenced by the treatments. However, full dose of nitrogen applied alone (T_2), and in combination with Azolla (T_5) or farm yard manure (T_3), as well as 75% N applied with Azolla (T_7) have recorded a higher test weight in the second crop season.

According to Gopalaswamy and Raj (1977), this character does not change considerably with increasing nitrogen levels. But higher solar radiation in the second crop season combined with increased photosynthesis due to high nitrogen supply in the treatments T_2, T_5, T_3 and T_7 might have enabled the translocation of more photosynthates to grain thereby producing more weight.

II. (3) Length of panicle

Result on panicle length presented in Table 6 shows that eventhough full dose of nitrogen applied with farm yard manure records maximum length in the first crop season, much variation is not observed between the treatments in the second crop season.

In high fertilizer responsive, varieties panicle number is influenced to a greater extent than the panicle length by nitrogen levels (Baba, 1959). Hence increase in panicle number obtained in this study in accordance with the levels of nitrogen applied either alone or in combination with Azolla, might have left the panicle length unaffected.

II. (4) Weight of panicle

Maximum panicle weight is recorded when full dose of nitrogen is applied with farm yard manure in the first crop season and with Azolla in the second crop season. Higher levels of nitrogen application has been found to increase panicle weight (Subbiah et al., 1977). Efficiency of Azolla nitrogen is more pronounced in the second crop season probably due to high nitrogen use efficiency generally observed in this season.

II. (5) Percentage of filling

Results presented in Table 7 and Fig. 5 indicate that in the first crop season, 75% N applied along with Azolla records maximum percentage of filling. In the second crop season also the same treatment records higher percentage of filling eventhough this is slightly lower than that of 50% nitrogen applied alone.

Increased nitrogen application has helped to enhance the number of spikelets produced (Fagade and De Datta, 1971). Fig. 5 illustrates that there is a steep decrease in filling when nitrogen level is increased beyond 75% N with Azolla in the first crop season. In this season, photosynthesis and translocation will be less due to cloudy weather (Sreedharan, 1975). Addition of excess nitrogen further aggravates this problem.

In the second crop season this decline is not drastic, probably because of high solar energy available. It is also to be noted that when 75% nitrogen is applied along with Azolla we get fairly good filling in both the seasons. This indicates the superiority of this treatment in reducing unfilled grains which might have been obtained through increased photosynthesis and effective translocation.

II. (6) Yield of grain

Results are presented in Table 8 and Fig. 6 from which it can be seen that, in the first crop season, application of 100% N either alone (T_2) or in combination with

FIG. 5. PERCENTAGE OF FILLED GRAINS.

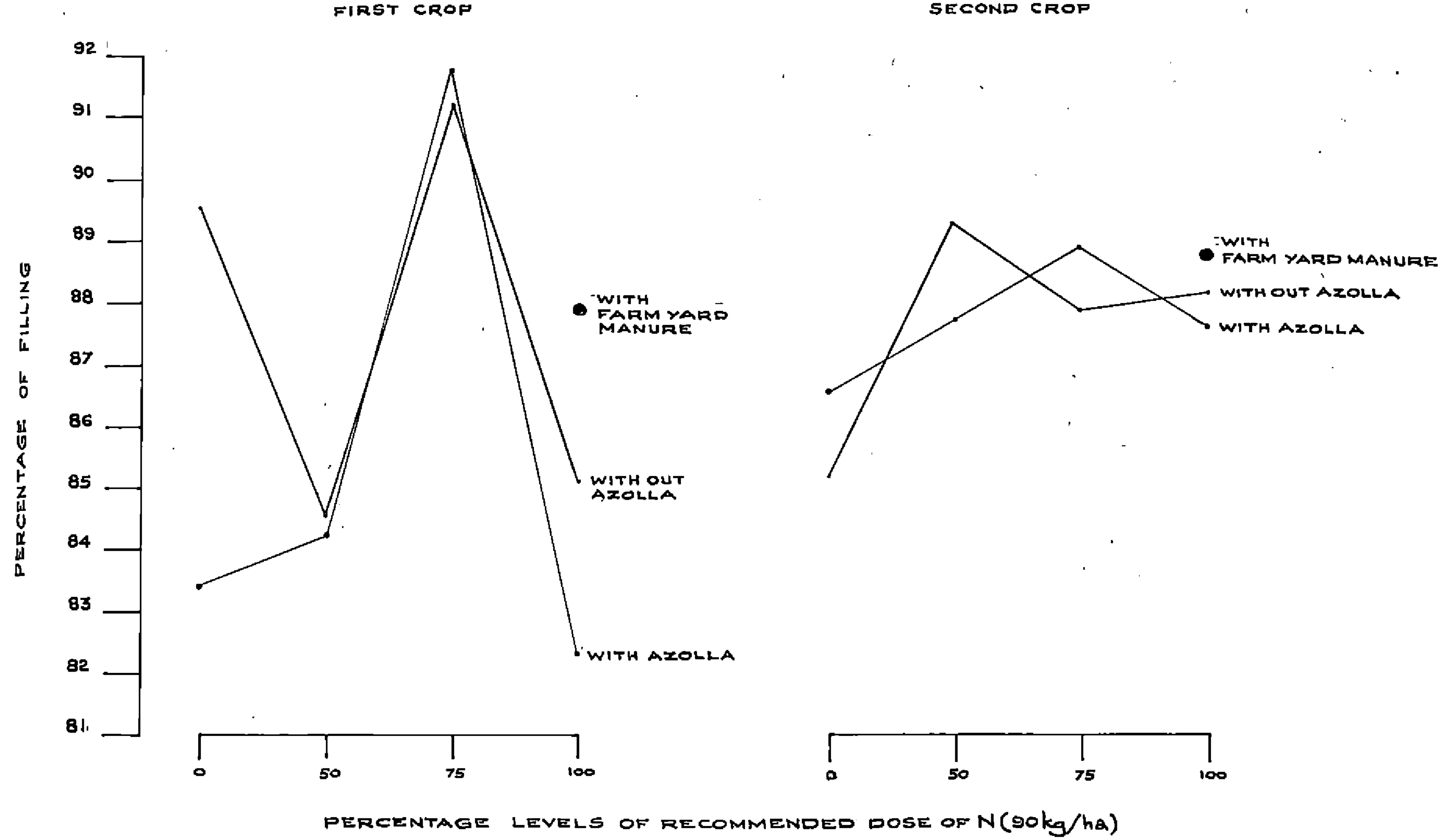


Table 15. Values of simple correlation coefficients between yield and yield components.

(a) First crop season

	No. of panicles per sq.m	No. of filled grains per panicle	1000 grain weight
Yield	0.447	0.680**	-0.14
No. of panicle per square metre	..	-0.151	-0.405
Number of filled grains per panicle	..	..	-0.2813

(b) Second crop season

	No. of panicles per sq.m	No. of filled grains per panicle	1000 grain weight
Yield	0.927**	0.286	0.822**
Number of panicle per square metre	..	0.053	0.797**
Number of filled grains per panicle	..	..	0.210

**Significant at 0.1% level

FIG. 5. PERCENTAGE OF FILLED GRAINS.

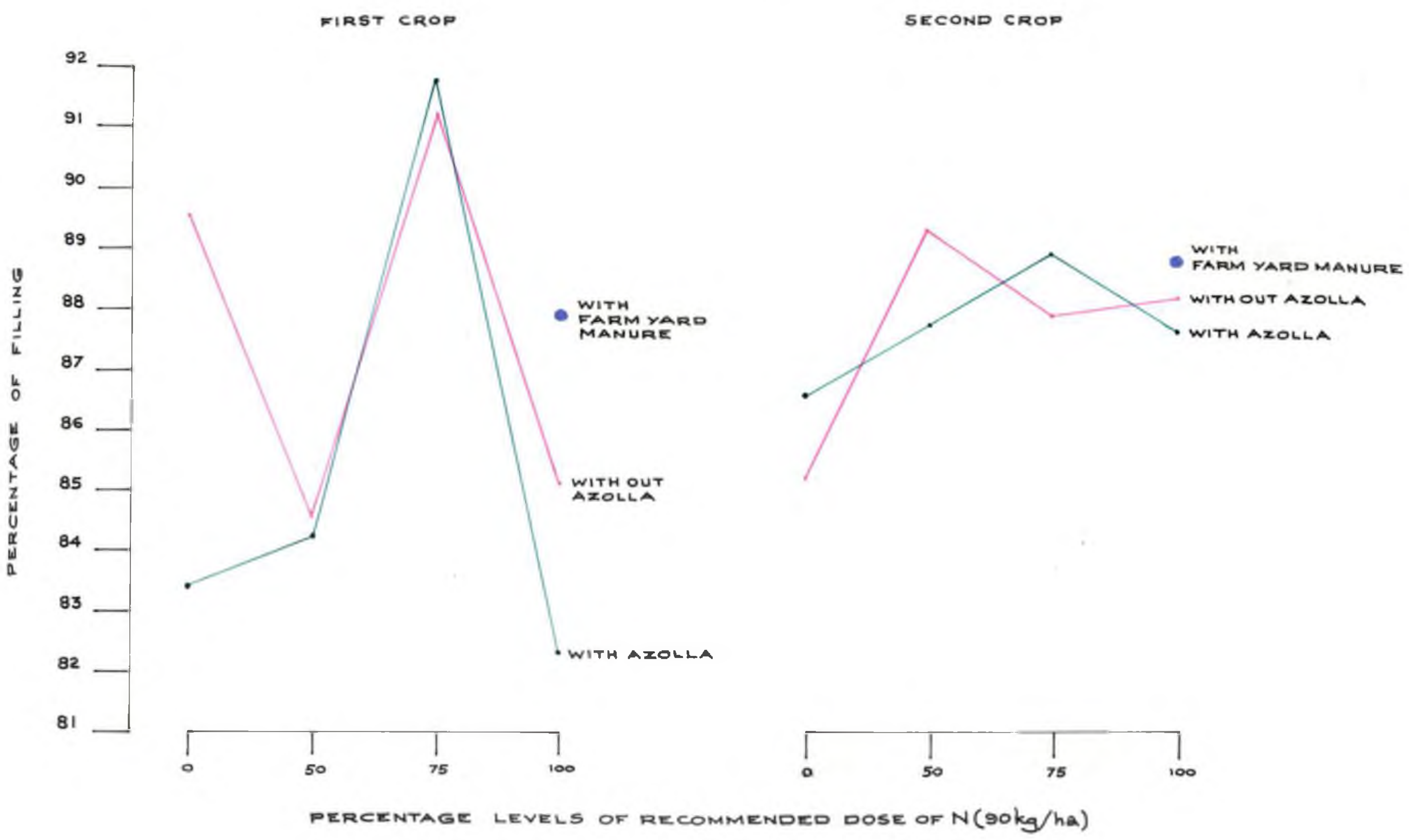
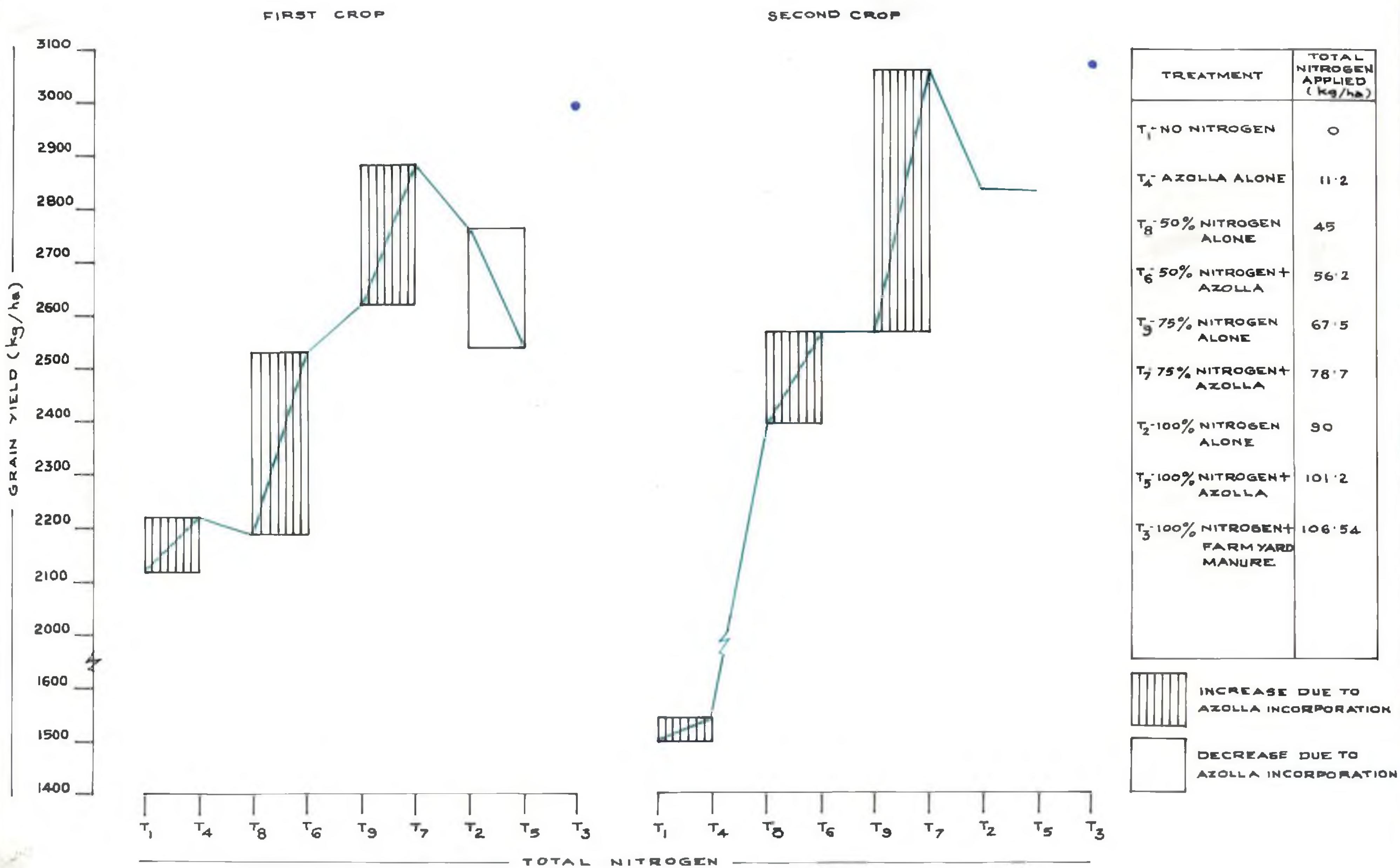


FIG. 6. GRAIN YIELD IN RELATION TO TOTAL NITROGEN APPLIED.



farm yard manure (T_3) and application of 75% N in conjunction with Azolla (T_7) resulted in significantly superior yield. But application of full dose of nitrogen with Azolla (T_5) records a significantly low yield.

Main yield contributing factors are number of panicles per unit area, number of filled grains per panicle and 1000 grain weight. It has been established that these components have high positive correlation with yield (Matsushima, 1976).

In the first crop season, the treatments receiving 100% N alone or with farm yard manure and 75% N with Azolla, record a much higher yield than all the other treatments because of higher number of filled grains per panicle which bears a high positive correlation with yield in this season (Table 15). The probable reason for decrease in yield in the treatment which received 100% N with Azolla may be due to utilization of excess nitrogen for vegetative growth and straw production instead of grain production as seen from Fig. 3, Fig. 7, Fig. 8 and Fig. 10.

In the second crop season the same treatments i.e., T_3, T_2 and T_7, record a higher yield than the rest. However, during this season, the treatment T_5 gives almost the same yield as that of T_3, T_2 and T_7.

Data on panicle production (Table 5(b), Fig. 4) show that a larger number of panicles are recorded in the above 4 treatments. 1000 grain weight is also higher in these treatments. Correlation coefficient values presented in

Table 15 indicate that in the second crop season, yield is significantly correlated with number of panicles as well as 1000 grain weight.

Results on leaf area index (Table 4) have also revealed that in both the seasons the above treatments recorded maximum leaf area index. Increase in leaf area has been found to benefit the plant to enhance photosynthetic production by tapping more solar energy (Rao et al., 1974a).

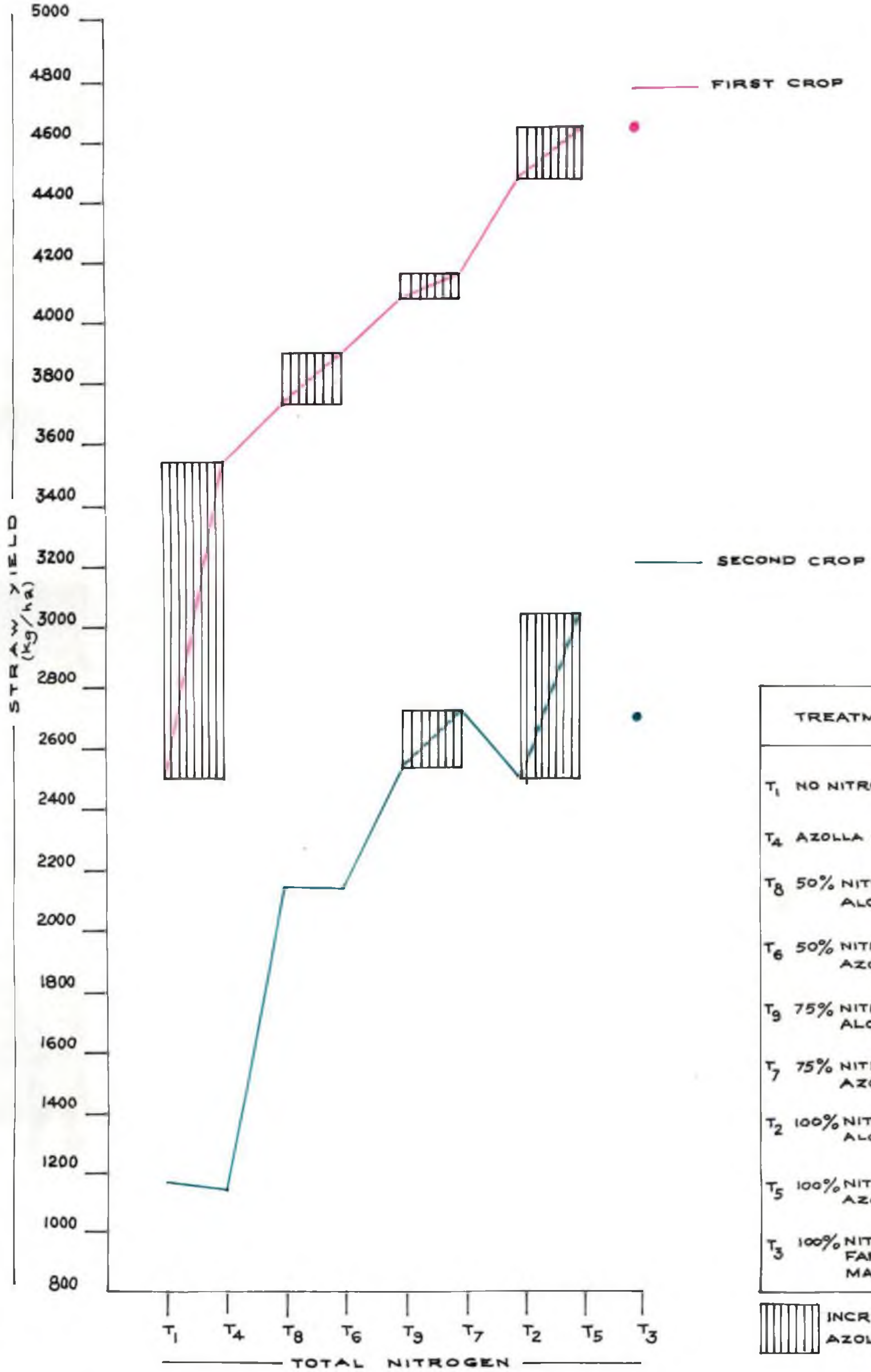
An important observation recorded in both the seasons is that when 75% N is applied along with Azolla, it performs equally efficiently as that of 100% N either alone or in combination with farm yard manure or Azolla. Response curve (Fig. 9) indicates that the optimum level of nitrogen with Azolla for maximum production lies around 75% N. Extra nitrogen supplied over and above this level through the treatments T_2, T_3 and T_5 has probably been utilised for straw production rather than for grain production (Fig. 8). Hence it reveals that 25% nitrogen can be saved if Azolla is incorporated. This is in agreement with the findings of Sundaram et al. (1979), Govindarajan et al. (1979, 1980), Srinivasan (1980a), Natarajan et al. (1980) and Natarajan and Sadayappan (1980).

One of the objectives of this investigation is to explore the possibility of replacing farm yard manure which is costly and limited in supply, with Azolla. This objective is seen fulfilled from the results obtained on yield and yield attributes. Both Azolla and farm yard manure are slow releasing sources of organic nitrogen. According to Watanabe (1977) 70% nitrogen present in Azolla is available to a single crop. Five tonnes of Azolla incorporated in this trial supplied 11.2 kg of N while 5 tonnes of farm yard manure contributed about 16.5 kg of N. But the nitrogen in farm yard manure is very strongly tied up and its availability to a single crop is generally 30% (Allison, 1973). Hence Azolla compares very well with farm yard manure. In this connection, it may be pointed out that Azolla has an added advantage over farm yard manure. Azolla is a self multiplying plant which can increase its biomass over time and can fix an abundant quantity of atmospheric nitrogen. Farm yard manure, which is a product of organic recycling, cannot put up its own mass. It requires some energy to be ultimately used as a manure.

II. (7) Yield of straw

Results presented in Table 9 and Fig.7 indicate that in the first crop season, 100% N applied either alone or with Azolla or farm yard manure records maximum straw yield with respect to all other treatments. In the second crop season, 100% N with Azolla produces maximum yield. The treatments receiving 100% N with farm yard manure and 75% N with Azolla can also be compared to this. The Fig. 7 further illustrates that increased nitrogen application increases straw yield which is generally observed in rice (Kalyanikutty and

FIG. 7. YIELD OF STRAW IN RELATION TO TOTAL NITROGEN APPLIED.



TREATMENTS	TOTAL NITROGEN APPLIED (kg/ha)
T_1 NO NITROGEN	0
T_4 AZOLLA ALONE	11·2
T_8 50% NITROGEN ALONE	45
T_6 50% NITROGEN + AZOLLA	56·2
T_9 75% NITROGEN ALONE	67·5
T_7 75% NITROGEN + AZOLLA	78·7
T_2 100% NITROGEN + ALONE	90
T_5 100% NITROGEN + AZOLLA	101·2
T_3 100% NITROGEN + FARM YARD MANURE	106·54

(vertical hatching) INCREASE DUE TO AZOLLA INCORPORATION

Morachan, 1974). Increase in the straw yield due to Azolla incorporation with inorganic nitrogen has also been reported (Singh, 1977c, d).

II. (8) Harvest index

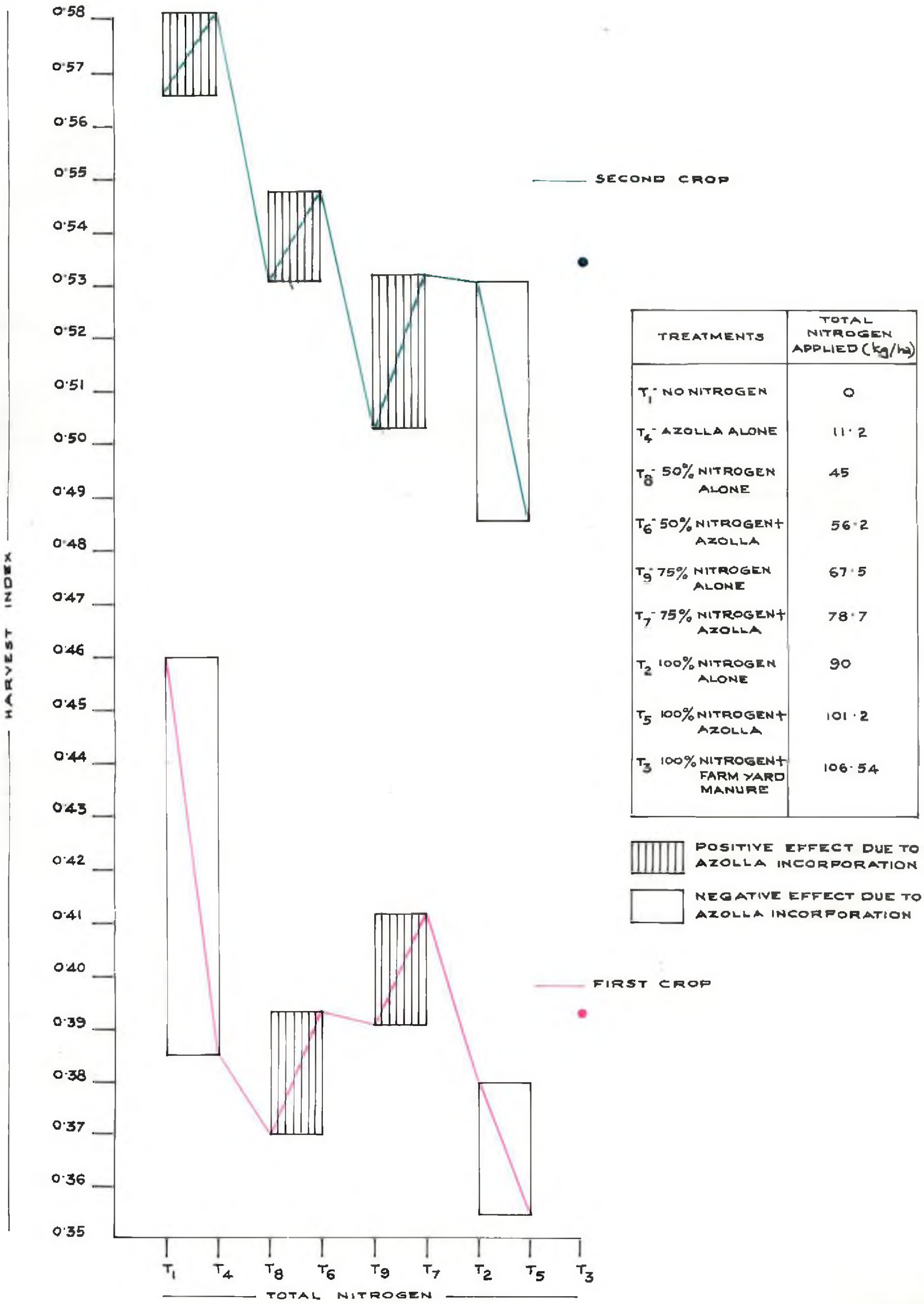
Results presented in Table 10 show that as levels of nitrogen application increases, the harvest index values decrease.

It has been observed that increased nitrogen application reduced harvest index (Kalyanikutty and Morachan, 1974), because of higher straw yield.

When harvest index values of the two seasons are compared (Fig. 8), it can be seen that the first crop season records a very low value compared to the second crop season. This is due to higher straw yield (Table 9 and Fig. 7) obtained in the first crop season because of low sunlight and cloudiness which favoured vegetative growth.

It is also noticed that the treatments viz., T_3, T_2 and T_5, which received higher nitrogen supply over and above 75% N with Azolla recorded a low harvest index. The increased nitrogen supply in these treatments has favoured straw production rather than grain production. It is also seen that whenever Azolla is incorporated either with 50% N or 75% N, harvest index values increase rather than that of latter alone. This again reveals that at these levels of nitrogen application, grain production is more benefitted than straw production through Azolla incorporation.

FIG 8. HARVEST INDEX IN RELATION TO TOTAL NITROGEN APPLIED.



III. (9) Chemical analysis studies.

III. 9. 1. Plant analysis

(a) N, P and K content of grain

Results presented in Table 11 reveal that N, P and K content of grain is not much influenced by the treatments.

It is already seen that the increasing nitrogen application either alone or in combination with Azolla or farm yard manure enhanced biomass production through grain and straw. N Uptake studies also reveal the same trend (Table 13, Fig. 10). Hence the content of N, P and K does not vary much. Subramoniam et al. (1974) and Rao et al. (1974b) have also recorded similar results.

However, in the first crop season, the treatments which received more nitrogen such as 100% N alone, or with farm yard manure, record higher N content. Uptake studies also reveal that in these treatments the increased nitrogen supply is better utilised for grain production than straw production.

In the second crop season, the high nitrogen treatments, such as 100% N either alone or in combination with Azolla or farm yard manure, generally record a low K content of grain. This is attributed to the higher grain production in these treatments, while receiving the same quantity of K_2O as in the other treatments.

(b) N, P and K content of straw

N, P and K content of straw is not much influenced by the treatments (Table 12). Higher uptake of these nutrients in accordance with higher levels of N is indicated in Table 13. Total biological output is also high (Table 8 and 9). Hence the content remains without much variation.

However, in the first crop season, the treatments receiving 100% N either alone or in combination with farm yard manure record a lower N content. It is seen from Fig. 10 that comparably low quantity of nitrogen is channelled towards straw production in these treatments.

K content of the straw is also low in treatments receiving higher N levels in the second crop season, because of higher straw production, while receiving the same dose of K_2O along with the other treatments.

(c) N, P and K uptake

It is revealed from the Table 13 that in first crop season maximum uptake is recorded when 100% N is applied along with Azolla (T_5) whereas 75% N with Azolla (T_7) registers highest uptake in the second crop season. Increased vegetative growth and straw production in relation to increased nitrogen availability in treatment T_5 in the first crop season and higher grain production in treatment T_7 during the second crop season have enabled the treatments to record these results in the respective seasons.

In general, it can be seen from Table 13 and Fig. 10 that higher levels of nitrogen application such as 100% N either alone or with Azolla or farm yard manure and 75% N with Azolla result in higher uptake of N, P and K in both the seasons. Increased uptake of N, P and K in accordance with N levels is commonly observed in rice plant (Gopalaswamy and Raj, 1977; Raju, 1970).

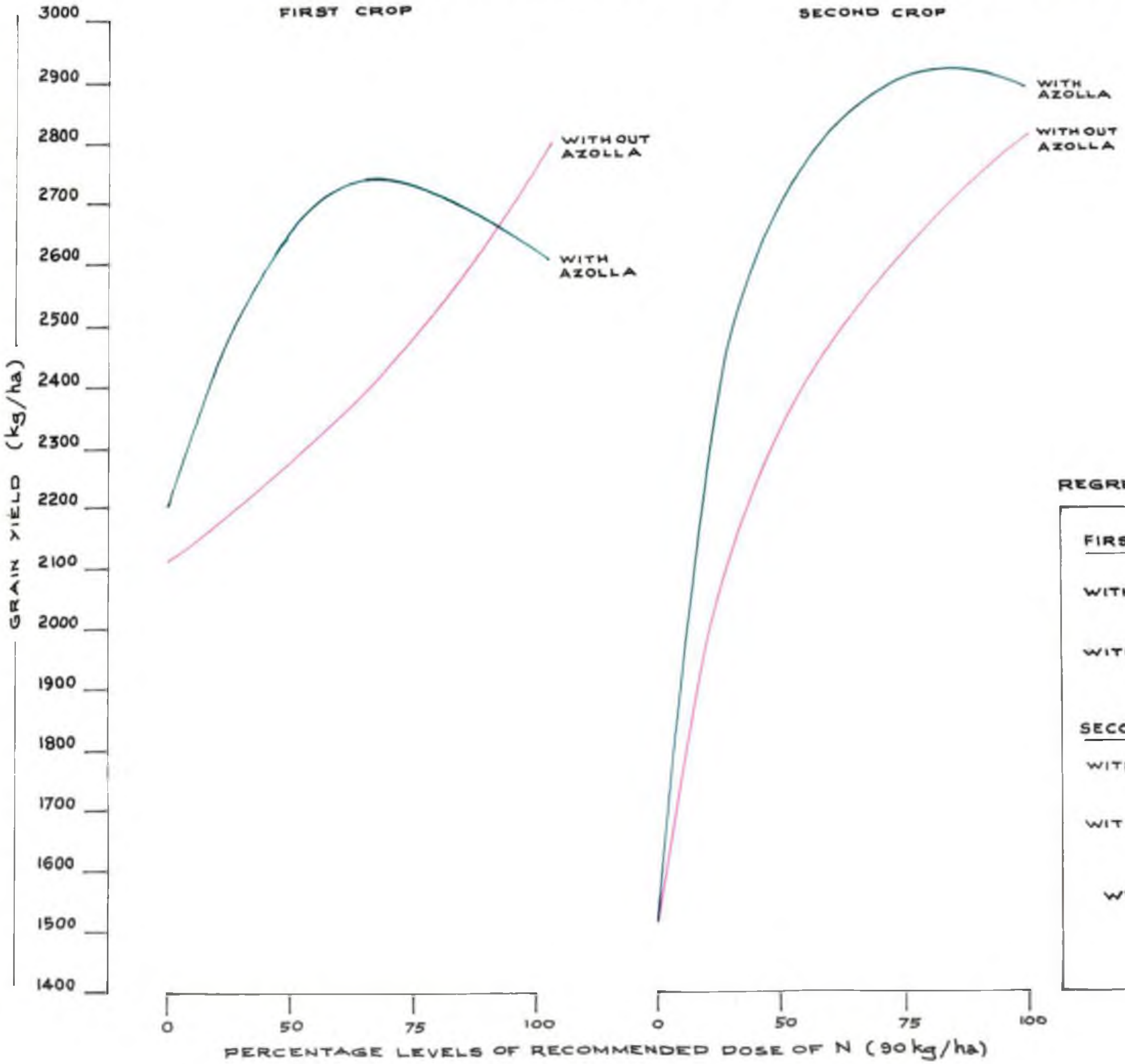
III. (9). 2. Soil analysis after cropping

Results on total N content, organic carbon, C:N ratio, available P and exchangeable K in the soil after cropping presented in Table 14(a) and (b) indicate that much variation is not observed between the treatments.

Total nitrogen content of the soil did not vary significantly in both the seasons in different treatments because of higher uptake in accordance with increasing nitrogen levels. However, in the second crop season, the treatments which received higher levels of nitrogen recorded numerically higher content. Such a trend is not noticed in the first crop season probably because of heavy down pour due to which the nitrogen might have been washed down.

In the first crop season, Azolla incorporated plots record numerically higher values of organic carbon content and larger C:N ratio. Data published by Subudhi and Singh (1980) has also revealed such a trend. In the second crop season, lowest C:N ratio is recorded in the control plot because of fairly low N content in this treatment. Arunachalam (1980) observed that Azolla treated plots gave a higher total nitrogen, organic carbon and available P content. A report by Venkataraman (1980) has also indicated the same trend with no change in phosphate status.

FIG. 9. YIELD RESPONSE WITH AND WITHOUT AZOLLA INCORPORATION.



REGRESSION EQUATIONS:

FIRST CROP

WITHOUT AZOLLA: $Y = 10.648X^2 + 129.505X + 502.382$

WITH AZOLLA: $Y = -16.409X^2 - 14.18X + 702.727$

SECOND CROP

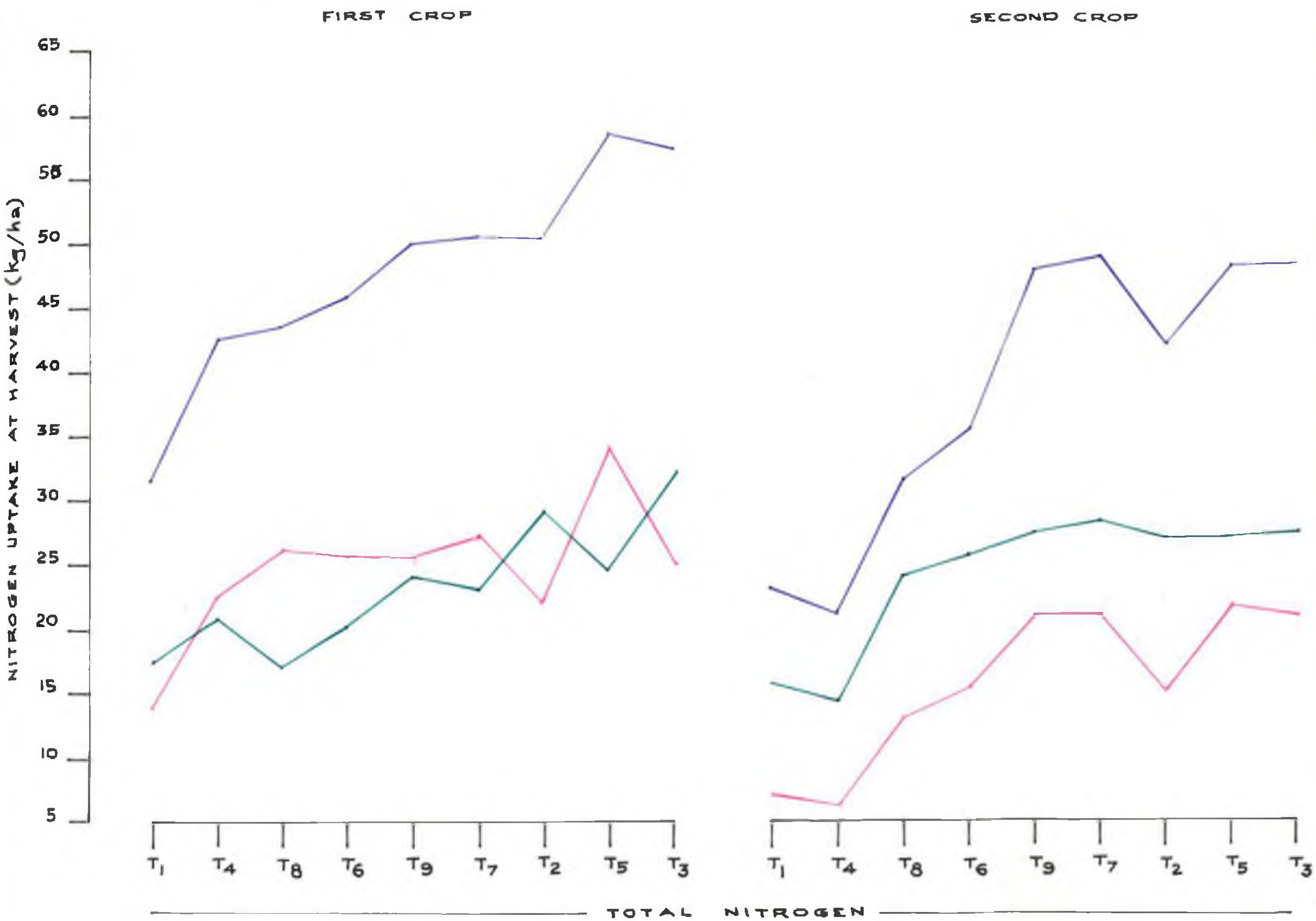
WITHOUT AZOLLA: $Y = -11.903X^2 + 113.959X + 634.872$

WITH AZOLLA: $Y = -30.313X^2 + 51.173X + 917.203$

WHERE Y = YIELD OF GRAIN (kg/ha) - 2000
AND

$$X = \frac{N(kg/ha) - 67.50}{11.25}$$

FIG. 10. NITROGEN UPTAKE IN RELATION TO TOTAL NITROGEN APPLIED.



TREATMENTS	NITROGEN APPLIED (kg/ha)
T_1 NO NITROGEN	0
T_4 AZOLLA ALONE	11·2
T_8 50 % NITROGEN ALONE	45·0
T_6 50% NITROGEN + AZOLLA	56·2
T_9 75 % NITROGEN ALONE	67·5
T_7 75 % NITROGEN + AZOLLA	78·7
T_2 100% NITROGEN ALONE	90·0
T_5 100% NITROGEN + AZOLLA	101·2
T_3 100% NITROGEN + FARM YARD MANURE	106·54

TOTAL NITROGEN UPTAKE
UPTAKE BY GRAIN
UPTAKE BY STRAW

Incorporation of Azolla or farm yard manure does not make a significant contribution towards enriching the soil. This may be due to the sandy nature of the soil which requires fairly high quantities of organic matter to improve the soil properties.

Nitrogen economy

It is already seen that 25% of the N requirement can be saved if Azolla incorporation is resorted to. Further, a regression equation was worked out to find out the optimum dose for maximum production (Table 16). The response curve was also fitted and is presented in Fig. 9.

It can be seen from Fig. 9 that the curve is quadratic when Azolla is applied along with inorganic in both the seasons. The curve is also quadratic when inorganic nitrogen alone is applied in the second crop season; but a linear trend is noticed for the same in the first crop season. In both the seasons, when Azolla is incorporated along with inorganic nitrogen, the curve always lies above that of inorganic nitrogen alone which reveals the beneficial effect of Azolla incorporation.

During the first crop season in Azolla applied field the optimum level of inorganic N is 62.64 kg/ha for the maximum production of 2706 kg grain. Optimum level of inorganic N alone cannot be worked out since the yield showed a linear trend. Considering the fact that 90 kg/ha of N (recommended dose) has given an yield of 2804 kg as per

Table 16. Optimum level of N for maximum production, average response ratio and average apparent N recovery with and without Azolla.

	First crop		Second crop	
	Without Azolla	With Azolla	Without Azolla	With Azolla
Optimum level of N (kg/ha) for maximum production	-	62.64	121.35	76.99
Grain yield at optimum level (kg/ha)	-	2706	2908	2939
Average response ratio	5.34	8.30	16.73	20.46
Average apparent N recovery percentage	24.85	29.63	29.86	35.57

regression equation, this might be compared with the optimum level for the combined application. This comparison reveals that only an additional yield of 98 kg of grain can be produced by the extra quantity of 27.36 kg N. Hence it can be inferred that in the first crop season, application of 62.64 kg N/ha (70% of recommended dose) in combination with Azolla 0 5 t/ha is the optimum dose giving maximum production. Azolla incorporation can save around 28 kg N in the first crop season.

In the second crop season, the optimum dose to produce the maximum yield of 2959 kg of grain is 76.99 kg/ha of inorganic N (85.6% of the recommended dose) when applied along with Azolla. When inorganic N alone is applied, the optimum lies around 121 kg with the maximum production potential of 2908 kg of grain. Comparing these two levels which give almost same yields, it can be assumed that a quantity of 44 kg N can be saved through Azolla incorporation in this season. However, 90 kg N/ha being the recommended dose, at least a saving of 13 kg N can be effected, if Azolla incorporation is resorted to.

The optimum level for the second crop season is found to be higher than that for the first crop season. This is mainly due to the high nitrogen efficiency generally obtained in this season. The linear response in the first crop season and much higher optimum in the second crop season for inorganic N alone application can be attributed to the soil type under investigation. In sandy soils, inspite of the 4 splits we have to apply more quantity of N to get the desired effect. Therefore the form of nitrogen seems to have played a very dominant role in determining the yield response. Azolla being an organic source of nitrogen has resisted leaching losses and has acted as a better ~~of~~ source of nitrogen to the crop.

Response ratio and apparent N recovery

Referring to the Table 16, it can be further seen that average response ratio is generally higher (2.5 - 3 times) in the second crop season. When Azolla is incorporated along with inorganic nitrogen, response is further increased to a considerable extent from 5.34 to 8.30 in the first crop season and from 16.73 to 20.46 in the second crop season.

A similar trend is also noticed in the case of apparent nitrogen recovery percentage. A remarkable increase is obtained in the second crop season and recovery is seen to be still higher with Azolla incorporation.

SUMMARY

VI. SUMMARY

An investigation on "Nitrogen economy through incorporation of Azolla in Rice" was carried out at the Agronomic Research Station, Chalakudy in the first and second crop seasons of 1979-'80. The main objectives of the experiment were:-

(1) To investigate the effect of basal incorporation of Azolla on the growth and yield of rice,

(2) To assess the saving of nitrogen by incorporation of Azolla,

(3) To study the relative efficiency of Azolla incorporation in the first and second crop seasons,

(4) To evaluate the importance of Azolla as an alternate cheap source of organic nitrogen for rice.

The treatments, consisting of different levels of nitrogen, i.e. 90 kg/ha (100 per cent recommended dose), 67.5 kg/ha (75%), 45 kg/ha (50%) and no nitrogen control either alone or in combination with fresh Azolla (5 t/ha) and 100% N with farm yard manure (5 t/ha), were replicated thrice and laid out in the Randomised Block Design. The results obtained are summarised below.

(1) Application of 75% N with Azolla was found to record the same height as that of 100% N, applied either alone or in combination with Azolla or farm yard manure.

(2) Tillering was not seen to be influenced by the treatments at early tillering stage, whereas 100% N applied along with either Azolla or farm yard manure recorded highest tiller production at the maximum tillering stage. Inorganic nitrogen applied in conjunction with Azolla gave more tiller production than application of N alone at this stage.

(3) Seventy five per cent N with Azolla produced the same LAI as that of 100% N applied either alone or with Azolla or farm yard manure.

(4) Inorganic N alone at 75% level was found to be sufficient for higher panicle production in the first crop season whereas in the second crop season, incorporation of Azolla in addition to 75% N was seen required for maximum panicle number. Further increase in N supply did not enhance this yield attribute in the respective seasons.

(5) Number of filled grains per panicle was maximum when 75% N was applied along with Azolla in the first crop season. No remarkable variation was observed among the treatments in the second crop season.

(6) 1000 grain weight was not influenced by the treatments in the first crop season. 75% N applied along with Azolla and other treatments receiving higher levels of N recorded the same test weight in the second crop season.

(7) Panicle length was not affected by treatments

in both the seasons whereas panicle weight was increased in accordance with N levels in the second crop season.

(8) Reduced percentage of filling was noticed at higher levels of N in both the seasons. This decline was drastic in the first crop season. Application of 75% N with Azolla recorded a higher percentage of filling, particularly in the first crop season.

(9) 75% N with Azolla was sufficient to produce as much grain yield as that of 100% N either alone, or with Azolla, or farm yard manure. Azolla was better utilised for grain production in the second crop season and its application compared favourably with farm yard manure as a source of organic N. Incorporation of 5 t/ha of Azolla could save 25% inorganic N requirement for rice.

(10) Straw yield increased with nitrogen levels especially in combination with Azolla or farm yard manure.

(11) Application of Azolla or farm yard manure in conjunction with inorganic N gave higher values of HI than the latter alone.

(12) Maximum uptake of N, P and K was recorded when Azolla was incorporated with 100% N in the first crop season and 75% N in the second crop season.

(13) Much variations could not be observed between treatments for total N, organic carbon, C:N ratio, available P or exchangeable K in the soil after cropping in both the seasons.

(14) Response study showed that 62.64 kg/ha of N was the optimum dose when applied in combination with Azolla giving an yield of 2706 kg/ha of grains in the first crop season. This was comparable to the grain production at 90 kg N/ha (2804 kg/ha). Hence Azolla incorporation could save 28 kg N in the first crop season.

In the second crop season, 76.99 kg N/ha was the optimum level for maximum grain production of 2939 kg, when applied along with Azolla. If application of inorganic N alone was resorted to, the optimum level would go upto 121 kg/ha, with a production potential of 2908 kg, which indicated the possibility for a saving of 44 kg N/ha with Azolla incorporation in this season.

(15) Average response ratio and apparent N recovery percentage were more in the second crop season. The combined application of Azolla with inorganic N recorded higher values than latter alone in both the seasons.

The following are some of the future lines of work suggested for further investigations.

(1) Nutritional and environmental requirements of Azolla grown as a pure and dual crop with rice.

(2) Possibilities of growing Azolla in the first crop season and utilisation in the Second crop season.

(3) Residual effect of Azolla incorporated in the first or second crop season and consequent saving in fertilizer N in the succeeding season.

(4) Comparison of Azolla with other easily decomposible organic manures.

(5) Possibilities of utilisation of Azolla in different rice soils.

(6) Decomposition and mineralisation pattern of Azolla, either incorporated or unincorporated with or without N application.

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APPENDICES

APPENDIX I

Meteorological data for the cropping period (1979-'80) and the average values for the last four years (1976-77 - 1979-80)

Standard week	Period	Total rainfall (mm) A	B	Mean minimum temperature(°C) A	B	Mean maximum temperature (°C) A	B	Mean pan evaporation (cm) A	B
27	July 2-8	245.4	184.2	23.6	24.0	28.3	28.9	.234	.308
28	9-15	215.2	150.1	23.0	23.5	28.6	29.4	.267	.288
29	16-22	45.2	144.4	23.9	23.5	30.4	29.8	.333	.320
30	23-29	166.0	226.8	23.6	23.4	28.1	28.0	.250	.287
31	30-5th August	208.2	120.3	23.1	23.8	27.2	29.3	.277	.319
32	6-12	118.0	96.1	23.1	24.1	30.0	30.3	.265	.317
33	13-19	21.0	48.5	23.3	23.9	30.1	30.5	.301	.320
34	20-26	100.2	105.1	23.4	23.8	29.9	29.4	.330	.288
35	27-2nd September	24.6	90.8	23.4	23.6	31.1	29.6	.349	.301
36	3-9	10.0	45.4	24.1	24.1	31.1	30.6	.401	.314
37	10-16	89.2	36.8	23.4	23.8	31.7	30.8	.409	.380
38	17-23	97.9	37.5	23.6	23.7	29.1	30.6	.222	.347
39	24-30	82.3	41.2	23.8	24.0	28.2	30.3	.238	.322
40	October 1-7	35.0	37.4	23.8	24.0	30.4	31.3	.344	.360
41	8-14	49.0	82.2	23.9	24.2	31.6	31.6	.359	.370

continued...

APPENDIX I continued

Standard week	Period	Total rainfall (mm) A	Total rainfall (mm) B	Mean minimum temperature(°C) A	Mean minimum temperature(°C) B	Mean maximum temperature(°C) A	Mean maximum temperature(°C) B	Mean pan evaporation (cm) A	Mean pan evaporation (cm) B
42	15-21	72.4	145.7	23.1	23.8	32.9	31.4	.333	.308
43	22-28	82.4	69.6	24.1	24.1	33.1	31.7	.350	.327
44	29-4th November	27.9	49.2	24.2	24.3	32.7	32.2	.319	.337
45	5-11	84.8	124.0	24.2	23.5	32.3	31.3	.354	.317
46	12-18	93.6	58.4	23.7	23.7	32.4	31.9	.305	.297
47	19-25	88.8	79.0	23.6	23.0	30.0	31.1	.252	.315
48	26-2nd December	56.4	47.9	24.2	23.6	32.1	31.9	.299	.304
49	3-9	3.0	6.3	23.9	22.8	32.4	32.6	.356	.354
50	10-16	3.0	9.8	23.3	21.5	33.2	32.4	.355	.351
51	17-23	Nil	Nil	20.6	21.6	34.0	33.2	.368	.360
52	25-31	Nil	24.3	20.4	21.1	33.2	32.8	.391	.375
1	1st January - 7	Nil	Nil	19.1	20.1	33.4	33.4	.361	.372
2	8-14	Nil	Nil	18.7	19.9	33.9	33.6	.471	.426
3	15-21	Nil	Nil	18.9	19.9	34.1	33.7	.452	.405
4	22-28	Nil	Nil	18.7	21.1	34.1	34.0	.439	.433
5	29-4th February	Nil	Nil	22.4	22.5	33.5	34.1	.449	.427
Total		2021.5	2052.6	-	-	-	-	-	-
Mean		-	-	22.8	23.0	31.4	31.3	.337	.341

A - During the cropping period B - Average for the last four years

APPENDIX II

Abstract of analysis of variance table for height (cm) at different stages of crop growth

Source	df	Mean square					
		Early tillering			Panicle initiation		
		First crop	Second crop	Mean	First drop	Second crop	Mean
Block	2	1.4219	0.3742	-	5.729	4.820	-
Season	1	-	-	307.260**	-	-	53.4020
Treatment	8	11.2829**	6.9400	12.3150	75.139**	32.087**	92.1640**
Treatment x Season	8	-	-	5.9190*	-	-	15.0620**
Error	16(32°)	0.6946	4.1530	2.4240	2.193	3.961	3.0770

° Value in parenthesis shows the df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX II continued

		Mean square					
		50% flowering			Harvest		
Source	df	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	1.4856	10.434	-	1.2987	3.071	-
Season	1	-	-	2338.53**	-	-	1646.95**
Treatment	8	31.7268**	22.489*	42.83**	32.2384**	10.893	34.43**
Treatment x Season	8	-	-	11.390	-	-	7.670
Error	16(32@)	4.0239	7.702	5.853	4.1819	6.476	5.329

@ Value in parenthesis shows the df for error of mean

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Abstract of analysis of variance table for total number of tillers per hill at different stages of growth and LAI at 50% flowering.

		Mean squares								
		No. of tillers/hill								
		Early tillering			Maximum tillering			LAI		
Source	df	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	0.6315*	0.1287	-	1.4283**	6.675*	-	0.1911**	0.702**	-
Season	1	-	-	10.498**	-	-	15.510**	-	-	0.2452
Treatment	8	2.2645**	1.1008	3.146**	3.8939**	7.666**	10.007**	0.20197**	0.294*	0.4157**
Treatment x Season	8	-	-	0.[illegible]25	-	-	1.553	-	-	0.0803
Error	16(32°)	0.1078	0.5235	0.320	0.07252	1.766	0.919	0.2965	0.0839	0.0568

° Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX IV

Abstract of analysis of variance table for percentage of productive tillers and yield components.

		Mean square					
		Percentage of productive tillers at harvest			No. of panicles per hill		
Source	df	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	30.253	51.004	-	1.232**	1.336	-
Season	1	-	-	143.34*	-	-	0.8313
Treatment	8	48.418	93.027	81.60*	2.004**	3.825**	4.175
Treatment x Season	8	-	-	59.87	-	-	1.728**
Error	16(32°)	24.41	43.471	33.94	0.1924	0.4147	0.3056

° Value in paranthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX IV continued

Source	df	Mean square					
		No. of filled grains/panicle			1000 grain weight		
		First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	4.972	29.679	-	12.512	2.766	-
Season	1	-	-	126.53	-	-	22.106
Treatment	8	119.699**	59.818	95.418	4.400	13.118*	6.651
Treatment x Season	8	-	-	84.099**	-	-	10.867*
Error	16(32°)	20.998	22.809	21.903	2.825	4.870	3.847

° Value in paranthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX V

Abstract of analysis of variance table for length of panicle, weight of panicle and percentage of filling.

Source	df	Mean square								
		Length of panicle (cm)			Weight of panicle (g)			Percentage of filling		
		First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	0.820	5.729**	-	0.00271	0.004958	-	6.253	5.834	-
Season	1	-	-	0.507	-	-	1.612**	-	-	18.073
Treatment	8	0.894*	1.115	1.793**	0.06496**	0.11735**	0.100	36.810**	4.814	21.351
Treatment x Season	8	-	-	0.216	-	-	0.0818**	-	-	20.375*
Error	16(32°)	0.281	0.5814	0.4313	0.00847	0.01735	0.0129	2.749	13.530	8.140

° Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level.

APPENDIX VI

Abstract of analysis of variance table for grain yield, straw yield and harvest index.

Source	df	Mean square								
		Grain yield (kg/ha)			Straw yield (kg/ha)			Harvest index		
		First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	69.5	33016	-	39467	261619*	-	.000144	.001095	-
Season	1	-	-	30104	-	-	40475111**	-	-	.2696**
Treatment	8	289734**	1053584**	1155333**	1329187**	1386630**	2541367**	.002587**	.002549*	.003943**
Treatment x Season	8	-	-	107986**	-	-	174450**	-	-	.001178
Error	16(32°)	14676	20362	17519	34020	62862	48441	.000324	.0009552	.000639

° Value in parenthesis shows the df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX VII

Abstract of analysis of variance table for N, P and K content (per cent) of grain.

Source	df	Mean square								
		N			P			K		
		First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	.02671**	.01547	-	.00039	.0004244	-	.00009	.003079	-
Season	1	-	-	.0512	-	-	.0006087	-	-	.4004
Treatment	8	.0595**	.009715	.01592	.00051	.001155	.0006865	.00108	.005752*	.00327
Treatment x Season	8	-	-	.030795**	-	-	.0009812*	-	-	.00357*
Error	16(32°)	.00133	.00889	.00511	.000346	.000466	.000406	.000822	.001829	.00133

° Value in parenthesis shows the df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX VIII

Abstract of analysis of variance table for N, P and K content (per cent) of straw

		Mean square								
		N			P			K		
Source	df	First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	.004624	.0001379	-	.00053	.001463*	-	.0109	.0649*	-
Season	1	-	-	.05947	-	-	.003469	-	-	10.4456**
Treatment	8	.02015*	.02331**	.02475	.00094**	.0007175	.0007099	.0123	.0452**	0.0283
Treatment x Season	8	-	-	.01872**	-	-	.0009470**	-	-	0.02914*
Error	16 (32°)	.005565	.003592	.00458	.000165	.0003299	.0002475	.00802	.0118	0.00989

° Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX IX

Abstract of analysis of variance table for N, P and K uptake (kg/ha) at harvest

Source	df	Mean square								
		N			P			K		
		First crop	Second crop	Mean	First crop	Second crop	Mean	First crop	Second crop	Mean
Block	2	9.715	8.274	-	1.913	1.0996	-	23.335	222.473*	-
Season	1	-	-	875.55**	-	-	174.349**	-	-	83.220
Treatment	8	198.576**	359.056**	504.68**	14.121**	36.716**	44.322**	257.324**	725.610**	856.090**
Treatment x Season	8	-	-	52.949**	-	-	6.508**	-	-	126.644**
Error	16(32°)	10.828	12.986	11.907	0.693	0.770	0.7313	17.892	36.536	27.214

° Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX Xa

Abstract of analysis of variance table for Total N, organic carbon (per cent) and C:N ratio of soil after cropping.

Source	df	Mean square: N, First crop	Mean square: N, Second crop	Mean square: N, Mean	Mean square: Organic carbon, First crop	Mean square: Organic carbon, Second crop	Mean square: Organic carbon, Mean	Mean square: C:N ratio, First crop	Mean square: C:N ratio, Second crop	Mean square: C:N ratio, Mean
Block	2	.000275*	.000517**	-	.003733	.01203*	-	18.674	29.083**	-
Season	1	-	-	.00072**	-	-	.3314**	-	-	157.662*
Treatment	8	.000114	.0000858	.00013*	.0271**	.003608	.01429	10.191	15.380**	2.562
Treatment x Season	8	-	-	.000067	-	-	.01643**	-	-	23.009**
Error	16(32©)	.0000728	.0000398	.0000563	.006283	.002996	.004638	5.779	3.937	4.658

© Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

APPENDIX Xb

Abstract of analysis of variance table for available P and exchangeable K in the soil (ppm) after cropping.

Source	df	Mean square: Available P – First crop	Available P – Second crop	Available P – Mean	Exchangeable K – First crop	Exchangeable K – Second crop	Exchangeable K – Mean
Block	2	359.865*	167.355*	-	31.194	22.028	-
Season	1	-	-	39.765	-	-	372.094
Treatment	8	63.247	38.580	45.471	63.625	59.005**	47.284
Treatment x Season	8	-	-	56.182	-	-	75.346*
Error	16(32⊙)	79.444	37.079	58.260	33.924	14.708	24.316

⊙ Value in parenthesis shows df for error of mean

*Significant at 5% level

**Significant at 1% level

NITROGEN ECONOMY THROUGH INCORPORATION OF AZOLLA IN RICE

BY

JAIKUMARAN. U.

Abstract of a Thesis
Submitted in partial fulfilment of
requirement for the Degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
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1981

ABSTRACT

An experiment was conducted at the Agronomic Research Station, Chalakudy, during the first and second crop seasons of 1979-'80. The effect of basal incorporation of Azolla on growth and yield of rice was investigated in order to assess the saving of nitrogen and evaluate Azolla as an alternate cheap source of N for rice crop. The treatments, comprising different levels of recommended dose of N (0, 50, 75 and 100 per cent of 90 kg N/ha) either alone or in combination with Azolla (5 t/ha) and 100% N with farm yard manure (5 t/ha), were replicated thrice and laid out in the Randomised Block Design.

The study revealed that when Azolla was incorporated, 75% N was sufficient to produce the similar height and LAI as obtained from 100% N applied either alone or in combination with Azolla or farm yard manure; But incorporation of Azolla or farm yard manure with 100% N was required to get maximum tillering at maximum tillering stage.

Incorporation of Azolla in addition to the application of 75% N was found to be required to achieve higher panicle production in the second crop season whereas the latter alone was sufficient in the first crop season. Azolla incorporation along with 75% N also recorded a higher number of filled grains per panicle and higher percentage of filling in the first crop season.

In both the seasons, application of 75% N along with the incorporation of Azolla was found to be enough to produce as much grain yield as obtained from 100% N applied either alone or in combination with farm yard manure or Azolla. Azolla could be compared favourably with farm yard manure as a source of organic nitrogen. Incorporation of Azolla could save 25% of the inorganic N required for rice.

Straw yield increased with nitrogen levels particularly in combination with Azolla or farm yard manure. Harvest index values were higher when Azolla or farm yard manure was applied along with inorganic nitrogen.

Maximum uptake of N, P and K was recorded when Azolla was incorporated with 100% N in the first crop season and with 75%N in the second crop season. Application of Azolla or farm yard manure did not have any influence on soil properties.

Response study showed that 62.64 and 76.99 kg of N per hectare were the optimum doses in combination with Azolla to produce maximum yields of 2706 kg and 2939 kg of grain in the first and second crop seasons respectively. On comparison of these with inorganic N applied alone indicated the possibility of a saving of 28 and 44 kg of N through Azolla incorporation in the first and second crop seasons respectively. Combined application of Azolla with inorganic N also resulted in a higher response ratio and apparent N recovery than with the latter alone.